CONFERENCE PROCEEDINGS

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GLOBALISATION 2.0

Rethinking supply chains in the new technological and political landscape

UNIVERSITY OF CAMBRIDGE

IfM Centre for International Manufacturing

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CHAIRMAN'S INTRODUCTION

The **21st Cambridge International Manufacturing Symposium**, in its annual tradition of facilitating open dialogue between industry, academia and policy makers, will this year focus on the theme of globalisation 2.0 and supply chain transformation.

Globalisation of operations has provided economies of scale and access to low cost resources and new markets but can also increase supply network complexities. De-globalisation on the other hand can pose a threat to the 'open' product, information and financial fl ws that we have experienced in recent years. The shift of global manufacturing to potentially new forms of multi-domestic operations presents exciting new opportunities and challenges to better integrate supply chains end-to-end, to capture relevant product, supply and through-life product use data, and potentially enable much higher levels of product customisation. Technology adoption is being accelerated by new developments in digital production processes, enhanced supply system capabilities and the ability to connect embedded devices that allow greater visibility across the supply chain. During the Symposium we will examine the impact of these changing technological and political landscapes on manufacturing supply chains and business models.

As per our usual format, we have some outstanding senior industrial speakers on the first day of our Symposium, representing exemplars of manufacturing supply chain initiatives. Senior executives from **DHL, GlaxoSmithKline, Grundfos, New Economy, Procter & Gamble, World Economic Forum** will be sharing their thoughts on the future configu ations of international manufacturing supply networks.

On day two we will be presenting insights from leading academics and from our recent engagements with global policy institutions on potential developments in international manufacturing supply chains. Our keynote academic speakers this year are Professors Joglekar (**Boston University Questro School of Business**), Vereecke (**Vlerick Business School**), and from an industrial policy perspective, Lehmacher (**World Economic Forum**) and Zhan (**United Nations Conference for Trade and Development**) who will share their research insights on the future development of international manufacturing operations. This will be followed by parallel tracks on the topics of e-Commerce supply (debunking so-called 'myths' on the economics and sustainability of last mile logistics), and continuation of our main themes this year, Globalisation 2.0 and Digital Supply Chains.

I am sure you will enjoy the engaging yet informal atmosphere of our rather unique academic-practitioner-policy community, one that has developed its own modus operandi in shaping the forward research agenda. As part of this continued exchange of ideas we are very much looking forward to welcoming you to the 2017 Cambridge International Manufacturing Symposium.

Dr Jagjit Singh Srai

Symposium Chair
Head of Centre for International Manufacturing
University of Cambridge Institute for Manufacturing

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AUTHOR
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Evaluating natural resource scarcity in supply chains: Evolutionary theory perspective

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Abstract

The main aim of this study is to develop a research framework, following Darwinian evolutionary principles, that is applied to explore firm's adaptive behaviour and learning in the water scarcity context. Water scarcity mitigation capabilities development in SCs applying an evolutionary theory perspective is an emerging area of SC research. The study suggests that when adapting to water scarce environment the firm goes through an actionable knowledge development process following evolutionary steps. Based on this acquired knowledge, water stress mitigation capability building takes place, which also following an evolutionary process. As a result, firms develop dynamic, static, or extreme weather event driven capabilities. Specifically, this study makes a distinction between specialist and generalist firm types, advocating that specialist firms are likely to develop dynamic capabilities and extreme weather event driven capabilities, while generalist firms will probably develop static capabilities failing to exploit extreme weather event driven capabilities. Preliminary findings of this research articulate the hypothesis suggesting that specialist firms developing dynamic capabilities are likely to follow major structural changes in their SC configurational patterns. On the other hand, generalist companies building static capabilities are likely to follow SC continuous improvement processes.

Keywords: Evolutionary theory, supply chain sustainability, mitigation capabilities, water scarcity

1 Introduction

Sustainable development has become a dominant topic in various studies (Mulder and van den Bergh, 2001) through different industry sectors, where the main focus is on interaction of business strategies with the biophysical environment. One of the elements of such biophysical environments is portrayed by natural resources. Therefore, changing levels of natural resource availability due to an imbalance in resource supply and demand that in turn is influenced by technological, environmental (climate change, biodiversity loss), societal (population increase, globalisation, urbanisation), political (Betton and Dess, 1985), and economic (consumption patterns, industrialisation) changes, increases the uncertainty levels in the business environment. This situation forces firms to mitigate and adapt (Mulder and van den Bergh, 2001) to these environmental changes developing effective supply chain (SC) approaches under vigorous business strategies (Morash, 2001*)*.

Nowadays, the role of SCs in modern society is immense. Food supply chains (FSCs) help to sustain human life delivering basic necessities such as food and water to communities. Healthcare SCs help to improve healthcare systems delivering and improving medicines worldwide. Efficient SCs facilitate economic growth of regions enabling the exchange of goods between businesses and consumers (CSCMP, 2017). While SCs are highly dependant on water, they also contribute natural resource scarcity that in turn affects company operations. Adapting to such changes in resource availability, different industries undergo various processes to develop distinct water scarcity mitigation mechanisms for their SCs.

Application of natural resource scarcity in the SC management domain is not widely explored from the perspective of evolutionary theory. The only domain that links Darwinian principles with resource scarcity is environmental and resource economics (van den Bergh and Gowdy, 2000). Therefore, natural resource scarcity driven SC configuration development from an evolutionary theory perspective presents a gap in the SC literature that has to be bridged.

This study takes an evolutionary perspective on actionable knowledge generation and mitigation capabilities development for two types of firms, namely specialist and generalist (Aldrich, 2008). Here the prominent role of environmental changes in organisational adaptive variation development leads to an analogy with natural selection processes under environmental constraints posited by Darwin, where a survival or fitness of organisations or their forms are driven by laws of nature. This paper argues that transformation of supply chains towards natural resource sustainability needs to be complemented by an evolutionary approach that focuses on variation, selection, and retention of specialist knowledge and capability development for water scarcity in supply networks mitigation.

2 Evolutionary theory

The Darwinian model of evolution has been widely used in various disciplines, e.g. linguistics, anthropology, and economics (Betton and Dess, 1985). Applying these Darwinian principles, scholars have further formulated evolutionary accounts (Srai and Alinaghian, 2013) to explain phenomena on various levels. For instance, at the individual level Campel (1969) has proposed a generic application of the evolutionary model in the context of socio-cultural evolution. Work by Miller and Mintzberg (1984) has been applied at the organizational level, proposing survival mechanisms and natural selection of organisations in the business environment (Vale 1980). At the industrial economy level, evolutionary theory examines the effect of global changes on organisational populations (Carroll and Hannan, 1989; Jacobides and Winter, 2005).

2.1 Organisational perspective

The main focus of current research is on the organisational level. One of the first studies that compares biological evolution with organisational evolution, developed by McKelvey and Aldrich (1983), has identified that organisations must develop evolutionary significant attributes that will enhance their ability to survive in changing environments. Here, the environment is defined by biophysical, political, economic, legal, cultural, and technological forces (Hall, (1982) in McKelvey and Aldrich 1983 p. 111) to which the firm has to adapt. Adapting to the changing environment, the organisation undergoes a number of evolutionary processes:

- The principle of variation is represented by any kind of change (McKelvey and Aldrich, 1983) or creation of new organisational forms (Van de ven and Poole, 1995; Srai and Alinaghian, 2013). Here variation is distinguished between purposeful variation as an intentional response to environmental pressures and blind variations, which happen independent of environmental pressures by accident (McKelvey and Aldrich, 1983).
- The principle of natural selection is employed to eliminate certain types of variations or characteristics in organisations that are less beneficial for acquiring finite resources (McKelvey and Aldrich, 1983). Selection primarily takes place through competition over scarce resources (Hannan and Freeman, 1977) in changing environments (Srai and Alinaghian, 2013; Van de ven and Poole, 1995).
- The principle of retention and diffusion includes mechanisms that perpetuate and maintain selected beneficial variations or organisational forms (McKelvey and Aldrich, 1983). This process allows organisations to "capture the value from existing routines" (p. 93, Srai and Alinaghian, 2013) that prove to be advantageous. Retention also helps organisations to maintain previous organisational forms and practices.

2.2 Organisational environment

In population ecology the environment is considered "a major force shaping organisational change" (p. 56, Aldrich, 2008). Following Darwinian principles selection occurs due to environmental pressures. As such, environments influence organisations through a process of making resources available or unavailable and affecting efficacy in attaining these resources.

This study is focused on the firm's environmental aspects that are determined by biophysical constraints expressed in terms of natural resource scarcity such as water. Natural resource scarcity presents imbalance in resource supply and demand (FAO 2012, FAO 2013). However, water scarcity is driven by a combination of various factors including climatic, geological, socio-economic, and political (Yatskovskaya and Srai, 2017).

Global population is expected to increase to 9.8 billion by 2050 (UN DESA, 2017). This situation leads to increased pressures on water availability to meet increased agricultural demand. The situation becomes even more complicated due to increasing incomes that lead to changing consumption patterns towards water intensive produce. While growing levels of urbanisation and industrialisation contribute to the problem of resource availability, they also influence water quality due to toxic discharges from cities and upstream industries that contaminate water sources (Yatskovskaya et al., 2016).

Weak water regulations and policies in certain countries have already brought about severe water scarcity problems affecting local communities and industries (Yatskovskaya and Srai, 2017). This situation is particularly acute in developing regions where agricultural policies are more focused on agricultural productivity and intensification, conventionally by means of water resources (FAO, 2011).

On top of all these factors climate change is projected to contribute to water scarcity by leaving more than 40 per cent of the world's population by 2050 in severe water stress conditions (UN Water, 2013). In addition, extreme weather events put significant pressures on water availability and security. For instance, events such as El Niño and La Niña have potentially catastrophic impacts on water availability (Yatskovskaya et al., 2016). And a combination of climate change and extreme weather events is likely to lead to an exacerbation of demand for water resources (Castex et al. 2015).

All these elements make water scarcity a dynamic problem.

2.3 Environmental fitness

Many leading corporations understanding the importance of water availability for their highly dispersed SCs are forced to undergo an evolutionary process e.g. SC configuration or mitigation strategies development in order to fit an environmental niche. The concept of an environmental niche was introduced by McKelvey and Aldrich (1983) and represents a distinct combination of the firm's resources and constraints that are sufficient to support organisational form (Aldrich, 2008). Here organisational forms represent "organised activity systems oriented toward exploiting the resources within a niche" (p. 28, Aldrich, 2008). Thus, the process of natural selection forces organisations to move towards a better fit within the environment. Based on types of activities firms can be classified as specialists or generalists (Figure 1).

Specialist firms engage only in a narrow range of activities and do well in a specific state of the environment, when it is stable and homogeneous, which is presented with slight deviations from a previous state. Specialists are more fit than generalists within a narrow range of the environmental change where they compete without maintaining extra capacity to meet a different state of the environment (Aldrich, 2008).

Generalist firms engage in a broader range of activities and do less well within a stable and certain state of the environment. Thus, generalists spread their fitness over a large number of environmental states and have a better fit to unstable and heterogeneous environments and cannot optimally adapt to any single environmental state (Hannan and Freeman, 1977). This type of firm has to maintain an excessive capacity for anticipation of future needs in order to take advantage of resources that become more or less available (Aldrich, 2008).

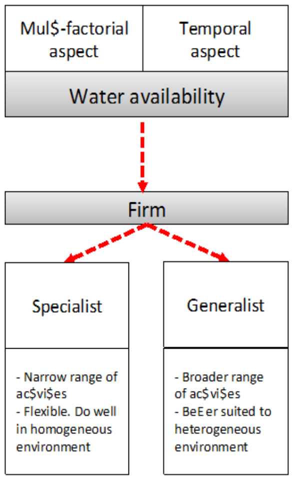

Figure 1 – Firm types

In stable environments "specialists outcompete generalists over the range of outcomes to which they have specialised" (p.950, Hannan and Freeman, 1977) due to the fixed level of fitness assumption. Conversely, "if the environment is only occasionally within the interval" (p.114, Aldrich, 2008) generalists will outcompete specialists. Generalists will do well when the differences between environmental states, even if occurring frequently, are small such that an extra capacity is not a burden. However, when the difference between different states of the environment is great, it is likely specialists will be selected. This is also the case when the environment is extremely unstable (Aldrich, 2008).

This study proposes an application of the concept of firm fitness to the context of a water-constrained environment. *Specialist firms* are organisations that have abilities to quickly adapt to the changing environment, developing or maintaining capabilities specifically for water stress mitigation. This type of firm can be generally presented by small specialised companies that have a capacity to quickly switch or improve their production processes towards water efficiency. Companies (suppliers) that produce certain components or products in water scarce regions could be identified as specialists in terms of their ability to adapt to water availability levels whilst maintaining production levels. *Generalists*, on the other hand, are firms that, understanding the importance of sustainability in their SCs, develop a capacity to build build mitigation capabilities slowly over time. These capabilities might not be specifically developed around water scarcity mitigation but rather are generally focused on various aspects of sustainability. As a result, these firms are not flexible to changes in environmental states. This type of firm is represented by large organisations with a broad range of activities and spatially dispersed SCs. Consequently, generalists don't develop abilities to rapidly alter their production processes to become adept in water sustainability. Adapting to water scarce driven environments firms follow different mitigation capabilities that are dictated by the firm's type. In order to adapt to water scarcity through capability development firms first have to go through the process of water availability evaluation, namely actionable knowledge development. This process has not yet been well analysed within a context of SCs from an evolutionary theory perspective. Thus, actionable knowledge generation, based on the process of water scarcity assessment, for subsequent water stress mitigation capabilities development through the prism of evolutionary theory will be further explored.

3 Water constrained environment: Framework

The environment presents a pool of constraints that forces a firm's evolutionary change. Evolutionary theory also conveys the concept of the environment as information or resource flows that companies exploit (Aldrich, 2008). Scholars in favour of the rational selection model tend to adopt the "information" view of the environment, while proponents of the ecological or natural selection model tend to view the environment in terms of resources (Aldrich, 2008). Current research

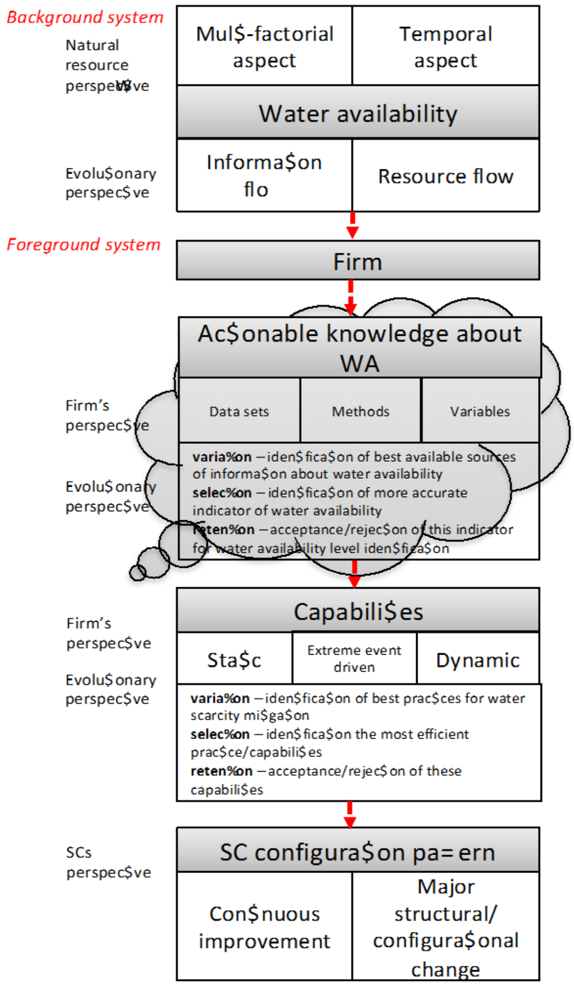

Figure 2 – Research framework

suggests that information flows represent informed data about the environment in which the firm operates, while resource flows represent the environment the firm employs to build capabilities. The current work proposes that both concepts of the environment should be considered consecutively.

In the water scarcity context the organisational environment is considered as a pool of information about the water availability that a company collects and interprets in order to further build mitigation capabilities employing various resource flows e.g. technologies, polices, assets, labour, etc. As a result, adapting to the water constrained environment, organisations develop adaptive behaviour and learning. Our study suggests that this process goes through two major stages: *actionable knowledge* generation that is driven by a necessity to understand or learn about the changing environment (based on information flows); and *mitigation capabilities* development (based on resource flows)–brought about by the necessity to survive under environmental constraints. Each of these stages contains sub-stages that follow an evolutionary process in their development (Figure 2) i.e. variation, selection, and retention. Each of the stages will be considered in turn.

3.1 Knowledge

Actionable knowledge generation refers to the learning process of organisations that connects heterogeneous elements about the environment in order to inform current and future actions (Antonacopoulou, 2006). Operating in water constrained environment firms are forced to adapt. Adapting to the environment organisations undergo a learning process about the environment(such as collecting, selecting, and interpreting information about water scarcity) in

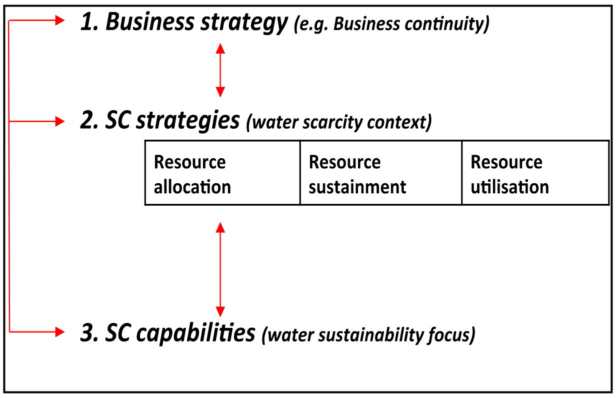

Figure 3 – Water scarcity mitigation capabilities framework k

order to further generate knowledge that firms can apply to form their business and SC strategies. This study suggests that the process of actionable knowledge creation has to go through evolutionary stages in its development.

At the first stage, "variation", the organisation pulls together various water availability information sources (information flows) including data sets and attempts to identify possible methods and variables to be used for the generation of accurate projections. However, frequently businesses seek to identify aggregated water evaluation tools that are currently available for public or commercial access. Unfortunately not all of these tools are designed for strategic purposes, covering only reporting (Table 1).

At the second stage, "selection", the firm seeks to identify the most accurate indicator or combination of datasets, methods, and variables for water availability evaluation and projection. At this stage the firm also might consult various organisations, experts, and scientists to identify the best available indicator. When an organisation explores the tools available to it, it selects the most accurate and completed tools.

At the last stage, "retention", the organisation employs either readily available identified indicators, generated by the tools selected at stage two, or self-generated indicators, based on pre-selected datasets, methods, and variables. Based on the indicators the firm develops an actionable knowledge about current or future water availability in the form of impact.

At this stage the produced indicators can also be rejected due to their inability to accurately identify water availability levels. In this case the process repeats until the most accurate indicator for actionable knowledge development is found. In case of success, generated actionable knowledge, based on the selected indicators, is further transmitted to other functional units of organisation to support a design of water stress informed business strategies and abreast SC strategies. These SC strategies are further supported by the development of specific water stress capabilities (Figure 3).

3.2 Capabilities

The ability to acquire and interpret information about the environment in which the firm operates helps the company to further generate mitigation responses in the form of new strategies and subsequent capabilities. Based on this acquired actionable knowledge, the firm develops a set of capabilities to respond to certain risks from water scarcity.

SC capabilities here represent one of the building blocks (Figure 3) connecting business strategy and SC strategy that leads to SC performance development Morash (2001). Whereas water stress mitigation strategies come in the form of three major approaches: resource allocation, resource sustainment, and resource utilisation (Yatskovskaya and Srai, 2017). These strategies, in turn, are supported by specific water stress mitigation capabilities. SC capabilities represent "tangible or intangible processes that are firm specific" (Srai et al., 2013, p.595). Notably, capabilities can also be distinguished as static or dynamic. Static capabilities are the processes a company develops over time including water reduction, water recycling, reclamation, emissions management, etc. (Srai et

Table 1 – Publicly available water stress assessment tools

Categories		Water stress assessment techniques					
		WBCD Global Water Tool	***GEMI Local Water Tool***	***WRI Aqueduct***	***WWF The Water Risk Filter***	***Water Footprint Network***	***CERES Aqua Gauge***
User application purpose	1. Reporting 2. Strategic operations planning 3. Tactical 4. Operational	Reporting		Reporting	Reporting	Strategic	Strictly reporting
Data and model visibility	1.“Black Box”- data and model are not visible 2.“Fixed Box” – data and and model are not editable 3.“Open Box” - data and and model are editable 4.N/A	“Fixed box”/”Black box”	“Fixed box”/”Black box”	“Fixed box”	“Fixed box”- possibility to amend weightings/” Black box”	“Fixed box”/“Fixed box”	N/A- borrows indicators from other tools
Type of indicators employed	1. Categorical (e.g. colour coding) 2. Numerical (e.g. threshold levels) 3. Both	Categorical	Categorical	Categorical	Categorical	Categorical	N/A
Type of the data employed	1.Qualitative 1.1. Expert opinion (e.g. scoring system) 2. Quantitative (e.g. water consumption) 3. Mixed 4. N/A – data is not visible	Quantitative	Quantitative	Quantitative	Mixed	Quantitative	Mixed
Types of methods employed	1. Statistical/Mathematical 2. Scientific 3. Mixed 4. N/A – method is not visible/not applicable	N/A	N/A	Statistical/ Mathematic al	N/A	Statistical/ Mathematical	N/A
Time horizon	1. Retrospective 2. Perspective/Forecasting 3. Both	Both	N/A	Both	Both	Retrospective	Retrospective
Spatial focus	1. Single location 2. Global 3. N/A – location is not covered	Global	N/A	Global	Global	Global	Global
Granularity level	1. Country level 2. Regional 3. N/A – data is not available	Country and Watershed	N/A	Watershed	Country and Basin level	Country, Region, River basin, Catchment	N/A
Application in Supply Chains	1) Primary supplier; 2) Manufacturing; 3)Packaging; 4)Distribution; 5)Retail; 6) Use phase; 7) N/A; 8)All above	N/A (Country level)	N/A (Site level: Product, Process)	N/A	N/A Country level	Product, process level - All above	N/A

al., 2013; Closs et al., 2011, Sarni, 2011. Dynamic capabilities are strategic routines, processes, product developments, and new supplier integration practice developments used to adapt to constantly changing environments, and which lead to long or short-term sustainable competitive advantages (Teece, 2007; Brusset and Teller, 2016; Beske et al., 2014; Lee et al., 2014). Examples of dynamic capabilities within the water availability context are capital investments in technology for water stress elimination, the adoption of water neutral approaches, etc. (Closs et al., 2011; Babin and Nikholson, 2011; Kleindorfer et al., 2005). Extreme weather events can result in severe droughts or floods. In order to mitigate these events this study suggests that the firm has to react swiftly employing already existing dynamic mitigation capabilities or developed extreme weather event driven capabilities.

This study adopts an evolutionary concept of the environment in the form of resource flows, i.e. water availability, which the firm examines in order to develop water stress mitigation capabilities. The current work proposes that the development of these mitigation capabilities should follow a three-step evolutionary process (Figure 2):

At the first stage, “variation”, the firm obtains information about existing strategic capabilities to mitigate water scarcity. At this stage scoping of possible available practices for certain levels of water scarcity at the given location under prevailing environmental, political, economical, and technological conditions takes place.

This stage is followed by a second stage, “selection”. At this stage the firm refines its water stress mitigation capabilities selecting dynamic or static capabilities that are the best fit for the defined period of time.

At the third stage, “retention”, the firm implements selected mitigation strategies in its production process design, product design, or along its value chain. If the selected mitigation

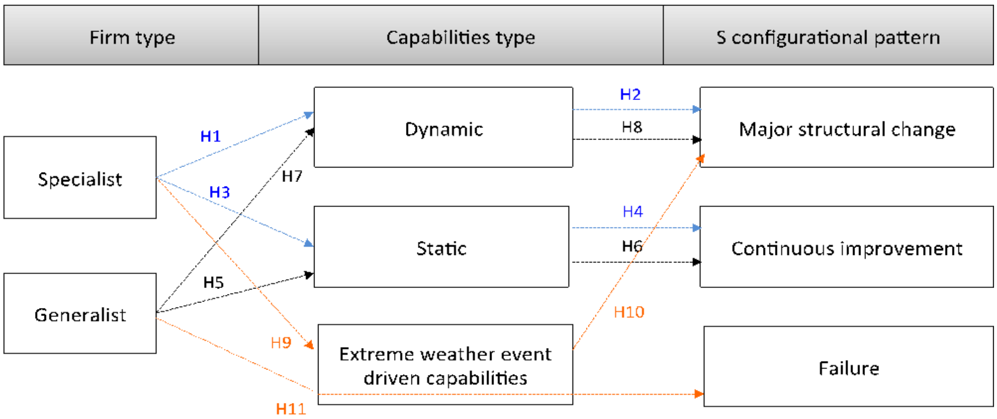

Figure 4 – Hypothesis about SC configurational patterns

capabilities work well, the firm continues applying them. Alternatively, the company modifies these capabilities to better fit to the changing environment.

The proposed framework (Figure 2) is based on an evolutionary theory perspective, linking concepts of the environment as information and resource flows, and advocates an adaptation process development following three evolutionary stages for actionable knowledge and capabilities generation.

4 Results and Discussion

This study suggests that a *background system*, which is organisation independent and presented in the form of resource and information flows, directly influences a firm's state, "*foreground system*" (Figure 2). Adapting to a changing water scarcity environment, companies are forced to employ adaptive behaviour and learning in order to fit this environment. The current study suggests that a firm's learning process is presented through the prism of evolutionary theory. The firm following a three-step process develops a reliable indicator based on which it generates actionable knowledge about current or future water scarcity states that are further transferred to organisational structural units. Reaching strategic business operations units this actionable knowledge helps to form adaptive behaviour in the form of mitigation responses for a defined water scarcity level in a given time frame. A mitigation capabilities development process also follows a three-step evolutionary process: variation, selection, and retention. As a result, the firm develops mitigation capabilities that can be categorised on: static, dynamic, and extreme weather events driven. This intercalated mechanism of the firm's adaptation to a water scarce environment through a Darwinian model perspective (Darwin, 1859) has been captured in the research framework (Figure 2).

In order to expand understanding of the SC configurational processes through the perspective of evolutionary theory this study links the organisational ecology concept of firms' types (specialists and generalists) and a categorisation of water stress mitigation capabilities to propose hypotheses about SC configurational patterns driven by a natural resource scarcity environment (Figure 4).

Specialist firms are organisations that quickly adapt to the changing environment developing and maintaining capabilities specifically for water stress mitigation e.g. quickly switching or improving their production processes towards greater water efficiency. This study suggests that:

H1: The specialist firm is likely to develop dynamic capabilities for water scarcity mitigation

Acquiring these capabilities the specialist firm builds resilience to adapt to a constantly changing water constrained environment. Therefore:

H2: Developing dynamic capabilities, SCs of the specialist firm are likely to go through major structural changes e.g. relocation of manufacturing operations, dispersion of SCs, re-sizing of the manufacturing units

H3: When the specialist firm starts developing static capabilities it transitions to the generalist firm

H4: A specialist firm that continually develops static capabilities converts to a generalist firm that is likely to acquire a continuous improvement configurational pattern for its SCs

Generalist firms are companies that are building mitigation capabilities slowly over time, therefore this type of firm is not flexible and does not have abilities to quickly adapt their operations to more sustainable ones. Generally, these firms focus on various aspects of sustainability but not specifically on water.

H5: The generalist firm is likely to develop static capabilities in order to mitigate water scarcity risks

H6: Developing static capabilities, SCs of generalist firms are likely to go through continuous improvement e.g. lean, agile, leagile SCs

H7: When the generalist firm starts developing dynamic capabilities it acquires a new specialist form

H8=H2

When a firm faces extreme weather events, e.g. floods or droughts, it has to adapt very quickly employing already existing dynamic mitigation capabilities or developed extreme event driven capabilities.

H9: Facing extreme weather events, the specialist firm is likely to employ already existing dynamic capabilities or develop new extreme weather event driven capabilities

H10: Developed by the specialist firm, extreme weather event driven capabilities would likely spur major structural change within the SC

H11: The generalist firm facing extreme weather events is unlikely to acquire extreme event driven capabilities and as a result SC configurational change is unlikely to occur

The last hypothesis suggests that the generalist firm developing only static mitigation capabilities won't be able to mitigate extreme weather event consequences as existing static capabilities are too generic and are not able to cope with a specific level of water availability. Therefore, only the specialist firm with already existing dynamic capabilities or the ability to quickly develop extreme weather event driven capabilities is able to face extreme weather events. Such capabilities development is likely to result in a major structural change within the SC.

5 Conclusion and future research

Water scarcity mitigation capabilities development in SCs through the prism of evolutionary theory is an emerging area of SC research. This paper makes an attempt to bridge the gap in the SC capability model development literature by adapting strategies for water scarcity mitigation (Yatskovskaya and Srai, 2016) following an evolutionary process. The proposed framework is built upon three literature domains. Evolutionary theory literature, which posits the importance of changing environments on the firms' evolutionary behaviour and change, is applied to water a scarcity context in SCs. Water scarcity, emphasising the importance SC adaptation in order to sustain production processes from a long-run perspective, incorporates SC capability theory as a novel approach to adaptive behaviour and actionable knowledge development in order to sustain long and short term competitive advantages along with SC performance development.

The current study suggests that adapting to water scarce environments, the firm goes through an actionable knowledge development process following evolutionary steps leading to a transformational change. Based on this acquired knowledge, water stress mitigation capability building takes place, also following a three-step evolutionary process. As a result, firms develop dynamic, static, or extreme weather event driven capabilities. The study proposes that specialist firms are likely to develop dynamic capabilities and extreme weather event driven capabilities, while generalist firms will probably develop static capabilities failing to exploit extreme weather event driven capabilities. Notably, specialist firms developing dynamic capabilities are likely to follow major structural changes in their SC configurational patterns. Yet generalist companies building static capabilities are likely to follow SC continuous improvement processes.

As part of on-going research we aim to articulate a definition of organisational evolution tailored for SC configuration driven by a natural resource constrained environment, where the environment is represented not only by physical resource flows but also by information flows. As such, evolution presents mechanisms of enquiring and interpreting information about natural resource scarcity based on which actionable knowledge and capabilities are developed.

At this early stage of our research, there are two major limitations. First, the proposed theoretical framework illustrates the process of a firm's adaptation mechanism development and learning. However, the framework does not involve empirical testing applied to the field of SC configuration influenced by natural resource scarcity. Second, the proposed hypotheses that link firm types, capability forms, SC configurational patterns have also not been tested through empirical work. These limitations of the current work set premises for future research.

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Interest, design and assessment of Eco-Industrial Parks in China within a circular economy paradigm

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Abstract

This descriptive research addresses sustainability developments within circular economy (CE). Firstly, a 7R framework that provides an updated base to assess, develop and compare Eco-Industrial Parks (EIPs) was developed and preliminarily checked with secondary data from the Suzhou Industrial Park, which enables relevant benchmarking among EIPs all over the world. Secondly, different typologies of industrial parks in China provinces were analysed and related role changes were described. The 13th Five-Year Plan on National Economic and Social Development, called for the third generation of EIPs, as enablers of sustainability and balanced development of urbanization in an eco-city that combines industrial growth with city development. Therefore, Corporate, Consumer and Citizen Social Responsibility (coined as 3CSR) are attached to pursuing economic growth, social progress, and environmental sustainability. This research sets the scene for significant CE future developments, by leveraging the role of modern eco-cities through EIPs guided by a new conceptual model (7R).

Keywords: Sustainability; Circular Economy; Eco-Industrial Parks (EIP); Suzhou Industrial Park; Eco-City; Chinese Industrial Parks; 3R principles; 5R model; 7R framework; EIP Benchmarking; EIP design

1 Introduction

The world population have been suffering a very high cost of resource wastage and environmental deterioration due to excessive industrial production, such as depletion of water and energy, disruption of soil and plants, biodiversity reduction and greenhouse effect.

Economic-technological Development Zones, High-tech Industry Development Zones, National Demonstration Eco-Industrial Parks (EIPs), and New Development Zones have operationalised some of the actions pursued by central and regional governments of China to promote sustainable economic growth. In particular, EIPs have been emerging over the last decades based on both the industrial symbiosis and circular economy concepts. So, a first research question arises concerning the current interest for EIPs, i.e. if they still deserve a research effort in China, which has become the true "world plant", in 2012. Therefore, this paper will help to set the scene concerning the current role of EIPs, since that all kinds of industrial parks have played a great role as "policy pioneers" (Shi & Yu, 2014). In fact, after the quick development of urbanization in China that has been taking place over the past decade, it is getting more and more urgent to create a win-win relationship between economy and environment during urbanization process in an industrialized town (Yu et al., 2015a). So, one might be led to think if the EIPs still play a relevant role (vide also Xing et al., 2017b). Within this Past scenario, the Chinese Government initiated an ambitious national demonstration EIP programme in 2001 and some trial EIP programmes later on (Behera et al., 2012; Shi et al., 2012) to increase environment awareness in harmony with industrial growth. Therefore, there appears to be some successful experiences and, also, failure lessons to be learnt, because circular economy and sustainable development are increasingly getting of the public domain concern.

On the other hand, Circular Economy (CE) is the integration of activities of reduction, reuse and recycle during producing, exchange and consumption (Shen & Qi, 2012), which is essentially an ecological economy that requires human economic activities to be aligned with the 3R principle. It changes the traditional one-way linear economic model into the feedback closed loop mode of "resource – product – waste – renewable resource", which conforms to the concept of sustainable development. Thus, resources usage and environmental protection are more effective, while maximal economic and social benefits are simultaneously targeted (Ying & Zhou, 2012).

Moreover, the United States Environmental Protection Agency (US EPA) has defined an Eco-Industrial Park as a community of manufacturing and service businesses aiming at enhanced environmental and economic performance by close collaboration in managing environmental and resource issues. Thus, these traditionally independent entities are brought together into a cooperative physical exchange of materials, energy, water, and by-products. This constitutes the named industrial symbiosis that happens within the scope of a green infrastructure of scavenger companies located on the common property of a EIP (Chertow, 2000; Popescu, 2008; Valenzuela-Venegas et al., 2016). To sum up, a EIP is a type of industrial park, which is designed and constructed according to Cleaner Production requirements, Circular Economy concept and Industrial Ecology Theory. It also obeys to the 3R principle of Circular Economy (Holländer et. al, 2009). However, the 3R principle has developed to include either the ecosystem maintenance or even the need to repair a destructed ecosystem (Shen & Qi, 2012; Li et al., 2015). This raises a second research question about the possibility to upgrade this cornerstone principle of the Circular Economy (3R) and so, of the EIPs support. In fact, if one is interested either in developing an EIP, in assessing it, or even in comparing it, there should be a reasonably updated and supported framework to provide some guidance to the above mentioned exercises. So, the role of the 3R principles might very well be a gap aiming at further discussion. In this paper, a conceptual proposal was developed from this background and motivations, and preliminarily tested in a descriptive study. The starting point of the literature review was the analysis of the connotation of 3R and 5R related to circular economy. Then, an attempt to propose an innovative conceptual framework coined as the7R principle was made (vide also Xing et al., 2017a).

2 Literature review

2.1 Concept of Eco-Industrial Park

China has witnessed a rapid economic growth from "Reform and Open door" policy, in 1978. In the transition of almost 40-year economic miracle, China government tried a serial of methods to promote the development of all walks of life, including agriculture, industry and service, some of which really work very well and fulfil some economic goals. In order to promote economic growth, some attempts have been tried by central and regional governments of China, such as the Economic-technological Development Zone, High-tech Industry Development Zone, National Demonstration Eco-Industrial Parks, and New the Development Zone. All kinds of industrial parks have played a great role as "policy pioneers" (Shi & Yu, 2014). Nowadays, an increasing number of researchers and practitioners both in China and foreign countries are interested in such themes as circular economy and Eco-Industrial Park (EIP).

The concept of Eco-Industrial Park (EIP) by the United Nations Environment Program was introduced to China in 1997 (Hashimoto et al., 2010; Shi et al., 2010). EIPs are a new form of industrial organization based on industrial symbiosis and circular economies emerging from the extensive recognition of sustainable development proposed in the International Union for Conservation of Nature (IUCN). Industrial symbiosis concern the engagement of entities that are traditionally separated in a collective approach to gain competitive advantage by involving physical exchange of materials, energy, water, and by-products (Chertow, 2000). An Industrial Park can be classified as an Eco-Industrial Park (EIP) if the community of businesses cooperate with each other, sharing resources (Valenzuela-Venegas et al., 2016) and, leading to economic gains, gains in environmental quality and equitable enhancement of human resources for the business and local community" (Popescu, 2008). So, these businesses seek enhanced environmental, economic, and social performance through collaboration in managing environmental and resource issues, including energy, water, and materials. Moreover, hot topics like industrial symbiosis, industrial parks and Eco-Industry Parks (EIP) have drawn extensive attention rapidly as the route to promote Circular Economy (Chertow, 2000), which operationalises the concept of sustainable development.

EIP practices in developed countries, such as Denmark, USA, Germany, and Japan, have provided useful references for EIP development in China (Yu et al., 2015b). The State Environmental Protection Administration (SEPA) of China launched EIP pilot projects in Guangxi, Inner Mongolia, and Shandong provinces in 2001, and explored EIP planning and construction at the national level in 2003. In 2007, SEPA, the Ministry of Commerce, and the Ministry of Science and Technology jointly issued the Management Method for the National Demonstration EIP Program to facilitate the development of Chinese EIPs. Among these national demonstration of EIPs, the Tianjin Economic and Technology Development Area, the Suzhou Industrial Park, the Yantai Economic and Technology Development Area, and the Dalian Economic and Technology Development Area are popularly used as typical case studies for EIP construction in China (Yu et al., 2015). The research interest on China's EIP includes EIP management, material and energy integration, IS, planning methods, performance assessment, and low carbon development (Tian and Wei, 2012).

2.2 3R/5R Frameworks

The principle of reducing waste, reusing and recycling resources and products is often called the "3Rs". Dhaka (2010) argues that (i) reducing means choosing to use things with care to decrease the amount of waste generated; (ii) reusing involves the repeated use of items or parts of items, which still have potential for use; and, (iii) recycling means the use of waste itself as a resource. In addition, Ying & Zhou (2012) explains that (i) reduce means reducing the amount of substance in the process of production and consumption; (ii) reuse is involved in extending the time intensity of product and service; and, (iii) recycle focuses on the regeneration of renewable resources after use. The 3Rs is sometimes called the waste hierarchy (Dhaka, 2010), because it sets an approach to address waste in order of importance. The waste hierarchy classifies waste management strategies according to the desirability of each R. Waste minimization can be achieved in an efficient way by focusing primarily on the first of the 3Rs, "reduce," followed by "reuse" and then "recycle." The waste hierarchy has remained the cornerstone of most waste minimization strategies. The aim of the waste hierarchy is to extract the maximum practical benefits from products and to generate the minimum amount of waste (Global Environment Centre Foundation, 2006).

A basic connotation behind the first R (reduce) is to limit the amount of energy consumption, the number of purchases or the amount of waste generated. The core meaning of the second R (reuse) involves the repeated employment of items, or of usable parts of them, as much as possible, before replacing them, and the third R (recycle) means ensuring the circular utilization of products and components, or transferring waste into resources and energy by the adoption of new technology and techniques.

There are some methods to achieve the goals of 3R and fulfil circular economy, in order to decrease the amount of natural resources used and, to cut down the amount of waste generated and disposed. This kind of measures can be efficient. Examples are as follows: changing the design of the product or the production process, extending the product life cycle by improving repair and maintenance technologies, or decreasing the volume of waste discharge. Reuse can be achieved by

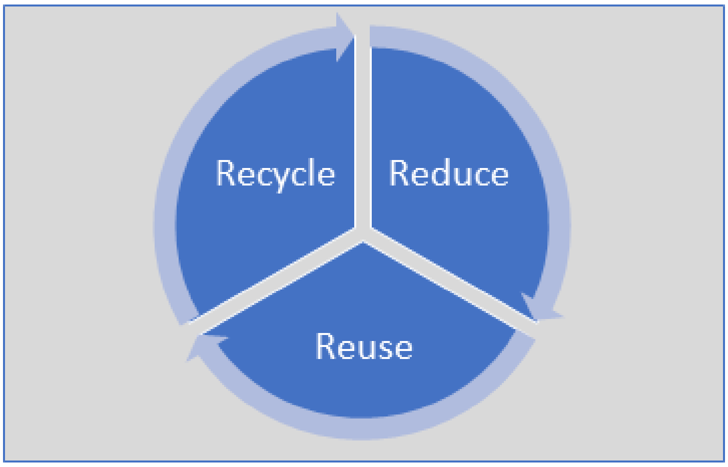

Figure 1 – Illustration of 3R principles

repeatedly using products with proper maintenance and storage. At the same time, Recycle can be fulfilled by appropriate share and also, by integrated industrial symbiosis. One product or parts of a manufactured component could be the resource or raw material of another one; this means to achieve recycle by exchanging physical materials, energy, water, and by-products among a serial of companies, as it happens, for instance, in the Kalunborg Eco-Industrial Park in Denmark, the first EIP in the world. The three keywords of 3R principle are correlated rather than separated. A simple illustration, in Figure 1, shows their circular and dynamic relationships.

In addition to the basic 3R principle, there are some other keywords contributing to circular economy such as rethink, recover, rescue, or repair. Shen & Qi (2012) hold a view that 5R principle appears with the addition of "to rethink towards the maintenance of ecosystem" and "to repair the destructed ecosystem". Li et al. (2015) regard 5R spirit in the life-cycle of the production process, as “Recycling, Reducing, Reusing, Recovery of Energy, and Reclamation of Land”. Generally speaking, besides the 3R principle, the remaining two Rs in 5R refer to "recover" and "rethink". Recover refers to the practice of putting waste products to use. Rethink, which is the last R, is sometimes added to the front of the waste hierarchy, meaning that people should consider their options and think about their impact on the environment. For example, decomposing garbage produces methane gas (one of the greenhouse gases), which some landfill sites recover and burn for energy rather than letting it dissipate. Felicio & Amaral (2013) suggest that EIP have been seen as an opportunity for companies to reduce their waste, recover values and achieve economies of scale, in their production processes. Nevertheless, some researchers refer the fifth R as to rescue, and argue that the recycling-based technologies should be promoted and implemented in EIP (Li et al., 2015). Figure 2 is an illustration of 5R principle (reduce, reuse, recycle, recover and rethink). From an innovative perspective, rethink is not a parallel keyword with others, because rethink means not only being aware of the impact any human behaviour on the environment, anytime and anywhere, but also making sure to reconsider all other Rs. That is why the area of rethink in this figure is a little bit overlapped to each of other keywords. To be more specific, Reduce can imply decreasing any physical items and curtail inefficient production activities, as well as, high energy consumption; Reuse can imply utilizing products and sharing goods at their most; Recycle refers to material recycle, substance recycle, energy recycle, application recycle and data recycle, etc.; Recover alludes to the resilience that we will analyze in our innovative proposal. So, among the 5R principle, the most important is to rethink holistically in an all-around way.

2.3 Proposal of an Innovative Conceptual Proposal – the7R Framework

Circular Economy is essentially an ecological economy, which requires human economic activities in line with 3R and 5R principles. It is Circular Economy that further strengthens the consciousness of both resources conservation and environmental protection, thus promoting the implementation of the strategy of green supply chain management and the popularization of EIP. EIP design is based

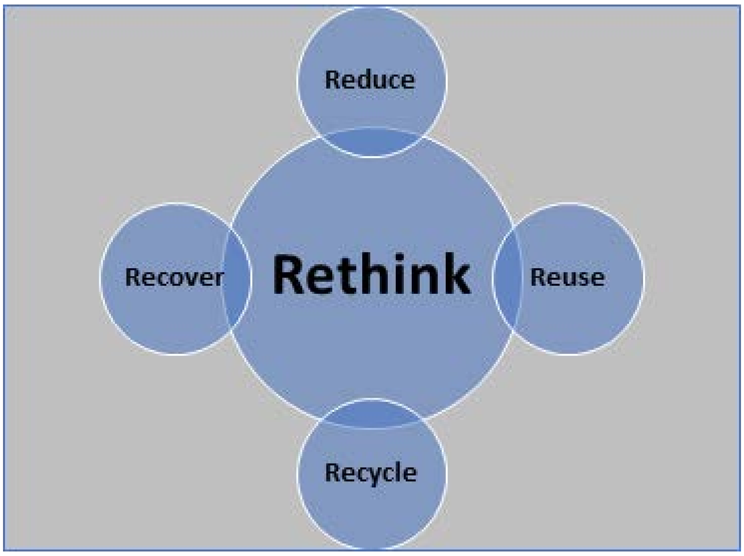

Figure 2 – Illustration of 5R principles

on the requirements of clean production, principles of circular economy and industrial ecology. It is composed of the enterprises inside the EIP, namely on the material and energy flows among the enterprises maintaining industrial symbiosis by means of shared resources and exchanged by-products. The goal of an EIP is to seek: (i) loop-closing circulation of material, (ii) multi-level energy utilization and (iii) waste minimization, by simulating the natural ecological system and establishing "producers-consumers-decomposers" circulation path in the industrial system (Li & Xiao, 2017). So, in this sense, 5R is still not enough. As is shown in Figure 3, the illustration of 7R principle proposal, two more Rs are introduced, i.e. Resilient and Regulate, respectively.

Resilience is the ability of a system to respond to change. Indeed, comprehensively analysing the possible perturbation process is crucial for developing adaptive capacity from both the topological structure and ecological feature in an EIP. To track the resilience progress in an EIP, not only snapshot analysis, but also time trend need to be followed, in order to develop novel mechanisms to avoid disruptions, improve the resilience of EIP and safeguard (Li & Xiao, 2017). As it is shown in "Transforming our world: 2030 Agenda for sustainable development" (Zachariah et al., 2016), the 9th of 17 sustainable development goals, addresses the development of a resilient infrastructure, the promotion of inclusive and sustainable industrialization and fostering innovation. The literal meaning of "resilient" is returning to the original form or position after being bent, compressed, or stretched. So, in the context of circular economy, "resilient" means the internal capacity of recovering from the depletion situation of resources and energy. On the other hand, "Regulate" refers to the necessary management, adjustment, control or enforcement from the government side, among others. For example, the following might be enumerated: some laws and regulations from the state and local governments, some conventions and proposals from trade associations, some suggestions and supports from non-profit sectors and some supervision and urges from mass media.

As it is shown in Figure 3, Regulate or Regulation is seating in the centre of the schematic diagram, and it causes an impact to all other Rs, because in our opinion, regulation is a pivotal driver to exert the efficiency of an EIP and circular economy, as well. Especially in developing countries, all other Rs can be a failure, if regulation is absent. EIP do work more efficiently under proper regulation and management from a holistic perspective. The proposed framework of 7R principle will be analyzed and demonstrated by the following case study on Suzhou Industrial Park, one of the most successful EIP, in China.

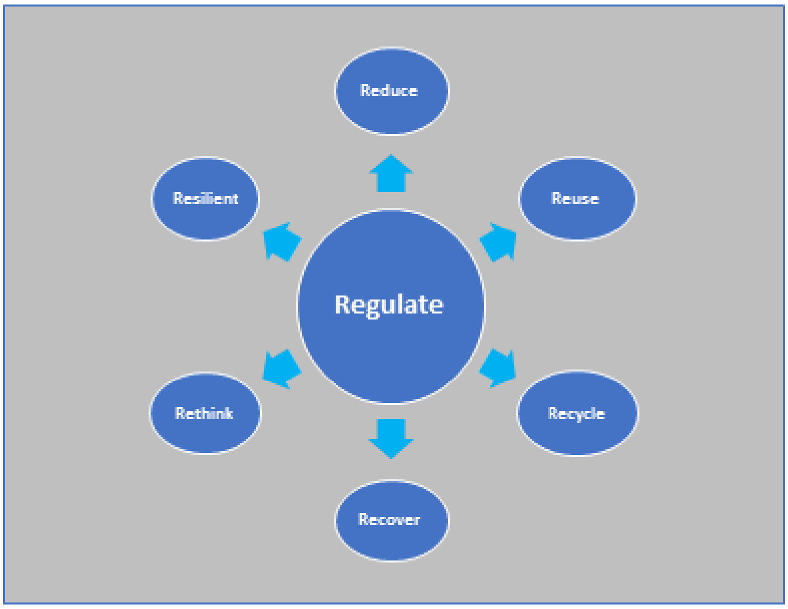

Figure 3 – 7R principle model proposal

3 Research methodology

This paper follows a descriptive methodology. As regards the first research question (RQ 1), aiming at finding out *if the EIPs still deserve a research interest and effort in China*, secondary data from the data centres of EIPs administration departments in China, Ministry of Environmental Protection, Ministry of Commerce and Ministry of Science and Technology of People's Republic of China were used. After being treated and refined in tables to facilitate the readers' understanding about the initial EIPs interest and its current status quo, some lessons were learnt and suggestions for future sustainable development were made.

The second research question (RQ 2), is aiming at promoting the *upgrade of the 3R principle of the Circular Economy to enable an updated base to assess, develop and compare EIPs*. Thus, a 7R conceptual framework is deducted from a literature review. Then, a descriptive case study will conceptually apply and test the deducted framework within the scope of the Suzhou Industrial Park (SIP). Thus, the performance of SIP in applying ideas and methods of circular economy is preliminarily appreciated. Secondary data from the official website of SIP (www.sipac.gov.cn) are used to check if the SIP practices follow the principles established by the 7R framework that is being proposed. The scope was delimited to a very few representative organizations in SIP, for the convenience of this preliminary qualitative analysis.

4 Empirical research

4.1 Understanding the Progress of EIPs in China (RQ 1)

From 1984 to 1988, Chinese industrial parks were first built in the eastern coastal areas, such as Tianjin, Yantai, Shanghai, and Guangzhou. After several decades, the number of industrial parks was at least 1568 in 2011 (Yu et al., 2015b). In the same year, the gross domestic product (GDP) growth rate of industrial parks (30.3%) was significantly greater than that of the national average (9.2%) (Yu et al., 2015b). Thus, industrial parks became one of the major contributors to the economic growth in China. Despite early environmental pollution control actions and management measures (such as end-of-pipe pollution control approach and environmental impact assessment), they have been unable to ease the environmental pressure caused by the high economic development of industrial parks. Thus, some parks have paid severe resource and environmental costs (Yu et al., 2015). The Chinese government has adopted the EIP program in the hope of benefiting both the economy and the environment, in order to solve the contradiction between economic development and environmental pollution. At the national level, the issue of Circular Economy (CE) was officially considered in the government decision-making agenda in 2003, and CE development was brought into the National 11th Five Year Plan in 2005. A series of policies about CE pilot city and parks establishment were published to promote CE development (Yu et al., 2015).

Kennedy & Johnson (2016) point out that The Draft Outline of China's 13th Five-Year Plan on National Economic and Social Development highlights that China should focus on improving environmental quality and solving prominent eco-environmental problems, devote greater efforts to eco-environmental protection, enhance the efficiency of resource utilization, provide more high-quality green products to consumers, and promote Chinese people’s well-being and prosperity in a beautiful China. The Draft Outline proposes: (i) to strengthen integrated environmental governance, to innovate in terms of concepts and methods of environmental governance, to carry out the most stringent environmental protection system, emphasize polluter's liability, to establish a co-governance system for government, enterprises and the public, and generally to improve environmental quality; (ii) to fully implement the action plans on pollution prevention and control, to mitigate against environmental risks, to strengthen the development of environmental infrastructure, and to reform the fundamental systems in environmental governance. The Draft Outline also proposes (i) to strengthen ecological protection and remediation, to give priority to the protection and restoration of nature, to facilitate the protection and remediation of natural ecosystems, to establish ecological corridors as well as biodiversity conservation networks, to comprehensively enhance the stability and the capacity of natural ecosystems to provide services, and to construct sound ecological security barriers; (ii) to comprehensively enhance ecosystem functions, to promote ecological remediation of key areas, to increase the supply of green products, and to preserve biodiversity. Finally, the Draft Outline proposes (i) to foster the green industry and the environmental protection industry, to support the development of service providers, to promote energy-saving and environment friendly products, to support innovation for technical equipment and services, to improve policies, to facilitate the development of the energy-saving and environmental protection industry; (ii) to increase the supply of environmental protection products and services, and to develop technical equipment for environmental protection, according to the Ministry of Environmental Protection of the People’s Republic of China (www.mep.gov.cn).

To sum up, the evolution of the EIPs in China can be divided into three stages: (i) stage one is about twenty years from 1980s to 2001; (ii) stage two is the period between 2001 to 2015; and, (iii) stage three, is from 2015 on (Table 1).

In the first Stage, Chinese government started to set up a serial of Economic- technological Development Zones and high-tech industry development zones under the background of Reform and Open door policy from 1978, Reform of the Economic System from 1984 and the exploration of institutional innovation, market mechanisms, technology and economic growth during those twenty years. The goals of these activities can be broadly summarized as attracting foreign investment through industrial projects, improving export, and promoting manufacturing industry, hi-tech and high added value. All these development zones are the sound background of EIPs in China, even though most of them are not called with a name of Eco-Industrial Parks. Almost all development zones kept the original names after they were approved as demonstration EIPs.

For the second stage, the symbol is the ambitious national demonstration of EIP programme initiated by Chinese government in 2001 and some trial EIP programmes, later on. People recognized the unsustainable limitation of natural resources and, also, the disruption of the ecosystem caused by industry development, so the goal of setting up EIPs is to explore and coin new economic development modes with keeping balance in economic growth, social development and environment protection.

With the release of China's *13th Five-Year Plan on National Economic and Social Development*, it comes to the third stage of EIPs, in China, with the expansion of resources consumption and the aggravation of environmental decay, coupled with increasing urbanization, rising population size in almost all big and medium sized cities in China. It seems hard to focus on accelerating economic development only by considering EIPs themselves and neglecting environmental concerns. In order

Table 1 – Timeline and characteristics of China's industrial parks

Three stages	Forms of industry parks	Background	Goals
From 1980s on	• Economic-technological Development Zone • High-tech industry development zone	• "Reform and Open door" policy in 1978. • Reform of the economic system in 1984 • Exploration of institutional innovation, market mechanisms, technology and economic growth	• Attract foreign investment through industrial projects • Improve export • Promote manufacturing industry, hi-tech and high added value
From 2001 on	• National Demonstration Eco-Industrial Parks	• Keep economic growth, social development, and environment protection • Natural resources limitation	• To coin demonstration economic development modes with high energy efficiency and industrial symbiosis
From 2015 on	• New district • Eco-city	• Urbanization • Environmental concerns	• To pursue sustainability and balanced development

to pursue sustainability and balanced development Chinese government had to combine industrial growth with city development, so the concepts such as new district and eco-city are put forward (third stage). A lot of EIPs are located in the new district of a city, for instance, the Huayuan Technology Park is located in Tianjin Binghai New District. Suzhou is called an eco-city, with the first and recognized most successful EIP of China, Suzhou Industrial Park and Suzhou High-tech Industrial Development Zone in Suzhou city. The policies of planning and designing new district and eco-city can impose a considerable impact on both the operation of EIP and the development of the city. As is shown in Table 1, the timeline of three stages, main characteristics of China's industrial parks, backgrounds and goals are listed by and large.

4.2 Status quo of EIPs in China

According to the official website of the Ministry of Environmental Protection of the People's Republic of China (www.sepa.gov.cn), the latest published list of eco-industrial parks in China shows a total of 48 National demonstration EIPs approved since their start in 2001 (Table 2), and of 45 National EIPs that are still under assessment and improvement (Table 3).

Based on the secondary data shown in Tables 2 and 3, some analysis is conducted and depicted in Figure 4. In order to facilitate the analysis, both approved and under assessment national demonstration EIPs are equally treated. So, the total amount of EIPs is 93. As a matter of fact, most of the EIPs under assessment were approved four or five years ago, even far back to 2001, e.g. the Guigang Sugar Industry National Eco-Industrial Park. From these two figures, it is obvious that : (i) only in Jiangsu province, there are 30 EIPs, which are almost one third of the total; (ii) most EIPs are located in the East of China; (iii) the total of Jiangsu, Shandong, Shanghai and Zhejiang together is 58, which accounts for 62.4%; (iv) by calculating all coastal provinces and cities of Eastern China, Tianjin, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong respectively, the total amount reaches 68, which represents a proportion of 73.1%. This means the EIPs are highly concentrated in Eastern China. Among the four municipalities directly under the Central Government, i.e. Beijing, Shanghai, Tianjin, and Chongqing, there is no EIP in Chongqing so far, and only one EIP in Beijing. At the same time, there still are some other provinces without EIPs such as Heilongjiang, Henan, Ningxia, Qinghai, Tibet and Hainan. This means a very unbalanced situation; on the whole there are very few Eco-Industrial Parks in the Central and Western areas of China.

Table 2 – Extract of the list of approved National Demonstration EIPs in China

National Demonstration EIPs	Approved date	Province
1.Suzhou industrial park	Mar 31 2008	Jiangsu
4.Yantai economic and technological development zone	Apr 1 2010	Shandong
12.Shanghai Jinqiao export processing zone	Apr 2 2011	Shanghai
15.Nanjing high-tech industry development zone	Mar 19 2012	Jiangsu
19.Shandong Guxiangguang Eco-industrial park	Feb 6 2013	Shandong
23.Shenyang economic and technological development zone	Jan 10 2014	Liaoning
34.Ningbo economic and technological development zone	Jul 31 2015	Zhejiang
48.Changchun Car industry economic and technological development zone	Nov 29 2016	Jilin

Table 3 – Extract of approved under assessment National Demonstration EIPs in China

National Demonstration EIPs	Approved date	Province
1.Guigang sugar industry national eco-industrial park	Aug 14 2001	Guangxi
2.North Lu corporation group company	Nov 18 2003	Shandong
3.Nanchang high-tech development zone	Apr 1 2010	Jiangxi
8.Taiyuan economic and technological development zone	Apr 2 2011	Shanxi
11.Guangzhou Nansha economic and technological development zone	May 30 2012	Guangdong
13.Qingdao economic &technological development zone	Feb 5 2013	Shandong
24.Langfang economic and technological development zone	Oct 14 2014	Hebei
45.Changsha high-tech development zone	Sep 21 2015	Hunan

4.3 *Preliminary Descriptive Test conducted in the Suzhou Industrial Park (RQ 2)*

The Suzhou Industrial Park (SIP) was established in 1994 and is a flagship of the economic cooperation project between Chinese and Singapore governments. It is located in the Eastern part of Suzhou, a city known as "the paradise on earth". Suzhou is also a traffic hub, about only 200 km of Nanjing, and around 100 km of Shanghai. It takes only 20 minutes to arrive in Shanghai and 45 minutes to Nanjing by high-speed train. With an advantageous transportation network, it appeals to more and more big enterprises and global talents. SIP covers a total jurisdiction area of 288 km2, among which, 80 km2 area belongs to China-Singapore Cooperative Zone. SIP is recognized as a pilot zone of reform and opening-up, a successful model of international cooperation, and one of China's fastest-growing development zones with the most international competitive edges. In SIP, the total number of permanent residents reached over 700,000 in 2012, including registered and non-registered population. Currently, approximately 25% of the land is industrial, and 30% is residential and commercial. The remainder is green space and water (Yu et al., 2015b). Nowadays, the development goals of SIP are to develop into a hi-tech industrial park with international competitiveness and, into an innovation eco-township of internationalized, modernized, information-based happy district of Suzhou (www.sipac.gov.cn).

4.4 *Achievements of the Suzhou Industrial Park (SIP)*

Concerning the performance in environment protection, SIP obtained the label of ISO 14000 National Demonstration Zone, in 2001. As the national EIP program was launched, SIP was approved as a pilot in 2004 and started to implement EIP planning in accordance with the national EIP development guideline. In 2008, SIP passed the evaluation and obtained the label as one of the first three National Demonstration EIPs. Currently, the energy consumption per GDP is 61% lower than the national level. The discharge amount of Chemical Oxygen Demand (COD) and SO2 are only one-eighteenth and one-fortieth of the national average, respectively. SIP is among the first national Integrated Resource Planning (IRP) demonstration parks, among the country's first demonstration

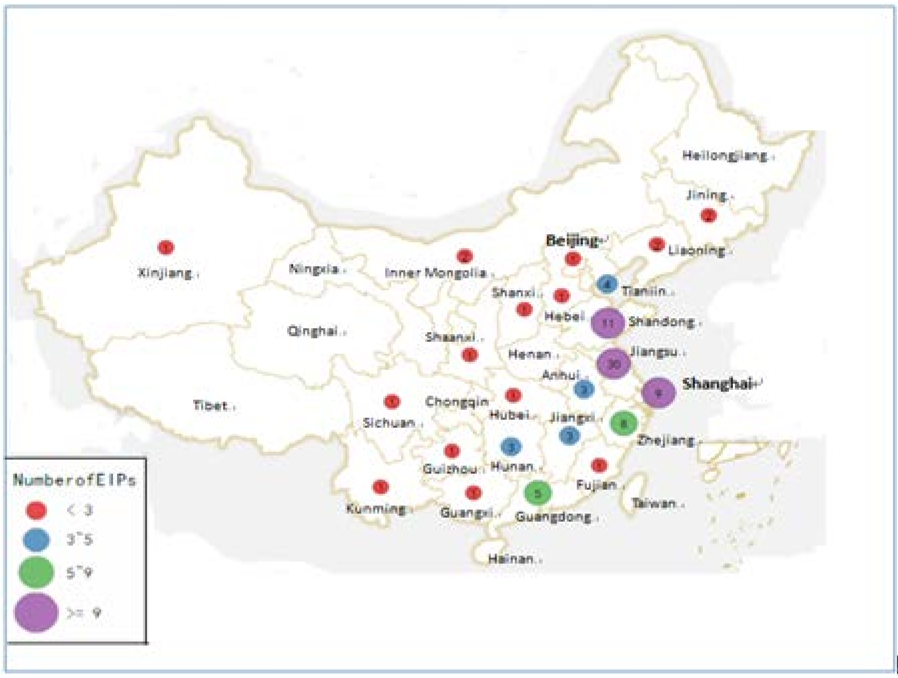

Figure 4 – Distribution of EIPs in China

eco-industrial parks, and among the first new-type industrial demonstration bases in China (www.sipac.gov.cn).

With respect to annual economic growth in SIP, 30% annual average growth occurs in key economic indicators, ranking second among national development zones in comprehensive development indexes. It accomplished four "Hundreds of Billions" of achievements, as follows: RMB 133 billion of GDP, RMB 165 billion of accumulated taxes, USD 18.9 billion of accumulated utilized foreign capital and RMB 197.2 billion of accumulated registered domestic capital. Besides that, there also are remarkable achievements in economic transformation and upgrading, as follows: RMB 147.2 billion of output value from new emerging industries, in 2010, accounting for 45.4% of scale industries ranking the first in Suzhou and, ranking the first, for years, in using foreign capital, among China's development zones (www.sipac.gov.cn).

As far as sustainable development is concerned, SIP achieved many awards. For example, it was recognized as China's only new-tech innovation & industrialization base, as China's only demonstration base of service trade innovation, as China's only national demonstration area of business tourism, no.1 among most competitive development zones, as China's first service outsourcing demonstration base and, as China's first experimental area on preferential policies for technologically advanced service enterprises (www.sipac.gov.cn).

4.5 7R principle application in SIP

When observing SIP, there is a large amount of exemplary enterprises, which conduct very good practices, in environmental protection and sustainable development, corresponding to each component of 7R principle, namely reduce, reuse, recycle, rethink, recover, resilient and regulate. Here we provide some supportive examples, analysis and beneficial implications, as follows.

Reduce: In SIP, it is obvious that there is a great amount of reduction on energy consumption. According to the official website of SIP, currently, the energy consumption per GDP is 61% lower than the national level. SIP learns from the experience of Singapore and adopts high standards in promoting energy-saving circular economy. In 2012, SIP recorded 0.28 ton of standard coal for producing 10,000-yuan GDP, with 0.149 kg COD, releasing 0.07, 0.008, and 0.151 kg of sulfur dioxide, ammonia, and nitrogen oxides, respectively. These are above national averages and made SIP the leader among national development zones, for four consecutive years, in the main indicators of environmental protection, energy conservation, and emission reduction (www.sipac.gov.cn).

Reuse: The SIP management has organized some representatives to learn from companies with outstanding performance in practicing Corporate Social Responsibility (CSR). For example, Fuji Xerox Eco-Manufacturing (Suzhou) shared with the participants the company's experience in recycling and reusing resources. From its establishment in January 2008, the company has been recycling the waste, copying machines, printers, and consumables as printing drums and powders from Chinese mainland, to make full use of resources and reduce their impacts on environment. The company, therefore, won the honorary title of SIP CSR Company 2013 (in the category of "Environment Responsibility") and was named "Model Company of Circular Economy" by Suzhou Economic and Information Technology Commission in 2014 (www.sipac.gov.cn).

Recycle: Green production has been part of corporate culture among most manufactures, in SIP. Nitto Denko (Suzhou), which is a member of Suzhou Industrial Park, since its founding in 2001, launched a clean production program, investing in energy-saving and emission-cutting projects. Their aim was bringing down energy consumption and waste water discharge. The company renovated the entire AC system and, as a result, saves 2.35 million kw annual use of electricity power and 8,000 tons of steam, which equals to 1,716.1 tons of standard coal. In order to save the water resource, the company recycles steam condensate and reclaimed water. Every year, the steam reused amounts to 420 tons (47 tons of standard coal) and the water recycled totaled 27,000 cubic meters (2.3 tons of standard coal) (www.sipac.gov.cn).

Recover: In order to optimize the regional environmental to build a beautiful SIP, for years, SIP has kept investing in environment-related infrastructure to improve the monitoring system and to use energies to their full potential. With 100% coverage of sewage pipe network, it manages to achieve Grade-1, a standard for all the waste water discharged. Moreover, the waste water treatment plant, the sludge drying plant, the thermal power plant, and the heating & cooling center create an integrated system maximizing the use of public amenities, resources, and energies as well as minimizing the discharge of pollutants. The efforts include the protection of the Yangcheng Lake, the source of potable water, 45.8% coverage of green grounds, surveys on biological diversity and ecological environment with 131 bird species being confirmed around the year, the river dredging projects, and the restocking of aquatic organisms in Jinji Lake (www.sipac.gov.cn).

Rethink: Taking Nitto Denko (Suzhou) as an example, the company introduced a lot of programs to stimulating rethink, among which "Green Design Action", which encourages employees to build up the belief that environment protection should become a part of its corporate culture. With the "Light Down" program, the employees are required to turn off their computers during lunch break. The company also regulates the AC (air-condition) temperature and arranges people to be in charge of lights and AC. The workshops should follow the plans and turn off the production equipment not in use. The company also participates in the "MOTTAINAI Campaign", a program aiming to promote environment awareness and to cultivate sense of responsibility among employees. The survey shows that the average awareness increased from 73.1% to 80.2%, which is transformed into a reduction of 11,557 kg of carbon dioxide emission (www.sipac.gov.cn).

Resilient: The Administrative Committee of the Suzhou Industrial Park has been calling on companies to work together to build SIP into a model of ecological civilization through Learning and Innovation. The committee often organizes all kind of forums. For example, there is a forum, which is part of the agenda for China International Green Innovative Products & Technologies Show (CIGIPTS). Enterprises are encouraged to contribute in building ecological industrial parks through international cooperation, and to demonstrate their achievements in exploring a new path of industrialization through technological innovation and low-carbon environment-friendly circular economy.

Regulate: Chinese Governments (both central and local) play an essential role in improving the performance of EIPs, especially when it comes to the integration and balanced development of industrialization and urbanization. In order to secure economic sustainability and optimize industrial structure to promote sustainable low-carbon economy, SIP authorities have vetoed down more than 400 projects totaling approximately 3-billion-dollar investment, which posed potential high hazards to surrounding environment. SIP government carried out energy auditing on 74 companies and set a record of 310 million RMB Yuan from local enterprises invested in technological renovation projects, cutting down energy consumption by 100,000 tons of standard coal. The enterprises are also encouraged to reuse water and wasted heat, to conform to standards on clean production, to invest in upgrading and renovating technologies and equipments, and to make a constant goal to reduce pollutant discharges. Meanwhile, SIP Eco-Science Hub and Suzhou Environmental Protection Sci-tech Industrial Park have contracted over 100 energy conservation and environmental protection companies, including Sujing and Great, with total output of 30 billion Yuan. SIP has three air monitoring stations and other two under construction, as well as three stations monitoring water quality and one under construction, which make possible to achieve real-time online monitoring and the releasing of PM2.5, PM1, and ozone, among 135 other atmospheric factors. 62 companies, including all key companies in the area, have installed 72 sets of automatic devices in total for online monitoring of pollution sources (www.sipac.gov.cn).

5 Expected results and contributions – setting the scene for the future

In this section the research questions are going to be revisited and the report will be closed on them.

RQ 2: Does the upgrade of the 3R principle of the Circular Economy to the 7R Framework enable an updated base to assess, develop and compare EIPs?

Holistic balance and sustainable development are getting more and more critical, in order to maintain the three bottom-line pillars, namely economic, social and environmental. When retrospecting the evolvement of these principles from 3R (reduce, reuse and recycle) to 5R (reduce, reuse, recycle, recover and rethink) and then, to the innovative conceptual framework of 7R principle (reduce, reuse, recycle, recover, rethink, resilient and regulate), it is safe to conclude that the 7R principle is essentially pivotal to practice circular economy and sustainable development. That is to say, all participants including enterprises in the supply chain, governments from different levels, local trade associations and consumers can get involved and shoulder responsibility by applying the 7R principle. Both Corporate Social Responsibility, Consumer Social Responsibility and Citizen Social Responsibility – coined in this paper as 3CSR – should be attached to pursuing economic growth, social progress, and environmental sustainability, as well. As a matter of fact, individuals can vastly contribute to protect the Earth by consistently practising 7R in many aspects and in a variety of ways.

To sum up, this preliminary confirmatory study tries to be inspiring to current research in the area of circular economy. In fact, the conceptual 7R principle proposal can be an adventurous attempt for pursuing theoretical efforts in the nR domain (e.g. 3R and 5R). For researchers, this is also a nice attempt to stimulate more systematic and systemic thinking. Finally, for practice, Suzhou Industrial Park is just an exemplary model to set a relevant benchmark among hundreds of EIP all over the world. Moreover, it will be significantly desirable if there is an increasingly number of industrial parks to introduce the 7R principle as an assessment framework.

RQ 1: Do EIPs still deserve a research interest and effort in China?

Chinese government had recently to combine industrial growth with city development, in order to pursue sustainability and balanced development, so the concepts such as new district and eco-city have been put forward, lately. Thus, the policies of planning and designing a new district and an eco-city can impose a considerable impact on both the operation of EIP and the development of the city. Although the performance of EIPs in China is highly recognized, there are still some obvious shortcomings, namely: (i) the failures regarding employee participation, (ii) the support from ordinary citizens, and (iii) the deficiency of overall planning from the different levels of government.

In addition, EIPs are highly concentrated in Eastern China. For example, the total amount of EIPs in Jiangsu, Shandong, Shanghai and Zhejiang is 58, which accounts for 62.4%. At the same time, there still are some other provinces without EIPs, such as Heilongjiang, Henan, Ningxia, Qinghai, Tibet and Hainan. This means a very unbalanced situation, as follows: on the whole there are very few Eco-Industrial Parks in the central and western areas of China.

As a consequence, there still is room for development, as regards EIP improvement and spread. Nevertheless, EIP performances also result from government policy guidance and advertising. Therefore, Chinese Governments (both central and local) play an essential role in improving EIPs' development, especially when it comes to the integration and balanced development of industrialization and urbanization. Thus, a new concept of EIP linked with the concept of eco-city is emerging, which reinforces the interest on EIPs.

On the other hand, the requirements to learn from other mature circular economy modes from developed countries (i), to enact more feasible laws and legislation (ii), to enhance the advertising of some concepts related to circular economy and sustainable development (iii), to encourage more engagement from all kinds of enterprises and companies (iv), to arouse vast environmental and circular economy awareness from urban citizens (v), to introduce more advanced technology & methods (vi) and, to conduct more scientific urban planning and construction (vii) call for an extended conceptual framework, i.e. the 7R model. This will enable the positioning of the problematic in a more systematic, systemic and organised way, in order to describe, analyse, assess, benchmark and discuss it to find out paths of future development.

Indeed, future research on the theme of EIP and in-depth theoretical exploration is worthy of much more effort by following the novel approach reported on this paper – i.e. the 7R framework – which informs organisations, society and state owned institutions to best configure circular supply chain networks to achieve viability under the umbrella of the 'triple bottom line' of sustainability. Therefore, despite some obvious limitations during this study are identified, such as the lack of primary data and the need for a more detailed and structured field study, the scene for future developments concerning circular economy was set in a significant way.

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Consumer-centric food supply chains for healthy nutrition

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Abstract

Digital technology, cutting-edge research and innovation are constantly shaping the supply chain arena. Despite these developments and the increasing social-sustainability concerns, the active role of the consumer in the supply chain still needs further consideration. Nutritional and food safety alarms (e.g. obesity, malnutrition, food crime) prioritise food supply chains in this context. The current work explores the key parameters required to bring consumer in the centre of the food supply chain. The proposed concept aims to bridge the available, yet sporadic tools towards an authentic and pragmatic consumer-centric food system. Mainly it constitutes the foundation of a roadmap for further research in the field of supply chain.

Keywords: Consumer, conceptual framework, digitalization

1 Introduction

Numerous researchers and different organizations have defined supply chains over the time, focusing on diverse angles e.g. flow of materials and information from suppliers to end users (Christopher, 1998), all stages in fulfilling customer request (Chopra and Meindl, 2006) and so on. Essence in every approach is the involvement of every stakeholder from production to consumption, the most of the times with a special focus on the consumers, as they are the end-users of the products or services handled by the SC. Similarly, from a supply chain management concept perspective the entire supply system should satisfy the customers' needs (Burgess, Singh, and Koroglu, 2006; Sigala, 2014; Storey, Emberson, Godsell, and Harrison, 2006). To that effect, literature on sustainable supply chains also emphasises on the significance of consumers, mainly through the social pillar (Seuring and Müller, 2008).

All the above are perfectly fine on a theoretical and academic basis, reality check on the other hand shows that this is not the case. Both academic publications (Anderson, Britt, and Favre, 2007) and business insights (Bapna, 2012) show an overall focus on economic efficiency and profit. Even the sustainability approach that seems to focus, among others, on environmental aspects of the SC eventually associates any such improvement with a better economic performance (Golicic and Smith, 2013; Philip and Stefan, 2014). Over and above, the most provocative consideration is that SC, in some cases, does not just operate against end-users' needs, but even against their health. This could be due to lack of cooperation among SC stakeholders (e.g. manufactures – consumers), problematic integration of key SC processes and myopic view on specific tiers and not on the entire chain.

For example, the vast majority of processed food products contains large quantities of salt and sugar. From a business and manufacturing perspective this is a win-win, since both ingredients serve as flavour boosters and preservatives. However, from a consumers' health standpoint this strategy is not that innocent; excessive consumption of these ingredients has been associated with several health problems (MacGregor and Hashem, 2014). An even more extreme example illustrating the "*profit over people*" scenario is the recurrent food scandals: horse meat (Levitt, 2017); eggs-fipronil (Roberts, 2017); pork-hepatitis (Gander, 2017).

Consequently, consumers developed serious concerns against the food system and its supply chain. Tackling these issues requires not only to ensure transparency in the SC and regain consumers' trust, but also to reconfigure the entire supply food system to support and promote a healthier nutrition. The proposed conceptual framework analyses the current situation from a supply chain perspective, outlines the desired status of the food system and proposes research required to cover the gaps in order to combine the available solutions towards business readiness.

2 Gap analysis

In business strategy, GAP analysis employed to assess the current situation and compare it with the desired one. Similarly, from research methodology perspective in the field of supply chain management GAP analysis has been adapted (Kotzab and Westhaus, 2005), for example to assess the quality of service in supply chain (Nitin, Deshmukh, and Prem, 2006; Parasuraman, Berry, and Zeithaml, 1991). The approach of this paper follows the exact same logic, applied not in full spectrum but in selective yet crucial subjects and cases. The desired status of the food system is well-defined by initiatives and guidelines from WHO, FAO and EU. Their common denominator is towards a future food system that will eliminate malnutrition, provide healthier nutritional options (i.e. less calories, less slat, less sugar) and ensure food safety. Thus, the focus of this analysis is on the current situation and the SC interventions as a roadmap to achieve the desired status.

On an academic basis, there are available several solutions on this matter: concepts; frameworks; tools; reconfigurations; evidence-based implications; policy-making mediations (examples Table 1). Nevertheless, no matter how reliable, applied and innovative these solutions are, from a food system approach point of view they are still considered fragmented. Boundaries due to product/process specific design, sample/data/method and focus limitations do not allow any attempt to generalize or combine in a wider -food system approach- application.

Similarly, at a business environment there are sporadic practical best-practices, applied from just one company and/or in a specific region (see examples Table 2). However, the biggest concern is to what end each and every solution/tool is used for. The company's agenda or manager's objectives could manoeuvre the orientation and eventually the final goal of a well-designed tool. For instance,

Table 1 – Examples of academic and research based solutions

Solutions	Integration and end-to-end application limitations			
	SC echelon	*Product/industry*	*Focus*	*Other*
SC ecosystem mapping, E2E processes and strategy	• End2end	• Automotive • Pharmaceutical • Food product specific	• Environment • Economy	• Company specific
Digital supply network design and strategy	• End2end	• Food (product specific - limited)	• Managerial	• Company specific
Last mile logistics, smart city	• Retail • Consumer	• Food (product specific - limited)	• Environment • Economy	• Company specific
Sustainable SN, EWR, modelling, optimization	• Processing	• Manufacturing	• Environment • Economy	• Company specific
Consumer behaviour analysis	• Retail • Consumer	• Food	• Demand	• Retail emphasis

consumer data analytics could provide insights on purchasing behaviour either to increase profit (e.g. market basket analysis to identify products bought together-coffee and sugar- position closely and increase the price only in one) or to understand nutritional needs and develop better products

Table 2 – Examples of business/applied based solutions

Solutions	Integration and end-to-end application limitations			
	SC echelon	*Product*	*Region*	*Other*
Personalised food app (allergy, vegans, low-sugar)	• Consumer • Retailer	• Processed • Packed	• Limited	• Number of users
Benchmarking app for farmers (soil and microclimate data)	• Farming	• Limited range	• Limited	• Crop limitations
IBM Blockchain (transparency and traceability)	• End2end	• Pilot in food	• Limited	• Company specific
Optimization tools (IoT, modelling data analytics, visualization, dashboards)	• Farming, or • Processing, or • Retailing, or	• Raw materials • Resources • Food products	• Limited	• Company size limitations
AmazonFresh (orders paced by lunch delivered by dinner)	• Logistics (last mile)	• Limited range	• Limited	• Company specific
Amazon Prime Air (packages in 30 minutes or less)	• Logistics (last mile)	• Non food	• Limited	• Company specific

towards a healthier diet.

Bottom-line, no integrated system approach solutions on theory, neither ready-business end-to-end applied exemplars. Consequently, there is a need to combine in a meaningful and applied way the existing solutions; define missing links in order to make these solutions work; lead research on these specific areas and reconfigure SC networks to that end.

3 Synthesize a conceptual framework for future food supply chains

The key concept behind the framework (Figure 1) is to re-design the entire SC utilizing digitalization, by reconfiguring the middle (i.e. processing-retailing) based on input from the one end (i.e. consumers) aligned with the input from the other end (i.e. farming).

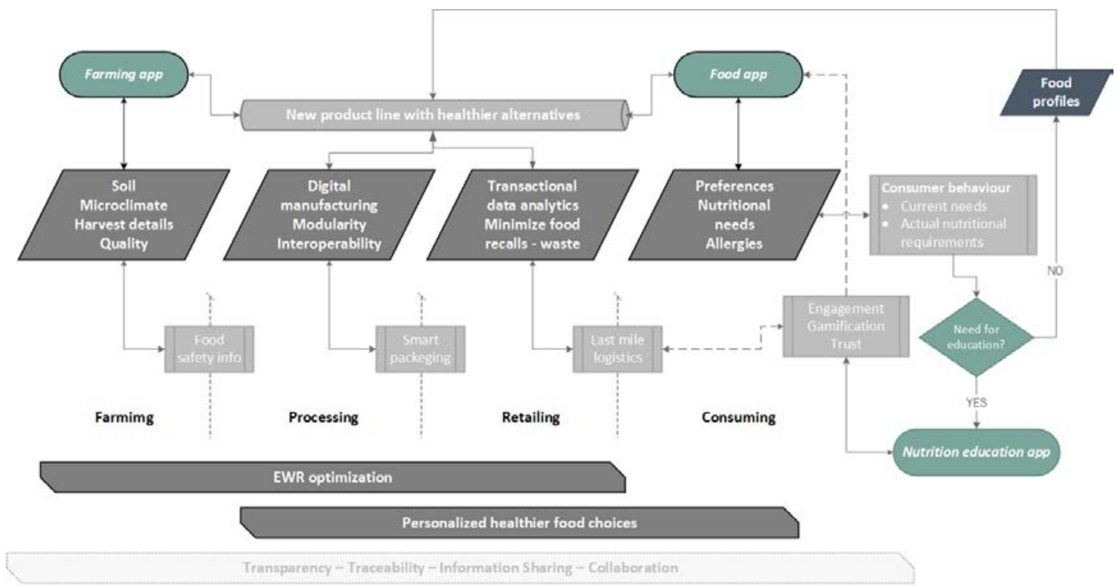

Figure 1 – Conceptual framework

Beginning from the consumers' side, food related smartphone applications collect data on food preferences and nutritional needs. Consumer behaviour and data analytics result in specific food profiles, used as input for the retailing and processing SC echelons. This way a new product line is developed, either from a retail chain (e.g. as private label) or from a food manufacturer. Key features of these products: healthier and personalised based on individual nutritional needs. On the other side, farming applications make available valuable information (e.g. soil/microclimate conditions, harvest details and product quality attributes) as an input for the processing and retailing echelons. A reconfiguration employing digital manufacturing and modularity principles ensures an actual production – consumption alignment, while delivers personalised healthier food products. In parallel, there is an EWR optimization (energy, waste, resources) at farming-processing levels and food recall minimization at retail-consumption levels. On top of that, essential production/processing/logistics info is accessible to the consumers via gamification features in the food applications. Consequently, consumers' trust in the food system is getting stronger and they are getting more involved into that, due to improved transparency and the availability of heathier, personalised food product alternatives.

4 Concluding remarks

The concept presented above aims to introduce a different thinking among the supply chain scholars. Key principle is to engage consumers into the food system and restructure the available supply chain practices towards fulfilling the actual needs of their end-users. This conception constitutes the foundation of a roadmap for further research in the field of supply chain; either as generic guideline for ground-breaking studies or reconfigurations in existing supply networks and better use of well-established innovations.

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Is last-mile delivery only viable in densely populated centres? A preliminary cost-to-serve simulation for online grocery in the UK

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Abstract
This paper proposes a conceptualisation of the 'cost-to-serve' linking the economic viability of last-mile delivery. Specifically, a cost-to-serve model is developed against business-specific indicators, such as share of online sales for a given catchment/geography. The outputs are then discussed in terms of e-commerce penetration and retailer density for the designated catchment/geography. Preliminary evidence is generated by means of computer simulation for a case in online retail of fast moving consumer goods (FMCG) with a focus on the UK. To this purpose a three-stage, pragmatic simulation approach is outlined, using widely available data in order to evaluate alternative last-mile network configurations, and their associated cost-to-serve cost curves. At each stage a sub-model generates, respectively, 1) order-generating locations; 2) basket composition; and 3) last mile delivery cost. Off-the-shelf tools are employed throughout to generate and visualise key analytics, thus facilitating replicability in real-world industrial settings. Results suggest that as well as having cost benefits with increased market penetration and/or increasing the number of drops per journey, as might be predicted, there appears significant potential to narrow the spread of cost variability for a given market penetration by influencing the available locations/time/price options to online customers. The proposed approach can support similar developments besides FMCG, for example in the pharmaceutical industry as direct-to-home medicine delivery becomes a credible option.

Keywords: e-commerce; FMCG; simulation; last mile logistics; field data analysis;

1 Introduction
With the increasing importance of e-commerce for the UK's retail landscape established mass grocery retailers are now expanding their online presence, leveraging on delivery to win online retail market shares (BMI, 2017). E-commerce sales in the UK amounted to £554 billion in 2015, 40% of which were received through a website (Prescott, 2016). Online sales of product categories such as food and beverages, personal and household care, health and beauty accounted for circa £1.9 billion, whereas £19.8 billion sales took place through convenience stores and £3.6 billion through pharmacies and drug stores (Market Line, 2017).

Given the changing nature of the UK omnichannel landscape, this paper introduces recent research on the economic viability of last mile (LM) delivery in different geographies in the UK. A 'cost-to-serve curve' conceptualisation is proposed, linking the economic viability of last-mile delivery to such indicators as market penetration and population density for a given geographical location to distinguish areas which are either economic or uneconomic to serve, or might become

Table 1 –Overview of exemplar literature (non comprehensive)

Refeference	*Application*			*Boundaries*			*Methodology*		
				Downstream		Upstream			
	e-commerce	Logistics	Pharma /health	B2B	LM		OPT/ SIM	SI/ DEA	SRV/ CSR
Pagès-Bernaus et al (2017)	●			●			●		
Shapiro (2007, Ch.9)	●				●		●		
Harrington et al. (2016)	●				●				●
Sultanow et al. (2016)	●		●		●				●
Park et al. (2016)		●			●		●		
Wygonik and Goodchild (2016)		●			●		●	●	
Longo (2012)		●		●			●		
Zhuan et al (2008)			●	●			●		
Chahed et al. (2009)			●		●	●	●		
Aized and Srai (2014)			●		●		●		
Gevaers et al. (2014)		●			●				●
Farahani and Elahipanah (2008)		●		●		●	●		

Abbreviations: B2B: Business to business; LM; last mile; OPT/SIM: optimisation (network or route) or simulation; SI/DEA: statistical inference or data envelopment analysis; SRV/CSR: survey or case study research

economic to serve depending on whether shared platform between retail partners and alternative end-user payment models are adopted. To achieve this, a multi-level modelling approach driven by real-world data that are likely available to the business is outlined. The suggested approach includes estimating typical catchment areas and basket composition for location and market penetration scenarios; and setting out likely economics of supply for a set of post-codes.

Findings from the research proposed in this paper are a preliminary step towards building a 'map' of the UK where LM delivery and e-commerce home delivery in its current format becomes a viable option considering 'location' factors which can act to reduce costs, such as penetration of e-commerce and density of e-commerce providers in a given geography. While based on a case in FMCG, the findings of this research can be of interest for other sectors. In particular, similar developments towards omni-channel, more customer centric structures begin to be observed in the pharmaceutical industry , including direct-to-patient delivery.

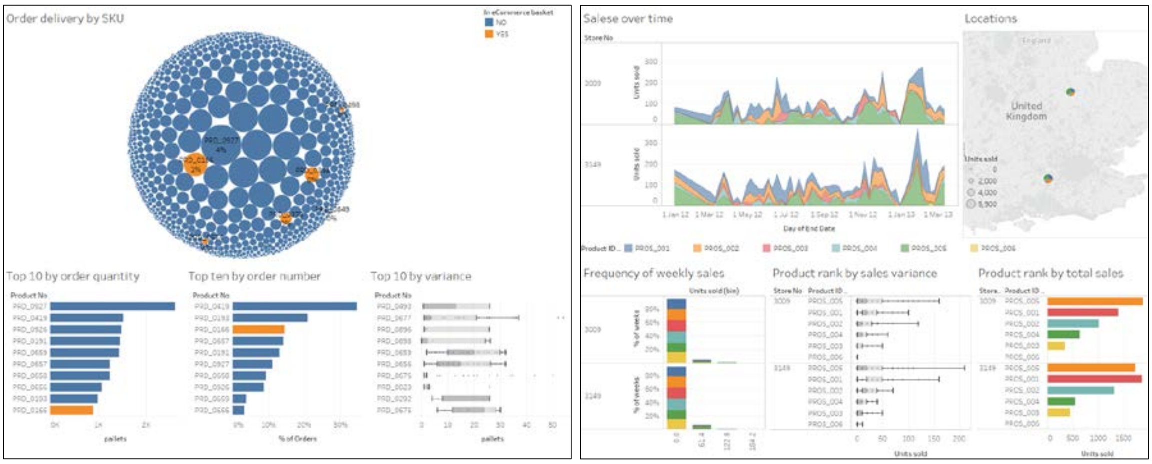
In the following sections, the methodology and data used in this research are introduced, followed by an illustration of preliminary findings generated through simulation for selected locations. Discussion of these finding leads to a conceptualisation of possible 'economic regions'. A closing section wraps up the research presented in this paper while pointing out its limitations and linking to future research agendas.

2 Material and methods

In principle, the analysis of near real-time streams of electronic data and the underpinning IT infrastructures play a major role in modelling e-commerce based supply chains – see Siddiqui and Raza (2015) for an overview. Without aiming to a detailed account of the literature, Table 1 summarises selected references with a focus on areas of application, boundary and scope of the analysis, and methodology employed. In the literature considered here, computer-aided supply chain optimisation and simulation is widely implemented to generate transportation optimisation scenarios for selected "Milk runs" (Downstream) or, alternatively, inventory profiles and location decisions for distribution facilities (Upstream). However, seldom is the analysis of real-world data available to businesses made explicit and included explicitly in the broader optimisation/simulation exercise, especially when it comes to understanding the demand signal coming from online sales.

This limitation is addressed here by outlining an approach to evaluate alternative supply network configurations, and the associated cost-to-serve informed by real-world data on an exemplar basket of fast moving consumer goods (FMCG) sold though e-commerce retail channels in the UK provided by industry partners. The proposed approach is based on the general principle of minimum cost flow through a network (Williams, 1998), and can be summarised as follows:

1. Harmonisation, visualisation and descriptive/prescriptive analysis of business data excerpts on both e-commerce retail (downstream) and B2B delivery (upstream) activities;
2. Set up and implementation of a computer-aided supply chain simulation to generate:



(a) (b)

Figure 1 –visual summaries of B2B order data (b); and e-commerce sales for selected locations (b)

- 2.1. Transportation optimisation scenarios for selected “Milk runs” (Downstream);
  - 2.1.1. Household order location simulation (Model A);
  - 2.1.2. Simulation of basked/order composition (Model B);
  - 2.1.3. Transportation cost and service time estimate (Model C);
- 2.2. Inventory profiles for selected delivery operations (Upstream).

3. Set out likely economics of supply for exemplar locations whereby cost-to-serve is conceptualised as a function of market penetration, for a given geographical location.

3 Findings

3.1 Time series data analysis

Preliminary analysis was carried out on the following data excerpts provided by industrial partners: 1) over 60k itemised B2B orders delivered from an FMCG manufacturer’s DC to a mass retailer’s DC involving circa 1.1k stock-keeping units (SKUs) over 2 months; and 2) 97.7k aggregated weekly online sales across 300+ stores over 53-weeks for 6 pre-selected SKUs.

A dashboard-type visual summary of these data is shown in Figure 1. The visualisation of B2B delivery data in Figure 1a contextualises the relative importance of those SKUs for which online sales data is collected in relation to the broader context of inventory replenishment. Although not shown here, further analysis was performed to investigate co-occurrence and associations in B2B order delivery leading to discovering patterns in purchasing behaviour. Conversely, due to the weekly aggregation of online sales data, and the focus on pre-selected SKUs rather than on individual orders, the analysis carried out at the store level could only be descriptive in nature. Figure 1b provides some insights into the distribution and variability of online sales, for use as constraints in the modelling activities described below. For illustrative purposes, Figure 1b shows only 2 geographies, as these will be further analysed in the following sub-sections.

3.2 Model A: simulation of customer ‘catchment’ area

In the absence of detailed household data associated with online sales, such as customer locations, the customers ‘catchment’ for a retail store has to be estimated by simulation as described, for example, in Schätter (2016, Ch. 6).

The proposed model to simulate order generating locations (‘model A’) is summarised pictorially in Figure 2. The top half of the figure shows publicly available data from the Office of National Statistics (ONS) on population density and postcodes with reference to Lower-layer Super Output

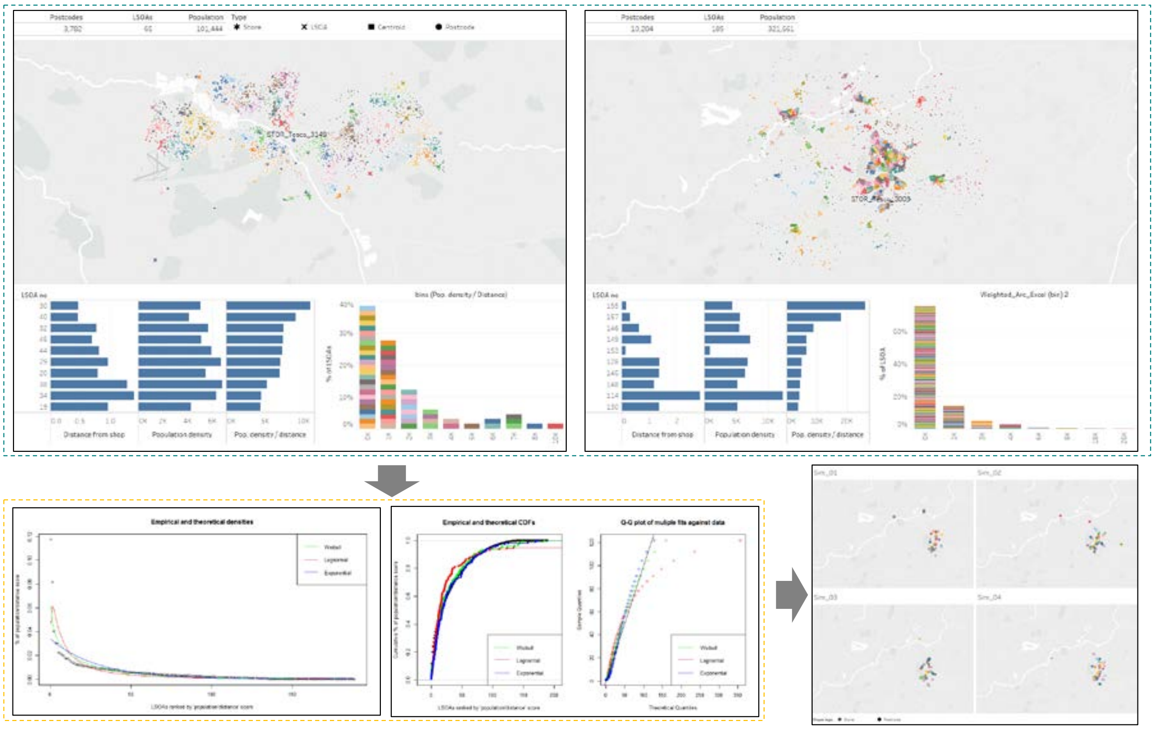


Figure 2 – simulation of potential order-generating locations based on public domain data on population density and distance from store in selected geographies combined with assumptions on market penetration

Areas (LSOA) for the chosen locations (ONS, 2016). In the chosen locations there are, respectively, over 3k and 10k postcodes which are serve here as a proxy for order generating locations. The two bar charts underneath each map in the top half of Figure 2 show, respectively the ranking and binning of each location's LSOA according to the ratio between population density and geographical distance from a given store. While the former is given, the latter can be estimated either as the centre of gravity of the postcodes assigned to it, or by computing an equivalent number of centroids/clusters means independently of the original attribution provided by the ONS. This information is used to fit and sample a theoretical density function so that those LOSAs that score higher are more likely to be generating an order (bottom-left corner in Figure 2). Individual postcodes within a sampled LSOA are assumed to have the same probability of generating an order.

The bottom-left part of Figure 2 shows the output of 4 iterations whereby 19 postcodes are randomly sampled, representing approximated order-generating locations, and hence drops/stops in the LM delivery. A rough estimate of the number of ordering locations/drops is based on the following assumptions: a bi-weekly order frequency for the SKUs of interest; and a market penetration of 7%. For the location with 3,782 postcodes (upper left part of Figure 2) this leads to the following estimate: $\text{drops per day} = \text{households} \times \frac{\text{market penetration}}{\text{order frequency}} = 3{,}782 \times \frac{0.07}{14} \cong 19$. For the location with 10,204 postcodes (upper-right part of Figure 2) the same reasoning leads to estimating 50 drops per day. However, this number is unrealistically high considering that the variability of daily sales for each SKU derived by crude approximation form the weekly data in Figure 1b is roughly the same for both locations despite the considerable difference in terms of number of postcodes.

In the absence of better evidence, the choice of keeping or rejecting the assumption that areas with higher population density and closer to a point of sale are more likely to generate an online order remains a subjective one.

3.3 Model B: simulation of basket composition

In the previous sub-section, a number of order-generating locations to be visited during a LM delivery was simulated based on market penetration, population density and distance from a given store. The next step is to estimate the order composition to be delivered at each drop ('model B').

Model B is necessary in the absence of details on orders and SKUs per order in the e-commerce sales data. Given that only aggregated weekly sales data are available for a pre-selected number of SKUs, the modelling process is as follows. First, express the variability in daily sales for each SKU as triangular distributions. In the absence of daily data the min, max, and most likely value in each distribution were roughly approximated as 1/7 of the min, max and median weekly sales (Figure 1b). Next, each distribution is to randomly generate a daily sales cap by SKU consistent with actual sales data. The daily sales cap thus generated serves as a constraint in setting up a binary programming model seeking to allocate an amount between 0 and 1 of each SKU to each one of the baskets (drops) determined by model 'A' as described earlier. The procedure is iterated four times to match the four random scenarios shown in Figure 2.

Key assumptions in model B is that the variability in daily sales can be obtained from weekly data by linear approximation; and that it is admissible to build a fictitious basket consisting only of those 6 SKUs for which data is available. The value of reasoning at the individual SKU level rather than considering an unspecified basket, is twofold: it provides a link between downstream LM delivery model and upstream inventory simulation models; and it provides useful insights for the allocation of compartmentalised space in temperature-controlled vehicles.

3.4 Model C: vehicle routing and journey cost estimation

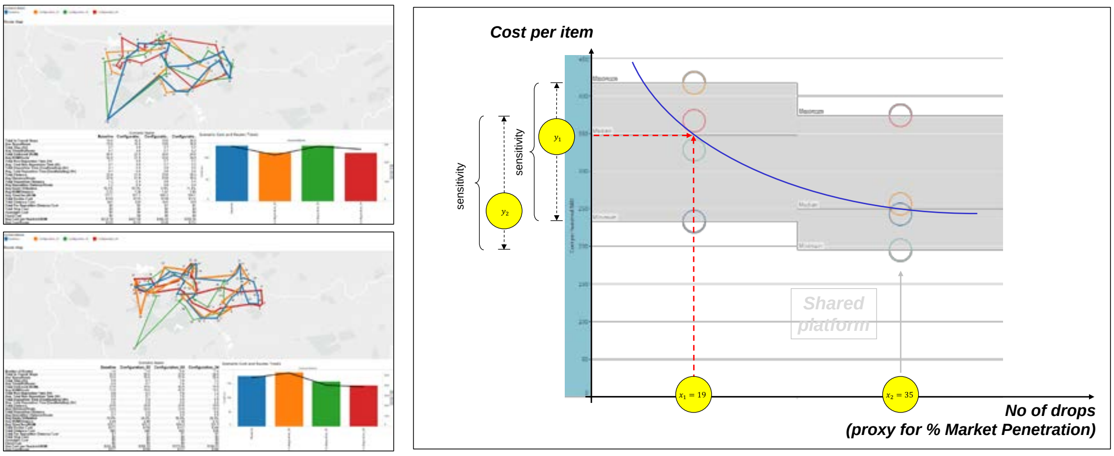
The insights generated by models A (drops/site locations) and B (shipments over time) provide inputs to the LM transportation optimisation problem referred to here as 'model '.

Like most vehicle routing problems (as in some references in Table 1), model C can be reduced to a so called travelling salesman problem, that is, a problem of finding the order in which a number of customer locations must be visited so that the total distance covered is minimised. The travelling salesman problem can be interpreted as a problem of finding the shortest Hamiltonian circuit – a closed walk that traverses every vertex exactly once – of the corresponding complete weighted graph were, vertexes represent customers locations and weights are distances between any two locations (Deo, 1974). In practice, this problem is typically formulated as an integer programming model (Williams, 1998).

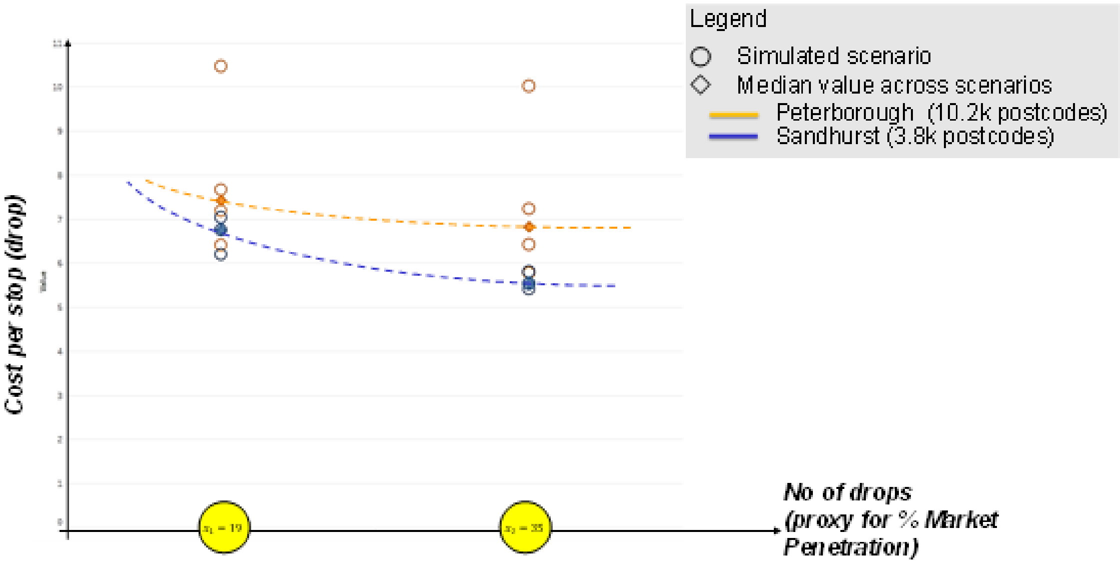
For the specific case considered here, 'models C' was set up and implemented using off-the-shelf software (Llamasoft Supply Chain Guru 8.4). The software, which is treated from now on as a 'black box', requires input data summarised below (each store is modelled as a separate problem):

- Products: the correspond to the pre-selected SKUs, and related attributes such as monetary value/price (to calculate inventory holding costs and revenues) as well as weight and volume (to calculate space utilisation and weight/cubic-based transport costs);
- Sites: these correspond to the locations of relevant stores and order-generating (customer) zones as per 'model A' described earlier;
- Shipments profile: these correspond to the order quantities generated for each product/customer/scenario combination through 'model B'. For the sake of simplicity, all the orders were assigned the same order date/time (assuming daily online orders received within a certain time window are aggregated), while the due date is specified as the next day;
- Transportation Asset: a range of features associated with the available vehicle or vehicle fleet. Exemplar value for such features, either physical (e.g. capacity constraints) or economic (e.g., cost per mile) were estimated based on interviews with industrial partners as well as by analysis of the academic literature, as specified elsewhere (Doetsch, 2017).
- Transportation policies: the software tool provides a range of pre-set policies. Relevant policies for the case considered here include "Full Truckload", which aggregates product bundles for shipment until the transportation asset's capacity in terms of weight (or cubic volume) fill level is reached; and "Pooled Inbound", which consolidates into the same transportation asset various product bundles inbound into a specific site (Watson, Lewis, Cacioppi, and Jayaraman, 2013; Ch, 6).

Figure 3(a), upper-left corner, shows the optimal last-mile routes segments obtained from running the transportation optimisation for one of the selected locations, in four scenarios



(a)



(b)

Figure 3 – Cost-to-serve simulation for exemplar locations

corresponding to different order-generating locations/order compositions. The range of key performance indicators obtained in each scenario with regards to the delivery, as well as the overall cost and service time are also shown.

The overall modelling procedure is repeated assuming an increased market penetration leading to a shift of the estimated number of drops from 19 to 35 (Figure 3(a), bottom-left corner). The sales increase might be thought of as either an increase in the daily sales volume for the store considered, or as the result of multiple stores pooling together online orders and delivering through a shared vehicle/fleet. The simulated LM cost-to-serve per item is plotted against the number of drops resulting from different levels of market penetration in the left-hand side of Figure 3(a).

The cost per journey is consistently higher in the 35 drops case (which appears reasonable given the largely linear relationships between the input cost parameters and the distance or duration of delivery). The median cost 'per stop' or 'per item' seems to decrease as market penetration increase (respectively £6.7 to £5.5/drop, and £347 to £249/hundreds SKUs). For the sake of conceptualisation Figure 3(a) shows a hypothetical curve passing through two points corresponding to the median costs per hundreds SKU obtained.

The results obtained through the procedure described above for both stores locations are plotted in Figure 3(b). It can be noted that, the approximated cost-per-drop curve plotted for the

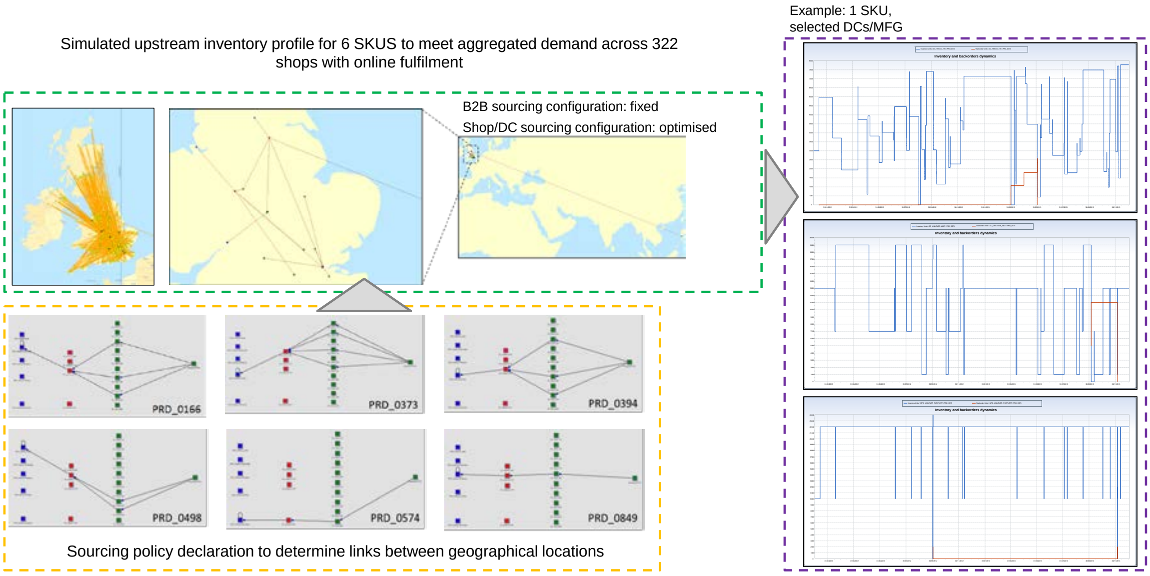


Figure 4 – data-driven upstream inventory simulation linked to online demand

location with the higher number of postcodes lies systematically below the same curve plotted for the location with lower number of postcodes.

It is worth noting that the following simplifications were made in model C at this stage, despite the practical relevance of the aspects involved: 1) the number of drops is equivalent to the number of vehicle stops; 2) additional trips due to missed deliveries are not considered.

3.5 Upstream inventory profile simulation

In simulating of LM delivery cost described above, online sales at individual stores acted as the point of focus. The aggregate online sales across all the stores with online fulfilment provide a total demand signal that can be used to simulate the inventory profiles at multiple echelons of the upstream distribution system – from the manufacturer's facilities and DCs through to the retailer's DCs supplying individual stores with the relevant SKUs.

Single sourcing relationships between manufacturing sites, DCs and retailer's DCs could be identified from documentation shared by industrial partners, for each pre-selected SKUs considered in the downstream LM delivery model. Multiple sourcing relationships were assumed between the retailer's DCs and stores. The resulting network structure is shown on the left-hand side of Figure 4. To select between multiple sourcing relationships, where necessary, a network optimisation procedure based on transportation costs (see e.g. Watson et al., 2013 Ch. 6) was implemented using Llamasoft Supply Chain Guru 8.4. The transportation cost coefficients and policies were estimated using business-specific data.

To simulate how the supply chain dynamically responds to customer orders being placed over time horizon, lead times in manufacturing and distribution were introduced (e.g., business' estimates on the duration of picking, loading and unloading operations), and the inventory policies at each echelons were declare (mostly subjective assumptions about reorder points, replenishment levels and initial inventories for each SKU). An exemplar inventory profiles generated by simulation for one of the SKUs at the retailer's DC, at the manufacturer's DC and at the manufacturing site is shown on the right-hand side of Figure 4.

4 Discussion

The findings illustrated in the previous section provide some preliminary evidence linking the economic viability of LM delivery to indicators such as share of online sales and catchment served in a given geography. The findings where contrasted with an initial conceptualisation whereby:

- LM 'cost-to-serve' is a decreasing function of market penetration;
- High population density locations being economic to serve as van loading journey drops enable to achieve target cost for a given market penetration;
- Low population density locations are either uneconomic, or require shared platform between retail partners, or end-user payment models

While only a limited number of market penetration scenarios was considered, the results seem to be partly support by the approximated curves plotted in the bottom-half of Figure 3. This suggests that cost-to-serve is also impacted by the following 'location' factors which can act to reduce costs (i.e. lower the profile of the cost – penetration curves):

- High levels of e-Commerce sales in a given geography – Penetration of e-Commerce);
- Low density of e-Commerce providers – enabling higher e-market share for the service provider

Furthermore, results suggest that as well as having cost benefits with increased market penetration and/or increasing the number of drops per journey, as might be predicted, there appears significant potential to narrow the spread of cost variability for a given market penetration by influencing the available locations/time/price options to online customers.

Conceptualizing these possible scenarios leads to the following possible 'economic regions' as

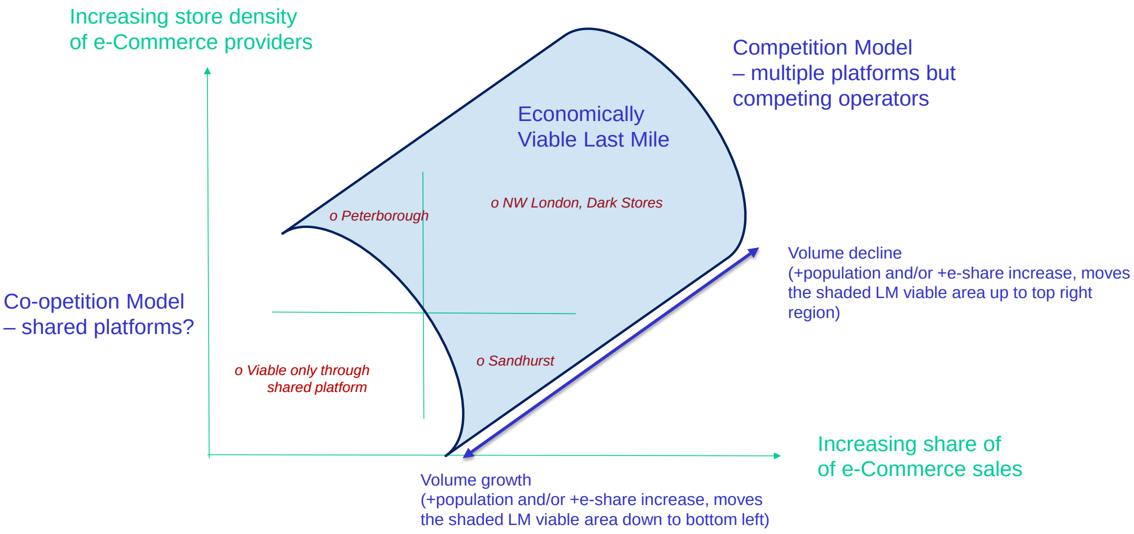


Figure 5 – Impact of store density on the economics of last mile delivery

shown pictorially in Figure 5. The proposed conceptualisation takes into account the changing nature of UK omni-channel landscape, potentially leading to a 'map' of the UK where LM Delivery and e-Commerce home delivery in its current format becomes a viable option. To support the proposed conceptualisation, analysis of representative locations for each quadrant in Figure 5 is required.

5 Conclusion

This paper uses visual data analytics and simulation to evaluate the economic viability of last-mile delivery (downstream), and the upstream repercussions in terms of multi-echelon inventory profiles for a case in online retail of fast moving consumer goods in the UK. With the aid of a numerical example underpinned by industry data, a three-stage, pragmatic simulation approach is outlined. Results generated at each modelling stage with the aid of off-the-shelf tools were illustrated, including: 1) order-generating locations; 2) basket composition; and 3) last mile delivery cost.

The findings suggest a 'cost-to-serve curve' conceptualisation linking to business-specific indicators, such as share of online sales and catchment served in a given geography, as well as sector-level indicators for the same geography, such as e-commerce penetration and retailers density. The proposed approach has a number of limitations. Some modelling steps were necessary in the absence of data on households order detail, introducing crude assumptions regarding for example daily demand for a given SKU. Such models may become unnecessary as further, more granular data becomes available. Using off-the-shelf tools, the inventory simulation and transportation optimisation algorithms were treated as a black box. Finally, several activities upstream of an e-ecommerce vehicle routing system were left outside the boundaries of the proposed analysis (for example, the electronic information exchange in terms of Web-based order entry and data management). Despite its limitations, this work provide initial impulse to research aimed at conceptualizing through simulated scenarios a 'map' of the UK where LM Delivery and e-Commerce home delivery in its current format becomes a viable option.

Future research will explore options for reducing variability in cost-to-serve, perhaps by influencing consumer behaviour through reduced locations and time options and price incentives. Extensions of the application of the modelling approach suggested in this paper should also be explored, as it could support the evaluation of options for similar developments in other sectors, such as direct-to-home medicine delivery.

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Product returns in omnichannel retailing: The trade-off between store accessibility and information availability

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Abstract

In omnichannel retailing, store accessibility influences the information available to consumers and the convenience to return products, affecting their risk perception. Based on transaction data from the largest furniture retailer in Italy, this paper investigates the sales and returns of 1.6 million consumers. Different metrics are employed to evaluate the distribution of sales, and an econometric model is used to investigate returns behaviour. The results indicate that channel information availability and store accessibility affect product purchase and returns behaviours. In fact, they reveal that for a product category rich in non-digital attributes, the level of information available in the channel is positively related with the eccentricity of sold products, and negatively with their rate of return, despite the distance between consumers and stores moderates these relationships. These results are relevant because of the implications for return policies, and assortment decision retailers can act across multiple channels.

Keywords: Omnichannel Retailing, Available Information, Store Accessibility, Product Return, Distribution of Sales

1 Introduction

Both practitioners and academics have recognised the growth in omnichannel retailing. While in the last decade multi-channel retailing has developed, the proliferation of digital technologies, especially mobile devices and social media, has allowed omnichannel to be defined as a new retailing paradigm (Brynjolfsson et al., 2013) offering a seamless retail experience regardless of the channel being utilised (Piotrowicz and Cuthbertson, 2014). This new retailing form is reshaping the industry and thus, is pushing retailers to follow this path (Rigby, 2011). The advent of the internet has enabled retailers to offer larger product variety as well as greater shopping convenience, beyond the limits of traditional physical locations. Online stores allow retailers to display a huge assortment, while consumers can find the desired products without great physical effort. However, operating through multiple channels brings not only the strengths of the single channel (Avery et al., 2012), but also exposes weaknesses (Rao et al., 2014), and creates problems that need to be solved (Neslin and Shankar, 2009). Both traditional retailers as well as new online retailers are moving towards developing omnichannels, and both are facing different problems.

Traditional retailers need to manage a single assortment that is limited by the available shelf space. These retailers usually provide only one channel to let consumers obtain and return their purchases, namely through the store. Furthermore, in physical stores, sales assistants support consumers during purchases and provide them personalised information, which increases their product awareness and reduces their perceived risk as well. Traditional retailers face increasing complexity as new channels are added.

Virtual retailers (e.g., online, catalogue) can potentially rely on huge space to display products, but at the same time, they need to manage deliveries, and more critically, product returns. They can only provide digital information (e.g. photos, descriptions), which is also limited by the communication means. For instance, online retailers can use pictures or 3D animations. Therefore, consumers approaching virtual channels will have a lower level of product knowledge and a higher risk perception too.

When all channels, traditional and online are merged, retailers should consider the effects generated by the interaction between the channels, in particular for complex products categories that require consumer inspection during the purchasing process. For instance, the consumers' proximity to physical stores might alter their risk perception, which is able to influence consumer behaviour in product selection (Kim and Krishnan, 2015) and return decision (Wood, 2001), so the perceived risk increases the consumer information seeking behaviour (Mitra et al., 1999).

This study investigates the relationship between information availability and risk perception in omnichannel retailing for a product category rich in non-digital attributes. In particular, based on the data provided by a major Italian furniture retailer, it analyses the differences between the distributions of sales and product returns across different retail channels (physical store, online store, and catalogues). Moreover, the study investigates how the consumer proximity to stores affects these relationships.

This paper is structured as follows; firstly, product distribution and returns across channels are briefly discussed, with the focus on furniture, then methodology is overviewed and findings from empirical data presented. Final sections are, the discussion, when findings are compared with literature, and conclusions for practice and academia.

2 Distribution of sales across channels

The literature reviewed indicates that retailers can benefit from displaying larger assortments online. Several researches have focused on demonstrating the advantages of offering wider assortments online than in traditional stores (e.g., Brynjolfsson et al., 2003,2011; Hinz et al., 2011). They have proven that online sales have a larger tail of distribution than traditional channels, thus, both consumers and retailers would have benefitted from larger shares of the niche of products online. Brynjolfsson et al., (2003) have proposed one of the first attempts to demonstrate that, comparing the width of the assortment between Amazon and brick-and.-mortars (B&M) retailers for products that range from Books to DVDs to cameras. Several other authors provide support to the phenomenon of the longer tail of online sales distribution, both empirically (e.g., Hinz et al., 2011) and analytically (Fenner et al., 2010; Yang, 2013). However, most of these authors only considered product categories rich in digital attributes (books, DVD and music), for which the online channel can substantially provide the same kind or a higher level (reviews, previews) of information than stores (Pauwels et al., 2011). Based on the literature review number of empirical studies in this area is limited, only Brynjolfsson et al. (2011) and Ma (2016) have proven the longer online tail of distribution for sensory products. The former analysed sales of a multichannel apparel retailer through a rank regression model (Brynjolfsson et al., 2011), proving that the online distribution of sales is less concentrated than the catalogue one, because of the role of online search tools and recommendation systems in defining the consumer preference for niche of products. While Ma (2016) demonstrated the benefits of providing a larger assortment online than in catalogue, though the analysis of the sales distribution of a multichannel apparel retailer, attributing these result the superior channel's information capabilities. Therefore, both proved the effect comparing the online channel to a channel that can provide a lower level of information.

However, the literature on this topic is controversial (Elberse 2008). In fact, other researchers are convinced that the online retail introduction is leading to the concertation of sales toward few "superstar" products because of the different recommending systems that are pushing sales of more popular products (Elberse 2008). Tucker and Zhang (2007) empirically proved that the online communication of popularity of personal services induces the concentration of the consumer demand across few options, because of the lower perceived risk. Moreover, Lee et al. (2011) attributed the steeper tail to the electronic word-of-mouth (eWOM), which effect varies with product characteristics (experiential or objective). They analysed Amazon's sales of different products and related them to the feedbacks received by customers. While Fleder and Hosanagal (2009) proposed an analytical model that reveal that different types of recommendation systems can lead to longer or steeper tails.

The previous contribution proves that both the long tail and the steep tail can coexist, but the nature of products and the type of recommendation systems could influence the concertation of sales. However, none of them investigated the differences in the distribution of sales between online and B&M stores for product categories rich of sensory attributes (e.g. apparel, furniture). The previous contributions have demonstrated that online sales are less concentrated than catalogues for these product categories. Ma (2016) attributes the phenomenon to superior information capabilities of the online over the catalogue channel. Therefore, this effect should be larger when evaluating the differences between online and B&M stores. When consumers buy online a product rich in non-digital attributes, they will be more prone to buy a less risky option because of the perceived risk (Kim and Krishnan, 2015). Thus, sales might be biased toward those options, which could increase the concentration of sales. However, when the customers take the risk, and are not satisfied, then are able to return the product.

3 Product return in omnichannel retailing

The remote purchasing process (both, online or catalogue) of product categories characterised by sensory attributes, usually follows a two steps pattern: first consumers select the preferred item founding the choice on the available information, and building expectations (Wood, 2001). Then, after the product receipt, a customer evaluates the gap between expected and actual product performance and decide whether to keep it or return it (Wood, 2001; Bechwati and Siegal, 2005). Product returns thus are critical to manage for online retailers because of the high cost of reverse logistics (Leeuw et al., 2016) and because of their frequent occurrence (Wood, 2001). However, they are unavoidable for online retailers because they reduce the consumer perceived risk when buying online, stimulating the demand (Petersen and Kumar, 2009). To that end, retailers should find solutions to prevent returns without reducing the return policy leniency, because it could have a negative impact on demand (Janakiraman et al., 2016).

Being able to return as result if mismatch in consumer expectations, prochoice process and the collection of information affects the consumer decision to keep the product or not. Bechwati and Siegal (2005) demonstrated this relation through laboratory experiments. Minnema et al. (2016) have explored the role of information; they proved the relation between online reviews and returns, analysing the sales of a major online retailer covering electronics and furniture.

Furthermore, the marketing-mix can affect the rate of returns. For instance, the assortment decision can have a high impact on reducing the number of returns. Rabinovich et al. (2011)

proposed a methodology for determining the optimal assortment through the analysis of sales and return concentrations. Alptekinoğlu and Grasas (2013) demonstrated that more eccentric products are more likely to be returned. Other factors that interact with the returns are price and discount level (Andereson et al., 2009), the communication of product scarcity and delivery time (Rao et al., 2014). In particular, short promised delivery times affect the perception of the returning cost, increasing the likelihood that consumers return products (Rao et al., 2014). Thus, the presence of distribution facilities can have an indirect impact on returns. However, the interaction between facilities and returns is still an open debate in the omnichannel literature. In particular, authors do not agree on the impact that B&M stores presence have on the consumer final decision to keep their purchases. According to Bell et al. (2015), the introduction of physical stores for an omnichannel retailer selling eyewear have reduced the number of returns in the interested area. They developed an empirical strategy to analyse sales and returns through a Difference-in-Difference model, proving that the higher level of available information reduces consumer disconfirmations of purchases. Contrary, Pauwels and Nelsin (2015) as well as Kumar (2016) have shown an increase of product returns because of the higher accessibility to physical stores.

In the light of the previous contribution, this paper aims at exploring the effect of channel information availability and risk perception on consumer product selection and return decision in omnichannel retailing. In particular, it investigates the consumer purchasing behaviour of product categories rich in digital attributes, and thus, affected by an higher perceived risk when bought by remote channels (Wood, 2001). The perceived risk is likely to influence consumer toward more popular, less risky option selection. However, the lower level of information provided will increase the consumer disconfirmation of expectations (Bechwati and Siegal 2005), and thus the return rate. Moreover, in a context of interaction between B&M and other channels, the lower perceived risk, because of lower costs of returning (i.e., monetary, time, effort), will reduce the consumer information seeking behaviour (Mitra et al., 1999), increasing the rate of return.

4 Sector and case description

This section presents the sector and case company. The study was performed analysing the data provided by the largest furniture retailer in Italy. Furniture is an interesting case of investigation for studying the consumer behaviour, this product category is rich in non-digital attributes, which consumer tend to experience before buying (Ofek et al., 2011), and it includes many product typologies with a broad range of characteristics that can lead to different purchasing patterns. Some products are rich in non-digital attributes (e.g., textures, colours) and require a complex decision process for buying them (e.g., kitchens), while others are more standardised, easy to code, and thus, require a lower consumer involvement. Moreover, the role of stores is central for this product category, because of its high unit value and low purchasing frequency (Andreu et al., 2010). In fact, furniture retailers tend to operate through large stores, despite the market is shifting to virtual channels and they are adapting their business, as furniture is the second product category in term of online sales growth in 2016 in the US (Baskin and Stevens, 2017), and Amazon has recently invested in facilities for handling furniture deliveries. Finally, this product category offers the opportunity to neglect consumers' opportunistic behaviours when buying and returning products because the effort required to transport the goods (i.e., monetary or physical) acts as a deterrent for such behaviours (Janakiraman et al., 2015).

The furniture industry in general, and in Italy in particular, have seen dramatic changes in the last two decades (la Repubblica, 2017). First, the Swedish company IKEA has changed the market rules, providing appealing products at a low price. This was possible thanks to an innovative business model, which has transformed the traditional furniture store and buying process. The new retailing paradigm proposed by IKEA changed consumer expectations and performance requirements (Kumar et al., 2000). Later, online retailing has raised and, among the other sectors, it has invaded the furniture retailing. The market entry of new players that operate through different channels not only could threat the IKEA leadership (Forbes, 2017), but also can lead new consumer behaviours to emerge.

The Italian furniture retail market is €13billion worth (la Repubblica, 2017), and it is characterized by a large number of small independent firms and a small group of large companies that control large shares of the market. In particular, two of them compete for the market leadership, while the others are much smaller in terms of turnover. The retailer under investigation, which is one of the two, has recently overpassed its first competitor, gaining around the 10% of the market share, and becoming the largest furniture retailer in Italy.

The case retailer sells any household furniture through company-owned distribution channels, which include 35 physical stores located throughout Italy, an online store, and catalogues. Each physical store has its warehouse located nearby. These warehouses manage the orders from each channel. In particular, when a customer places an order, she will obtain the product from the closest warehouse where the product is available in-stock. For instance, when she consult the retailer's online store, she will get the information on the product availability in her closest store and a quotation of the time to get it delivered from there. Customers can collect product directly from stores or get the product delivered at home, paying an additional fee.

The retailer offers a two days delivery guarantee policy for make-to-stock products. Within the last six years, the retailer has strongly invested in warehouses in order to increase the shares of make-to-stock products and to reduce the delivery time offered to customers. This strategy has been a great deal of success for the retailer, which has increased its revenues at 2-digits rate yearly in this period, reaching €1.1billion in 2016 and becoming the larger furniture retailer in Italy.

The retailer offers the same assortment of make-to-stock products across the different channels, but in store, customers can customize their purchase (e.g., size, colour, and textile), buying make-to-order products. Here, sales assistants support consumers during all the purchasing process, providing them information, budgeting, and helping them through digital media too. While in the online stores, also available for mobile devices, potential customers can inspect products thanks to a large amount of high definition and detailed photos, plus detailed descriptions are present. The retailer has recently updated its website, including a digital assistant, but during the period under investigation, it was not available. Finally, catalogues are small books (around 150 pages) that the retailer distributes freely by postal mail every three months in each household throughout Italy, thus, it is a well-known brand in the country. Due to its space limit, catalogues display only a few photos and a brief description for each product. The retailer collects catalogue orders by telephone.

The retailer return policy allows customers to return products for any reasons within 14 days from the order received. However, they cannot return customized product, except for not conformity issues. In this case, the retailer offers a 2-year guarantee for all its products, but the analysis of this policy is not the scope of the present study. The return fulfilment process follows the same path of the delivery, in fact, whether the retailer has carried the product to the customer, he will collect it from the same location without charging additional fees. The same, if the customer collects the product from the retailer's warehouse, he will be in charge to return it.

5 Methodology and dataset

This study is quantitative, based on analysis of empirical data from the company. The retailer provided data referring to 3.76 million products sold between the 1 January 2015 and the 30 March 2017. The data includes information about products, transaction, and customers, at a level of detail that allows identifying whether a single customer has returned a single product included in a single transaction.

The variables are organised on a 3-level structure (customer, transaction, and product): each customer is associated at least with one transaction, and each transaction contains one or more products. At the lowest level, products are characterised by univocal codes, by a brief description of their attributes (e.g., sizes, colours), by their product typologies (e.g., couches, chairs, tables), by price and discount levels applied when they are sold, and by a binary variable that express whether the product has been returned or not. The return variable is set to 1 if the product has been returned or 0 otherwise. The typology variable is a categorical variable that not only expresses the single product type, but in some cases, it represents a bundle of products, and more in general, it can proxy

Table 1– Descriptive stats of the variables included in the dataset

Domain	Variable	Type	Number of cases	Minimum	Maximum	Mean	Std. Deviation
Product	*Code*	Categorical	915	-	-	-	-
	Code Sales	Numerical	792	3	84,211	4,113	7751
	Code Type	Categorical	21	-	-	-	-
	Price	Numerical	327	€ 18	€ 1615	€ 220	€ 181
	Discount Level	Numerical	10	0%	50%	8%	10%
	Return	Binary	2	0	1	0.039	0.193
Transaction	*Transaction*	Categorical	2.53M	-	-	-	-
	Sales Channel	Categorical	3	-	-	-	-
	Delivery Channel	Categorical	3	-	-	-	-
	Day	Categorical	7	-	-	-	-
	Month	Categorical	12	-	-	-	-
	Year	Categorical	3	-	-	-	-
Customer	*Consumer*	Categorical	1.63M	-	-	-	-
	Total Transactions	Numerical	24	1	36	1.55	0.96
	Distance	Numerical	4,861	0KM	443.8KM	23.8KM	23KM
Context	*Population*	Numerical	110	54,508	3,766,463	1,451,127	1,272,305
	%Illiteracy	Numerical	110	0.20%	3.81%	0.79%	0.53%
	Income	Numerical	20	€ 21,807	€ 34,831	€ 30,526	€ 3,729

the product size. The products purchased by the same customer in the same sales channel on the same day compose a single transaction. The transaction is characterised by univocal codes (i.e., Transaction), by the sales and the Delivery Channel chosen by the customer, by the date and the store in which the order was placed. Several information are available in the dataset about each customer. Each customer has an identification code that is associated with his personal details, including address and phone number in order to avoid multiple codes associated with the same customer. The retailer keeps track of all the previous purchases carried out by the same customer. Moreover, the data allows to discriminate whether the customer is a business customer or a consumer.

The dataset also includes contextual variables that describe the geographic areas where consumers live, such as the population, the percentage of analphabetic, and the average yearly income.

Before starting the analysis, in order to accomplish the aim of this research, the dataset has been cleaned and several tests performed. First, to avoid differences between the assortments offered by the different channels (i.e., store, online, catalogue), and thus to detect differences between their sales distribution, only the make-to-stock products were selected. Moreover, it has been checked that each product code was actually sold on each channel, in order to be sure that all the products were available on each channel during the period under investigation. Furthermore, all the product accessories were excluded from the dataset because they are usually sold with other products. Hence, they do not add information, and their sizes can vary significantly (e.g., a set of screws or a shelf). Finally, the last month of observation has been removed to allow the return fulfilment to be completed.

The study aims at investigating consumer behaviour. Thus, the business customers were excluded from the sample, because their behaviour might substantially differ from consumers', undermining the validity of results.

Table 1 describes all the available variables in the dataset organised by domain. The products that have been sold across all the channels within the period are 915 (Code) that are grouped in 21 Product Type categories. Actually, product types were 22, but accessories have been excluded.

Table 2– Channel, sales, and returns

Sales Channel	Sales (units)	Rate of Return
Catalogue	323,256	7.24%
Online	138,361	4.31%
Store	3,301,912	3.53%
Total	3,763,529	3.88%

Prices range from €18 for a basic chair to €1615 for a complete living room (i.e., a bundle of products). The rate of return changes across channels as shown in Table 2 and on average is 3.88%. During the period under investigation, roughly 1.63M Consumers were served for a total of 2.26M Transactions, which means that each consumer has made 1.55 transaction on average. As already mentioned, the information on customers includes their addresses. These were employed to compute the Euclidean distance (Distance) between consumer's postal code and the store she is more likely to visit (i.e., the closest store).

The address provided is the same where purchases are delivered. Hence, the use of this metric requires to assume that remote transactions were placed from the location where the product were delivered. In fact, it could happen that a consumer purchases a product for her second house (e.g., a holiday house), visiting a store nearby her residence. In this case, the address provided does not allow considering the real distance between the consumer and the store. Therefore, several tests were performed to verify this assumption. First, the analysis of store consumer buying behaviour has revealed that in the 97% of cases consumers visited the closest store to the location where the product is delivered. Then, the multichannel consumer (i.e., store and online or store and catalogue) purchases were tracked when they bought in a store. These consumers account for 10% of online transactions and the 21% of catalogue ones and the analysis of their behaviour reveals that in the 95% of cases they visit the closest store. Thus, this second home phenomenon is estimated to range between the 3% and the 5% of transactions, hence, it can be safely neglected.

Finally, the Euclidean distance might not represent the actual travel distance between consumers and stores, calling the need for further investigation to test its representativeness and to the implementation of more sophisticated tools.

5.1 Analysis - the distribution of sales

The paper aims at estimating the effects of the retail channel information capabilities on the consumer purchasing behaviour, in terms of product selection and return decision. In particular, besides the analysis of the differences between channels, in an omnichannel setting, the physical store presence plays a significant role in defining consumer preference (Wood, 2001). In fact, consumers living in proximity of stores are more likely to visit it before placing the order from other channels, especially for the product category under investigation, which is characterised by a long decision process (Andreu et al., 2010). Therefore, the store accessibility, on the one hand, can moderate the consumer behaviour typical of a different channel, proving a further information channel, on the other hand, it can induce to an impulse buying, because of the lower perception of risk associated with the wrong purchased.

To that extent, the empirical strategy proposed and hereafter described, allow to preliminary investigate the difference between channels in terms of sales composition and returns, considering the effects of the physical stores.

In order to investigate the differences between the distribution of sales across channels, first, the Lorenz Curves and the Gini Coefficients are calculated, and then the HHIs are computed for each channel. These measures not only are widely employed to evaluate the distribution of wealth between geographic areas, but they also found applications to detect differences between distribution of sales over time or between retail channels (e.g., Brynjolfsson et al., 2009; Rao et al.,

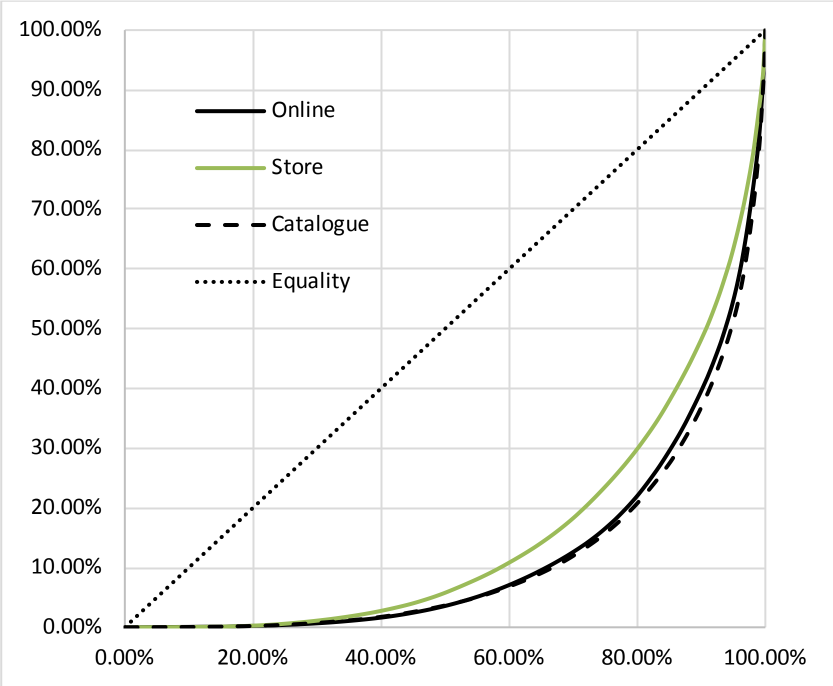

Figure 1 – Lorenz Curves

2014). In fact, they allow to visualise and to estimate the differences in sales concentration between channels at an aggregate level. Their implementation only requires the aggregate level of sales for each product (i.e., Code).

The Lorenz Curve graphically compares the cumulative percentage of product codes with the cumulative percentage of sales. Whether these two measures are equal (i.e., Equality line), the sales are uniformly distributed across all the products, otherwise, the larger is the distance between the Lorenz Curve and the Equality line the more sales are concentrated. The Gini Coefficient is the ratio of the area between the Lorenz curve and the equality line to the total area below the equality line. Accordingly, it offers a way to assess descriptively the relative concentration of the sales distributions.

The HHI is calculated summing the squares roots of each product shares of sales, then multiplying the total by 10,000 to rescale it. Thus, it can potentially range from 0, when infinite products cover very low shares each, to 10,000, when one product accounts for all the sales.

Both these measures suffer when comparing populations (i.e., channels in this case) with a different number of individuals (i.e., products). However, in the case under investigation the number of individuals is the same for each channel, thus, this is not an issue. Nevertheless, they lack statistical tests for evaluating whether the difference between channels is significant, calling for further investigations to test it. Moreover, they only measure the asymmetry of distributions, without focusing on the single individuals, neglecting information. Therefore, they can be employed in a preliminary phase, but they call for further investigations.

The Lorenz curves in Figure 1 shows the difference between channels, revealing that Store sales are less concentrated than the online ones that are less concentrated than the catalogue ones respectively. Moreover, the Gini Coefficients and the HHI indexes (Table 3) computed on the same data, confirms these relationships, despite do not prove that the differences are statistically significant.

These results support the intuition that the level of available information affects the consumer product selection. However, they call for further analyses to confirm them and to determine whether the differences between distributions are statistically significant. In particular, the rank regression

Table 3– Channel, sales, and returns

	Gini Coefficient	HHI
Online	0.751	69.92
Store	0.685	46.83
Catalogue	0.764	81.92

analysis, or the quantile regression analysis (Brynjolfsson et al., 2003) seems the most appropriate methodologies for the scope.

5.2 Analysis - The return behaviour

The investigation of the factors related to the consumer return behaviour requires the development of an empirical model. The model needs to estimate whether the channel choice, thus, the channel capabilities and the distance between consumers and stores affect the decision to return products. Moreover, the model needs to process a large amount of data, thanks to the high granularity of the dataset provided by the retailer, and to control for several factors that can influence this relationship. Therefore, the most suitable empirical model is a regression, and among the others, logistic regression (McFadden, 1980). Logistic regression, in fact, allows estimating the likelihood of an event occurrence, namely the product return in the case of investigation, given a series of independent and control variables. Researchers employ these type of models are for evaluating consumer behaviours and in particular return behaviour (e.g., Rao et al., 2014). In particular, fixed effects logistic models enables the analysis of situations with non-complete information available. In the case under investigation, different product typologies, for instance, have different return behaviours, but the available information cannot explain the motivations.

Therefore, the model proposed for the analysis is a two-stage logistic regression model with fixed effects. The reduced model aims at evaluating the difference in returning likelihood between channels; while, in the second stage, the full model estimates first, whether the distance between consumers and stores adds information to the reduced model and then, the relationship with the product return.

The reduced model considerers the binary variable Returns as dependent variable and Sales Channel as independent, plus the variables Delivery Channel, the Price, the Discount Level, the Code Sales, and the total Number of Orders placed by the same customer as covariates, Population, Regional Income, Type, and time series variables (i.e., weekly Day, Month, Year) as controls. The model has been developed following theoretical elements and to demonstrate the effect of physical distance on consumer return behaviour.

In fact, the influence of sales channel on consumer propensity to return product has already been tested in the literature (e.g., Bell et al., 2015; Kumar, 2016). However, a direct comparison between different channels for similar product categories lacks in literature. The Delivery Channel variables not only introduce the consumer selection for the delivery option in the model, which adds monetary value to the transaction, but also it expresses the effort required by consumers to return the product, because, as aforementioned, the return fulfilment process follows the delivery path. The price of a product influence the likelihood to return products, not only because price affects demand, thus, indirectly influencing returns, but also because the price affects consumers' expectation on product value, and hence, on defining their preference and decisions to return (Anderson et al., 2009). Furthermore, the Discount Level adds value to the consumer surplus, increasing the perceived value associated with the product, and thus, reducing the likelihood to return it (Anderson et al., 2009). The popularity of products is related with their rate of return, in fact, eccentric products are more likely to be returned (Alptekinoğlu and Grasas, 2013), thus, the model includes the Code Sales to represent it. Loyalty is associated with a higher rate of return (Mollenkopf et al., 2007). Therefore, the number of orders placed by the same customer (i.e., Total Transactions) increases the return likelihood. Moreover, the model controls for the nature of the product, because product attributes can affect consumer return decision (e.g., size, level of digital attributes) and demand as well; it also controls for geographic demography (i.e., Income, Population size), which can influence the demand level and the consumer behaviour (e.g., channel selection).

In addition to the previous model specifications, the full model includes the distance between consumers and stores in the analysis to test the trade-off between information availability and store accessibility (i.e., risk perception) effects. Moreover, it includes the interaction between the Distance and Sales Channel to control for the consumer propensity to channel choice.

Due to scale heterogeneity, the variables Distance, Price, and Code Sales are converted on a logarithmic scale, while Population in million people.

Table 4 reports the results emerged from the reduced and the full model. The reduced model reveals that considering the Store as a base case, product purchased by online and by catalogue have a higher likelihood to be returned, and catalogue higher than online respectively. Moreover, all the explanatory variables follow the theoretical relationships. Furthermore, all the beta coefficients are statically significant, being the p-value of the standard errors lower than 0.1% for all the variables, and the Nagelkerke R Square reports a sufficiently high value to prove that the model fitting with the data.

The introduction of the Distance variable increases the information explained by the reduced model, proving that the full model specification is significant, and thus, the distance variable can offer meaningful results. In particular, the beta coefficient associated to the variable has a negative sign, thus, regardless the retail channel, the delivery channel, and the product typology, the further consumer live to store, the lower they are likely to return the product.

6 Discussion

The results show that channel information capabilities can influence consumer purchasing behaviour regarding the selection of product with sensory attributes and their return. Moreover, the physical store accessibility affects consumer disconfirmations. Results indicate that consumers are more likely to buy eccentric products with sensory attributes in stores than online or by catalogues. However, they prove that the return rate is lower for store transactions than for online and catalogue ones. This relation between the popularity of product sold and their return rate might seem counterintuitive because of the nature of the products sold; however, the level of information available within three channels can explain it (Ma, 2016). As already mentioned, the channels provide different levels of information. Catalogues only show a few images of the desired product (i.e., between one and three pictures) and the content is static, while online consumers not only can inspect the same images at a higher level of quality, but also they can search for further photos, being the available space to display them potentially infinite. Finally, in store, consumers have access to all the information available online and in catalogues, plus they are supported by the salespeople and can inspect products. Therefore, the level of information available in the channel might encourage consumers to buy more eccentric products, at the same time reducing the gap between expected and actual performance as well as affecting the product return rate. These results confirm the literature on the difference between sales distributions for sensory products (Brynjolfsson et al., 2011; Ma, 2016), proving that online sales are more concentrated than catalogues'. However, findings extend these contributions, demonstrating that in some cases online sales can be less concentrated than traditional channels (i.e., stores)

Moreover, results prove that the cross channel interaction cannot be neglected because it can affect the previous relations. In fact, conversely to what one would expect, the store accessibility increases rather than reduces the likelihood that consumers return products. These might seems a contradiction because the higher level of information available information should concur to reduce the gap between expected and actual performance. However, the distance from the store might influence consumers perceived risk when buying (Kumar, 2016). Consumers living closer might be more risk prone because their cost associated with a "wrong" purchase is lower than if they would

Table 4– Return behaviour model results

Dependent variable: Return	Reduced Model				Full Model			
	Beta	Standard Error	p-value	Exp (B)	Beta	Standard Error	p-value	Exp (B)
ln (Distance)	-	-	-	-	-0.17	0.013	0.000	0.844
Sales Channel: Catalogue	2.997	0.015	0.000	20.032	3.45	0.077	0.000	31.508
Sales Channel: Online	1.258	0.033	0.000	3.519	1.056	0.212	0.000	2.875
Distance by Catalogue	-	-	-	-	-0.096	0.018	0.000	0.908
Distance by Online	-	-	-	-	0.053	0.048	0.275	1.054
Delivery Channel: Carrier	0.031	0.063	0.651	1.032	0.105	0.064	0.101	1.111
Delivery Channel: Customer	-0.186	0.026	0.000	0.831	-0.205	0.026	0.000	0.815
ln(Price)	0.305	0.015	0.000	1.356	0.31	0.015	0.000	1.364
Discount Level	-0.871	0.081	0.000	0.419	-0.875	0.081	0.000	0.417
ln(Code Sales)	-0.097	0.007	0.000	0.908	-0.096	0.007	0.000	0.908
Total Transactions	0.426	0.003	0.000	1.531	0.424	0.003	0.000	1.529
Population (Million)	0.301	0.005	0.000	1.351	0.272	0.005	0.000	1.313
%Illiteracy	102.317	0.927	0.000	2.728+e44	105.752	0.944	0.000	8.46+e45
constant	-8.711	0.123	0.000	0.000	-8.026	0.134	0.000	0.000
Code Type (20)		*Confirmed*				*Confirmed*		
Day (6)		*Confirmed*				*Confirmed*		
Month (11)		*Confirmed*				*Confirmed*		
Year (1)		*Confirmed*				*Confirmed*		
D.F.		*48*				*51*		
Chi-Square		*84,125.65*				*84,539.19*		
Nagelkerke R Square:		*0.281*				*0.282*		
% of correct cases predicted by the model (cut 0.5)		*99.20%*				*99.20%*		

live further. In fact, they can easily visit stores for complaints, get products delivered or returned rapidly and with lower risks of delays. Therefore, they might be more inclined to incautious purchases (e.g., eccentric products), and thus, more likely to return them.

These results suggest that information availability and risk perception could influence consumer decision in both terms of product selection and return. Moreover, these elements are related each other, in fact, information search is a common mechanism consumer adopts to face perceived risk (Mitra et al., 1999).

In the case under investigation, the store accessibility reduces the consumer perceived risk, affecting the information seeking behaviour, despite the information is available at a lower cost. While, larger distances increase the perceived risk as well as the need of information, but the cost to obtain them is high. The econometric model demonstrates that the distance decreases the likelihood that product is returned, and thus that the risk perception effect seems to prevail on the information availability. However, the model neglects whether the same relation persists at different distance levels, for instance, within or above the store catchment area, calling for further investigations. Results suggest that retailers should consider two elements that can affect the distribution of sales across the channel and that can prevent product returns: the level of available information and the consumer risk perception.

First of all, the channel information capabilities can influence consumer product selection. Despite retailers can display a potentially infinite assortment online, and online search tools can reduce the product searching costs (Brynjolfsson et al., 2011), in the case under investigation, the distribution of online sales is more concentrated for internet and catalogue transactions. Therefore, consumers tend to buy here a lower variety of products. Previous researches have demonstrated that for some product categories (e.g., books, movies, music), online sales have a more disperse distribution (e.g., Brynjolfsson et al., 2011). However, they tested this relation for products with high level of digital attributes, low price and high frequency of purchase (e.g. books, music, movies). Therefore the differences between channels regarding the information provided are low, as well as the consumer perceived risk. In addition, the available information can affect consumer return decision because it reduces the gap between expected and actual product performance (Wood, 2001). However, being the available information related to the store accessibility, retailers should carefully consider that the risk perception influences the consumer behaviour to search for information (Mitra et al., 1999).

The paper contributes to the literature on differences between online and offline channels on sales distribution, interpreting these phenomena through the information and perceived risk perspective (Wood 2001). In fact, both of them can explain the differences across channels in terms of sales distributions as well as regarding the return rate, and the role of distance in defining consumer preference. The results confirm the previous contribution on the longer tail of online sales for product with sensory attributes (i.e., Ma, 2016, Brynjolfsson, 2011), in fact, they support the longer tail of online sales over the catalogue one because of the channel information capabilities. Moreover, they provide support to the literature on the increase of product returns driven by the store accessibility in the omnichannel setting (Pauwels and Neslin, 2015; Kumar et al., 2016).

7 Conclusions, implications for practice and academia

Due to its recent rise and promise of success, omnichannel retailing is a field that needs to be explored and to be carefully understood by both practitioners and academics. Therefore, the investigation of consumer behaviour in product selection and return decisions for a product category, which includes many different products that are characterised by a large variety of attributes, can provide meaningful insights. The analysis of the purchasing and the return behaviours in an omnichannel retail setting have the potential not only to gain insights for the retailer operating in that modality but also to help single channel retailers to understand the competitive environment in which they operate. These preliminary results would suggest that retailers may be better off by reducing the assortment offered online and through catalogues and increasing the level of information available on each channel. Moreover, they suggest modifying the consumer risk perception, for instance by differentiating return policies on a geographical basis or adding return fees. However, because the study is at a preliminary stage, further analysis and testing will need to be performed before providing more definitive conclusions.

The results provide evidence that for product categories rich in sensory attributes, channel information capabilities affect both the distribution of sales and the return rate across the different channels, proving that the lower the information level supported by the channel the more the sales are concentrated around a few "popular" products, albeit the higher their rate of return. Moreover, the results demonstrate that store accessibility alters the consumer risk perception, inducing them towards more risky purchases, and thus, a higher rate of return.

These results offer insights for assortment decisions across different channels in order to optimise the number of products. Moreover, they suggest the importance of considering the role of the channel information capabilities in order to prevent product returns. Finally, the results highlight the need to evaluate the factors that could alter consumer risk perceptions and to find solutions to influence it (e.g., information provision, introduction of policies).

This study investigates whether the information capabilities of retail channels have an impact on consumer product selection and return decisions. Moreover, it studies how physical store accessibility affects them. However, both the sales distribution across channels (Lee et al., 2011) and the impact on product returns are still controversial topics in the literature (Kumar et al., 2016).

However, the present study still leaves several areas to be investigated. Among them, worthy of note are:

- The use of the actual trip time between consumer homes and stores instead of the approximation of the Euclidean distance might improve the results, especially in urban contexts, where the distances may poorly reflect trip times.
- The introduction of the digital sales assistant in the online store might have enlarged the tail of the sales distribution because of the higher level of available information.
- The implementation of the Rank Regression Model and Quantile Regression Model would allow an evaluation of the statistical significance of the results as well as their robustness
- The analysis of returns behaviour along the distance may help to evaluate the trade-off between store accessibility and information availability more in depth.

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Last-Mile Supply Network (LMSN) Configuration in Omnichannel Retailing: Hypotheses and Simulation Framework

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Abstract

Omnichannel retailing, which uses all possible channels (including physical store, online channel, social media, catalogue, etc.) to fulfil customer demands, imposes great pressure on the back-end supply chain, especially the last-mile delivery. The last-mile supply network (LMSN) design is of great challenge facing various retailers. This paper aims to understand the characteristics of LMSN using simulation. A set of hypotheses is developed regarding the trade-off relationship between the structural form of LMSN configuration and product variety and delivery responsiveness. To overcome the constraint of obtaining quality data in this emerging phenomenon, this paper develops a discrete-event simulation framework following a rigorous simulation process to generate data and test the hypotheses in order to gain insights on the operational characteristics of LMSNs within the omnichannel context

Keywords: Last-Mile; Omnichannel retailing; Configuration; Simulation

1 Introduction

> *"e-retailers without the scale and volumes to deeply understand customer demand and forward deploy local inventories into major metro markets will be at a disadvantage in product categories and customer segments where immediacy of fulfilment dominates product feature or assortment."* (Mayor and Lambert, 2017)

Omnichannel retailing is a relatively recent phenomenon that has been transforming the retail landscape. For retailers, providing consumers with a seamless and consistent shopping experience across both physical bricks-and-mortar and digital e-commerce channels has been most demanding (Piotrowicz and Cuthbertson, 2014). It requires complex trade-offs between delivery responsiveness[1], product variety2[2], and the structural form of last-mile distribution (Laseter et al., 2015). The design of the "last-mile", often the most expensive segment of a logistics supply chain (Harrington, et al., 2016) is the focus of this paper. Following a review of past definitions by Lim et al. (2016), LMSN distribution concerns the last stretch of a business-to-consumer parcel delivery,

[1] Delivery responsiveness is a function of how far in advance customers must place their orders in order to receive them prior to the time they are needed.
[2] Product variety measures the range of products offered to consumers at a given time. The number of stock keeping units (SKUs) is often use as a proxy of product variety (Randall et al., 206).

spanning the order penetration point to the final consignee's preferred destination point, and involve a set of active and inactive entities.

The current state of omnichannel retailing is in a state of flux. While there are numerous innovative same-day and on-demand last-mile distribution models being operationalized in recent years such as, Deliv Fresh, Instacart and Amazon Fresh for groceries; Sun Basket for pre-prepared meals, and Dropoff, Amazon Prime Now and Prime Air for general retail, many retailers fail to adequately consider the intricacies of operating these models, leading to failures despite committing significant investments (Lopez, 2017). For example, Wal-Mart recently scrapped its shipping pass programme, dubbed a "copycat" of Amazon's prime membership scheme, within two years of introduction. While two well-known British retail chains entered bankruptcy: 116-year old menswear brand, Austin Reed fell into administration in June 2016 amid a challenging retail market and cash flow issues. A total of 120 stores were closed and 1,000 jobs lost. The 88-year old department store, British Home Stores (BHS), lost 164 stores and about 11,000 employees over the same period.

These anecdotal examples stand in stark contrast to the established literature development on last-mile logistics suggesting a misalignment that fail to address key industry challenges. For instance, Mangiaracina, Song et al. (2015) identified 42 factors[3] influencing distribution network design. However, the decisions related to network structure were centred on the planning aspect (e.g. facility, location and capacity) rather than the structural characteristics of last-mile distribution models. Lee and Whang (2001), Chopra (2003), Boyer and Hult (2005), and Vanelslander, Deketele et al. (2013), have each developed last-mile structural types to assist design under different consumer and product attributes. These studies mostly capture the linearly "chain-centric" last-mile models, prevalent in the pre-digital era. Moreover, these studies did not provide an environment to allow retailers to simulate various distribution models under specified boundary conditions prior to actual implementation. As a result, retailers often pay the price of failure as they evaluate the feasibility of a specific delivery model after implementation. Given the nascence of omnichannel retailing, it is challenging to collect real-world data to empirically examine last-mile supply networks (LMSN) configuration to develop theories. Simulation is the most appropriate research method in this situation, as it is particularly suited to the development of theories that are still relatively undeveloped, limited by weak conceptualization, few propositions and vague underlying theoretical logic (Davis and Bingham, 2007). This is indeed the situation for our context, i.e., omnichannel retailing. Moreover, simulation can serve as a prescriptive model to investigate non-existing systems, like omnichannel retailing, which has not been fully adopted in practice (Harrison, et al. 2007).

Our study therefore seeks to address the LSMN challenge facing retailers by developing a simulation framework to investigate the question: what is the optimal LSMN configuration for omnichannel retailing? To achieve this aim, a discrete-event simulation framework is developed to test a set of hypotheses regarding the impact of key operational parameters on the structural forms of LMSNs.

To improve the vigor of our simulation study, we follow the procedures set forth by Manuj et al. (2009) when designing our simulation framework, that is: (1) Problem formulation; (2) Choice of dependent and independent variables; (3) Validation of conceptual model; (4) Data collection; (5) Verification of computer model; (6) Model validation; (7) Performing simulations; and (8) Analysis techniques. Because this research is still on-going, we only report the resulting simulation framework developed after the first three steps.

This paper is structured as follows. Section 2 reviews the relevant literature and provides key definitions. Section 3 develops the conceptual model of the simulation framework. Section 4 specifies key input parameters and presents the experimental design. Lastly, Section 5 concludes the paper and details future work.

[3] The 42 factors are grouped into five groups: product characteristics, service requirements, demand features, supply characteristics and economic variables.

2 Literature review and hypothesis development

2.1 Literature review

Our paper contributes to two streams of literature in omnichannel supply chains: studies examining downstream distribution via framework development and empirical modelling and those investigating the configuration and impact of delivery options within the omnichannel context, mainly via analytical modelling and simulation. In the former stream of literature, Ishfaq and Raja (2017) develop a framework to evaluate three fulfilment options based on a retailer's existing network of stores and DC facilities, direct-to-customer fulfilment centres, and collaborating with vendors to facilitate dropshipping across a set of operational and cost metrics. Lim et al. (2017) conduct a literature review on last-mile logistics models, and develop a prescriptive design framework. Moreover, Hübner et al. (2016) develop a planning framework for last-mile fulfilment and distribution. While these studies have constructed useful frameworks that provide managers with prescription regarding the adoption of a specific form of last-mile distribution, scarce studies exist that provide a simulation framework to examine the structural forms and their evolutions in different operational contexts within the omnichannel environment. The absence of which means retailers have to risk experimenting different models in order to observe their viability.

In the latter stream of literature investigating the configuration and impact of delivery options, Gao and Su (2016) study the impact of the buy-online-pick-up-in-store (BOPS) initiative on store operations via the development of a stylized model where a retailer operates both online and offline channels. There are also studies that examine outsourcing decisions (Rao et al., 2009) and the conditions supporting retailers to dropship rather than hold inventory (Netessine and Rudi, 2006). While studies in this domain have captured the various forms of last-mile distribution and the conditions promoting the usage of a specific form, none of these studies have considered the boundary conditions that influence the structural forms of last-mile distribution. In particular, the extant literature provides limited understanding as to the conditions causing a specific structural form to change. This understanding is critical for retailers. The better understanding of these conditions allows retailers to preempt change in order to maintain alignment between the LMSN structure and its operating environment.

Based on a synthesis of these literature streams, our study develops a simulation framework that captures the various LMSN structures (i.e. BOPS, dropship, ship-from-store and ship-from-DC) and incorporates delivery responsiveness and product variety as the key determinants of LMSN structure.

2.2 Last-mile supply network structure

A supply network is "essentially an organizational form in a larger context or a system of firms" (Choi and Hong, 2002, pp. 470). We draw on the literature on organization design complexity (e.g., Daft, 1989, Price and Mueller, 1986), supply network (Choi and Hong, 2002) and logistics (Klaas, 2003, Stock, Greis et al., 1998) to examine network structure in terms of centralization, vertical integration, horizontal integration, and geographic dispersion. We define centralization as the degree of authority or power a firm exercises over other firms in the network. Extends to inventory aggregation context where stocks are pooled at centralized locations; vertical integration as the extent to which a firm owns the various stages of the LMSN; horizontal integration as the degree of multiplicity of each LMSN stage or function; and geographic dispersion as the extent to which productive units in the LMSN are dispersed geographically.

2.3 Development of Hypotheses

This section details the set of hypotheses to be tested via the developed simulation framework.
Distribution involves a set of activities and processes that moves and stores a product from the origin (e.g. supplier site) to the consumer's desired location. Retailers targeting consumers with tolerance of long response time or slow delivery responsiveness require fewer inventory locations that may be farther away from the consumer segments (Chopra, 2003). This arrangement permits

retailers to focus on increasing the capacity at each of these inventory facilities. By contrast, retailers would need to locate inventory facilities closer to the consumer segments if they are targeting consumers who value short response time or fast delivery responsiveness. In turn, these retailers must have more facilities, each with a lower capacity, in order to adequately service the consumers. As a result, inventories are disaggregated (Lim et al., 2016).

Therefore, we propose our first hypothesis:

H1: The higher the desired delivery responsiveness, the lower the degree of centralization of LMSN.

It is known that increasing product variety not only increases complexity in product portfolio management but also across several operational activities including inventory and logistics management (Jacobs and Swink, 2011). Therefore, the lower the product variety, the more likely retailers could manage the activities along the vertical value chain due to the lower complexity in managing these activities, ceteris paribus. In turn, the higher the product variety, the more likely retailers would outsource certain parts of the value chain activities to specialist providers (e.g. 3PLs), thereby reducing the degree of vertical integration. Consequently, the degree of multiplicity of each LMSN stage increases due to heterogeneity in operational processes when managing distinct products. For example, low sortable items like washing machine may require special handling in which an 3PL would be more capable to handle the delivery.

Based on this argument, we posit the following:

H2: The higher the product variety offered, the (a) lower the degree of vertical integration, and (b) higher the degree of horizontal integration of LMSN.

Synthesizing the reasoning for developing H1 and H2, retailers managing a product portfolio of high variety, coupled with slow delivery responsiveness would have more lead-time to target faraway consumers and more abled to target different consumer markets due to the high product variety it offers to service heterogeneity in consumer preferences. In this case, geographic dispersion increases by having facilities sparsely located from each other. By contrast, fast delivery responsiveness reduces the degree of geographic dispersion to focus on servicing high value consumers within a small catchment area (e.g. urban areas) (Stock et al., 1998). Moreover, due to the shorter lead-time and increased operational cost of on-demand delivery, retailers have to concentrate their facilities in a limited area and often rely on the ecosystem such as partnering with other retailers and service providers in order to offer attractive service proposition that delivers on promise (Lim et al., 2016).

Therefore, we posit:

H3a: High product variety coupled with slow delivery responsiveness is more likely to lead to high geographically dispersed LMSN.

H3b: High product variety coupled with fast delivery responsiveness is more likely to lead to low geographically dispersed LMSN.

Lastly, combining low product variety and slow delivery responsiveness permits retailers to cover markets that share similar preferences but located farther away, resulting in a moderate geographically dispersed LMSN. On the other hand, retailers offering fast delivery responsiveness would have LMSNs characterized by elements of low and moderate geographic dispersion dependent on product types and the adopted fulfilment strategy (Boyer et al., 2005). More specifically, LMSNs operated based on orders fulfilled by DCs are more abled to target markets located farther away leading to moderate geographic dispersion vis-à-vis LMSNs operated based on

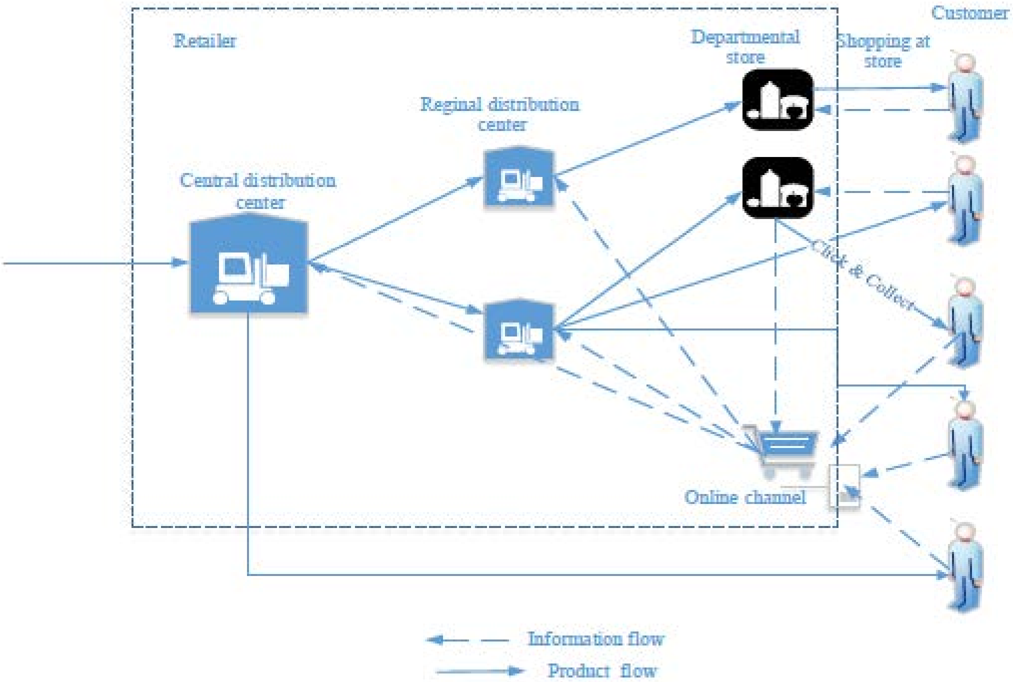

Figure 1 – Last-mile supply network of an omnichannel retailer

orders fulfilled by physical stores (Lim et al., 2016). In this latter case, the LMSN is characterized by low geographic dispersion.

Based on the preceding discussion, we posit:

H4a: Low product variety coupled with slow delivery responsiveness is more likely to lead to moderate geographically dispersed LMSN.

H4b: Low product variety coupled with fast delivery responsiveness is more likely to lead to LMSN with features of low and moderate geographic dispersion.

2.4 Operationalisation of Constructs

We operationalize the key constructs as follows:

- Degree of centralisation of LMSN as the number of fulfilment facilities in the supply network. The more facilities in the network, the lower of centralisation degree;
- Product variety is proxied by the breath of product assortment in terms of stock keeping units (SKU);
- Vertical integration as the number of the echelons operated by the focal retailer from CDC to the customer, the higher the count, the more integrative is the LMSN (high and low vertical integration in the experiment); and
- Horizontal integration by the number of RDCs in the same echelon, the lower the count, the more integrative of the LMSN (high and low horizontal integration in the experiment).
- Geographic dispersion by the density of RDCs.

3 Development and Validation of Conceptual Model

In this paper, we test the hypotheses by simulating the logistics system from the perspective of an omnichannel retailer operating both department store and online store (e.g. website, Mobile app, social media) format, schematically represented in Figure 1. Customers can either shop at the store and get the products directly or place order online. If the store is out of stock, the customers may place an order at the store or give up purchasing the product. Online orders can be fulfilled and delivered via different modes such as click-and-collect and ship-to-home. The order could be fulfilled by the departmental store, Regional distribution centre (RDC) or Central distribution centre (CDC), depending on the delivery time chosen by the customer. The inventories in the departmental stores and RDCs are replenished periodically following a certain replenishment policy.

To achieve the objectives of this research, our model makes the following assumptions:

Assumption 1: We assume that CDC always has enough inventory and we do not consider the ordering cost at CLC. This assumption is appropriate because our research is restricted within the scope of a retailer. As such, the interaction between the retailer and a manufacturer could be ignored.

Assumption 2: The stores replenish inventories according to the past two weeks' sales and the RDCs replenish inventories based on the past two weeks' inventory depletion.

This assumption is only used to simplify the model. Otherwise, our simulation framework is flexible enough to accommodate any inventory replenishment policy.

Assumption 3: We assume that each store only places order with the nearest RDC. Again, this is to simplify the simulation. Moreover, this policy is commonly used in practice.

Assumption 4: Cross-selling in click-and-collect is not modelled. One benefit claimed in the literature on click-and-collect is the cross-selling effect when customers go to the store to collect their online orders. To simplify the simulation, we do not consider this.

Assumption 5: Product return is not modelled. "Buy anywhere, get anywhere and return anywhere" is claimed as the ultimate goal of omnichannel retailing. However, many companies are using specialised third-party logistics providers (3PL) to deal with the returns. For example, John Lewis uses a 3PL to wholly manage the returns process. In this research, we do not model the product returns process. However, our simulation framework is general enough to include the product returns process via an extension.

The model flow for this study can be divided into the following stages:

(1) Demand generation
(2) Order receiving and processing
(3) Demand fulfilment
(4) Inventory replenish at stores and RDCs
(5) Product delivery

3.1 Demand generation

Omnichannel retailers usually sell products in multiple categories with multiple brands, e.g., John Lewis and Wal-Mart. Consumers often purchase multiple items in one shopping journey. Therefore, consumers' shopping basket choice process should be modelled. In this study, we use the Multivariate Logit (MVL) Model to generate the demand for each consumer in the simulated geographical region. Following Richards and Bonnet (2016) and Song and Chintagunta (2006), we assume that consumers $h = 1,2,3,\dots$ select items from among $i = 1,2,3,\dots N$ categories, c_{iht}, in assembling a shopping basket, $\boldsymbol{b}_{ht} = (c_{1ht}, c_{2ht}, c_{3ht}, \dots, c_{Nht})$ on each trip, t, conditional on their choice of store, r. The set of all possible baskets in r is defined as $\mathbf{b}_{ht}^r \in \mathbf{B}^r$. The joint probability of choosing the entire vector $\mathbf{b}_{ht}^r$, is as follows:

$$\Pr(\mathbf{b}_{ht}^r|r) = \frac{\exp(\boldsymbol{\pi}_{ht}^{r}{}'\mathbf{b}_{ht}^r + \frac{1}{2}\mathbf{b}_{ht}^{r}{}'\boldsymbol{\Theta}_h^r\mathbf{b}_{ht}^r)}{\sum_{\mathbf{b}_{ht}^r\in\mathbf{B}^r}\left[\exp(\boldsymbol{\pi}_{ht}^{r}{}'\mathbf{b}_{ht}^r + \frac{1}{2}\mathbf{b}_{ht}^{r}{}'\boldsymbol{\Theta}_h^r\mathbf{b}_{ht}^r)\right]} \tag{1}$$

Where $\boldsymbol{\pi}_{ht}^r = (\pi_{1ht}^r, \pi_{2ht}^r, \pi_{3ht}^r, \dots, \pi_{Nht}^r)$ is the baseline utility vector for each category, and $\boldsymbol{\Theta}_h^r = (\Theta_{1h}^r, \Theta_{2h}^r, \Theta_{3h}^r, \dots, \Theta_{Nh}^r)$ the matrix for the cross-category effect, each Θ_{ih}^r represents a column vector of an $N \times N$ cross-effect $\boldsymbol{\Theta}_h^r$ matrix with elements Θ_{ijh}^r. The baseline utility is assumed to depend on a set of category ($\mathbf{X}_i$) and household ($\mathbf{Z}_h$) specific factors such that: $\pi_{iht}^r = \alpha_{ih}^r + \beta_{ih}^r\mathbf{X}_i + \gamma_{ih}^r\mathbf{Z}_h$, where perceived need, in turn, is affected by the rate at which a household consumes products in the category, the frequency that they tend to purchase in the category and any other household demographic measures. Category factors are those marketing mix elements, for example, prices and promotion. The purchasing of a shopping basket follows a multi-variate logistic distribution. Therefore, we can use this distribution to generate the consumer demand in the simulation. The data needed to estimate the parameters are the category and household specific factors as well as the cross-category effect matrix. For more information about the estimation process, the readers are referred to Song and Chintagunta (2006).

After generating the basic consumer potential demands, the channel choice should be generated. We assume that a proportion λ of consumers prefer the departmental store and a fraction $1 - \lambda$ of consumers place order online. Among the physical shopping consumers, if the product is out of stock, a proportion μ of them will turn to the online shopping. For those digital savvy consumers, the preference on different delivery options follows a certain discrete distribution. The above parameters can be obtained through surveys conducted by consulting companies.

Using the abovementioned method, we can generate the profile for each consumer including the basket choice, channel preference, delivery choice and alternatives if out of stock.

3.2 Order receiving and processing

Orders placed at the store will be fulfilled immediately with a cost c_s for each order, mainly including labour cost. While orders placed online will be stored and processed automatically in terms of choosing the best fulfilment option. The cost for each order is c_o.

3.3 Demand fulfilment

The demand fulfilment is mainly focused on choosing the best fulfilment center and delivery option to satisfy a certain demand to minimise the fulfilment cost. For click-and-collect orders, the store inventory will be used to satisfy the demand if it is available, otherwise, an express delivery will be used to send the product from the nearest RDC to the store. Ship-to-home (or a certain address) orders could be fulfilled from the CDC or RDC or store. The fulfilment rule is as follows: the retailer lists the potential fulfilment points $k = 1,2,3, \ldots, M$ (M is the total number of fulfilment facilities in the supply network) which have available inventory, and rank them based on transportation cost (c_{Tj}, $j = 1,2, \ldots, k$), and then find the point which has lowest transportation cost and satisfies the time constraint.

3.4 Inventory replenish at stores and RDCs

The inventories in the stores and RDCs are monitored continuously. Once a status change has occurred, the inventories will be checked and decide if replenishments are needed. If the inventory level is above a certain level (the trigger point), no replenishment is needed, otherwise, a quantity equals to the past two weeks' sale will be ordered. This rule is adopted from Tielbeek (2016). Similar rule is used for the replenishment of RDCs. We assume that the ordering cost for stores and RDCs are the same, which is c_r.

3.5 Product delivery

Product delivery occurs transportation cost based on the distance from the fulfilment point to the consumer address. Assume that the unit transportation cost per order is c_t, the total cost for deliver-to-address is $c_t \times$ distance. For click-and-collect, if the order is fulfilled by the store inventory, the delivery cost is the same as the cost of dealing with a physical shopping consumer, which is c_s. However, if it is shipped from a store, a premium will be charged by the express delivery company, which is assumed to be c_p per order. The detailed simulation flow is presented in Figure 2.

4 Parameters and experiment design

4.1 Parameters

The input parameters are listed in Table 1.

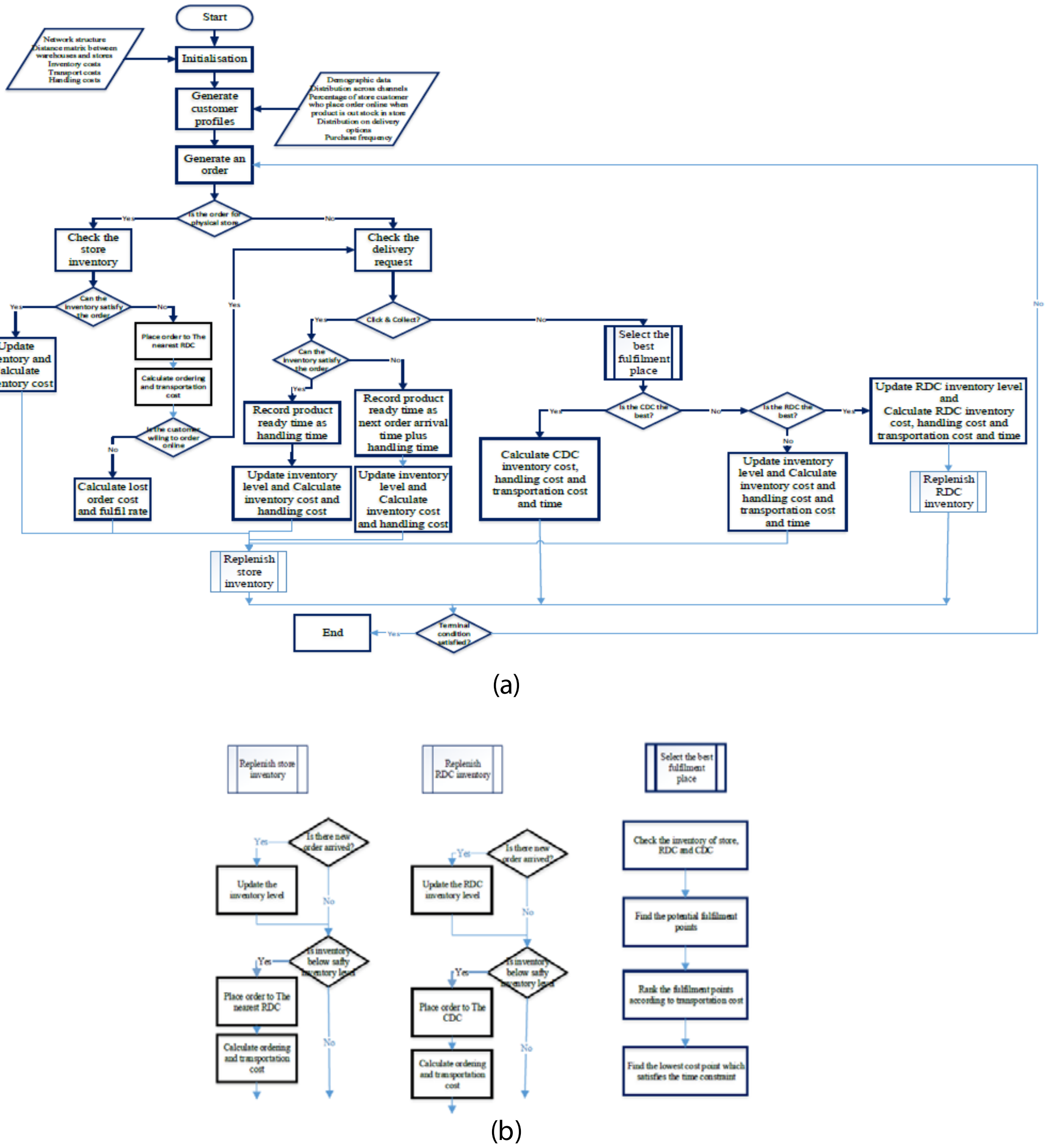

Figure 2 – Simulation flow chart

4.2 *Performance evaluation criteria*

In this study, we use the average supply cost per product to measure the overall performance of each network configuration.

4.3 *Experiment design*

To test the hypotheses, we generate two scenarios for each construct that is high and low, for example, high product variety and low product variety. Each scenario is an experiment in the simulation. Thus, we have 2×2(H1) + 2×2×2(H2) + 2×2×2(H3) =20 experiments in total. For each experiment, the simulation time is one year. We repeat the simulation 50 times and thus collect 50 samples from the simulation. Two-way ANOVA will be used to analyse the data and test the hypothesis.

Table 1 – Last-mile supply network of an omnichannel retailer

Parameter description	Symbol
Product assortment	N
Fulfilment facility number	M
Location of CDC, RDC and stores	(x_i, y_i), i=1,2,…,M
Consumer location	(x_j, y_j), j=1,2,…,H
Category specific factor for the consumer base utility	$\mathbf{X}_i$, i=1,2,…,N
household specific factor for the consumer base utility	$\mathbf{Z}_h$, =1,2,…,H
Proportion of consumers who prefer physical store	λ
Proportion of physical store consumers who turn to online order when out of stock	μ
Distribution on delivery choice	$\mathbf{p} = (p_1, p_2, \dots, p_L)$, L the number of delivery options
Cost of store order processing	c_s
Cost of online order processing	c_o
Unit transportation cost/mile	c_t
Express transportation for urgent order	c_p
Ordering cost at stores, RDCs, CDCs	c_r

5 Conclusion and future work

This research investigates the LMSN configuration for an omnichannel retailer. Different hypotheses have been proposed to characterise the features of the LMSN. To test the hypotheses, we developed a discrete-event simulation framework to generate data. Experiments have been designed and data analysis methods have been proposed. Next step will be to validate the conceptual model using experts from both academia and the retail industry, followed by data collection from a company to verify the simulation model. Consequently, the simulation will be implemented repeatedly to generate data based on the experiments. The generated dataset will then be statistically analysed to test the proposed hypotheses.

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Methodological Approaches for Next Generation Supply Chains

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Abstract

Collaborative management research approaches (e.g. Action research, Intervention research) emerged to overcome what is considered as a lack of integration between empiricism and theoretical knowledge. In such approaches, researchers will not be just observing the phenomenon, however, they should be immersed in the empirical settings, and the research process will be performed collaboratively through engaging all the stakeholders (researchers, practitioners, policy makers). Through a content analysis, the present research draws on the findings of scholarly publications which employed collaborative management approaches in their research design. The paper presents a research agenda for knowledge co-generation between different supply chain stakeholders. The potential drawbacks of adopting collaborative management research approaches in supply chain research - for instance concerns on the methodological rigor - are also scrutinised. The findings of this paper contribute to a better understanding of managing collaborative research processes, which engages practitioners in the research process, and involves researchers in the practitioners' system.

Keywords: Collaborative Management Research, Action Research, knowledge co-generation, Participatory Research, Intervention Research

1 Introduction

Progressive collaborative platforms lies in the heart of next generation supply chain management (GCI and Capgemenini, 2016). With the rapid dissemination of technological innovations, a relatively larger number of stakeholders is envisioned to be engaged in the management of these future supply chains. Researchers, therefore, are expected to develop theoretical perspectives, and to adopt methodological approaches that can address the challenges of the advancement in the empirical field and bridge the so-called relevance gap (Starkey and Madan, 2001; Jahre et al. 2015), with the main aim of designing a research process that leads to research informs practice and practice informs research synergistically (El Tantawy et al., 2015, p.899).

Collaborative management research (CMR) approaches emerged as means to address the relevance gap, while in parallel ensures scientific rigour (Gibbons et al. 1994). Examples of CMR approaches are; Action research, clinical enquiry, intervention research, consultancy (contracted) research (Shan et al., 2004). The central theory behind CMR is establishing collaboration and ensuring active participation of all the stakeholders in the research process in an iterative or a cyclical manner, leading to a transformation in the practitioner's systems and to a contribution to theory building (i.e. developing actionable knowledge) (MacLean et al. 2002; Pasmore et al. 2007).

As such, the researcher will not be just observing the phenomenon, however, researchers will be immersed in the practitioner's (empirical) settings and will act as agents of change in a real life setting (Shani et al., 2012). Practitioners will also be involved in the research problem formulation and data collection. The implementation of the improvement solutions and their evaluation will be performed jointly between researchers and practitioners (Coughlan and Coghlan (2002). The improvement iterations and transformation philosophy behind CMR concepts allows for a continuous improvement business environment, and an increased preparedness to any disruptions or uncertainty in the real-world (Brydon-Miller et al. 2003). Collaborative management research faces critique of rigour due to the possible concerns of practitioners influencing data analysis. Therefore, it is highly advised to identify the research theoretical underpinnings of the research beforehand starting the project, so as to avoid any possible manipulations (Coughlan and Coghlan, 2002; Sabri, 2017), as well as triangulation of methodologies and researchers (Näslund et al. 2010). Its transdisciplinary nature and the embedded transformation philosophy, makes CMR a well-suited candidate for the supply chain research domain (Coughlan and Coghlan, 2002; Näslund et al. 2010; El Tantawy, 2015). Supply chain researchers who employed CMR approaches (see e.g. Ivan Su et al. 2011, Coghlan and Coughlan, 2007) advocate for its benefits in addressing real-life problems. Yet, the adoption of CMR approaches in supply chain research is scarce (Birkie et al. 2013). To this end, the present research reviews the extant scholarly publications of supply chain management, where the research methodology was collaborative, participatory and transformational. The authors of this piece of work aspire to inform the research community on the status of CMR adoption in supply chain domain, and to inform on the relevance, reflectiveness, and rigour issues.

2 Research Design

2.1 Approach

The paper aims to understand the extent of usage of collaborative management research approaches in the domain of supply chain management with the intent of identify ways for better addressing research relevance-rigor gap (e.g. Pasmore et al., 2008) particularly relevant in the field of supply chain management. Therefore, in this study, a systematic literature review coupled with content analysis has been employed. While the literature review enables us to identify and focus the literature base to start with, detail content analysis helps to hold more extensive discussion on detail mechanisms of conducting collaborative management research in SCM. The steps followed in our review are briefly explained in the sub-sections that follow.

2.2 Selection of papers for review

In order to capture a large number of initial literature in the domain of concern, we have decided to do search on Web of Science, Scopus as well as Google Scholar and compare the findings. A set of agreed keyword combinations was used to do the search based on initial exploratory work on methodological papers on collaborative management research. Only articles in peer reviewed journals and book chapters from 2002 onwards have been the focus of this search. Only documents written in English have been captured. Eight different keyword combinations have been tested and only that returned non-zero results were combined to clean for duplicates. These combinations are:

1. collaborat* research AND supply chain management, 2) action research AND supply chain management, 3) case stud* AND supply chain management AND action research, 4) case stud* AND supply chain management AND intervention*. The search was focused on title, keywords and abstracts, which collectively are referred to as topic in some databases.
2. The search in Scopus and Web of Science with the above keywords and filters resulted in 126 and 96 papers respectively. The list was then cleaned for duplicates, and a few additional unique papers found on Google Scholar were added, making the final eligible list for starting content

Table 1 – Distribution of publications by year

Year of publication	Count	%
2002	1	1
2003	3	2
2004	9	5
2005	16	9
2006	10	6
2007	8	4
2008	10	6
2009	12	7
2010	13	7
2011	13	7
2012	13	7
2013	11	6
2014	9	5
2015	22	12
2016	22	12
2017	8	4
Total	180	100

based screening to 180 articles. Descriptive details of these papers are provided in Table 1 and Table 2.

2.3 Shortlisting and content analysis

The three authors of this paper have then gone through each abstract of the 180 papers to select papers that would qualify for detail content analysis. Papers with no mention of collaborative or case based approaches, as well as the subject of investigation is beyond what can be regarded as core supply chain and operations management were subject to exclusion. As initial work for this conference, papers that have got a yes for further analysis by all three researchers for further analysis. Detailed analysis reported subsequently in this paper is based on those 15 articles.

Papers in this initial list of articles were published between the years 2007 and 2016; they had at least 1 citation. However, we refrained from using citation as a shortlisting criterion as this would practically lead to exclusion of more recent publication which does not help us with the forward looking objective of this study. As shown in Table 3, most of the journals that had high count in the initial list (i.e. Table 2) were also well represented.

These shortlisted papers have then been subject to detail content analysis following recommendations of proponents of the methodological fields. For this purpose, the details of action research cycle (e.g. Coughlan and Coghlan, 2002; Pasmore et al., 2008; Maestrini et al., 2016; Coughlan et al., 2016) has been considered in setting the criteria. To kame our content analysis more structured, we have used the enumerated criteria shown in Table 4 so that a more objective directions and guidelines for future research can be extracted. The criteria reflect the basic tenets of Mode 2 knowledge production that action research and different other collaborative management research approaches are based on.

3 Content Analysis and Discussion

This section presents the content analysis of 15 papers that were selected for this review. Table 5 lists the papers chronologically and provides a short summary of each.

Table 5 demonstrates that papers selected for this review deal with various topics pertinent to supply chain management. Except [P3], [P14] and [P15], all the papers included in the review are empirical works and adopted some kind of collaborative management research approaches. [P14] and [P15] provide general guidelines for conducting collaborative management research in the field of supply chain. Therefore, other than these three papers, contents of all the papers [P1], [P2], [P4]-[P13] are critically analysed according to the attributes mentioned in table 4. The analysis is presented in table 6. Table 6 reveals many things about context of application of collaborative

Table 2 – Distribution of publications by source title

Source title	Count	%
Supply Chain Management: An International Journal	12	7
International Journal of Production Economics	10	6
International Journal of Operations and Production Management	7	4
International Journal of Physical Distribution and Logistics Management	6	3
International Journal of Production Research	6	3
Journal of Purchasing and Supply Management	6	3
British Food Journal	5	3
Journal of Manufacturing Technology Management	5	3
Production Planning and Control	5	3
Research Methodologies in Supply Chain Management: In Collaboration with Magnus Westhaus	5	3
Journal of Cleaner Production	4	2
Computers & Chemical Engineering	3	2
Industrial Marketing Management	3	2
nternational Journal of Productivity and Performance Management	3	2
Journal of Business Logistics	3	2
Journal of Construction Engineering and Management	3	2
7 sources with 2 papers each	14	8
80 sources 1 paper each	80	44
Total	180	100

Table 3 – Source distributions of shortlisted papers

Source title	Count
International Journal of Operations and Production Management	2
International Journal of Physical Distribution and Logistics Management	2
International Journal of Production Economics	2
International Journal of Production Research	2
Supply Chain Management: An International Journal	2
Human Relations	1
Industrial Marketing Management	1
International Journal of Logistics Research and Applications	1
Journal of Cleaner Production	1
Systemic Practice and Action Research	1
Total	15

management research. The papers analysed applied collaborative research in various contexts from food sector (Taylor 2006; O'Reilly, Kumar, and Adam 2015) to nuclear fuel industry (Baker and Jayaraman 2012) and from automobile (Koplin, Seuring, and Mesterharm 2007; Danese and Vinelli 2009; Pereira et al. 2011) to construction industries (Hameri and Paatela 2005; Eriksson 2010). Table 6 also identifies a number of topics such as supply network (Hameri and Paatela 2005; Danese and Vinelli 2009), lean (Taylor 2006; Eriksson 2010), sustainability (Koplin, Seuring, and Mesterharm 2007; Garcıa-Arca and Prado-Prado 2014) can be handled with such collaborative research methodologies. Moreover, a plethora of problems such as reduction of lead times (Hameri and Paatela 2005), lack of coordination of supply chain partners (Taylor 2006) and implementation of sustainable packaging logistics (Garcıa-Arca and Prado-Prado 2014) can be solved with collaborative research methodologies.

On methodological aspects, such collaborative research projects are found to be initiated by both researchers (Taylor 2006; Koplin, Seuring, and Mesterharm 2007; O'Reilly, Kumar, and Adam 2015) and companies (Eriksson 2010; Ivan Su, Gammelgaard, and Yang 2011; Baker and Jayaraman 2012). Some of these projects (Hameri and Paatela 2005; Taylor 2006; Eriksson 2010; Ivan Su, Gammelgaard, and Yang 2011; Baker and Jayaraman 2012; Garcıa-Arca and Prado-Prado 2014; Eltantawy et al. 2015) have active involvement of researchers and practitioners which means

Table 4 – Review Criteria

Attributes	Description
A. Overall issues	
1. Methodological approach	Which type of collaborative management research
2. Justification for using methodological approach	What are the justification provided by the authors for using a collaborative management research in supply chain
3. Industry sector	What are the type of industry e.g. food
4. Duration of the study	What was the length of the study?
B. Nature of the involvement of academician and practitioner	
5. Research Initiation	Who and how the collaborative research process was initiated
	Was there a collaborative framing of the research agenda and the research question
	Was the theoretical underpinnings of the real life problem stated beforehand starting the intervention process?
	Top management commitment to the research process?
6. Research Setting	Researcher involvement in the practitioner system
	Practitioner involvement in the research process
	Level of collaboration and coordination
	Who are the additional stakeholders (community? Customers?)
	How the research question evolved over the research process?
7. Data Collection	Deciding on the unit of analysis (jointly?)
	Data and information sources
	Who is collecting the data
	Was data collected from all the involved stakeholders?
8. Data Analysis	How and WHO analysed the collected
	Was there (co-production of knowledge)
9. Implementation Design	How the data analysis was fed back into the practitioners system?
	How the implementation (intervention) is designed?
	Improvement iterations?
10. Evaluation	Was the implementation evaluated
	How the implementation results were evaluated
	Who was involved in the evaluation (did it lead to improvement?)
	What are the learnt lessons
11.Transformation (research impact)	Did the collaborative methodology led to a transformation in the real life setting?
	Did the collaborative methodology led to a progress in addressing organisational/supply chain challenges?
	Theory building?
	How?
12. Monitoring	Was the research process monitored in all its stages by researchers?
C. Contribution related issues	
13. Problem solved	What is the problem the paper offers solutions to?
14. Benefits achieved	The benefits cited by the authors for using collaborative management research
15. Recommendations for future researchers	Recommendations for future researchers for using collaborative management research

researcher and practitioners co-design the research project by forming a team. For instance, Ivan Su, Gammelgaard, and Yang (2011) notes that

> *Two of the authors of this paper were engaged at the hospital as expert consultants (one internal and one external) in order to assist the hospital in creating new logistics processes. A cross-functional project team comprising the hospital logistics manager, heads of nursing units and the head of management information system (MIS) was formed to pursue the logistics improvement goals.*

Table 5 – Summary of the papers included in the review

#	Author(s)	Summary
1	Hameri and Paatela (2005)	This paper purports that supplier networks along with their inherent dynamics create new business opportunities for fast moving companies.
2	Taylor (2006)	This paper shows that value chain analysis techniques coupled with lean principles provide a powerful framework for the analysis and improvement of supply chain activity.
3	Koplin, Seuring, and Mesterharm (2007)	This paper demonstrates how companies can integrate social and environmental standards into supply policy and supply management.
4	Coghlan and Coughlan (2008)	This paper describes how the participating managers and academic researchers used action learning and action research to achieve collaborative improvement in supply chain.
5	Danese and Vinelli (2009)	This paper presents problems occur, solutions adopted, and critical contingent factors of a supplier network delocalisation project in a capital-intensive context.
6	Eriksson (2010)	This paper delineates how different aspects of lean thinking are implemented in a construction project as well as how these aspects affect various actors of the supply chain and their performance.
7	Ivan Su, Gammelgaard, and Yang (2011)	This paper identifies logistics innovation process is dynamic and dependent on internal and external stakeholders as well as can include suppliers and improve buyer-supplier relationships.
8	Pereira et al. (2011)	The paper argues that buyer's fair for first and second tier suppliers can make the procurement process of large companies and the selection process of small and medium enterprises faster and less-expensive.
9	Baker and Jayaraman (2012)	The paper exhibits that how implementing lean operating supplies program reduced inventory level and improved process information flow.
10	Garcıa-Arca and Prado-Prado (2014)	This paper examines the aspects of internal and external transformation in companies within a supply chain during implementation of a sustainable packaging logistics approach
11	Dey, Bhattacharya, and Ho (2015)	This paper contends that evaluating strategic supplier using an integrated analytical framework can result in positive impact on operational and business performance of the client organization.
12	Eltantawy et al. (2015)	This paper addresses the issue of supply management coordination of a focal company with a first and second tier suppliers.
13	O'Reilly, Kumar, and Adam (2015)	This paper explores the potential impact of Hierarchical Production Planning (HPP) among small and medium enterprises.
14	Touboulic and Walker (2015)	This paper inspects opportunities for the application of action research methodology for knowledge development in the sustainable supply management research.
15	Liu, Wu, and Goh (2016)	The paper scrutinizes the motivations, expectations, and communication involved in the process of collaborative research between academics and practitioners.

In other projects practitioners (Danese and Vinelli 2009; Pereira et al. 2011; Dey, Bhattacharya, and Ho 2015; O'Reilly, Kumar, and Adam 2015) are passively involved which means that practitioners act only as the providers for data with no real involvement in the research process. An example of such projects is O'Reilly, Kumar, and Adam (2015) notes how researchers take up more responsibilities for such projects:

The research team, working with the agency expert, identified a list of potential case companies. Three case companies were sought for the action research project as this provided a good basis for cross-case analysis.

Table 6 – Content Analysis of the papers

#	A. Research context			B. Methodological Issues						C. Research Impact	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1	Shipyard, Construction, electronics manufacturing	Supply network	Reducing lead times	Not specified	Active involvement of both	2 years	Case study based action research, interviews	Researchers	Researchers	For testing the developed propositions	Reducing lead times
2	Food (red meat)	Lean	Lack of coordination of among chain actors	Researcher	Active involvement of both	Not specified	Case study based action research,	Researchers and practitioners	Researchers and practitioners	Cogeneration of actionable knowledge	Common competitive advantage as a chain
3	Automobile	Sustainability	Incorporating environmental and social aspects	Researcher	Active involvement of both	One and half years	Literature review, workshops, interviews, surveys	Researchers	Researchers	Cogeneration of actionable knowledge	Incorporate sustainability into supply management
5	Automobile	Supplier network	Supplier network relocation	Not specified	Passive involvement of practitioners	Over 2 years	Not specified	Researchers	Researchers	Critical aspects during a supplier network relocation are investigated and solutions proposed	Delocalization of supply network
6	Construction	Lean	Identifying lean aspects	Company	Active involvement of both	Not specified	Case study based action research, surveys, workshops	Researchers	Researchers	Identification of various aspects of lean construction	Delivery of construction project within time and budget
7	Healthcare	Logistics innovation	Implementation of logistics innovation process	Company	Active involvement of both	1-2 years	Meetings, internal documents/database, interviews	Researchers and practitioners	Researchers and practitioners	Confirms customer-oriented logistics process model	Collaborative learning of innovation process and improved relationship with suppliers.
8	Automobile	Industrial Procurement	Reducing time and cost of procurement process	Not specified	Passive involvement of practitioners	Over 1 year	Case study based action research, interviews	Researchers	Researchers	Not specified	Creating reliable suppliers
9	Nuclear fuel manufacturing	Inventory Management	Reducing inventory	Company	Active involvement of both	9 months	Case study based action research	Researchers and practitioners	Researchers and practitioners	Cogeneration of actionable knowledge	Streamlining information processing and maintenance of inventory
10	Retailing	Sustainability	Implementing sustainable packaging logistics	Not specified	Active involvement of both	2 years	Action research, meetings	Researchers	Researchers and practitioners	Not specified	Successful implementation of sustainable packaging logistics
11	Carpet manufacturing	Strategic supplier performance	Implementation of supplier performance evaluation model	Not specified	Passive involvement of practitioners	Over 9 months	Case study based action research	Practitioners	Researcher	Dynamical update of strategic supplier evaluation model	Adoption of supplier performance evaluation model
12	Personal care (contact lens)	Strategic sourcing	Adopting concepts of swift and even flow	Not specified	Active involvement of both	2 years	Meetings, internal documents/database, interviews	Researchers and practitioners	Researchers and practitioners	Application of swift and even flow philosophy to supplier operations	Improved supply chain coordination
13	Food (confectionery, sea food)	Hierarchical production planning (HPP)	Development and implementation of HPP framework for food manufacturing industries.	Researcher	Passive involvement of practitioners	4-6 months	Action research, semi structured interviews, analysis of historical data and informal discussions with company's senior management	Researchers	Researchers	Contributed to HPP framework	Development and successful implementation of HPP framework

The duration of such collaborative management research projects is typically longer and varies from as low as six months to over two years. Such projects also typically use a number of data collection methods such as surveys, workshops, meetings, interviews, observations within the case study base action research frameworks. Such methods facilitate multiple interaction opportunities between researchers and practitioners. Data analysis are mostly done by researchers though in a number of studies (Taylor 2006; Ivan Su, Gammelgaard, and Yang 2011; Baker and Jayaraman 2012; Garcıa-Arca and Prado-Prado 2014; Eltantawy et al. 2015) practitioners also actively participated to analyze the data.

In creating research impact, collaborative research can produce actionable knowledge as well as have significant managerial implications. For instance, Eriksson (2010) contends that they generated actionable knowledge of identification of lean aspects in various lean implementation phases. Eltantawy et al. (2015) claim to achieve direct benefits such as lower inventories and inventory costs as well as indirect benefits such as improved customer service and better material planning and scheduling because of carrying out collaborative management research projects. In summary, these 12 papers show that collaborative management research projects can be carried out across many industrial sectors of supply chain and can handle and solve a number of problems. However, such project requires time and need extensive researcher practitioner involvement in the knowledge creation project. If such co-creation of knowledge can be ensured, such research project can have significant contribution to practice.

4 Conclusion

The present research provides some useful insights on the extent of collaborative management research approaches adoption in supply chain management domain. The majority of the reviewed papers has informed on the multiple benefits of collaborative approaches, not only on the practitioner's systems and the theory building/testing, but also on the research teams themselves. In the research process, most reviewed papers were trying to solve/improve an existing issue while addressing the relevance-rigour gap. This is a work in progress paper, future research prospects include expanding our review to include the rest of the approved literature sample, building a detailed framework for adopting CMR approaches in supply chain management domain, and providing guidelines on ensuring methodological rigour and quality assessment.

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Exploring transformation archetypes for seafood supply chain: Japanese perspective

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Abstract

In this study, in relation to the supply chain network between seafood manufacturing companies and seafood service industry, future archetypes of the network are explored hough a project that focuses on rebuilding the small and medium-sized seafood manufacturing companies after the 2015 Great East Japan earthquake. As the result, most seafood-manufacturing companies will do historical business by supplying only a specific type of processed seafood product to a seafood service company in the network. For example, the company would only provide final products to FMCG companies. Eventually, in order to compete with other companies within the same area, these companies will be challenge to develop and manufacture various products by combining fish varieties and processing methods. However, their production would enable them to develop their own market in the wide supply network. The proposed model of seafood supply chain will help these companies to consider the new market development strategy.

Keywords: Seafood Supply Chain, SMEs, Resilience

1 Introduction

This study aims to the re-construction from Great East Japan earthquake (Higashi Nihon Daishinsai) in Tohoku, the north region of Japan, on 11 March 2015. Main industry of this region has been seafood manufacturing industry that has been owned by many small-and medium sized enterprises (SMEs). The type of the industry naturally belongs to food industry which products the third largest of value of manufactured goods shipments from Census of Manufacture in 2014 by Ministry of Economy, Trade and Industry in Japan (METI, 2015). Owing to the earthquake, most factories along seaside were destructed and the business related to the industry was suspended. Japanese government and private giant companies accepted huge budget and newest knowledge to restore the region as quickly as possible. However the economic conditions of the region at the present is lower than that after the earthquake. Turing your eyes to competitors in other regions in Japan, they have low and rigid mobility to innovate their business because it is all they can do to keep the exciting business by the limited management resources.

Based on the recognition of the aforementioned golden opportunity, this paper aims to explore seafood supply chain with the concept level to consider next business strategy of the region. Specifically, the network between a seafood manufacturing company and its customers is focused on understanding the exciting business style of the seafood manufacturing company and grasping the possibility of cultivating routes to new customers. This study tries to draw the network structure between one seafood manufacturing company and its candidate customers because a clarification of the relation among participants firstly needs to retrieve investment points for business expansion. The description is performed based on an observation and an interview of several seafood processing companies in the rebuilding project after the earthquake for three years. The authors of the present study have gradually understood these companies' business structure through investigation and a trial-and-error method. This study presents the results.

2 Background

Seafood have recently become important materials to meet diversified customer needs resulting from the food crisis caused by population explosion and the requirement of seafood which is essentially healthy (i.e. low calorie count and nutrient intakes) and which provides convenient meals for a two-income family, a child-rearing family, and aging society in advanced counties. To match the resultant explosive demand, the globalization of the seafood supply chain has increasingly progressed with technological innovation. For example, the cold chain has expanded to maintain the freshness of materials through improvement of freezing technologies for transport worldwide (Salin, 2013). A traceability system has been developed to obtain the trust of customers by informing them of the safety of materials by a physical sensor system and information technologies (Farooq, 2016).

In the Japanese context, to aim for the creation of a tourism nation and for the next summer Olympic Games in 2020, an enrichment of the food supply chain is required. Actually, the productivity of food industry is lower than the other major industries in Japan such as transportation equipment industry and chemical and allied products industry. The Japanese dietary culture called 'Washoku', registered as a 2013 Intangible Cultural Heritage by United Nations Educational, Scientific and Cultural Organization (UNESCO), must also be a powerful weapon for executing the strategy. Furthermore, the occurrence of climate change including global warming and abnormal weather and over-fishing by neighbouring countries causes a decrease of marine resources in the Pacific Ocean.

Many studies related to the seafood supply chain have presented new perspectives, including open innovation of seafood value chain (Silva, 2013), an international distribution system (Abrahamsen 2007; 2011), firm structure (Brydon, 2011), quality assurance with labelled seafood products (Jaffry, 2004), a sustainable system (Alden, 2011), marketing and economic innovation (Wessells, 1992; Quagrainie, 2006; Seung, 2006), seafood supply chain management (Roheim, 2008), and an inventory system (Murata, 2015). However, there are not enough studies related to innovation of the supply chain model which give an overall perspective to change the present business structure under the rebuilding condition like the case that is picked up in the study.

3 Seafood Supply Chain Model

Figure 1 indicates general seafood supply chain model which consists of four players: fisher & aquaculture, seafood manufacturing industry, seafood service industry including restaurant and retail businesses, and customers. This paper focuses on the two middle players in the model.

3.1 Production system of seafood manufacturing

The factory within a seafood manufacturing company has the main processes to manufacture products which have not changed from ages past, as shown in the left of Figure 1: stocking, cleaning, processing, and seasoning. The processes exist mainly to add value to fresh fish. Many techniques and skills are included to make the materials taste even better. The detailed explanation of each type is as follows:

Stocking: This process is considered a preparation part for processed seafood production involving obtaining the materials. The quality level of the materials depends on size, weight, appearance, freshness, variety, and so forth. Over-fishing and climate change seriously affect a haul of fish. A fishing quota by multiple nations and enclosed aquaculture with the newest biotechnologies are countermeasures for sustainable marine resources. The process possesses the functions to frozen materials and deliver them to maintain their freshness while restraining freezer burn if possible and to maintain a sufficient inventory.

Cleaning: The complicated body of fish and seafood causes a decline in the productivity of seafood processing. It is basic and important to protect customers' safety from dangerous parts which they cannot eat (i.e. hard fish, thick bone, and the internal organs of a fish including poisonous substances). The variety of processes includes carving, boning, scaling, and filleting. Accurate fileting of large fish like salmon requires immense skill with yield rate and waste disposal

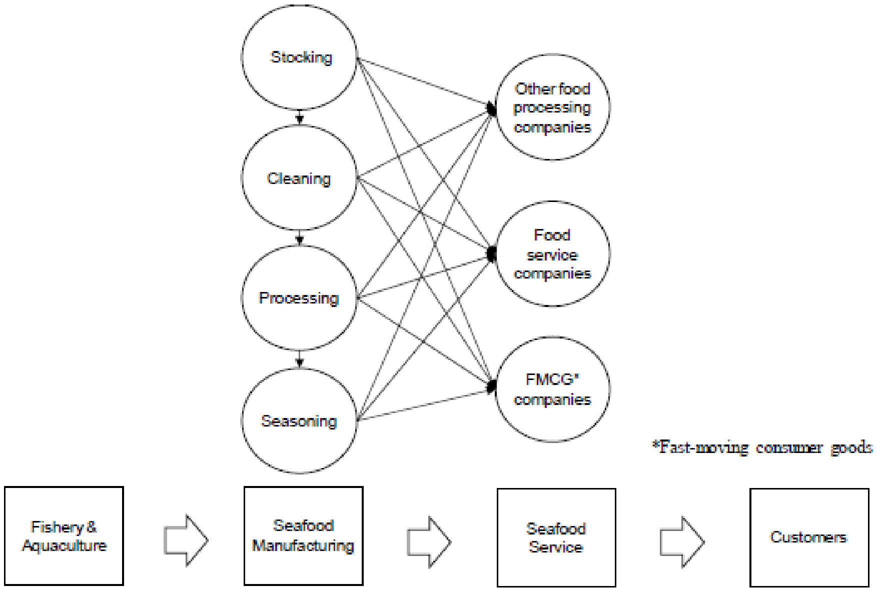

Figure 1 – Seafood supply chain model

Processing: This process is the main portion of seafood processing. Representative methods of the process are grilling, reducing, frying, steaming, and drying. The selection of each method relates to a core business of a seafood processing company with a large investment in production facilities. The design of the process profile of production by the selected method is a company secret relating to the organoleptic feel of processed seafood because many co companies adopt the common categories of methods noted above

Seasoning: This process is the portion that adds tastiness and flavour-value to a processed item. In Japan, there are five traditional popular seasonings, such as sugar (Sato), salt (Shio), vinegar (Su), soy sauce (Shoyu), and soybean paste (Miso). They characterize the taste of Japanese seafood called 'Washoku', which was registered as a 2013 Intangible Cultural Heritage by UNESCO. Chemical seasoning widens the possibility of new ways to enjoy processed seafood.

3.2 Types of seafood service companies

Customer candidates for seafood manufacturing companies are rich in variety. The main candidates are three types of seafood service companies: other food processing companies, food service companies, and fast-moving consumer goods (FMCG) companies in Figure 1. The explanations of each type are as follows:

Other food processing companies: These customers use the product supplied from seafood manufacturing companies as one material of their final products. For example, raw materials are supplied from a company which manages a large-capacity frozen warehouse to store them cheaply and in huge quantities. Cleaned materials (i.e. seafood paste and fish cut into small cubes) also have high value for customers who do not have technical know-how.

Food service companies: These customers are food service companies including restaurant businesses; home-delivery services; services for the provision of meals by a school, hospital, or welfare facilities. They basically have a kitchen which has the capacity for making and serving meals with materials supplied from seafood processing companies to their customers. Moreover, if their business model is a franchise chain, they construct a supply network with a central factory which executes the middle processing of materials for speedy and effective servicing of meals at all their shops.

FMCG companies: These customers are types of FMCG companies (e.g. a convenience store, supermarket, shopping mall, or department store). They mainly offer two services. One is the direct sale of goods supplied from seafood processing companies. The other is the sale of a daily dish including simple processed/cooked materials. Their customers are end users who live near these small shops. FMCG companies obtain large sales accumulated across their many branches, but the number of end users is limited for one store.

3.3 Network between a seafood manufacturing company and seafood service industry

The relationship between a seafood manufacturing company and seafood service industry is a complex network in Figure 1. The reason is for the notable characteristic of the system that is a multi-branch production system with the potential to supply semi-processed products as final products to customers. Owing to the capability of the industry, candidate customers are rich in variety, as shown in the right side of the figure. While centring on seafood manufacturing companies, they should consider all combinations between four processes of seafood processing and three types of seafood service companies. In particular, the following four paths are useful for seafood manufacturing companies to realize their service while reducing initial workloads.

A path from stocking to processing (STP): In this path, seafood manufacturing companies supply frozen/defrosted materials to other food processing companies. The added-value is a supply system of materials sufficient both in quality and quantity. Seafood manufacturing companies must improve the refrigeration capacities of inventory and transportation. Owing to these functions, other food processing companies outsource procurement operations.

A path from cleaning to service (CTS): In this path, seafood manufacturing companies supply frozen materials to seafood service companies. The added-value is a system to clean masses of fish and seafood. The seafood manufacturing company must improve its capability through training of skills related to the operation and its automation. Owing to this function, food service companies will concentrate on creative cooking and close servicing, which are considered to be their core functions.

A path of processing to service (PTS): In this path, seafood manufacturing companies supply processed materials to seafood service companies. The added-value is a mass production system of processed seafood. Seafood manufacturing companies should improve the main process in their business. Owing to this function, food service companies will provide effective and uniform services to their customers with simple cooking.

A path of seasoning to retail (STR): In this path, seafood manufacturing companies supply seasoned materials to FMCG companies. The added-value is a mass supply system of processed seafood. Seafood manufacturing companies should improve the main processes in their business. Owing to this function, retail companies can sell various moderately priced and tasty items to end users every day.

4 Case Study

4.1 Framework

Figure 2 indicates the framework to analyze a case that consists of five perspectives: seafood manufacturing, a customer, a value (products), a supply chain, and barriers to entry. The cases described in the following sub-section are analyzed with these perspectives. The detailed explanation of each perspective is as follows:

Seafood manufacturing: The analysis from the perspective is performed by the characteristics of seafood manufacturing process described in the section 3.1.

Customer: Eating is the final process to synthetically evaluate the quality of products and supply chain by consumers. In the perspective, not only the taste of processed seafood, but also a dishing, including a selected plate and a side dish, influences the total impression. The family styles of

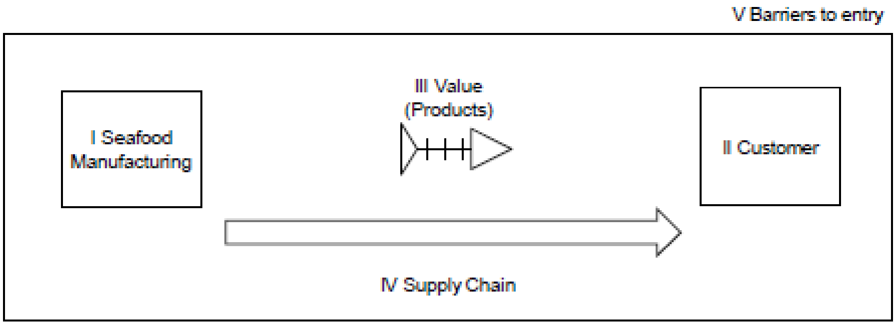

Figure 2 – Framework to analyze a case

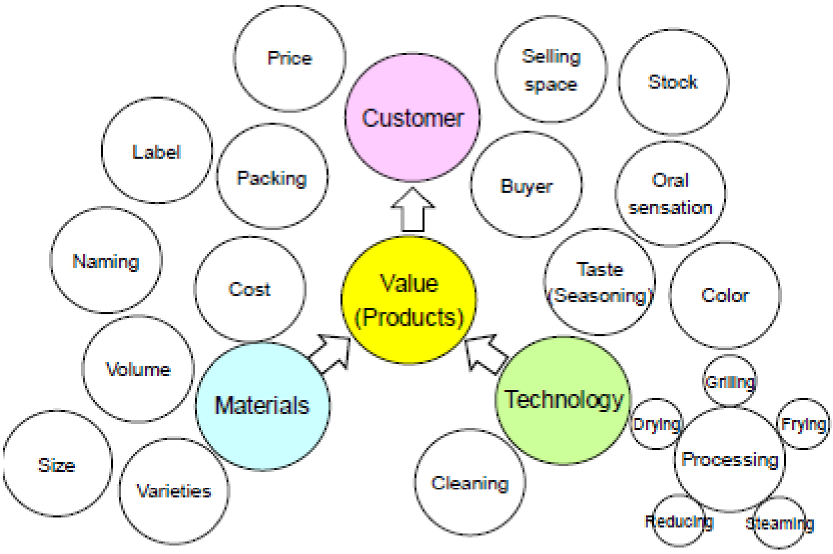

Figure 3 – Mapping of value elements of seafood products

advanced countries, such as a two-income family, a child-rearing family, and the aging society, also require the convenience of a microwave oven and reheat pouches.

Value: The function of new product development (NPD) on seafood manufacturing can be considered as the process that materials is added to new value by various production methods. In addition, marketing function is also important to draw the customers' attention to the developed seafood products. Figure 3 shows the points to carefully think in the both functions, which are found from the observations and interviews to the case companies. The all points are not always thought in all opportunities by the case companies. Even if all points are also thought enough, new products is not always success. They have made an effort to search the pinpoint elements to boost sales though communicating with the buyers who belongs to services companies.

Supply Chain: In the present age, the division of the five processes, fishing, cleaning, processing, seasoning and eating, between fisheries and consumers depends on consumers' requirements. It indicates the following five models proposed in Figure 4. Consumers do not need support from fisheries in Model 0, which constitutes a hobby. In the case of Model 1, the fishing industry will exist in a market near a fishing port with consumers. In the three models consisting of two processes and more by fisheries (i.e. Models 2 to 4), the division of roles occurs among three industries: fishery & aquaculture, seafood manufacturing industry, and seafood service industry.

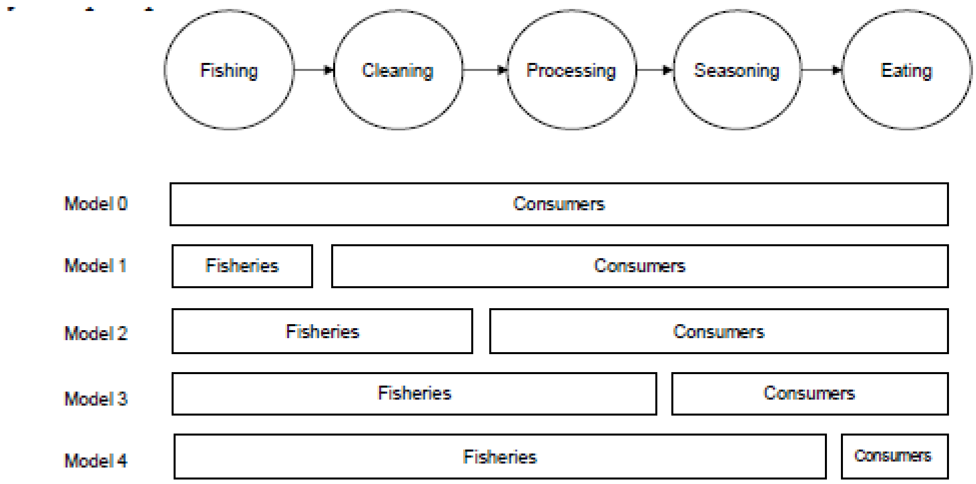

Figure 4 – Division of roles between fisheries and consumers

The division is considered based on the two following assumptions: 1) Fishery & aquaculture is necessarily in charge of the fishing process. 2) The orders of the three industries do not become reversed. Nineteen sub-models of the three models are summarized in Table 1. Models 2, 3, and 4 contain 3, 6, and 10 sub-models. Processed seafood is sold directly to consumers or through a mail-order system and internet service when the sub-model consists of the fishery and aquaculture and the seafood service. The seafood manufacturing asks the seafood service to sell their products in addition to the above-mentioned selling methods when these two entities exist in the sub-model. This table shows that the seafood manufacturing can choose, in theory, appropriate sub-models from the alternatives. The flexibility seems to suggest the possibility of expanding the business of each seafood manufacturing company. In the case study, the models of each case will be identified and discussed by the perspective.

Barriers to entry: The perspective is about the barriers to entry new business strategy. Huge money and many talented persons are inputted to support the re-construction project of the region where the case companies are located. These investments deliver a possibility to cultivate new customers who cannot meet before the earthquake. The invested facilities/equipment should be deliberated, in order to effectively establish new relationship with suppliers and customers. In the case study, the new invested barriers to entry of each case are identified by the perspective.

4.2 Case outline

The study picks up three cases in Figure 5. Case 1 is the exciting case before the earthquake. It is the STR path that is one main path of the region in the network between seafood manufacturing companies and seafood service industry until now and in the future. Case 2 and 3 are the cases to overcome the mentioned-below problems that case 1 have possessed. Case 2 is the path to directly connect to end users without going via seafood service companies. Case 3 is the STP path that stocking process is only passed described in the section 3.

4.3 Discussion

The summary of three case studies shows Table 2. Most seafood manufacturing companies located in the region do business along one path of the network model described in the proposed network in Figure 1. They consider the path as the only path for their business. Then they operate on a small scale and sell processed seafood to identified customers according to their requirements. However, they should understand two characteristics of their industry. Then they must overcome difficulties and reinvent themselves to obtain new markets and customers worldwide through business innovation for the future. One is the flexibility of their production system. It is possible to supply

Table 1 – Sub-models of Models 3 to 5

Sub-model \ Processes	Clean-ing	Process-ing	Season-ing	Note
M2-01	I	-	-	Selling directly to customers
M2-02	II	-	-	Selling by a service industry or directly to customers
M2-03	III	-	-	Selling directly to customers
M3-01	I	I	-	Selling directly to customers
M3-02	I	II	-	Selling by a service industry or directly to customers
M3-03	I	III	-	Selling directly to customers
M3-04	II	II	-	Selling by a service industry or directly to customers
M3-05	II	III	-	Selling directly to customers
M3-06	III	III	-	Selling directly to customers
M4-01	I	I	I	Selling directly to customers
M4-02	I	I	II	Selling by a service industry or directly to customers
M4-03	I	I	III	Selling directly to customers
M4-04	I	II	II	Selling by a service industry or directly to customers
M4-05	I	II	III	Selling directly to customers
M4-06	I	III	III	Selling directly to customers
M4-07	II	II	II	Selling by a service industry or directly to customers
M4-08	II	II	III	Selling directly to customers
M4-09	II	III	III	Selling directly to customers
M4-10	III	III	III	Selling directly to customers

products from any process in their production system. In the case 1, the current path in the network model is STR and semi-products of the path have the possibility to become fully final products for the other paths (e.x. CTS, and PTS) without large facility investment. The other is that they have many candidate customers. If the current path of the network model is CTS, the same product could be supplied by CTR. The development of a new path is naturally difficult, even if the potential of the path is recognized. However, it will be a valuable trial to expand business in the future.

On the other hand, STP, the path of case 1, has two structural problems that cannot have been resolved. One is the severe control of market price and item planning by giant service companies. The other is the disposal of huge nonstandard materials. The paths of Case 2 and 3 are the countermeasures to overcome the first and second problems respectively. Case 2 aims to high-added valued business though the shift to directly connect customer. Seafood manufacturing companies usually do not directly access end users except in face-to-face sales like at a regional festival and special sales once a year. They contact end users to sell their products through a mail-order system with mass-communication and a system of online electronic commerce. This opportunity will also increase in the era of the internet. Then the new product development of seafood manufacturing companies will be more creative because they can decide freely pricing and planning of item by themselves. The strategy also have the backing of wealthy families seeking the convenience of not only cooking but also buying when entering the aging society in an advanced countries. Case 3 aims to long-tail business. It may be considered at a glance that the seafood manufacturing company that choose the path don't do the work to add a value to materials. In the case, core barriers to entry are realized by huge investments to the following functions: an effective and clear sorting function of large materials on size and quality etc., the function of agile and huge freezing mass raw fishes, and the function of the transport system of mass refrigerated fishes. Through the investment of new refrigerators to strength these functions, the massive quantity of small-size fishes that was not effectively used before the earthquake is started to send to overseas fish-burger factory by the regional cooperative association including the case companies.

5 Concluding Remarks

This study explores the supply chain network between seafood manufacturing companies and seafood service industry to consider future archetypes of the network though a project that focuses on rebuilding the small and medium-sized seafood-manufacturing companies after the 2015 Great East Japan earthquake. In order to compete with other seafood manufacturing companies within the same path in the network, these companies have to be challenge to develop and manufacture

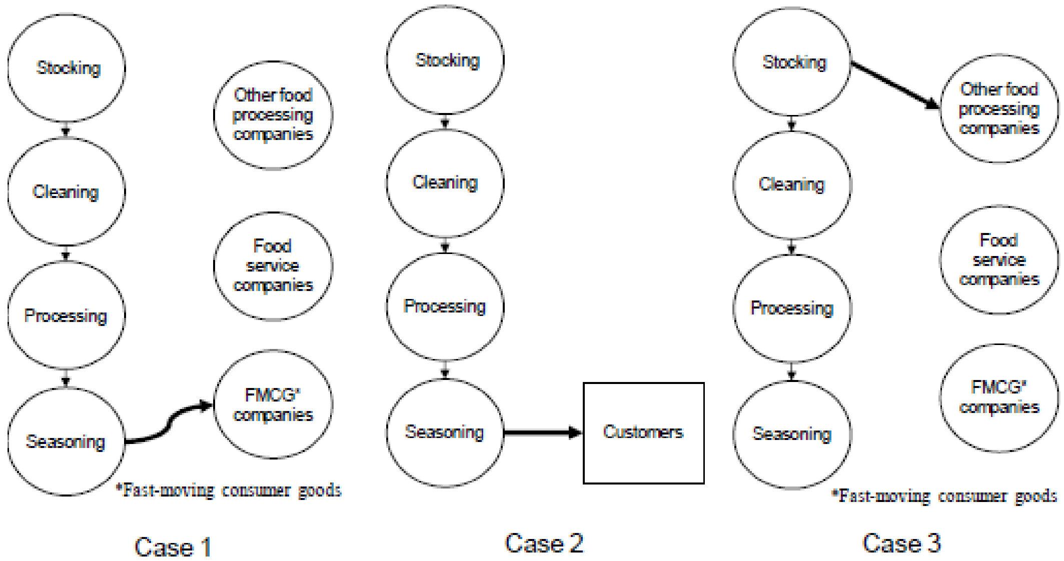

Figure 5 – Paths of three cases

Table 2 – Summary of three case studies

Case	Seafood manufacturing	Customer	Value (Products)	Supply Chain	Barriers to entry
1	Full processes	Convenience of cooking Two-income family, Child-rearing family	Low price, Volume, Label with a recipe, Safety	M4-07 with selling by a service industry	Power to negotiate with buyer who belongs to food service industry, Speedy NPD capability
2	Full processes	Convenience of not only cooking but also buying Aging family, Wealthy familiy	Fish species, Varieties (taste, how to cook etc.), Richness (High quality), Simple package	M4-07 with selling directly to customers	Information technology (IT), Direct-order system, Continuous NPD capability
3	Only stocking process	Overseas	Volume, Low price	M1 (only stocking)	Huge refrigerator, Sorting function on size and quality, Refrigerated transport system

various products by combining fish varieties and processing methods. However, their production would enable them to develop their own market in the wide supply in the network. The proposed model of seafood supply chain will help these companies to consider the new market development strategy. Especially, aiming to the escaping the control of market price and item planning by giant service companies and the effective using massive non-standard materials that were disposed before, this paper discusses the two cases after the earthquake that the regional seafood-manufacturing companies tackle with under the respected supports by huge investments.

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Sales excellence by changeable sales planning process

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Abstract

The growing customer requirements and resulting globalisation of operations make it more attractive for automotive suppliers to operate in production networks. On the other hand it increases supply network complexities and thus requires clearly structured planning processes. Additionally to changes in client requirements altering framework conditions in production networks are observed. Because the change in value at the beginning of altering conditions is not known it makes it difficult for the production networks to sense the change and to react to it with relevant activities. This paper names all the relevant factors that may influence the organising of sales planning process in automotive supply industry and finally suggests appropriate planning processes for different scenarios.

Keywords: production networks, sales planning process, changeability, automotive supplier

1 Introduction

thyssenkrupp Bilstein is an operative business unit in the business area of Components Technology. With about 30,000 employees worldwide, the business area produces high-tech components for the automobile industry and mechanical engineering. In the auto-mobile sector, the product range extends from engineered camshafts and cylinder head modules with integrated camshafts, to crankshafts, steering and damper systems to springs and stabilisers, as well as the assembly of axel modules. In the industrial sector, the components division of thyssenkrupp delivers components for construction machines, wind power stations and numerous applications of general mechanical engineering. In fiscal year 2015/2016, the business area achieved sales of 6.8 billion euros. thyssenkrupp Bilstein itself stands globally for innovation and high-tech in suspension technology. With competence for the entire suspension, the company delivers products for the entire suspension spectrum with production facilities in Europe, America and China. Moreover, thyssenkrupp Bilstein has been a sought-after partner in motor sports and for tuning for many years.

The constantly changing customer requirements placed on tk Bilstein as well as on all other automobile suppliers, such as tailored products with short delivery times and low prices, make it more attractive for the companies to act in production networks. The proximity to customers achieved as a result and the improved fulfilment of customer wishes resulting from the benefits of specialisation on the positive side are at the same time connected with an increased need for coordination because of the complexity of structures on the other side. This has an impact with

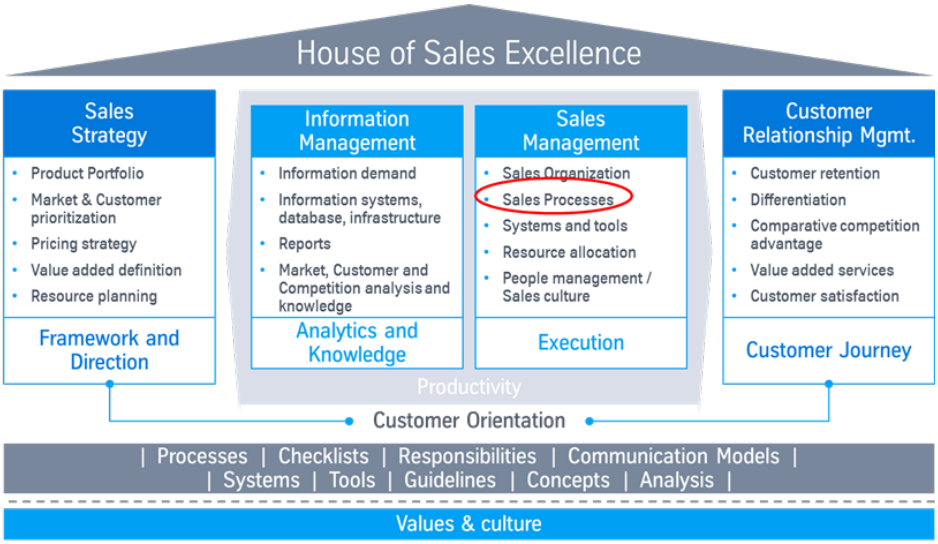

Figure 1 – House of Sales Excellence (cf. Homburg, Schäfer et al., 2008)

regard to the coordination and the organisation of network-wide planning processes. (Lücke, 2005) In doing so, the ability to plan becomes an important competitive factor in order to meet customer requirements. Integrated planning processes improve the ability to plan of the entire production network (Bauhoff et al., 2011). The most important starting point for the entire integrated planning is formed within the framework of sales planning in the sales department. This also means that this stage of integrated planning in particular must be carried out with great care.

In addition to changing customer requirements, a change in other framework conditions in production networks is observed. Since the drivers of change are often unknown when the change begins, it is difficult for the production networks to perceive the change in good time and to react with the appropriate measures. The production companies or networks which manage to continue to satisfy the demanding customer requirements irrespective of changes have significantly better chances of successfully surviving on the market (Wiendahl, 2009; Dürrschmidt, 2001). A decisive step towards the changeable production network is taken through ensuring the changeability of the planning process, which represents the basis for all value adding activities.

Based on the practical challenges presented and the resulting need for action, the goal of this paper is to develop a methodical support to organise the network-wide, changeable, integrated sales planning process.

The results presented later in the paper could be derived from the experiences of tk Bilstein and then positioned for all automobile suppliers irrespective of the company.

2 Theoretical background

2.1 Sales Excellence

Many current research works and practical approaches pursue the goal of increasing productivity in such business areas as production or logistics, whereby in the view of many managers sales should still be dominated by improvisation and intuition, doing almost completely without systematic decision making. The greatest productivity potentials are therefore in sales in particular. The Sales Excellence approach by Homburg addresses this loophole and starts a professionalisation offensive in sales, in which he suggests a methodical support to increase productivity and increase customer orientation in sales.

In order to achieve these two goals, according to the Sales Excellence approach, professionalisation must be achieved in the following four areas: Sales Strategy, Sales Management, Information Management and Customer Relationship Management (cf. Figure 1).

In the area of sales management, the approach deals with the organisation of structures and processes as well as the management of people and sales culture (Homburg, Schäfer et al., 2008) The methodical support to be developed in this paper can clearly be allocated to this component of the Sales Excellence approach. A standardised but simultaneously changeable sales process, which includes the sales planning process, among other things, forms the basis to achieve the professionalisation in sales strived for.

2.2 Changeability

Today, companies are exposed to constantly changing framework conditions. As a reaction to this, more and more companies are coming together in value creation networks or setting up new sites distributed globally. By forming networks, it becomes possible to satisfy customer wishes optimally in spite of increasing market uncertainty. Thanks to the rapid interchangeability of individual network elements, individual companies achieve changeability as a whole (Wildemann et al., 2005) Knowledge and production capacity can be exchanged independently of current framework conditions and therefore be deployed flexibly according to customer requirements (Wildemann et al., 2005). Ensuring a changeable network-wide order processing process, which also includes sales planning (Toth, 2008), supports and supplements the network's changeability (Wildemann et al., 2005).

In the current literature, there are many different and partly contradictory definitions of changeability, depending on the subject considered (Dürrschmidt, 2001). Therefore, a working definition is derived on the basis of the known definitions highlighting the points of view which are of particular relevance to the subject being dealt with. In order to define changeability, the concepts of flexibility and flexibility corridors must first be defined.

So-called flexibility corridors represent requirement spaces, in which a system does not exceed the limits by operative adjustments to fluctuating requirements. Flexibility is therefore the potential to undertake operative adaptations to a system with volatile environmental requirements of such a kind so that the limits of the defined flexibility corridor are not exceeded (Zäh et al., 2005; Adaev, 2013). Flexibility is expressed, for example, in the operative adaptability of the planning system to change the product mix, the required volume or the delivery time (Dürrschmidt, 2001). Changeability, on the other hand, is the ability to permanently and quickly adapt the flexibility corridors of a system to changing environmental requirements with suitable tactical or strategic measures (Zäh et al., 2005; Adaev, 2013). The changing environmental requirements or influencing factors on the organisation of the planning processes, such as a changed network constellation, require a strategic re-organisation of the fundamental planning approach for the introduction of new planning strategies. The influencing factors thereby represent variable framework conditions determined internally within the network or externally by customer behaviour for an integrated planning process. By setting up various scenarios in the form of combinations of the influencing factors' values and the planning strategies or approaches suited to each scenario in the form of so-called solution elements, the changeability of the planning process can be ensured. Solution elements are standardised planning components which facilitate the modelling of the planning process with individual process chains and therefore ensure the changeability of the planning process.

3 Sales planning as part of the integrated planning process in the automobile supplier industry

The term integrated planning is composed of the individual concepts of integration and planning. In order to define integrated planning, these concepts must first be defined.

In general, planning can be defined as an estimate of future options for action taking account of current framework conditions (Colsman, 2007). Planning of logistics and production systems in the form of formative planning processes is to be clearly differentiated from the dispositive planning processes at this point. Structured planning processes are planning activities which arise occasionally. An example of structured planning processes can be the reorganisation of the arrangement structure. In the case of dispositive planning processes, on the other hand, these are continuous planning activities accompanying logistics and production, such as sales forecasts or capacity planning. (Kuhn et al., 2010) The focus of this work is the planning processes within the meaning of the Supply Chain Operations Reference Model (SCOR model), which introduces and constantly develops a cross-sector standard for processes in supply chains. According to the SCOR model, there are procurement, production, delivery and planning processes in each production company. The planning process which forms the focus again extends across planning for procurement, planning for production and planning for delivery. (Becker and Ellerkmann, 2011). Sales planning is therefore the forecast of the demand and the provision of transparency with regard to demand planning in the production network as the basis for all other resource planning (ten Hompel and Hellingrath, 2007). One of the central goals of production companies is to have a long-term sales plan (Eggert, 2003). Sales form the final step of the operation process. Its task is to transform the products from the company to the customer, so that the customer receives the right amount of the produced output at the right time and at the right place. The level of difficulty lies in that a balance must be struck between the production of a product and its consumption. The most important task of sales planning is therefore to plan deadlines and volumes which forecast when what sales volume is to be expected (Eberling, 1996). The sales plan forms the basis for all other planning processes and is therefore placed in the foreground of this paper.

Integration means renewing a whole (from integrare = to restore, make whole) (Mertens, 2013). With regard to planning processes with all of their existing interfaces in one production network, integration means objective and temporal coordination across all network levels and planning units (Colsman, 2007). The importance of integration will be made clear using a brief example. Material demand planning can turn out to be a difficult planning task if there are large numbers of variants and complex production structures. A plan for material volumes which is successful in spite of the challenges presented does not in itself lead to good production planning, however. In order to achieve a realistic result, the sales volumes and deadlines forecast by the sales department must also be considered or integrated into the plan. A realistic planning result can therefore only be achieved through a fixed interlocking of individual planning tasks (Schmiedeberg and Gnamm, 2010).

If the two definitions of planning and integration are combined, integrated planning can be defined as the temporal and objectively coordinated networking of all subplans in the case of redundance-free and consistent storage of data, which are freely accessible for all planning departments involved (Colsman, 2007; Friedemann, 2004; Schmiedeberg & Gnamm 2010). By integrating the planning processes, the artificial barriers between departments, network partners and processes should be removed and as a result, the personnel expenses for data input will be reduced. Since the data are distributed to all planning units concerned within the framework of the integrated planning approach, this allows for greater process security (Schmiedeberg and Gnamm 2010).

The tactical integrated planning process in this industry typically comprises one year. The basic structure and other process models can be visualised using the process chains of the Dortmund Process Chain Model. The basic components of the process chain model include individual process chain elements to describe individual planning activities, sources and recesses as start and end-points of a process chain, as well as connectors to connect process chain elements and connectors to branch or combine multiple pro-cess chain elements.

Figure 2 illustrates the basic structure of integrated sales, procurement, production and logistics planning using the example of an annual plan. On the basis of the sales forecast from the sales department, the capacity requirements are determined to cover expected sales. The working method per resource is determined within the framework of rough capacity planning. If the available capacity is not enough, adjustments must be made. First, attempts will be made to adjust production capacity. At this point, a review of the possibilities of third-party production or extension of capacity by way of investment is made. If it is not possible to adjust capacity, the expected sales stated by the sales de-partment must be changed, taking the priorities determined by the sales

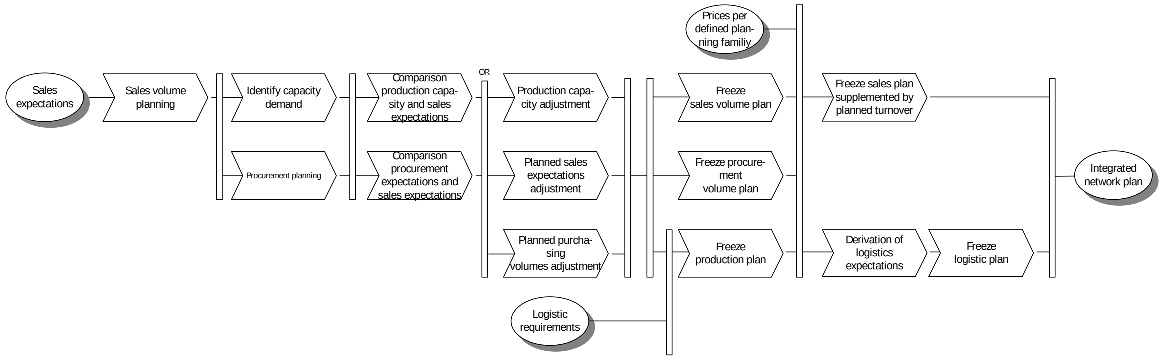

Figure 2 – Basic structure of integrated planning using the example of an annual plan

department into consideration. Prioritisation can be, for example, per product group according to the profit contribution. An excess capacity will likewise be communicated to the sales department and taken into consideration in the sales plan, where applicable (Heidrich, 2004). Procurement planning is likewise established on the basis of the expected sales stated. In a coordination process, the integrated rough sales and capacity plan will be developed taking logistical requirements into consideration. Once a year, logistical requirements, such as avoiding or reducing traffic, transfer on more cost-effective means of transport or minimisation of logistics costs can be formulated. These requirements will be converted into production-technical restrictions. Then the sales, production and procurement planning as well as logistics planning will be derived for the next fiscal year from the available information. Parallel to logistics planning, the sales plan created on the basis of the sales volumes and prices taking into consideration the savings to be granted will be documented. On a detailed planning level, the annual plan presented above can be adjusted in quarterly and monthly cycles in accordance with the principle of rolling planning.

Using the above for the typical sequence of the integrated tactical planning process for the automobile supplier industry, it becomes apparent that the sales forecast lays the fundamental basis for all further planning and will therefore be studied in more detail in this paper.

4 Influencing factors

On the basis of the workshops and interviews held with planning experts in the industry considered, the influencing factors on the structure of sales planning described below could be identified.

When making a decision regarding the structure of the sales planning process, in the first stage the level of centralisation or decentralisation or, in other words, the planning approach, must be determined, which depends heavily on the form of the network. While intra-organisational networks are made up of several divisions which belong to one organisation, such as production sites or departments, inter-organisational networks are forms of cooperation which go beyond a company (Zundel, 1999). It was possible to derive a further differentiation of the term "inter-organisational networks" from the organisational structures of tk Bilstein. It could be observed that the decision regarding the planning process structure is influenced by whether it concerns the integration of the planning results of multiple planning units of an operating unit (planning result per key account) or the entire business unit made up of multiple operating units (cf. Figure 3).

Insufficient market orientation and inward orientation of sales planning of production networks is often criticised. Many companies focus on the costs and their own production program when planning and less on pursuing market-based goals, like greater customer orientation. (Homburg, Artz et al., 2008) In order to increase customer satisfaction and to achieve better planning results, it is beneficial to have collaborative planning with customers (Seifert, 2002). The customer's readiness to cooperate, which is a prerequisite for creating joint demand forecasts is however not always available or is very low (Schick and Hambuch, 2004). The customer's readiness and will for joint planning are therefore included in the influencing factor space (cf. Figure 3).

Figure 3 – Influencing factors framework

When making the decision or structuring the planning process, it is important to correctly define the output database. The calls sent by the customer, the range of which varies from customer to customer, however, could be a good basis for sales volume planning. When structuring the annual plan which is the focus of this paper, it is therefore important whether the available calls can be selected as a single planning base (range of at least 12 months) or must be supplemented with other factors (range of less than 12 months) (cf. Figure 3). Depending on the customer or the agreements on the on-going changes of the calls already made in the contract with this customer, there can also be a differentiation between a high and a low accuracy of customer calls with regard to the time at which the customer calls are frozen as the planning base for the next annual plan. In this context, VDA Recommendation 5009 recommends the approach described be-low to assess the forecast quality of the call or the accuracy of the calls mentioned in this paper. The assessment of the accuracy of the calls is made retrospectively, in that the ratio of so-called forecast demands to a reference demand is formed. This will be calculated using the following formula:

$$\frac{\sum_{i=1}^{n}|P_i - R|}{R \times n} \geq 0 \qquad (1)$$

where

R reference demand,

P_i i-th forecast required demand for the demand period,

n number of forecast demands in the forecast period.

The reference demand states the retrospectively derived actual demand of a part number in the period considered. (VDA Recommendation 5009, 2008) In the following example, this should amount to 51 items for the month of August 2017. It is also known from the end of August 2017 that the calls readable from the system in May 2016 for the part number considered was 50 items for the end of June 2017 and was 100 items for the end of August 2017, as well as that the system entries have changed by 52 and 100 items in June 2016 respectively, producing an accuracy for calls of 3.9% (|(50 – 51)| + |(48 – 51)| / 51×2).

Next, the question is posed about which fluctuations in demand can be allocated a high or low accuracy. In this context, the VDA Guideline expresses the recommendation as represented below in Table 1.

In doing so, it is important to mention that this recommendation should only serve as a possible basis for the contractual agreements between the automobile suppliers and OEMs, and is to be adjusted in individual cases, such as in the case of low-runner parts (VDA Recommendation 5009, 2008).

5 Solution elements

While identifying relevant influencing factors and their values, it was already apparent that the framework determined included, on the one hand, factors which have an influence on the choice of

Table 1 – Suggested categories of accuracy of calls (VDA Recommendation 5009, 2008, p. 15)

Horizon	Demand period	Forecast period	Accuracy in %	Classification
Short-term	Day	Week 0 to -2	<3%	Good
			3-8%	Average
			>8%	Poor
Medium-term	Weeks	Week -3 to -8	<5%	Good
			5-10%	Average
			>10%	Poor
Long-term	Months	Week -9 to -x	<10%	Good
			10-15%	Average
			>15%	Poor

planning approach – or in other words the degree of centralisation or decentralisation – (first group "Planning Approach" (PA)). On the other hand, there are factors which the decision on the correct database for the sales plan depends on (second group "Database" (DB)).

There is a fundamental differentiation between a centralised and a decentralised planning approach. Within the framework of a centralised planning approach, the planning tasks are carried out by a centralised planning authority. The centralised planning authority can be, for example, one of the network partners which assumes a higher planning function (Pibernik and Sucky, 2004; Hegmanns, 2010). In this approach, a central sales plan is created for the entire production network according to the principle of the total optimum, which should be fulfilled by the individual network partners. Within a company, there could be a planning department, which creates a central sales plan on the basis of the information provided by the responsible key account managers. Often the requirements for centralised planning, such as the readiness of partners to surrender their own planning autonomy, are not met. In this case, the centralised planning task will be distributed across all network partners and then performed by them in isolation. The creation of isolated plans by the individual decision-making authorities makes up the decentralised planning approach (Pibernik, 2004). The successive planning approach represents the extreme case of decentralised planning, whereby the results of local planning are passed on to other network partners if the network structure requires it. This highest degree of decentralisation described proves to be insufficient within the framework of cooperation in production networks, however. With the aim of achieving a total optimum in spite of a high degree of decentralisation, a collaborative decentralised planning approach is proposed. The collaborative decentralised planning approach distributes planning responsibilities to individual network partners, like the decentralised approach. The plans developed decentrally are then coordinated in a common decision-making process. (Hegmanns, 2010) Since this paper concentrates on the planning process in both intra- and inter-organisation networks, the central (PA-SE1) and collaborative decentralised planning approach (PA-SE2) will be included in the solution space. (ADAEV, 2015)

Within the framework of the solution elements for the structure of sales planning, traditional sales planning using generally applicable forecasting methods (Mertens, 2012) and detailed customer information will be considered on the one hand, and the collaborative sales planning using methods like CPFR (collaborative planning forecasting and replenishment) will be considered on the other hand. Within the framework of traditional sales planning in the automobile supplier industry, an approach based on customer calls has proven itself. In order to allow a more comprehensive forecast, other factors will be considered alongside the customer calls per defined time unit set. In doing so, attempts will be made to find the actual point on the product lifecycle curve by mapping the times from SOP and EOP as well as the volumes delivered to date since SOP in order to carry out a plausibility study of the existing customer calls as against the predicted volume course in the next step. The deviations determined, such as those which result from customer errors or the fact that at the time of planning not all calls are set yet, will be coordinated with the customer. In individual cases, additional customer information and the sales volumes agreed in the customer contracts and using correlation and regression methods as well as including causal factors for planning will be drawn upon (Knolmeyer et al., 2000).

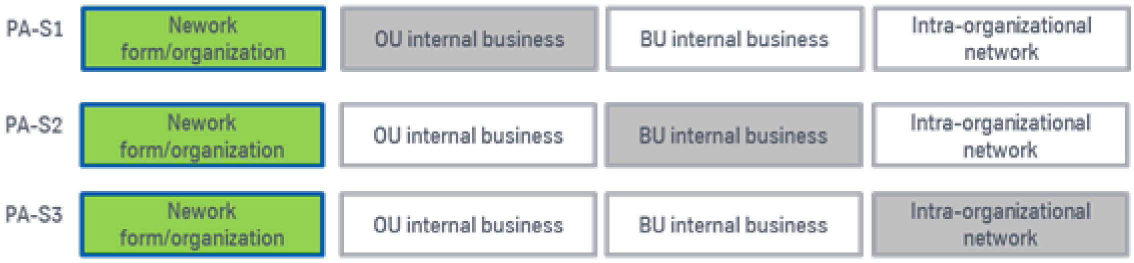

Figure 4 – Scenarios in Planning Approach group

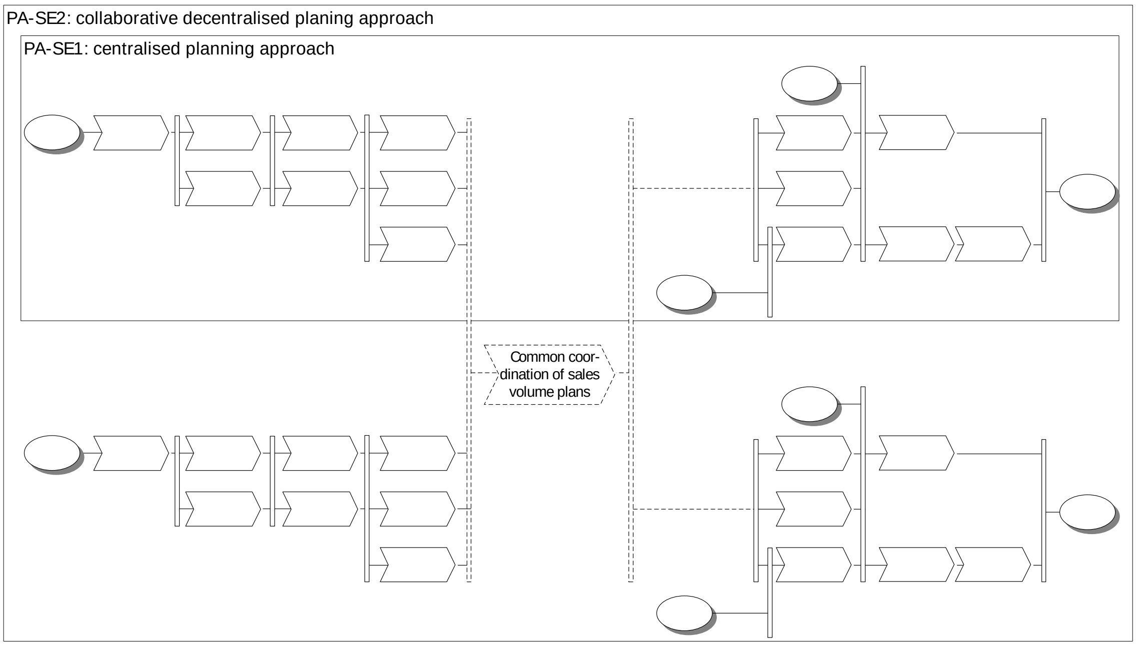

Figure 5 – Centralised and collaborative decentralised planning approach

Within the framework of collaborative sales planning, the product network and its customers create a joint sales plan which includes data available from both sides (Seifert, 2003). The accuracy of the sales forecast will be improved by a single, amalgamated forecast. In this way, potential synergies can be exploited. In addition, the opportunity to allow relevant customer data as well as research results and empirical values from the customer to influence sales planning is opened up. (Seifert, 2003).

6 Development of practical scenarios and allocation to defined solution elements

In order to develop scenarios of the first group "Planning Approach", the combinatoric will be used whereby all possible combinations of the factor values are first sifted through systematically (Figure 4). The maximum number of combinations is the product of the respective total number of values (Meier, 2004). Since the first group of influencing factors is simply made up of one influencing factor with 3 values, this produces the three scenarios represented below.

In coordination with selected planning experts from the automobile supplier industry, the first scenario PA-S1 can be allocated to centralised planning approach PA-SE1, since the existing central organisational structure allows this. Because partners often lack the readiness to surrender their planning autonomy, it is recommended to choose the collaborative decentralised planning approach (PA-SE2) in scenarios PA-S2 and PA-S3. From a process point of view, the defined solution elements can be illustrated as below in Figure 5.

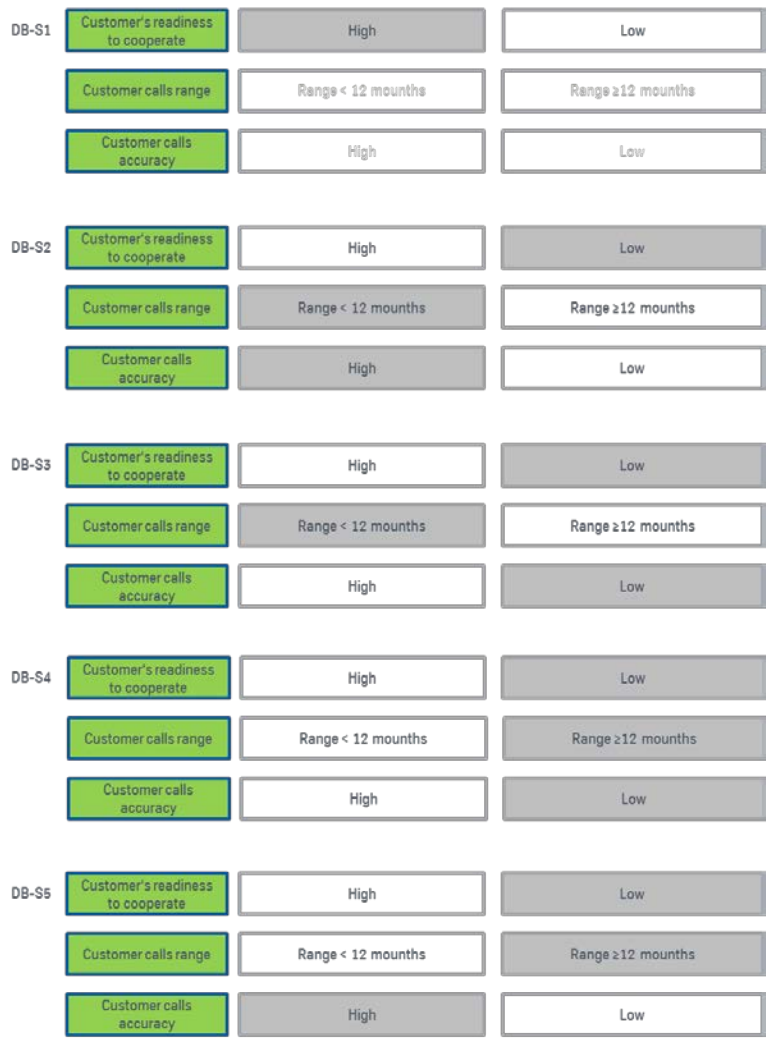

Figure 6 – Scenarios in Database group

The basic structure of an integrated changeable plan (annual plan) can be established in accordance with the centralised or collaborative decentralised planning approach (PA-SE1 and PA-SE2). The second variation will as a result be formed by doubling or reproducing (depending on the number of decentralised planning units) the basic structure as well as by including coordination process chain elements (cf. Figure 5).

The second group of the framework allows a maximum of eight scenarios according to the rules of the combinatoric. The special feature of the first value of the influencing factor of customer's readiness to cooperate is that it has a dominating character. If the high level of the customer's readiness to cooperate exists in a typology, this value is then definitive for the classification. Other values therefore no longer have any relevance. In coordination with selected planning experts from the automobile supplier industry, the number of combinations of forms is therefore reduced to five practical scenarios considering this special feature (cf. Figure 6).

In the first scenario DB-S1, collaborative sales planning is recommended because the most important requirements in the value of a high level of customer readiness to cooperate are met. From a process perspective, this approach can be described as represented in Figure 7.

When deciding on a collaborative sales plan based on cooperation with customers (AP-SE2), new sources and some process chain elements based on the need for coordination will be incorporated into the basic structure.

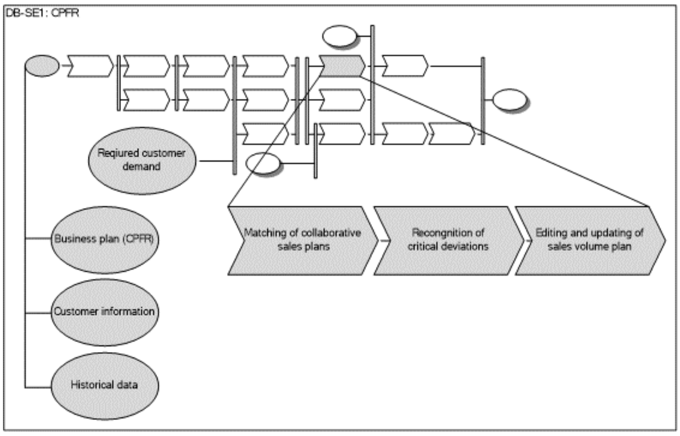

Figure 7 – Collaborative sales planning

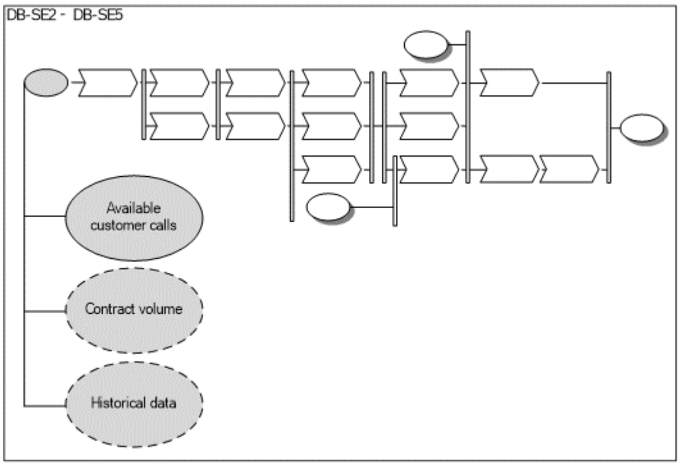

Figure 8 – Traditional sales planning

The business plan created jointly within the framework of the CPFR approach will be implemented in a sales forecast using own past data and additional customer information. After the end of the internal network coordination process between the forecast sales and the production capacity provided, the first version of the sales plan taking ac-count of the demand volumes reported by the customer will be created. In the next step, the customer's forecasts and those of the production network will be balanced. If there are critical differences they will be investigated and the sales plan will be updated (cf. Figure 7).

The remaining scenarios in the group will be allocated different modifications of the traditional sales planning described in the previous chapter in coordination with selected planning experts of the automobile supplier industry. The following Figure 8 illustrates the approach in the basic structure of the integrated planning process.

In scenarios DB-S2 and DB-S3 it is preferable to carry out sales planning as traditional sales planning (DB-SE1) on the basis of available calls as well as contract volumes and past values for the remaining months of the year being planned, whereby in scenario DB-S3 the calls should also be checked for plausibility because of their low accuracy (cf. Figure 8). Scenario DB-S4 describes starting situations which are the least favourable for planning, in which the calls are not known for all months to be planned and which still have poor accuracy. In this context, it is therefore preferable to consider other factors alongside customer calls. Attempts are therefore made to find the current point on the product lifecycle curve by mapping the times of SOP and EOP as well as the volumes delivered to date since SOP in order to carry out a plausibility study of the existing customer calls as against the predicted course in the next step. Scenario DB-S5 stipulates sales planning based merely on calls.

7 Conclusion and outlook

The goal of this paper was to develop a methodical support to structure the network-wide, changeable, integrated sales planning process. With the aid of the framework developed, automobile suppliers are now in the position to structure their sales planning process in accordance with current framework conditions. In order to know exactly which framework conditions currently exist and how they should be reacted to when structuring planning, the most important influencing factors on the structure of the planning process considered were identified within the scope of this paper. In the next step, the solution elements were identified in the form of standardised planning elements and different scenarios developed in the form of realistic combinations of factor values. The last step was formed by allocating solution elements to scenarios. By incorporating the sales planning process studies in the overall basic structure of the most important planning processes of automobile suppliers, it was also possible to ensure the integration of the changeable sales planning process. As an outlook for further research, the framework developed can be extended to other planning processes and the approach can be studied for its application in other industries.

With the framework developed composed of practical scenarios and suitable processes, automobile suppliers are offered a new kind of methodical support to react in the right way to changing framework conditions.

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Performance Analysis on Electric Power Supply Chain for Smart-Grid with Conventional Large-Scale Distance Supplier: An Application of Inventory Control Model

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Abstract

For many years, supply performance of products to demand sites has been analysed, designed and improved by various ways such as Heijunka concept and methodology. Generally, basic structure of this approach is to adapt demand speed and fluctuation by managing work-in-progress. Additionally, in recent years, the spread of ICT devices leads virtual integration of plural local facilities by real-time cooperation of them. This research, taking electricity supply operations on the smart-grid platform with virtually integrated photovoltaics-based power generation and rechargeable battery as the objective system, proposes the management model of electricity and examines its performance. Performance analysis is examined by simulation experiments and obtained results suggest that Heijunka of power supply is realised in time-domain.

Keywords: Supply Chain Management, Smart-Grid, Renewable Energy, On-Time-In-Full (OTIF).

1 Introduction

In production and logistics industry, supply performance of products to demand sites has been analysed, designed and improved by various ways such as Heijunka (level production) concept and methodology for many years. Basic structure of this approach is, in general, to adapt demand speed and fluctuation by managing work-in-progress (WIP). Additionally, in recent years, the spread of ICT (Information and Communication Technology) devices has been realising to monitor and control plural conventionally hidden variables in various facilities. It leads virtual integration of local facilities by real-time cooperation of them and it is fundamentally changing the way of business activity among various industries.

Meanwhile, energy loss reduction in electricity supply operations contributes to consist of supply stability, cost rationality, resource savings, etc. among electric power industry. Furthermore, to increase the share of renewable natural energy sources in total energy consumption is a modern social trend for increasing energy self-sufficiency and reducing environmental load. Especially, after the accident of nuclear power plant at Fukushima in 2011, the requirement for stable power supply system with renewable energies is extremely increased in Japan. On the other hand, the introduction of renewable energy involves challenges such as unstable output, high costs and installation constraints. For solving these problems, introduction of the smart-grid (interconnected electricity network with power conditioning, production control and distribution management functions) and microgrid (semi self-contained smart-grid with self-generation of electricity) platforms are advocated, researched and demonstrated in recent years. Nevertheless, high costs of facilities deteriorate profitability. Therefore, it is gradually changing for the better but fully isolated operation of microgrid is difficult to be prospective as a business for independent housing suppliers in present costs and efficiency yet (Watanabe, 2017). By contrast, electric power industries installed and demonstrated microgrid platform in some remote islands. In these cases, how to stabilise the unstable output of electricity power generation by renewable energy sources and cooperate with external electricity supply network are important issues (Nikkei, 2012, Fuji Electric, 2013 and Kyushu Electric Power, 2015).

This research, taking electricity supply operations on the smart-grid platform with virtually integrated photovoltaics-based power generation and rechargeable batteries as the objective system, proposes the management model of electricity supply operation for stabilising auxiliary power feeding and realising to cooperate with external electricity supply network. Performance analysis of the proposed management model is examined by simulation experiments and obtained results suggest that Heijunka of power supply is realised in time-domain.

2 Objective System and Its Previous Studies

A "smart-grid" concept is an electrical grid network that conditions power generation and controls electricity supply operations for realising cost reduction, energy loss reduction and supply stabilisation by interconnected ICT devices and infrastructures such as smart meters, HEMS (Home Energy Management System) and other smart appliances. Additionally, bidirectional energy flow of distributed power generation can be handled by transmission and distribution infrastructure of smart-grid. For this reason, electricity supply stability and flexibility of a smart-grid platform has a high affinity for solving the challenges to expand the share of renewable energy sources. Based on these smart-grid feature, microgrid concept is advocated, researched and demonstrated in recent years. Figure 1 shows the schematic diagram of the electricity supply operations in the photovoltaics-based microgrid. Murata et al. (2012) developed the mathematical programming model of interconnected electricity supply operation of microgrid platform with distributed photovoltaics-based power generation and auxiliary power feeding from conventional long distance electricity supply network. From a result, it was suggested that introducing microgrid system is an effective way for reducing energy losses by realising to shorten the sum of distances between supplier and customers.

For proposing efficient electricity supply rules of microgrid system under various conditions and analysing their stability, He et al. (2015) and Murata et al. (2015) developed the model of electricity supply operations in the photovoltaics-based microgrid platform based on inventory controlling model and investigated several parameters, e.g. number of the photovoltaic panels, capacity of the storage batteries, etc., for realising fully isolated electricity supply operation. Further the on-going discussion of the concept, Takeyama et al. (2016) and Katayama et al. (2016) modified the above model and discussed the realisation to divert the rechargeable batteries of EVs (Electrical Vehicles) in each household for storaging electricity of microgrid. These previous studies analysed in case of only fully isolated operation; nevertheless, power generation of photovoltaic panels depends on transition of weather and it cannot be controlled. Therefore, huge and inefficient investments are required for realising fully isolated operation.

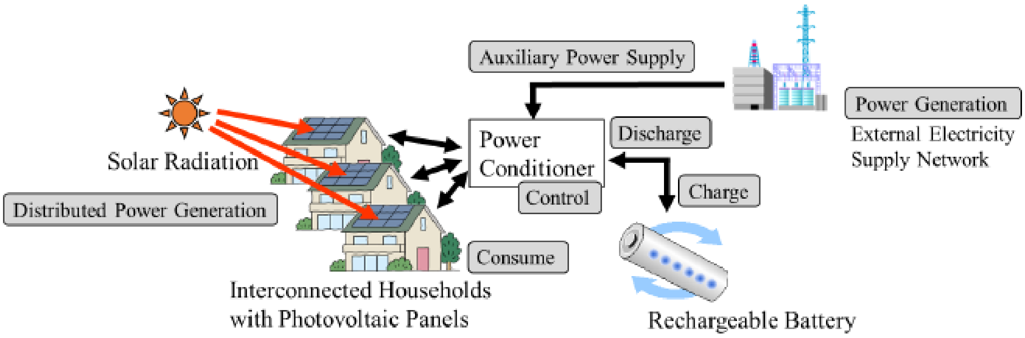

Figure 1 – Electricity supply operations of photovoltaics-based microgrid with auxiliary power feeding from external electricity supply network

For this reason, Sato et al. (2017) modified the above model for interconnected operation of microgrid and analysed its stability and economical rationality. This paper, focusing interconnected operation of microgrid as the objective system, proposes the management model of auxiliary electricity supply with prediction model of power generation based on weather forecast and examines its performance.

3 Experimental Method

3.1 Simulation Model of Photovoltaic Power Generation

This section describes the electricity supply model of photovoltaics-based microgrid with storage battery. This paper estimates power generation by given actual data from April 1, 2016 to March 31, 2017 of weather, temperature and global solar radiation on a horizontal plane at Tokyo (Japan Meteorological Agency, 2017). The sum of the power generation of photovoltaic panels in each household is expressed in Eq. (1) (He et al., 2015).

$$sp_i(t) = \max\left\{0, \min\left(\varepsilon(T(t))\int_t^{t+\Delta t}\gamma\frac{H_s(t)}{3.6}dt\cdot s_i, P_{\max}\cdot s_i\right)\right\} \quad (1)$$

where

t	Time (Japan Standard Time)
$T(t)$	Temperature at time t [deg. C]
$sp_i(t)$	Power generation of i-th household at time t [kWh]
$\varepsilon(T(t))$	Temperature coefficient of electricity output of photovoltaic panel at temperature $T(t)$
γ	Power generation efficiency of photovoltaic panel at 25 deg. C
$H_s(t)$	Global solar radiation on a slope at time t [MJ / Panel]
s_i	Number of photovoltaic panels of i-th household
$P_{\max}$	Maximum output power of photovoltaic panel [W]

The parameter $T(t)$ in Eq. (1) should be used the temperature of each photovoltaic panel; however, the data are not available. Reducing thermal diffusion equation is an effective way for more accurate estimation of time series of power generation (Monden et al., 2012), but the calculation involves complicated process. Thus, this paper uses the data of air temperature as $T(t)$ for simplifying analysis. The parameters of photovoltaic panels are defined as Table 1, which are based on the specification of the commercial panel (Toshiba Corporation, 2012). The parameter $T(t)$ in Eq. (1)

Table 1 – Specification of the photovoltaic panel

Max Output	Conversion Efficiency	Slope of Temperature Coefficient	Width	Height
250 W	20.1 % @ 25 deg. C	-0.4 % / deg. C	1,559 mm	798 mm

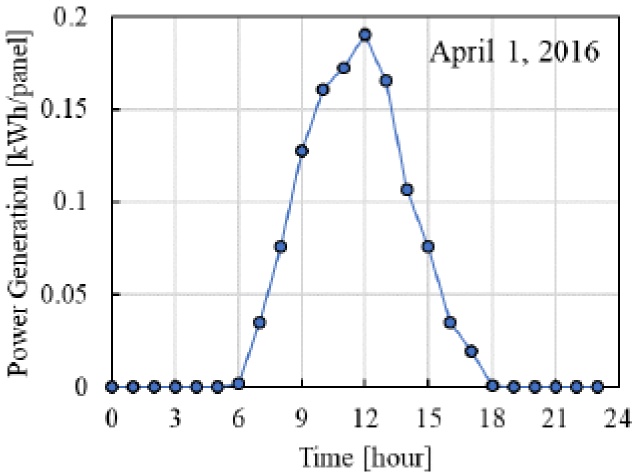

Figure 2 – Estimated power generation of a photovoltaic panel in a day

should be used the temperature of each photovoltaic panel; however, the data are not available. Reducing thermal diffusion equation is an effective way for more accurate estimation of time series of power generation (Monden et al., 2012), but the calculation involves complicated process. Thus, this paper uses the data of air temperature as $T(t)$ for simplifying analysis. The parameters of photovoltaic panels are defined as Table 1, which are based on the specification of the commercial panel (Toshiba Corporation, 2012).

Meteorological observatory of Tokyo is located at lat. 35.692 deg. N. and long. 139.75 deg. E. Hence, for maximising annual power generation, azimuthal and radiation angles of photovoltaic panels are defined as 0 and 30 deg., respectively. Power generation depends on solar irradiance on a slope. Therefore, for estimating global solar radiation on a slope, this paper estimates direct solar radiation on a horizontal plane and sky solar radiation (diffuse component) from annual data of global solar radiation on a horizontal plane by Erbs' decomposition model (Erbs et al., 1982). Solar radiation at the top of the atmosphere for using Erbs model is estimated by calculated solar elevation angles at each time (Nagasawa, 1999). Figure 2 shows the time series of estimated power generation of a photovoltaic panel in a day, which is based on the above models.

3.2 Simulation Model of Electricity Supply Operations

This section describes the simulation model of electricity supply operations of microgrid system with auxiliary power feeding. Photovoltaic panels generate DC (direct current) power and power conditioners convert DC to AC (alternating current). Generally, AC-DC conversion ratio is lower than DC-AC conversion ratio; therefore, this paper defined to use auxiliary power feeding from external supply network preferentially for reducing energy conversion losses. The charging / discharging model of rechargeable batteries in microgrid system is expressed in Eq. (2). The parameters of charging, discharging, DC-AC conversion and AC-DC conversion efficiencies are described as μ_{in}, μ_{out}, μ_{DA} and μ_{AD}, respectively and their values are determined based on typical parameters of commercial products

$$ep_i(t) = \begin{cases} \min\left\{\sum_{i\in n} C_i, \max\left\{0, \frac{(\mu_{DA}\sum_{i\in n} sp_i(t) + bp(t) - \sum_{i\in n} cp_i(t))}{\mu_{\text{out}}} + \sum_{i\in n} ep_i(t-\Delta t)\right\}\right\}, & bp(t) - \sum_{i\in n} cp_i(t) < -\mu_{DA}\sum_{i\in n} sp_i(t) \\ \min\left\{\sum_{i\in n} C_i, \max\left\{0, \mu_{in}\left(\sum_{i\in n} sp_i(t) + \mu_{AD}\left(bp(t) - \sum_{i\in n} cp_i(t)\right)\right) + \sum_{i\in n} ep_i(t-\Delta t)\right\}\right\}, & bp(t) - \sum_{i\in n} cp_i(t) \geq 0 \\ \min\left\{\sum_{i\in n} C_i, \max\left\{0, \mu_{in}\left(\sum_{i\in n} sp_i(t) + \frac{(bp(t) - \sum_{i\in n} cp_i(t))}{\mu_{DA}}\right) + \sum_{i\in n} ep_i(t-\Delta t)\right\}\right\}, & -\mu_{DA}\sum_{i\in n} sp_i(t) \leq bp(t) - \sum_{i\in n} cp_i(t) < 0 \end{cases} \quad (2)$$

where

$ep_i(t)$	Power storage in the battery of the i-th household at time t [kWh] p
$cp_i(t)$	Electricity demand of the i-th household at time t [kWh]
$bp(t)$	Auxiliary power feeding from external electricity supply network at time t [kWh]
C_i	Capacity of the battery in the i-th household [kWh]
μ_{in}	Charging efficiency of the battery, which is defined as 1
μ_{out}	Discharging efficiency of the battery, which is defined as 0.94
μ_{DA}	DC-AC conversion efficiency of the power conditioner, which is defined as 0.95
μ_{AD}	AC-DC conversion efficiency of the power conditioner, which is defined as 0.8
n	Number of interconnected households in the microgrid network, which is defined as 30

This paper analyses the case that the number of households in the microgrid system is 30. The daily data of electricity demands of each household have been generated randomly in advance, which are contained within the range of plus / minus 50% from the estimated demand structure of electricity in a day (Agency for Natural Resources and Energy, 2011) and the data of monthly average in the year 2010 in Japan (Statistics Bureau, Ministry of Internal Affairs and Communications, 2010). Figure 3 shows the generated data of electricity demands in the microgrid system.

Note that the electricity distribution losses of the intra microgrid network, facility deterioration and the self-discharging losses of the rechargeable batteries are not considered for simplifying the analysis in this model. In this case, the all rechargeable batteries in the microgrid system can be handled as a virtuually integrated large battery. In this model, power deficiency and excess of the intra microgrid network are expressed in Eqs. (3) and (4), respectively

$$dp(t) = \max\left\{0, \sum_{i\in n} cp_i(t) - bp(t) - \mu_{DA}\left(\sum_{i\in n} sp_i(t) + \mu_{\text{out}}\sum_{i\in n} ep_i(t-\Delta t)\right)\right\} \quad (3)$$

$$op(t) = \begin{cases} \max\left\{0, \mu_{in}\left(\sum_{i\in n} sp_i(t) + \mu_{\text{AD}}\left(bp(t) - \sum_{i\in n} cp_i(t)\right)\right) + \sum_{i\in n} ep_i(t-\Delta t) - \sum_{i\in n} C_i\right\}, & bp(t) - \sum_{i\in n} cp_i(t) \geq 0 \\ \max\left\{0, \mu_{in}\left(\sum_{i\in n} sp_i(t) + \frac{bp(t) - \sum_{i\in n} cp_i(t)}{\mu_{\text{DA}}}\right) + \sum_{i\in n} ep_i(t-\Delta t) - \sum_{i\in n} C_i\right\}, & bp(t) - \sum_{i\in n} cp_i(t) < 0 \end{cases} \quad (4)$$

where

$dp(t)$	Electric power deficiency of the intra microgrid network [kWh]
$op(t)$	Electric power excess of the intra microgrid network [kWh]

For examining the performance of the proposed management model, this paper defines the parameters of microgrid system as the number of photovoltaic panels and capacity of rechargeable batteries are insufficient for fully isolated electricity supply operation throughout the year. The number of photovoltaic panels and the capacity of rechargeable batteries are defined as 15 (rated output of photovoltaic power generation system is 3.75kW) and 20kWh per-household.

3.3 Prediction Model of Solar Radiation

This section describes the prediction model of photovoltaic power generation based on weather forecast. From calculated solar elevation and azimuth angles (Nagasawa, 1999), direct and diffuse components of solar radiation in fine weather can be expressed by Bouguer's Law (Bouguer, 1729 and Lambert, 1760) as Eq. (5) and Berlage's Law (Berlage, 1928) as Eq. (6), respectively.

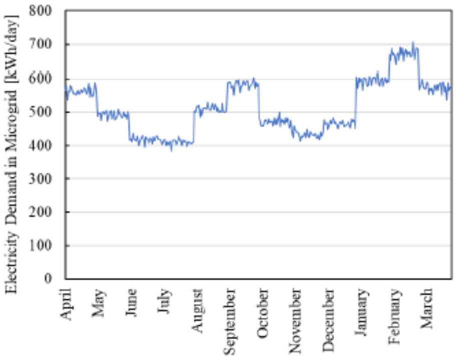

Figure 3 – Sum of the generated electricity demands of households in the microgrid system

$$H_{Dfn} = 1.367AT^{\left(\frac{1}{\sin\alpha}\right)} \quad (5)$$

$$H_{df} = \frac{1.367}{2}\sin\alpha \frac{1 - AT^{\left(\frac{1}{\sin\alpha}\right)}}{1 - 1.4\ln AT} \quad (6)$$

where

H_{Dfn}	Direct solar radiation in fine weather [kW/m^2]
H_{df}	Sky solar radiation (diffuse component) in fine weather [kW/m^2]
α	Solar elevation angle
AT	Atmospheric transmittance, which is defined as 0.6

This paper defines atmospheric transmittance as 0.6, which is based on the reported value (Nakamura *et al.*, 2014). From direct and diffuse components, direct and global solar radiation on a slope is expressed in Eq. (7) – (8)

$$H_{Dfi} = H_{Dfn}\left(\sin\alpha\cos\theta_p + \cos\alpha\cos A\sin\theta_p\cos\phi_p + \cos\alpha\sin A\sin\theta_p\sin\theta_p\right) \quad (7)$$

$$H_{sf} = H_{Dfi} + H_{df} \quad (8)$$

where

H_{Dfi}	Direct solar radiation on a slope in fine weather [kW/m^2]
H_{sf}	Global solar radiation on a slope in fine weather [kW/m^2]
A	Solar azimuthal angle
θ_p	Elevation angle of photovoltaic panel
ϕ_p	Azimuthal angle of photovoltaic panel

Figure 4 shows the results of correlation analysis between actual global solar radiation on a slope in (a) sunny, (b) cloudy and (c) rainy (including thunderstorm and snowy) days and estimated one in fine weather condition at the same days. From results of correlation analysis, solar radiation coefficients for prediction model of photovoltaic generation in sunny, cloudy and rainy days are determined as 0.968, 0.65696 and 0.3201, respectively. In case that forecasted weather varies from hour to hour within a day, this paper determines solar radiation coefficient as the median value. Figure 5 shows the time series of accumulation of actual and predicted global solar radiation on a slope. Solar radiation of the above prediction model is based on given weather forecast data which are reported by Japan Meteorological Agency at the day before objective date (past data are

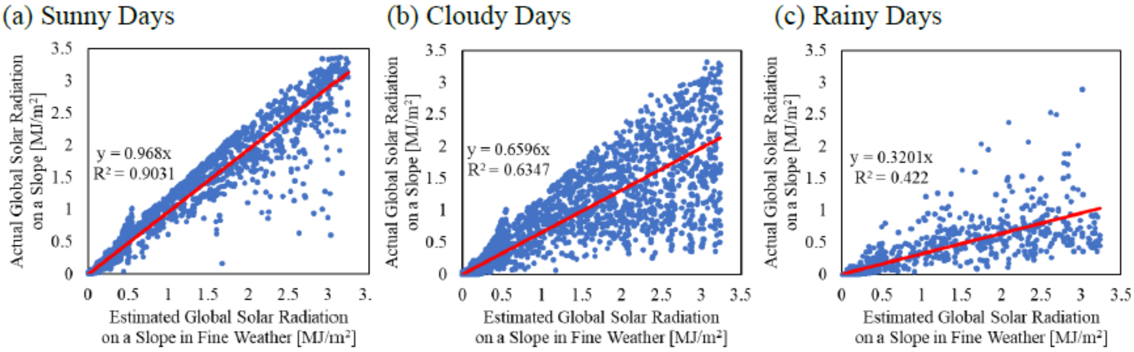

Figure 4 – Correlation analysis between estimated and actual global solar radiation on a slope

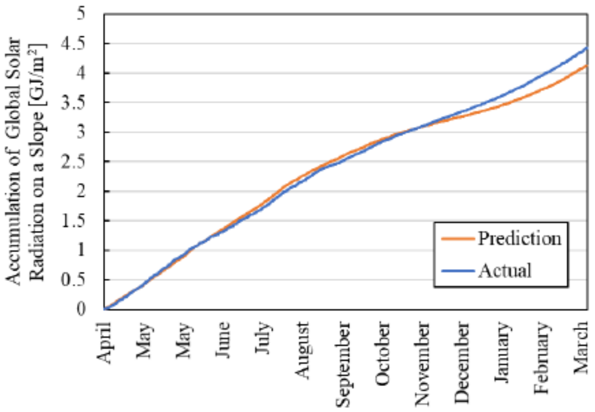

Figure 5 – Time series of accumulation of actual and predicted global solar radiation on a slope

summarised by Sawaki PE Jp Office, 2017). From a result, the data of the prediction model based on weather forecast correspond reasonably well with the actual data.

3.4 Management Model of Electricity Supply Operation

This section proposes the management model of electricity supply operation of photovoltaics-based microgrid system with auxiliary power feeding. Figure 6 (a) and (b) show the schematic diagram of flows of general production instructing model and isolated electricity supply operation of microgrid system, respectively. Vassian (1955) introduced a production instruction rule that minimised the fluctuation of inventory on an assumption; however, it is not surprising in the objective microgrid system, power generation cannot be controlled because it depends on weather. For this reason, conventional approaches of inventory management and production instruction model cannot be used for isolated electricity supply operations of microgrid (He et al., 2015, Murata et al., 2015, Katayama et al., 2016 and Takeyama et al., 2016). By contrast, interconnected electricity supply operations of microgrid, whose schematic diagram is shown in Figure 6 (c), can be handled by general WIP management model. In this case, the unit of photovoltaic generation system including photovoltaic panels, power conditioner and rechargeable battery (enclosed by a red frame in Figure 6 (c)) facilitates as same as the warehouse of Figure 6 (a).

This paper proposes periodic ordering model for stabilising auxiliary power feeding. Figure 7 shows the flowcharts of the proposed management model. This paper defines the ordering interval (the period of contract with electric power industry) that is 7 days as a week and constraints that the external electricity supply network offers certain pre-determined electricity by contract during a week from the day after ordering. Therefore, this paper uses the prediction model of solar radiation based on weekly weather forecast, which is expressed in the last section. The management model minimises auxiliary power feeding under constraints to prevent predicted power shortage in all the

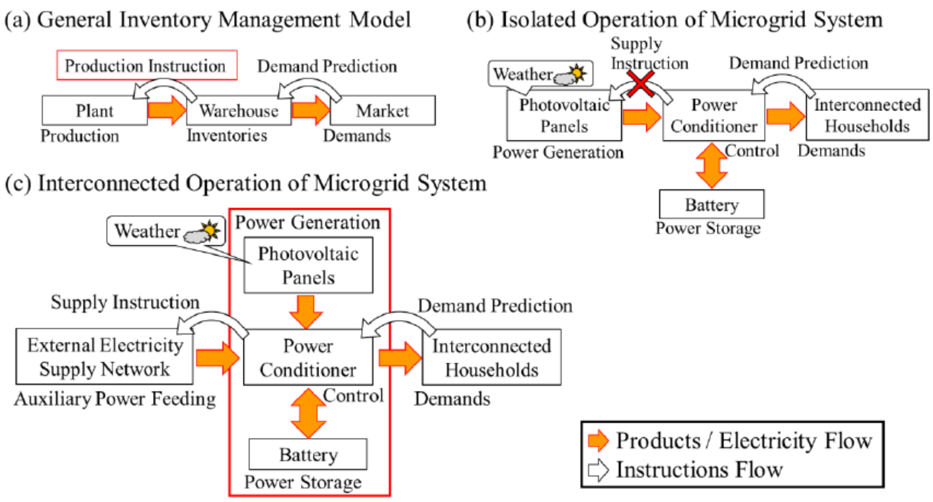

Figure 6 – Schematic diagram of general inventory management model and electricity supply operations of microgrid system

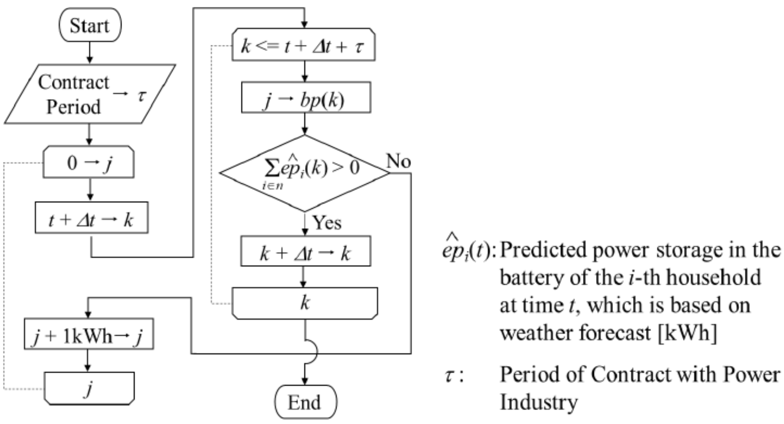

Figure 7 – Flowcharts of the proposed management model of electricity supply operations

days of the contract period until the next date for ordering. The past average data of electricity demands at each month are used for the prediction model.

4 Results and Discussions

4.1 Performance Analysis without Management Model

At first, this paper analyses the performance of the present electricity supply operation. In this case, the microgrid system operates without auxiliary power feeding from external electricity supply network. Figure 8 shows the time series of (a) power storage of rechargeable battery and (b) power excess of the microgrid network without management model throughout the year. From the results, large fluctuation of the power storage depends on day-by-day weathers is revealed. In this case, accumulation of the power excess throughout the year is 5,060kWh.

By contrast, from the time series of the power deficiency as shown in Figure 9, large fluctuation of the power deficiency (shortage) is revealed. Accumulation of the power deficiency and the power failure times are 50,209kWh and 2,666 hours throughout the year, respectively. In general, microgrid system should be supplied electricity as much as power deficiency by external electricity supply network when power shortage is occurred. Thus, it is corresponding to the required load of external electricity supply network. Therefore, the fluctuation of power deficiency increases the load of external electricity supply network and power plants.

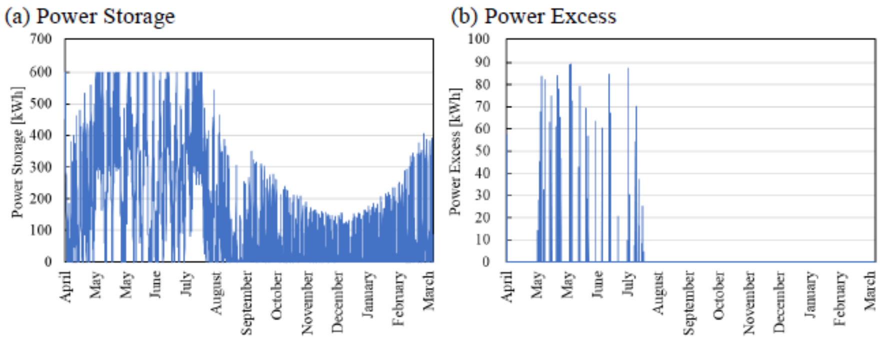

Figure 8 – Time series of (a) power storage and (b) excess without management model throughout the year

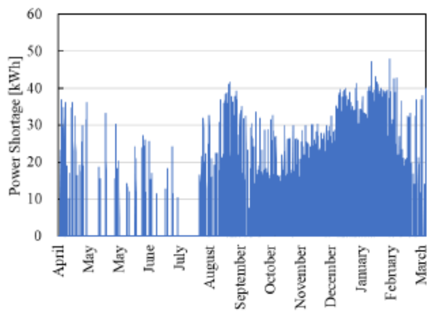

Figure 9 – Time series of power deficiency without management model throughout the year

4.2 Performance Analysis of the Proposed Electricity Management Model

This section analyses the performance of the proposed electricity management model. Figure 10 shows the time series of (a) power storage of rechargeable battery and (b) power excess of the microgrid system, which are managed by the proposed model. From the results, fluctuation of the power storage is decreased from electricity supply operation without management model as Figure 8; however, accumulation of the power excess is increased to 23,077kWh throughout the year.

By contrast, the power shortage and its occurring frequency throughout the year are extremely decreased with Heijunka power supply of auxiliary power feeding. Figure 11 shows the time series of (a) planned auxiliary power feeding and (b) the power deficiency throughout the year, which are managed by the proposed model. In this case, accumulation of the power deficiency is 2,509kWh and the power failure time is 190 hours throughout the year, respectively.

The sum of the planned auxiliary power feeding (Figure 11 (a)) and the power deficiency (Figure 11 (b)) is the really required power feeding into the microgrid system, which is shown in Figure 12. From a result, the fluctuation of the total requirement of auxiliary power feeding is extremely decreased from Figure 9. Therefore, it is expected that the proposed electricity management model is effectively facilitates to realise Heijunka production of external electricity supply network in time domain.

Note that the increased surplus of electricity becomes a waste loss in the microgrid system. A part of them can be sold to electric power industry via connected external electricity supply network; nevertheless, a lot of power selling leads to increase the peak load electricity sources in total energy consumption. Therefore, more improvement of the management model for reducing both power deficiency and excess without overcapacity of rechargeable battery is required; which is possible subject for future examination.

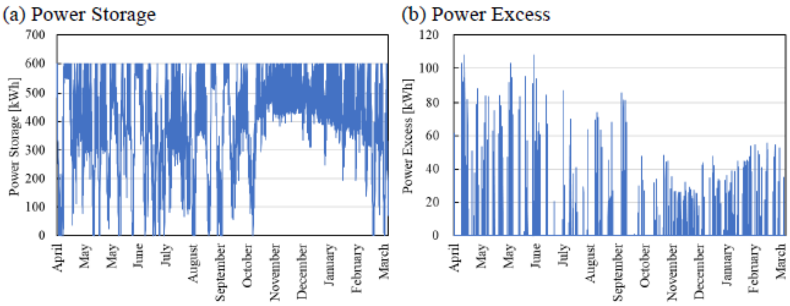

Figure 10 – Time series of (a) power storage and (b) excess, which are managed by the proposed model throughout the year

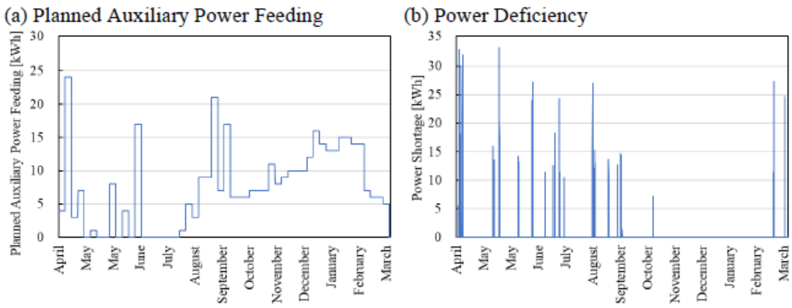

Figure 11 – Time series of (a) planned auxiliary power feeding and (b) power deficiency throughout the year, which are managed by the proposed model

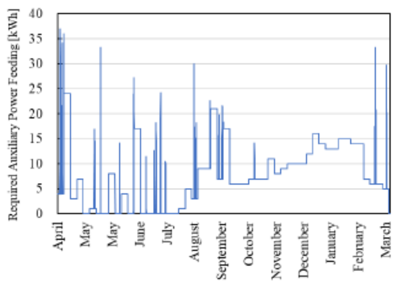

Figure 12 – Time series of the total requirement of auxiliary power feeding from external electricity supply network into the microgrid system

5 Concluding Remarks

This paper proposed the electricity management model for stabilising auxiliary power feeding from external electricity supply network into the microgrid system and analysed its performance. From the results, fluctuation of the auxiliary power feeding was extremely decreased by the proposed model and it is expected to realise Heijunka production of external electricity supply network in time domain. Therefore, the obtained results suggest that the application of inventory control model is effective to reduce the share of peak load electricity sources in total energy consumption and cooperation of renewable energy sources and baseload electricity sources is expected to realise by electricity supply management.

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How is Net Working Capital affected in an Engineer-to-Order business?

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Abstract

This paper is intended to contribute to the process of building a set of tools that will help in the debate on the Working Capital impact on firms' profitability. It analyzes the impact on the working capital needs and profitability of the industrial goods sector business based on different levels of product standardization and compares the Engineer-to-Order capital needs to businesses with more standardized products. ABB's (Asea Brown Boveri) Transformers business is used for this study – a roughly five billion U.S. dollar business – which includes more than 40 worldwide factories. The customized, complex products and the underlying uncertainties of markets define the capital needs of the business, however this paper also shows that working capital management affects profitability.

Keywords: net working capital, profitability, Engineer-to-order, Cash Conversion Cycle

1 Introduction

The purpose of this paper is to provide empirical evidence on how can Working Capital affects competitiveness in an Engineering-to-Order (ETO) business. Working capital is defined as the result of the time lag between the expenditure for the purchase of raw materials and the collection for the sale of the finished product (Shin and Soenen, 1998).

Net operational working capital is then defined as operational current assets minus operating current liabilities. It is typically equivalent to cash, receivable accounts and inventory minus payable accounts and delayed accounts (Mueller, 1953). Efficient working capital management is a key component of corporate strategy to create shareholder value (Shin and Soenen, 1998) and it entails of applying methods, which remove the risk and lack of ability in paying short-term commitments in one side and prevent over investment in these assets in the other side by planning and controlling current assets and liabilities, which in turn reduced the Cash Conversion Cycle (CCC). Management of working capital affects the profitability of the firms (Gill et al., 2010) and thus directly affects the shareholder value.

Firms may have an optimal level of working capital that maximizes their value. Large inventory policy may lead to higher sales, especially when there is a market downturn or too much competing capacity. The larger inventory also reduces the risk of a stock-out, causing lost manufacturing capacity. Another component of working capital is accounts receivable. Accounts receivable are the amounts a firm has a right to collect because it sold goods or services on credit to a customer. As with inventories, generous trade credit policy may lead to higher sales and countless firms are

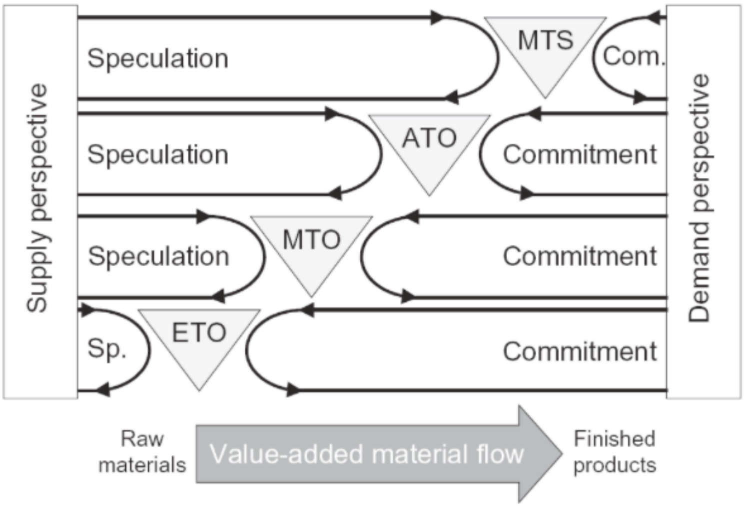

Figure 1

prepared to change their credit terms in order to win customers and to gain large orders (Cheng and Pike, 2003). However, uncollected accounts receivable can also lead to cash inflow problems for the firm.

Finally, accounts payable to suppliers allows firms to access the quality of bough products and can be a flexible source of financing, however delaying payments can be expensive if the firm is offered a discount for early payment (Raheman and Nasr, 2007), especially in periods of lower cost of capital.

2 Engineer-to-Order Supply Chain

This paper focuses on engineer-to-order business, which has not been explored as much as other recognized business types. Based on well-known literature (Gosling and Naim, 2009; Hoekstra and Romme, 1992; Lampel and Mintzberg, 1996; Naylor et al., 1999; Yang and Burns, 2003), six supply-chain structures can define to describe operations: engineer-to-order (ETO), buy-to-order (BTO), make-to-oder (MTO), assemble-to-oder (ATO), make-to-stock (MTS) and ship-to stock (STS).

Wikner and Rudberg (2004) use the concept of customer order de-coupling point (CODP) to provide a way of differentiating between manufacturing approaches (Rudberg and Wikner, 2004). The CODP defines where in the manufacturing process a product is linked to a customer order. A literature-review by Wikner and Rudberg focuses on four CODPs that are most frequently applied: ETO, MTO, ATO and MTS (Wikner and Rudberg, 2001). These are shown in Figure 1

In ETO environments, firms' products are highly customized to meet individual customer specifications and are produced in low volume. Certain parts of the design are highly customized, while others are standardized or modularized. This situation makes it difficult to outsource components and subsystems, since these are only specified once the design process is finalized and approved (Hicks et al., 2000), and increases overall costs and lead times.

Firms aim to increase the standardization and modularization of their products, not only to reduce design costs, but also to reduce procurement costs and lead times that bring reduced payables and inventories. Procurement costs are reduced through consolidation of materials defined in the design phase, which in turn reduce indirect costs related to the warehouse and logistics. The risk of material obsolescence is reduced and thus the needed provisions. Inventories are reduce in twofold: lower material costs and reduced lead time due to more standardized manufacturing process.

Cash Conversion Cycle (CCC) is also a good approach to describe Working Capital management. The CCC expresses the number of days, that it takes for a firm to convert resource inputs into cash flows. It attempts to measure the amount of time each net input dollar is tied up in the production and sales process before it is converted into cash. This metric is defined as: CCC= Days Inventory Outstanding (DIO) + Days Sales Outstanding (DSO) – Days Payable Outstanding.

Thus, we hypothesize that in business with higher engineering needs per design, i.e. ETO, Net Working Capital and CCC will be higher than in businesses with standardized products.

Hypothesis 1: Higher level of product standardization leads to lower net working capital and thus longer Cash Conversion Cycle

CCC and firms' profitability is an area widely revisited by academia and several scholars have established a link between profitability and the CCC (Cheng and Pike, 2003; Lazaridis and Tryfonidis, 2006). According to Deloof (2003) working capital management has an impact on firms profitability and a certain level of working capital does maximize returns.

This paper aims to establish a relationship between CCC and profitability in an ETO environment. As previously discussed, ETO environments might need larger Working Capital requirements than other "more standardized" environments, like ATO, MTO or MTS, leading to longer CCC. A long cash conversion cycle might increase profitability because it leads to higher sales. However, corporate profitability might decrease with the cash conversion cycle, if the costs of higher investment in working capital rise faster than the benefits of holding more inventories and/or granting more trade credit to customers (Gill et al., 2010). Therefore, even if a certain level of CCC reduction increases profitability, this will be mostly based on the level of standardization of the products.

Hypothesis 2: Product standardization reduces the optimal CCC that maximizes profits

Standardization is usually sought due to external events, i.e. emerging competitors that base their competitiveness purely based on price might force a firm to standardize their products to compete in the lower price range and keep volume, while keeping a high degree of engineering in the higher ranges to maintain margins.

In this context, the objective of the current work is to provide empirical evidence about the effects of working capital management on profitability for a panel made up of 18 firms during the period 2014-2016. This work contributes to the literature in two ways. First, no previous such evidence exists for the case of ETO companies. We use a sample of European and US Transformer factories that operate with full profit and loss responsibility under the same conglomerate umbrella. Second, we could not find previous work that tested how different levels of standardization affected working capital needs.

3 Sample and Descriptive Statistics

The data for the analysis are drawn from Asea Brown Bovery (ABB) firms. The sample firms belong to the same global corporation but keep a high degree of independence due to the nature of the business. The data collected is between the periods of 2014 and 2016, and it includes eighteen factories from twelve countries in Europe and North America.

As determinants of business performance, we use orders received and operational EBITDA defined as: operational EBITDA = Revenues – Expenses (Excl tax, interest, depreciation & amortization).

Using the firms' data, this paper explores the different levels of engineering affect the overall cash management performance. Descriptive statistics are given in Table 1 and Table 2. From the tables it can be seen that on, average, firms' receive 9.8 million USD orders per month, while 8.9 million USD are translated into revenues. Inventories, however, were rather high, 14.7 million USD on average and NWC % 23.8%. Moreover, on average, firms had almost 5 months of CCC or 139.8 days, with a correlation between CCC and ETO level of 0.68.

Table 1

	Orders	Revenues	NWC	NWC % spot	Operational EBITDA	Inventories	CCC spot	ETO level
Mean	9.8	8.9	18.9	23.8	0.7	14.7	139.8	2.5
Median	6.1	7.4	17.7	23.0	0.3	13.3	130.3	2.5
Std dev	17.2	8.0	15.1	14.9	1.9	8.1	88.5	1.1
Min	(1.1)	(0.7)	(27.6)	(13.0)	(2.7)	0.9	23.3	1.0
Max	211.7	53.6	75.5	68.0	14.7	39.6	558.8	4.0

Table 2

	Orders received	Revenues	NWC	NWC % spot	Operational EBITDA	InventorieS	CCC spot	ETO level
Orders	1.00							
Revenues	0.67	1.00						
NWC	0.11	0.26	1.00					
NWC % spot	(0.28)	(0.44)	0.43	1.00				
Operational EBITDA	0.61	0.72	0.02	(0.30)	1.00			
Inventories	0.32	0.55	0.44	(0.22)	0.23	1.00		
CCC spot	(0.03)	(0.11)	0.44	0.60	0.01	0.31	1.00	
ETO level	0.11	0.07	0.20	0.11	0.20	0.36	0.68	1.00

4 Data analysis

The model considers the simultaneous relationship between a set of variables measured across time for a set of factories, a cross-panel dataset. Cross-sectional analysis allows extrapolation of results to a population, while time-series analysis is helpful in determining causality as well as seeing whether the same relationship holds across time (Garriga et al., 2011).

After checking for correlation, a least square regression to was used to test the hypotheses. The regression model becomes the following:

$$y_{it} = \beta_0 + X_{1it}\beta_{1it} + \cdots + X_{kit}\beta_{kit}$$

y_{it}: dependent variable
X_{kit}: independent variables

Finally, four models are created using the regression equation to evaluate the impact of an ETO business on working capital management impact and business profitability.

5 Results and Conclusion

Recent interest in working capital management, its optimization and influence on firms' profitability makes it important to understand the impact of different business models type, from Manufactured to Stock to Engineered to Order. The effects of product standardization were measured using ETO level (see Model 1 in Table 3). We hypothesized that standardization leads to a lower net working capital and thus to a longer cash conversion cycle. The results, seen on Table 3 support this hypothesis, they show how the ETO level – which is inversely correlated with product standardization – the higher the ETO level the longer the CCC.

The second hypothesis is tested on Table 4. It is confirmed that a shorter Cash Conversion Cycle increases operational EBITDA. However, the analyses don't show how product standardization

Table 3

Cash Conversion Cycle		
Independent variables	Coefficient	
ETO level	51.71	***
	(1.99)	
Net Working Capital %	3.15	***
	(0.14)	

Statistical significance denoted as: *p<0.1, **p<0.05, ***p<0.01

Standard errors in parentheses.

Table 4

Operational EBITDA		
Independent variables	Coefficient	
Cash Conversion Cycle	(0.02)	***
	(0.00)	
ETO level	0.26	*
	(0.16)	
CCC & ETO level	0.00	***
	(0.00)	

Statistical significance denoted as: *p<0.1, **p<0.05, ***p<0.01

Standard errors in parentheses.

affects the optimal CCC that optimizes profit – they show CCC with ETO level has a small impact on profitability. These results are also affected by external factors that might affect profitability, such as countries economic growth or emerging competitors with better cost structures.

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A prototype construct for strategic category management in purchasing

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Abstract

Although several strategic portfolio models and their variants have been suggested in the purchasing and supply management literature, there are very few attempts to define and describe the strategic category management process more comprehensively, especially through a rigorously applied scientific process. The aim of this conceptual paper is therefore to suggest a prototype construct design for a strategic category management system. We align our research process with design science, and explicitly with the first steps of the constructive research approach. First, we obtain a comprehensive understanding of the topic through a review of the extant literature for identification of system design principles. Second, we design and construct a prototype system with three phases based on the design principles. As further research, we suggest practitioner engagement for refining the prototype, and efforts to demonstrate the applicability and validity of the solution through a multiple case-study with solution-market tests.

Keywords: category management, purchasing, strategy, constructive research

1 Introduction

With a significant share of external spend in modern companies, distributed across a multitude of direct and indirect items and services, the more strategically oriented purchasing and supply management (PSM) functions have adopted an approach for reducing complexity and driving value for internal and external customers, namely that of category management. For the sake of understanding this concept, it is noted that a purchase category has been defined as 'a group of similar items that are required for specific business activities of the firm' (Trautmann et al., 2009, 58), or as 'a homogenous set of products and services that are purchased from the same supply market and have similar product and spend characteristics' (Cousins et al., 2008; Van Weele, 2010). Further, the management of these 'market facing' categories 'is the practice of segmenting the main areas of organizational spend on bought-in goods and services into discrete groups' and working on them in cross-functional manner (O'Brien, 2012, 2). Despite the apparent prominence of this approach in practice, more complete definitions seem to be difficult to find in the literature (e.g. Cox, 2015; Heikkilä and Kaipia, 2009), and indeed, a call for theoretical foundations and improved conceptual understanding of the concept of category management has been aired in the literature (Hesping and Schiele, 2015).

Furthermore, approaching the task of PSM through categorizing spend seems to be linked firmly to the strategic approach to PSM, as several authors suggest that strategizing must necessarily be category specific due to the varying circumstances and contingencies in each of the categories of purchase. For example, Luzzini et al. (2012, 1015) suggest that achieving 'strategic alignment requires considering purchasing categories', and Ateş et al. (2015, 205) synthesize that firms 'do not adopt a single, overarching purchasing strategy', but 'examining purchasing strategies at more micro levels, such as the purchase category', is more relevant. Indeed, the workhorse of strategic PSM, i.e. the purchasing portfolio model by Kraljic (1983), and other alternative strategic portfolio approaches (e.g. Cox, 2015), have been suggested to be used for conducting strategic analyses and classifications at the category level (Hesping and Schiele, 2015).

Although several of these strategic portfolio models and their variants have been suggested in the PSM literature (e.g. Kraljic, 1983; Olsen and Ellram, 1997; Nellore and Söderquist, 2000; Pagell et al., 2010; Luzzini et al., 2012; Drake et al., 2013; Cox, 2015), with the most notable ones subjected to extensive testing (e.g. Caniels and Gelderman, 2007; Terpend et al., 2011; Padhi et al., 2012), there are very few attempts to define and describe the strategic category management process more comprehensively, especially through a rigorously applied scientific process, and with a broader evidence-base (cf. O'Brien, 2012; Carlsson, 2015). The most notable exception is the work of Hesping and Schiele (2015), who propose a model with five levels of strategy development in purchasing, based on the strategic alignment -focused work by González-Benito (2007). The process starts from firm and functional level strategies, suggests alignment of category strategies, and focuses on the implementation of category strategies via a set of sourcing levers (Schiele, 2007, Schiele et al., 2011; Hesping and Schiele, 2016). Despite its theoretical foundations, the proposed model lacks the detail for practical testing and further development.

Indeed, while the work of Hesping and Schiele (2015) is quite useful from theoretical perspective, and lays the foundation for further work on implementing category strategies, we suggest that a gap exists in terms of research that would enable the practical construction of systems for category management. Such normative knowledge is much needed, as it appears that category management approaches often do not exist in a defined and structured form in companies. In order to lead the development of systems for category management, academic research must seek to enable the rigorous design of the 'artificial' (Simon, 1996), i.e. objects that do not yet exist, also for category management. In such design research oriented set-ups, the main question is about whether the suggested designs work, and the aim is to 'produce knowledge that is both actionable and open to validation' (Romme, 2003). In other words, the mission of design science is to develop knowledge for solving field problems (Denyer et al., 2008), which in our case would be related to how to design a strategic category management process or system for PSM? The kind of normative theory, which would address such a question, may be in the form of principles for a process or system design (Romme, 2003). Setting these research gaps as a point of departure for our research, the aim of this paper is to suggest a prototype construct design for a strategic category management system.

For addressing this research aim, we align our research process with design science, and explicitly with the constructive research approach as suggested by Kasanen et al. (1993). In line with this approach, we start a process for designing and testing a solution oriented construct for strategic category management (i.e. a set of 'models, diagrams, plans' and processes; Kasanen et al., 1993, 243), by obtaining a comprehensive understanding of the topic through reviewing the extant literature for identification of system design principles, and by innovating and constructing a prototype system through literature synthesis. As further research, we suggest practitioner engagement for refining the prototype, and efforts to demonstrate the applicability and validity of the solution through a multiple case-study with solution-market tests (Kasanen et al., 1993). In the following, we first develop design principles for the prototype construct, both from the perspective of the substance and theory of strategic category management, as well as from the perspective of management tool design. Second, we suggest the prototype design, and finally, we conclude the paper with a summary and laying out the plan for further research in terms of designing the strategic category management system.

2 Developing design principles for the prototype construct

2.1 Substance-oriented design principles

The literature that contributes to the knowledge on strategic category management can be roughly divided into two streams. First, several contributions, among them some of the most often cited works in the field of PSM (e.g. Kraljic, 1983), have been dedicated to the various focused areas of strategically managing categories of spend. Second, and a much more limited body of literature, covers the category management process more broadly (e.g. O'Brien, 2012). Integrating the accumulated knowledge from these contributions, is one of key outputs of this research. In order to bring further structure to the discussion of the literature, we adopt a framework for classifying research in terms of how it contributes to the management of categories from a strategic perspective.

According to Rumelt (2011, 6), strategy can be defined as 'a coherent set of analyses, concepts, policies, arguments, and actions that respond to high-stakes challenge', with the 'kernel of strategy' comprising of diagnosis, guiding policies, and coherent action. Diagnosis explains the nature of the challenge, and involves the identification of critical aspects and obstacles in responding to the challenge. Teece (2014) links Rumelt's diagnosis phase of strategizing to 'sensing', which is an important element of dynamic capabilities for achieving and sustaining competitive advantage (Teece et al., 1997). Guiding policy, in turn, defines a method or an overall approach for dealing with the challenge and the specific obstacles identified as a result of diagnosis (see also Teece, 2014). Both the guiding policies, as well as the coherent actions for carrying out the guiding policies, e.g. in terms of allocating resources and undertaking maneuvers, have been linked to 'seizing', the second key element of dynamic capabilities (Teece et al., 1997; Teece, 2014). The linkages between the distinct concepts of strategy and dynamic capabilities have been suggested to lead to a framework where dynamic capabilities and strategies codetermine performance (Teece, 2014).

From this it may be extrapolated that strategizing in PSM should follow the basic cycle of diagnosis, guiding policy analysis, as well as planning and implementing coherent action, and that such a cycle should first and foremost take place at the level defined by the basic unit of analysis for strategizing in PSM, namely the purchase category. A strategic category management system design, according to this first principle, would allow a category manager to sense needs to reconfigure and transform, and further to seize opportunities to sustain and improve performance at the category level in a dynamic business and supply environment (cf. Teece et al., 1997).

As much of the relevant literature that contributes to the knowledge on category management does not explicitly identify itself with this concept, we must draw on our adopted strategizing framework in order to point out contributions and the knowledge base for designing the prototype construct. The most natural way of going about this would be to start form the guiding policies, and ask what kind of guiding policies are needed for category management, or in other words, what are the 'high-stakes challenges' for the category manager? The most high-level challenge for PSM could be suggested to be the problem of how to create value for the internal and the end-customer (cf. Amit and Zott, 2001)? Operationalizing value in terms of the concept of economic value added (EVA), suggested to be the 'comprehensive financial measure of value creation' (Presutti, 2003, 220), and defined as operating profit less the cost of capital, allows the pointing out of elements that PSM should seek to influence, i.e. revenue, cost of operations and cost of capital. Indeed, there are multiple challenges in the domain of strategic category management, the addressing of which allows the category manager to influence these components of EVA; however, the most fundamental guiding policies should be oriented towards enabling the alignment of category management with strategic goals and environmental contingencies (Ketokivi and Schroeder, 2004), as this directly leads to value creation.

The challenge of alignment between the competitive priorities of the company and the PSM function (Krause et al., 2001), has been discussed early on in the literature (e.g. Treleven and Schweikhart, 1988; Narasimhan and Carter, 1998), with evidence showing that strategic alignment of business strategy with purchasing strategy, as well as the alignment of purchasing strategy with purchasing practices, i.e. purchasing efficacy, is important for improving business performance (González-Benito, 2007; Baier et al., 2008). It follows that a relevant high-stakes challenge is the alignment of category management with the order winning and qualifying factors of the business, and with the requirements of the internal customer, as in this way PSM may influence all the EVA components, including revenue. Relating to this challenge, the seminal work of Kraljic (1983) on transforming operative purchasing into strategic supply management, has been criticized for its lack of fully considering alignment and how category management can drive value (e.g. Cox, 2015), i.e. beyond the default priorities of availability and cost. With focus on the 'importance of purchasing' and 'complexity of supply market', it might be suggested that the purchasing portfolio matrix by Kraljic (1983) and its variant by Olsen and Ellram (1997), are somewhat more oriented towards producing category level guiding policies which are more aligned with the supply market and the product characteristics (difficulty of managing the purchase situation; Olsen and Ellram, 1997), although the core competencies and value adding potential are also considered. However, the variety of competitive priorities and how PSM should respond to them is not explicitly addressed.

In considering this criticism, the more recent contribution by Drake et al. (2013) is thus very welcome, as it introduces an approach for turning company's competitive priorities, such as quality, cost, time and flexibility (Hayes and Wheelwright, 1984), into guiding policies for purchasing and category management. The proposed portfolio model suggests either non-critical, lean, agile or leagile guiding policies (Towill and Christopher, 2002), and goes on to consider literature-based coherent actions for each. Although, not as explicit as Drake et al. (2013) in considering competitive priorities, Cox (2015) also suggests an approach for producing guiding policies, in which the customer and business –side alignment are achieved with the 'criticality matrix', with operational criticality evaluated on the x-axis and commercial criticality on y-axis. The sustainable purchasing portfolio matrix by Pagell et al. (2010) allows alignment with sustainability priorities.

Having reviewed portfolio approaches for procurement, Nellore and Söderquist (2000, 246) pointed out that the so far published models had three steps in common, namely analysis of the products (categories) and their classification, analysis of supplier relationships, and action plans for 'matching product requirements with the supplier relationships'. It is evident that Cox (2015) also suggests the consideration of the 'criticality matrix' jointly with the 'power matrix', which relates buyer power resources to supplier power resources, with implications on supplier relationships and their design. The consideration of the supply market, through power balance (Cox, 2015), strength balance (Kraljic, 1983), the supplier's view (O'Brien, 2012) or relationship strength (Olsen and Ellram, 1997), is an indication of a need to include the implications of supply market on buyer-supplier relationships into the design of guiding policies (see also the 'Dutch windmill' in e.g. van Weele, 2010).

As a synthesis of the above discussion, we may conclude that the most high-stakes challenge for PSM is achieving alignment at the essential level of PSM strategizing, i.e. the purchase category. Value may be created by alignment in three respects: (1) in terms of strategic alignment with competitive priorities (e.g. quality, cost, time, flexibility, innovation, sustainability; Krause et al., 2001; Schneider and Wallenburg, 2012), (2) in terms of requirement alignment with category characteristics (e.g. profit impact, share of total cost, quality and logistics requirements; e.g. van Weele, 2010) and (3) in terms of supply market alignment with characteristics of the factor markets (e.g. supplier or buyer power, market structure; e.g. Kraljic, 1983; Cox, 2015). According to the Cambridge Dictionary, alignment means 'an arrangement in which two or more things are positioned in a straight line or parallel to each other', and indeed the guiding policies and coherent actions, as embodiments of strategic category management, should be thus positioned in terms of the three key aspects which influence category management. This provides the second key principle for designing strategic category management systems. Supporting our conceptualization for multiple alignment types, several authors identify and elaborate on multiple types of domain relevant alignment, such as for strategic information systems management (Gerow et al., 2015) or organization (Kathuria et al., 2007).

How does the output from the considered strategizing frameworks look like, or what kind of guiding policies do they offer, jointly, for the proposed three-dimensional alignment? Selecting the Kraljic's (1983) matrix for requirement and supply market alignment, the power matrix of Cox (2015) for further supply market alignment, and the Drake et al. (2013) –matrix for strategic alignment, we may have three guiding policies for a category that should be jointly considered for a set of coherent actions. For example, an imaginary alignment analysis for the indirect category of office supplies, may suggest such guiding policies as 'noncritical items' (Kraljic, 1983), 'market / independence' (Cox, 2015), and 'non-strategic items' (Drake et al., 2013), and implying such coherent actions as (1) standardization, efficient processing and inventory optimization, (2) development of competence for bidding and negotiation, and (3) efficient purchasing, complexity reduction, standardization, automating transactions and using simple source selection processes to govern relatively short contracts, respectively. The recommended coherent actions seem similar, and the benefit of going through a process of using three separate analytical frameworks is not readily apparent. However, the benefits of more complex analysis are realized when there are imbalances of power, and more demanding or specific requirements from the business and internal customer. For example, the buyer may not be an attractive customer for the suppliers (van Weele, 2010), for example due to low volumes, and suppliers may have power resources over the buyer, for example due to buyer's switching costs, suggesting a dependency of the buyer, with supplier dominance (Cox, 2015). In effect, the Kraljic (1983) matrix may suggest a leverage strategy, but based on the power-matrix analysis, PSM may have to consider ways to reduce supplier's power resources or increase its own, for example by opting for a smaller supplier. Furthermore, if the competitive priorities of the company or internal customer requirements emphasize rapid design changes and short delivery times, i.e. agile supply (Drake et al., 2010), long-term relationships for information exchange and a proximate local supplier, again with smaller size for attentiveness and responsiveness, may be preferred over competitive bidding.

While the three-dimensional alignment process provides an agenda with coherent action for driving value, there are other high-stakes challenges for the category manager to respond to. For example, guiding policies may be needed for such strategic issues as make-or-buy (Humphreys et al., 2000), supply base structure (Gadde and Håkansson, 1994), coordination of sourcing in an MNC for synergies (e.g. Gelderman and Semeijn, 2006; Trautmann et al., 2009), from where to source (i.e. international supply; e.g. Smith, 1999), PSM function's meaningful role (Ellram and Tate, 2015), risk management (e.g. Zsidisin et al., 2000), and sustainability (Pagell et al., 2010). Many of these challenges are naturally contingent on the nature of category (e.g. products vs. services, specific requirements), company (e.g. multinational corporation or a small firm) and supply market structure and availability of external capabilities. Also, other contingencies such as stakeholder drive for increased low-cost country sourcing, or M&A activity fueled need for coordination, may determine high-stakes challenges for PSM and category management. It should be noted that the main alignment driven guiding policies influence the guiding policies related to some of these other strategic challenges, as for example risk management and supply market intelligence would be a high priority for a 'bottleneck' category or item (Kraljic, 1983), and international sourcing from low-cost countries have been suggested to make sense primarily in the case of 'leverage' categories or items (Kamann and van Nieulande, 2010). Strategic imperatives related to sustainability may require managers to make a 'purposeful increase in supplier risk', i.e. the so called leverage categories are treated similarly to strategic categories, as partnerships are implemented for information asymmetry reduction and ensuring common prosperity across the supply chain (Pagell et al., 2010). From the perspective of designing a strategic category management system (the third principle), we suggest that depending on several contingencies, such as category characteristics and company context, a set of frameworks for identifying appropriate sub-level guiding policies may be included on the agenda.

Having so far focused only on the guiding policy –phase of Rumelt's (2011) kernel of strategy framework, as a starting point of the strategic category management system design, the preceding diagnosis phase and subsequent coherent action phase need to be covered as well. The content of the diagnosis phase should aim to identify the obstacles and aspects of the business and supply market on which to respond in order maintain and achieve alignment. In other words, the agenda of the diagnosis phase is primarily driven by the analytical and information needs for using the strategic frameworks for alignment, an important design principle for the construct. Diagnosing category importance and complexity of supply market (Kraljic, 1983), both the buyer and supplier power resources (Cox, 2015), as well as the importance of various performance dimensions on the competitiveness of the end-product (Drake et al., 2013), allows decision makers to form a category profile for subsequent analysis on guiding policies. Again, determining the contingent sub-level guiding policies may determine other diagnostic needs, such as logistics costs for international supply (Smith, 1999), synergy potential across the corporation (Trautmann et al., 2009), threat to triple bottom line (Pagell et al., 2010), or various aspects contributing to the complexity of purchase, such as internal politics (Ellram and Tate, 2014). However, some sub-level guiding policies, such as for supply base structure, draw directly on competitive priority diagnostics already on the agenda, as well as the outcomes of guiding policy analysis (Ateş et al., 2015). Summarizing the above into the fourth design principle, we suggest that secondary items on the agenda for diagnosis may be determined by analysis needs for sub-level guiding policies.

Finally, the agenda for coherent action should be firmly addressing the seizing of opportunities for value creation. The agenda may be determined by the actions derived from the primary guiding policies for alignment or the sub level guiding policies for addressing category contingencies. For example, the literature on the underlying frameworks for three-dimensional alignment, lists tasks and recommendations that help identify coherent actions (e.g. Kraljic, 1983; Drake et al., 2013). Furthermore, strategic imperatives ate the company level may directly determine actions, such as doggedly increase the share of low-cost country sourcing. It is also important to note the dynamic nature of categories in relation to these frameworks, as some guiding policies are more desirable than others from the PSM perspective (e.g. non-critical over bottleneck), and a particular characteristic of the requirement or the supply market may change or be actively altered. As a result, 'hold and pursue' strategies may be undertaken through coherent action (Gelderman and van Weele, 2003).

Additionally, the concept of sourcing levers is often also connected to this 'action plan' oriented phase (Nellore and Söderquist, 2000), or the tactical phase in strategic category management process (Hesping and Schiele, 2015; Cox, 2015). According to Schiele (2007, 279), a sourcing lever can be defined for example as 'a set of measures that can improve sourcing performance in a commodity group' or category. In addition to the seven sourcing levers suggested by Schiele (2007), the practitioner literature identifies various sets of levers, such as the sixteen connected to the Chessboard by A.T. Kearney or the fifteen in five categories by O'Brien (2012). The set of seven by Schiele (2007), has received the most attention in the academic literature, for example in terms of estimating the cost-saving potentials of the levers and categorizing them into bundles for implementing particular strategies (cost leadership or differentiation; Schiele et al., 2011), as well as matching the levers with the Kraljic (1983)-matrix. The results of the latter suggest that purchasers 'use a mix of all tactical sourcing levers in all portfolio quadrants', and that 'rather than being viewed as alternatives, tactical sourcing levers are used in an additive way' (Hesping and Schiele, 2016). Recognizing that the set of seven sourcing levers may not yet be complete, it is still a useful general framework for the coherent action phase to identify projects for category performance improvement and value creation, across all guiding policy defined situations. For such a purpose, Schiele et al. (2011) suggest steps for conducting lever analysis workshops. Summarizing the above into the fifth design principle, we suggests that the agenda for the coherent action –phase of strategic category management may be determined by company strategic imperatives, the implications of the primary and sub-level guiding policies, but then also include the consideration of a set of generic souring levers for identifying and maintaining a pipeline of category projects for creating value.

2.2 *Technically oriented design principles*

A construct for strategic category management system might also be conceptualized as a management tool, defined broadly as 'a document, framework, procedure, system or method that enables a company to achieve or clarify an objective' (Brady et al., 1997, 418). Whereas for example the action research literature offers perspectives on how the tool design process should be executed (e.g. Moultrie et al., 2007; Lindgren et al., 2004), there is less accumulated knowledge on the characteristics of good or successful management tools. In a supplier performance measurement tool design context, Doolen et al. (2006) seem to suggest that simple tools with visual cues and concise designs would be appropriate. Moultrie et al. (2007) recognize that tool design often needs to carefully balance comprehensiveness and usability, and that delivery of a tool is key in the formation of perception of the tool, influencing buy-in. Using language that is familiar to users, using specific worksheets for supporting thinking and encouraging actions, as well as allowing for pragmatic adaptation to the needs of the users, may be some of the key aspects for designing a buy-in focused delivery

In the context of technology management, Phaal et al. (2006, 338) provide a synthesis of good practice principles for tool design, and suggest that tools should be 'founded on an objective best-practice model; simple in concept and use; flexible, allowing 'best fit' to the current situation and needs of company; not mechanistic or prescriptive; capable of integrating with other tools, processes and systems; result in quantifiable improvement; and support communication and buy-in.' Many of these provide useful perspectives and foundations for principles for designing strategic category management systems. For example, much of the previous discussion on the substance oriented design principles is meant to provide a foundation that is based on the research and practice supported concept of purchase category, as the appropriate unit of analysis for strategizing in PSM. As the tools adopted for the three-dimensional alignment are all based on 2x2 matrices (Kraljic, 1983; Cox, 2015; Drake et al., 2013), the prerequisites for a simple and usable design exist (Phaal et al., 2006); however, joint use of these elements, with analytic diagnostics and levers for coherent actions, nevertheless would still need to adhere to the principle of simplicity.

Phaal et al. (2006) also suggest that matrix-based tools are 'fairly flexible', allowing customization for particular category contingencies. The degree of flexibility appears to be determined by the choice of how to operationalize and measure the dimensions of the matrix. Operationalizations determine positions and guiding policy outcomes, and indeed, this aspect, on one hand driving flexibility, has been, on the other hand, concluded to be the weakness of portfolio models (Gelderman and van Weele, 2003). Gelderman and van Weele (2003) offer three alternative measurement methods for the Kraljic (1983) –matrix, applicable to the other matrix-tools as well, namely the consensus methods (focus on relatively fast discussion-based use and flexibility), the one-by-one method (with single operationalized measures for each dimensions for objective, comparable and fast use), and the weighted factor score –method for including several factors per dimensions and for customization and flexibility. From academic perspective, a fuzzy multi-attribute scoring method for measuring the dimensions of the Kraljic (1983) –matrix has been found useful (Padhi et al., 2012). Relating to the tool design principles of Phaal et al. (2006), the consensus method is most likely to prevent mechanistic application, perhaps in contrast to the other methods, as this approach facilitates the 'profound, open discussion about purchasing issues', that are found to be 'the most critical part of strategy development' (Gelderman and van Weele, 2003, 210).

In terms of designing a category management system that would be able to integrate with other tools, processes and systems, perhaps already existing in the company, it is useful to take note of the apparent pervasiveness to which the Kraljic (1983) matrix, or its varying incarnations, is used in practice (Gelderman and van Weele, 2003; Pagell et al., 2010). A strategic category management system, based on the Kraljic (1983) –matrix would therefore be desirable, as the more comprehensive new system would potentially build on the existing knowledge and competencies of the users. While return-on-investment might be difficult to demonstrate from the use of specific approaches to category management, research shows that strategic alignment in PSM results in

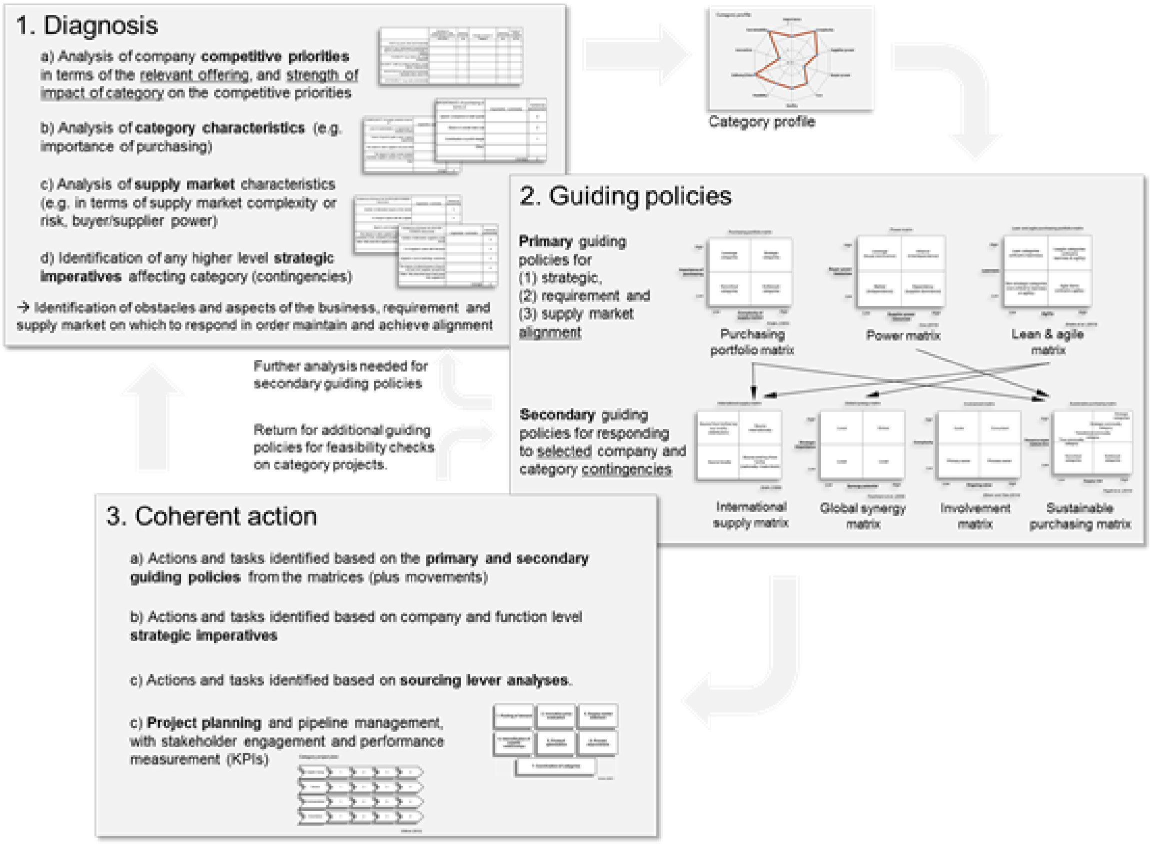

Figure 1 – Prototype strategic category management system

quantifiable improvement (González-Benito, 2007; Baier et al., 2008), and that the use of the Kraljic (1983) –matrix specifically, is sign of purchasing sophistication (Gelderman and van Weele, 2005).

For buy-in, the simple consensus method may be useful, as guiding policies that are a result of open discussion in a cross-functional category team context, may be more likely to enjoy acceptance in comparison to mechanistic application of black-box tools (cf. Muralidharan et al. 2002). However, managers tend to be biased as well in non-structured decision making situations, regarding for example supplier selection (Verma and Pullman, 1998; Kannan and Tan, 2002). The insights by Moultrie et al. (2007), recognizing the trade-off between comprehensiveness and usability, suggest the use of familiar terms, worksheets or workbooks, and allowing for adaptation as drivers for maximum buy-in.

Summarizing, we suggest technical design principles for the prototype strategic category management system construct. First, a design that is to large extent based on visually communicable 2x2 matrices may likely meet the criteria for simplicity and flexibility, especially, if the dimensions and positions of categories and items are based on a consensus oriented discussion, perhaps with operationalizations and explicit valuations with worksheets. Second, the consensus method also prevents mechanistic and opaque application, and if appropriate terms and worksheets for concretizing the positioning tasks are utilized, a higher buy-in than would otherwise have been expected, may be achieved. Third, a design that is based on the Kraljic (1983) –matrix is more likely to be integrated into tool sets that are actually used, as such are likely to build on an existing knowledge and competence base of the users and stakeholders (cf. Cox, 2015).

3 The prototype construct

Based on the above developed five substance-oriented and three technically-oriented design principles, we propose a literature-based prototype construct for strategic category management in purchasing (Figure 1). Based on the first substance-oriented design principle, the system is

Drivers for IMPORTANCE of purchasing:	Arguments / comments	Categorical assessment
Spend compared to total company spend		
Share in overall BOM cost		
Contribution to profit margin		
Other: Why is the category important?		
Overall assessment for IMPORTANCE of purchasing:		Medium

Fig. 2 – Example of a template for measuring dimensions for guiding policy matrices

structured to comprise of three distinct sections, (1) for diagnosis, (2) for guiding policies and (3) for coherent actions. These sections may be considered in order to or steps may be taken back, for example for diagnostic needs for secondary or sub-level guiding policies, or for checking for feasibility with guiding policies as a result of brainstorming for actions with the sourcing levers.

Based on the second substance-oriented design principle, the system ensures strategic, requirement and supply market alignment of category strategies and actions with three matrices (Kraljic, 1983; Cox, 2015; Drake et al., 2013), jointly determining the primary guiding policies for the category. Based on input from the diagnosis phase, or the coherent action phase, secondary or sub-level guiding policies may be determined with a selection of appropriate tools (matrices) from a "library", as the third substance-oriented design principle suggests. It is recognized that some of the primary guiding policies influence secondary guiding policies, such as specific cases of international supply.

The obvious implication of the alignment targeting guiding policy frameworks is the identification of certain analytical needs for the diagnosis phase, such as in terms of competitive priorities, category characteristics and supply market characteristics. As depicted in Figure 1, these fundamental aspects of the category may be visualized in a category profile, allowing stakeholder communication and comparison across any of the purchase categories in the company. Furthermore, company and functional level strategic imperatives should be identified at the diagnosis phase (Figure 1). Finally, and according to the fourth substance-oriented design principle, secondary or sub-level guiding policies may drive additional diagnostic needs, depending on the company context and other contingencies.

The fifth substance oriented design principle suggests that the primary and secondary guiding policies, any identified strategic imperative with direct task implications, as well as sourcing lever – based analyses determine the agenda in terms of coherent actions for improving category performance and value creation. Finally, important elements in the coherent action phase are project planning and performance measurement tools and frameworks, as such practices has been shown to have a favorable effect on project success (Zwikael and Sadeh, 2007; Cooke-Davis, 2002; Pohl and Förstl, 2011)

The technically-oriented design principles also guided our efforts for constructing the prototype system. Aligned with the first design principle, we suggest the use of 2x2 matrices in determining and communicating guiding policies, with the key foundational element being the Kraljic (1983) – matrix (see third design principle), allowing for improved buy-in. The second design principle for technical delivery is perhaps the most challenging to implement, as explicit guidance on operationalizing the dimensions of the matrices for primary guiding policies in a practical setting is scarce. How to actually design and implement a consensus-based method for measuring supply market complexity, buyer-power, or requirements for agility? As some form of worksheets seem to be recommended for concretizing and facilitating discussions, we also propose simple templates for such purposes.

	Importance to competitiveness of the relevant offering (customer OWP/OQP)	Numerical assessment (a)	Category's strength of impact	Numerical assessment (b)	Priority for category management (a x b)	
COST (e.g. price, total cost of ownership)		2		2	4	For leanness
QUALITY (e.g. conformance to specifications, superior performance e.g. in terms durability or reliability)		2		2	4	4,0
FLEXIBILITY (e.g. volume, mix, design modification)		3		2	6	For agility
DELIVERY / TIME (e.g. delivery lead time, on-time delivery, response time)		3		3	9	7,5
INNOVATION (e.g. latest/advanced technology, innovation churn / short PLC)		1		2	2	
SUSTAINABILITY (e.g. social, environmental)		3		3	9	

Fig. 3 – A template for measuring dimensions of competitive priorities for category management

First, for purchasing importance, supply market complexity, as well as buyer and supplier power, we propose a template where the dimension has been given three to four operationalizations, as well as an option for thinking any other driver for the dimension. Space is provided for noting arguments and comments, and then the template encourages the decision maker(s) to make an explicit interpretation in terms of whether measure would be low, medium or high (Figure 2). Traffic light –type visual cues are used in the excel-based template. And finally, an overall value is given based on the discussion across several measures. It should be noted that this overall value is not an average of the constituent measures, but rather a consensus outcome of considering all aspects, as it is hardly the case that a measure with "low" value, could necessarily compensate for a "high" value in another, for example in terms of supply market complexity or risk (Gelderman and van Weele, 2003).

A second type of template is used for considering the competitive priorities of the firm and the respective alignment of the category management efforts (Figure 3). The template is based on the generic competitive priorities of operations management (Hayes and Wheelwright, 1984), adapted to the PSM context (Krause et al., 2001), and extended with the dimension of sustainability (e.g. Schneider and Wallenburg, 2012). Drawing on the Drake et al. (2013), we employ a simple numerical assessment method, in which (1) the importance to competitiveness of the relevant offering, and (2) the category's strength of impact, are evaluated in terms of each of the competitive priority dimensions on scale from 1 to 3, corresponding to low, medium and high. Using the numerical assessments, based on the underlying discussions, allows the simple calculation of the priorities for category management, which are the product of the two previously mentioned evaluation targets. Using color shading for visual cues, decision maker(s) may form an alignment enabling understanding of the customer requirements, and averages for leanness (cost and quality) and agility (flexibility and delivery) are calculated as well for use in guiding policy analysis.

It is proposed that these simple and transparent templates provide a platform for alignment oriented diagnosis for strategic category management. It should be noted that focus should not be in mechanistic selection of values, but rather on open discussion and a consensus-based crystallization of the category profile in terms of values and a radar-chart (Figure 1).

4 Conclusions and further research

The aim of this paper has been to suggest a prototype construct design for a strategic category management system. Having aligned our research process with design science, and explicitly with the constructive research approach as suggested by Kasanen et al. (1993), we review the literature for system design principles, i.e. five substance-oriented and three technically-oriented principles. These may be summarized as follows:

1. Strategizing in PSM should follow the basic cycle of diagnosis, guiding policy analysis, as well as planning and implementing coherent action, and that such a cycle should first and foremost take

place at the level defined by the basic unit of analysis for strategizing in PSM, namely the purchase category.
2. Guiding policies for strategic category management should primarily focus on achieving alignment in three respects: (1) in terms of strategic alignment with competitive priorities, (2) in terms of requirement alignment with category characteristics, and (3) in terms of supply market alignment with characteristics of the factor markets.
3. Appropriate sub-level guiding policies may be identified for strategic category management based on several contingencies, such as category characteristics and company context.
4. The agenda for the diagnosis phase of strategic category management is primarily driven by the analytical and information needs for alignment, and secondarily by diagnostic needs for sub-level guiding policies.
5. The agenda for the coherent action –phase of strategic category management may be determined by company strategic imperatives, the implications of the primary and sub-level guiding policies, and the consideration of a set of generic souring levers for identifying and maintaining a pipeline of category projects for creating value.
6. A design for strategic category management should be based on visually communicable 2x2 matrices for simplicity and flexibility.
7. A design for strategic category management should be largely based on the consensus method for preventing mechanistic and opaque application, with appropriate terms and worksheets used for concretization and buy-in.
8. A design for strategic category management that is based on the Kraljic (1983) –matrix is more likely to be integrated into tool sets that are actually used.

By adhering to the stated design principles, we proceeded to construct a prototype system through a literature synthesis. A design was suggested with the strategic cycle of Rumelt (2011) as an overall structure, and with prominent strategic PSM frameworks incorporated for guiding policy analysis (Kraljic, 1983; Cox, 2015; Drake et al., 2013), and a sourcing lever framework (Schiele, 2007) for planning coherent action.

As further research, we suggest practitioner engagement for refining the prototype, and efforts to demonstrate the applicability and validity of the solution through a multiple case-study with solution-market tests (Kasanen et al., 1993). The particularly interesting areas of refinement may be considered the operationalization and measurement of dimensions for guiding policies (e.g. is the consensus-method superior to for example the weighted-factor method due to its flexibility, transparency and discussion facilitating properties?), the appropriate inclusion of guiding policy frameworks (simplicity vs. comprehensiveness), and the degree to which the sourcing lever framework of Schiele (2007) fully captures the range of methods to improve category performance. Furthermore, in order to accumulate knowledge on the association or even causality between the use of constructs for strategic category management and category or PSM performance, the framework suggested by Denyer et al. (2008) for analyzing the context, intervention, mechanism and outcome of strategic category management, could be used for conducting case studies.

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Stimulating Supply Chain Manufacturing Growth: Can Policy Create Supply Chains from a Void?

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Abstract

The UK has introduced in 2014 the Supply Chain Plan, which requires that a sufficient number of parts and services associated with the construction of a wind farm are sourced from the UK. This requirement is the last instalment in a series of policy measures attempting to increase local content, but its effectiveness is questionable in terms of achieving the industrial dynamics associated with the creation of centres of excellence through smart specialisation. Based on the experience acquired in 3 different applied research projects about creating local offshore wind supply chains, we use a behavioural theory of the firm theoretical approach to assess the alignment between policy and stakeholders respective behaviours. We conclude that the Supply Chain Plan is very likely to be a case of escalation of commitment, and as such, a policy of questionable rationality

Keywords: supply chain, policy, offshore wind, escalation of commitment

1 Introduction

The UK Department for Energy and Climate Change introduced in 2014 the so-called 'Supply Chain Plan' (DECC, 2014). Developers of wind farms above a certain power output have to demonstrate that arrangements have been made to ensure that many of the parts and services needed for the construction of wind farms to be installed in UK waters will be sourced from the UK. The supply chain plan is the spinoff of a consultation process which is summarised in the 2013 *Offshore Wind Industrial Strategy: Business and Government Action* report as follows:

> *'As part of our new industrial policy, we want to see UK-based businesses grow to create a centre of engineering excellence that delivers cost reduction for UK projects and exports to overseas market. To achieve the vision set out in this strategy, we need to grow our manufacturing base to be world-leading in more areas of offshore wind supply and to achieve levels of UK content in our offshore wind farms which are similar to those achieved by our North Sea oil and gas industry where more than 70% of capital expenditures is through UK-based suppliers*' (DECC, 2013, p. 2).

The same report estimates that only 30% of offshore wind spending is, on average, sourced from UK suppliers (p. 71). Whereas up to 2014, industrial policy support for the offshore wind sector was centred around innovation, for example with the *GROW: Offshore Wind programme* (a fund for Manufacturing Supply Chain Programme for Regional Growth) the supply chain plan adopts a different direction as it does not exclude achieving its 70% target through foreign investment. This is exactly what is happening in Hull with the building of a 'green port' by one of the leading turbine manufacturers in Europe, Siemens, and its partners. The news of the first wind turbine blade manufactured there have been commented on widely and positively in the national press, which also quotes ministers for stating that this factory is a proof that "*manufacturing has a glittering future in the UK*" (Vaughan, 2016).

The Supply Chain Plan is clearly a success in terms of regional job creation (1000 jobs in a city with the UK's highest unemployment rates; Vaughan, 2016) but the celebration of Hull's green port is the sort of news item that one would expect to read about an emerging economy rather than a country with a level of technological knowledge such as the UK. The Supply Chain Plan is a policy which is an interesting and unusual case study in the institutional analysis of structural economic change, as it raises many questions.

First, the Supply Chain Plan is essentially a local content requirement and thus a form of protectionism. In the context of Brexit and of a government sporting the traditional unconditional British allegiance to free trade principles, imposing local content requirements on European trade partners is an odd position. An interview of Siemens UK's chief executive (Vaughan, 2016) acknowledges that exports will only be considered when the factory brings its costs down; a statement that echoes the typical lack of performance associated with local content requirements (Belderbos and Sleuweagen, 1997; Kuntze and Moerenhout, 2013).

Second, such cost disadvantages inscribe themselves in a larger debate about the competitiveness of local versus global supply chains. In order for the UK to build wind farms with the lowest lifecycle cost of electricity, relying on a global supply chain benefitting from either competitive or comparative advantage effects (e.g., Christopher *et al*., 2006) sounds like a robust strategy. There is a growing paradoxical tension, especially at the policy making level, between advocating global versus local supply chains, and the UK Supply Chain Plan is a good example of this tension.

Third, the Supply Chain Plan departs from the vertical policies associated with smart specialisation support policy (Foray, 2014) as it does not try to directly stimulate entrepreneurial excellence (whereas previous initiatives such as Offshore: Grow Wind did).

Finally, the fourth and most challenging issue comes from the fact that UK-based first movers in wind power technology in the 1980s were not deemed worthy of policy support, and the small industry that they formed eventually died off. Thus, the Supply Chain Plan is an attempt to re-create an extinct cluster, but this time, from a void.

The overall objective of this paper is to investigate the conditions under which a local content requirements policy such as the Supply Chain Plan is feasible and valuable. This requires considering the following topical questions for any country willing to develop its manufacturing base: can entire supply chains be created from a void? Are local content requirements an effective way to do so? How can we make sense of the contradictions of policy simultaneously advocating local and global supply chains?

2 Offshore Wind: A Global Overview of Markets and Supply Chains

The wind power industry has grown steadily in continental Europe for the last 20 years, but its recent accelerated growth in 'follower' countries is down to a number of international, European, and national directives with the purpose of reducing carbon emissions and of increasing the share of renewables in national energy mixes. First movers, both in terms of wind energy production and of the fabrication of wind power equipment, were Denmark, Sweden, and the USA. They were the only three countries to generate electricity with commercial wind farms in 1983 [1]. Wind farms were built

[1] All statistics in this section are from the International Energy Statistics database, www.eia.gov, and the Global Wind Energy Council, www,gwec.net.

in 1986 in India and the Netherlands. In Germany and the UK, wind electricity generation began in 1988. By 2016 though, the UK hosted the 6th largest wind power capacity in the world with 14.5 GW, composed of 10GW of onshore wind farms and 5GW of offshore wind farms. The largest users are China with 169GW, the USA with 82GW, and Germany with 50 GW. In these countries installed capacity is predominantly onshore.

In recent years, the UK has almost entirely ceased investing in onshore wind. This can be explained by the relatively small landmass which does not provide much opportunity for siting wind farms especially in a context of frequent social opposition to wind farm projects (Bell et al., 2005; Van der Horst and Toke, 2010). The larger coastal areas and associated stronger, steadier winds along with much reduced issues of social acceptance means that the UK is now focusing on offshore wind growth. As a result the UK has stepped out of the shadows and is now the largest offshore wind market with 36% of the global installed capacity, right in the geographical centre of offshore wind growth, as Northern Europe hosts 88% of the market share. The 10 largest commercial wind farms in operation today are in the North Sea, with London Array being currently the largest wind farm in the world with a capacity of 630MW. Plans to build more (and larger) wind farms mean that the UK offshore wind market is estimated to be worth more than £100 billion in the next 20 years.

This growth is not without challenges though, as offshore wind electricity is considerably more expensive than onshore wind (Blanco, 2009). Whereas onshore wind is nearing competitive parity with traditional fossil fuel sources, offshore wind farms can only be operated through subsidies. This subsidisation has been a key feature of the UK energy policy (chronologically through the Renewable Obligation and the Contract for Difference policy instruments). It is likely that the subsidy rate, typically ranging from 50 to 100% of the electricity rate, has motivated the UK government to find ways to demonstrate value for money beyond carbon reduction and increased energy security. Inspired by the examples of a handful of countries where the growth of offshore wind had resulted in the creation of new and vibrant industrial districts, such as Germany and Denmark, the UK, and most European countries, built an expectation that the construction of offshore wind farms would generate economic spillovers resulting in significant local job creation and in the type of structural changes typically associated with smart specialisation. Alas, in the majority of the cases these spillovers did not materialise. For example, the Kent region did not experience significant spillovers, and this, despite being offshore wind first movers in the UK (Leseure *et al.*, 2014). This realisation led to the consultation mentioned in the introduction and eventually to the adoption of the Supply Chain Plan.

To better understand the nature of this market, it is useful to consider the product breakdown structure of a wind farm project. A large offshore wind farm, such as London Array or Rampion in Brighton, will typically cost about £2 billion in capital expenditures. 43% of this budget is for the wind turbine manufacturer and 33% for the balance of plant (foundations, cables, and substations), leaving 24% for the developer's installation, commissioning, and project management expenses. Typically, the wind farm is built with an expected 25 years operating life, and annual operations and maintenance expenses will be 3% of the original construction budget. The operations budget includes recurring expenses such as leases, connection fees, operating base, staff, etc, that add up to 50% of the budget. The remaining half of the budget is spent on spare parts.

A very simplified representation of an offshore wind supply chain is a 3-level linear supply chain composed of the user (typically a utility company), the developer (who will typically operate the facility for the first five years after construction), and the first tier level of suppliers. Key players in the first tier are the turbine, cables, and foundations manufacturers. The turbine manufacturers have their own traditional manufacturing supply chains. Whereas supplying to other first tier suppliers requires a specialist trade (e.g. cables), the turbine manufacturers rely on a much more diverse set of suppliers. This, along with the high percentage of the budget going into the turbine, explains why the turbine supply chain has been the main focus of policy. Ten companies hold 72% of the global market share for turbines: 1 from Denmark, 2 from Germany (1 based on the acquisition of a Danish operator), 2 from the US (including the merger with a Spanish manufacturer), 2 from India, and 3 from China. Although the UK has a number of firms manufacturing small scale as well as mid-size turbines suitable for onshore installations, the only firms that could have been players in the offshore sector either went out of business in the 1980s or were bought out and moved to Scandinavia. There is currently no firm in the UK with the ability to manufacture offshore turbines. There are UK businesses with experience of foundations manufacturing (for oil and gas platforms), subsea cables production, as well as a few foreign-owned specialist manufacturing centres (e.g. blades).

3 An Industrial Strategy Perspective

Given the context described in the previous section, does the Supply Chain Plan seem to be a sensible and promising industrial policy? It is tempting to try to find an answer to this question by relying on the traditional industry view of strategy, i.e. by using Porter's Diamond (Porter, 1998). Given the high rate of building offshore wind farms in the UK, the demand conditions are certainly very strong. There are sufficient factor endowments in terms of material and knowledge as well as related industries (offshore and oil and gas sectors). However, when it comes to the strategy, structure, & rivalry, which drive in Porter's Diamond, the ability to maintain a competitive advantage through innovation, there is no large player or alliances that can fulfil this role.

A similar conclusion can be reached by using the lenses of smart specialisation. Entrepreneurial discovery is at the heart of the process of smart specialisation, and in the absence of any entrepreneurs invested or willing to invest in this area, nothing will happen.

However, in a comparative study of several countries industry policy support mechanisms, Lewis and Wiser (2007) conclude that "*whether new wind turbine manufacturing entrants are able to succeed will likely depend in part on the utilization of their turbines in their own domestic market, which in turn will be influenced by the annual size and stability of that market. Consequently, policies that support a sizable, stable market for wind power, in conjunction with policies that specifically provide incentives for wind power technology to be manufactured locally, are most likely to result in the establishment of an internationally competitive wind industry*". This conclusion suggests that the Supply Chain Plan is a feasible and worthy initiative but it has to be mitigated by the fact Lewis and Wiser's (2007) conclusion is based on an historical examination of first mover countries only. All these benefited from direct and indirect support from their government to develop a local wind power industry (see Lewis and Wiser for a full account of the different policy instruments used) and worked initially at a national scale before the industry became truly global. The only case study that could be compared to the UK is Japan, a late entrant with no prior experience in the sector (Lewis and Wiser, 2005), that now has 3 large scale turbine manufacturers. Such a case study resonates with academic criticisms of Porter's Diamond, e.g. Davies and Ellis (2002) report cases of the successful creation of business clusters in the absence of an innovation core. To add to these opposing viewpoints, local content requirements are presented as key policy mechanisms in Lewis and Wiser (2007) but their use in the renewable energy industry have also been criticised as ineffective policy instruments (Kuntze and Moerenhout, 2013).

4 Theory

This paper explores these opposing viewpoints from the theoretical perspective of the behavioural theory of the firm (Cyert and March, 1963). Cyert and March challenged the classical theory of the firm's proposition that managers maximise shareholder's wealth. As most managers make decisions in contexts best described with bounded rationality and imperfect information they look for satisficing solutions that are good enough to please shareholders, rather than make optimal decisions. The behavioural theory of the firm has never been previously applied at the policy making level, but policy makers belong to organisations which are exposed to problems of equal, if not higher, complexity than firms. They, too, have to make 'rational' decisions under uncertainty to please a vast array of stakeholders.

The behavioural theory of the firm offers many sub-theories with which to investigate the behaviour of decision makers. Cyert and March (1963) explain that in the face of uncertainty and different decision alternatives, organisations are likely to divide into different coalitions, and the process of decision making becomes a process of establishing the power or dominance of a coalition. They also replace the idea of optimising with the concept of an organisational search. Different coalitions will adopt different directions of search. March (1991) contrasts explorative searches (innovation and experimentation) vs. exploitation (the use of tested and known business models) and concludes that there is an optimal trade-off between exploration and exploitation. Gavetti and Levinthal (2000) compare cognitive searches that look forward and analyse conditions for change to take place with experiential searches, which look backward before making a decision. They conclude that the ability to change a cognitive representation is important for adaptation. Coalitions have been associated with the role of ideology in decision making, and especially with the existence of irrationality in organisational action (Brunsson, 1982) and for explaining the escalation of commitment to a course of action (Staw, 1981).

Lewis and Wiser (2007) point out that nearly all countries using wind turbines are attempting to establish a local supply chain, and this, regardless of their level of capability, experience, knowledge, and timing of entry. In other words, all are searching for a way to create a new promising industrial sector and the associated jobs. Based on the behavioural theory of the firm, the following propositions can be made to explain the creation of the Supply Chain Plan and to assess its worthiness.

4.1 Proposition 1

There exists in UK policy maker circles, a dominant coalition which is concerned with the political argument that UK taxpayers are not getting enough for the high subsidies paid to the offshore wind sector, and that the real beneficiaries of these subsidies in monetary terms are foreign manufacturers and utility companies. This dominant coalition therefore considers that the creation of a UK-based manufacturing sector is a fair and justified offsetting mechanism. In this scheme of things, the goal is to create jobs, ideally in areas in need of regeneration. Whether or not actual spillovers will take place is not necessarily a prime consideration, and this coalition may be content with the idea that the knowledge base of the sector in the UK may remain that associated with contract manufacturing, with only limited technology transfer taking place. In other words, this coalition is happy with the idea that this is an exploitation policy that can only generate benefits in the short term and offers limited and uncertain growth potential.

4.2 Proposition 2

UK policy makers have been impressed by the global strength and size of emerging offshore wind clusters and by the accounts of Germany and Denmark (see for example Bergek and Jacobson, 2003). Further inspired by the fact that for different reasons the UK has created a strong and stable domestic demand, policy makers see in offshore wind an ideal sector for vertical policy support, i.e. an off-the-shelf solution to their problem of 'identification and discovery' (Foray, 2014). This resulted in the categorisation of offshore wind as a promising 'smart' investment. As initially attempts to create clusters such as the Centre for Offshore Renewable Energy (COREs) were not all successful and classic R&D support (such as *Offshore: Grow Wind*) did not lead to the emergence of strong local first tier suppliers, the Supply Chain Plan is a case of escalation of commitment. Escalation of commitments rarely, if ever, lead to satisfactory outcomes.

4.3 Proposition 3

UK policy makers are well aware of the numerous past market co-ordination failures in the establishment of a UK-based offshore wind supply chain but believe that this is an industrial sector where a follower may eventually lead the industry by benefitting from the loss of real option value to first mover advantage and instead search for follower advantages (Cottrell and Sick, 2002).

5 Methodology

5.1 Qualitative field research

The authors were involved from 2012 to 2015 in 3 separate applied research projects commissioned respectively by a regional interest group, a local government, and INTERREG Channel to investigate the potential and feasibility for local small businesses and regions to become involved in an offshore wind supply chain. For 3 years, we collected data and performed analysis to develop recommendations about how to 'make the most' out of offshore wind opportunities. This required extensive involvement with all stakeholders at a local, regional, and national level and for this reason our methodology is best described as qualitative field research. Our data sources and method of data collection are described in the next section. Through these projects, we have been active participants of the ongoing search for the development of the offshore wind sector in the UK, and this gives us the ability to characterise behaviours, values, and coalitions that we have observed. Our focus is not so much the independent factors of industrial strategy frameworks (e.g. strong demand conditions) but more the dynamics (or lack thereof) between these factors. Recent work in Technology Innovation Systems (TIS; Bergek *et al.*, 2008) confirm that these dynamics, core to both Porter's Diamond and smart specialisation, are of central importance to achieve effective agglomeration economics effects.

5.2 Projects

The authors were first contracted to populate a database of potential suppliers for the new Rampion windfarm before building started off the coast of Brighton. This was done by mapping local businesses areas of expertise against a detailed breakdown structure provided by the client. This led to a follow-on project for the Kent region. Kent is interesting as a region in the context of this paper for two reasons. The first is that it is there that the first UK offshore wind farms were built (Kentish Flats and Thanet). It is also within reach of other 'first mover' wind farms (Greater Gabbard and Gunfleet sands). It also the home of London Array. The second reason is that local economic spillovers were much lower than expected (cf. Leseure et al., 2014). Therefore, Kent is an ideal 'test bed' to analyse the root causes of lack of local economic spillovers. The project was to extend the supplier mapping exercise for Kent but also to promote the sector and to provide recommendations to the region about how to stimulate local small business engagement with the industry. As part of the Kent supply chain project, several interactive workshops were organised in order to capture the perceptions of local businesses in terms of the opportunities and barriers associated with offshore wind. The last workshop included an exhibition where potential suppliers could see a range of spare parts that could be supplied.

The third project was Channel-MOR, an INTERREG Channel project. The objectives of Channel-MOR were to provide recommendations to regions in the Channel Arc Manche area in order to facilitate and promote the uptake of MRE opportunities by local businesses. The Channel Arc Manche regions include all coastal Channel regions, from Brittany to Nord-Pas de Calais on the French coast and from Cornwall to Norfolk on the British coast. The MRE technologies that were considered were offshore wind, tidal energy and wave energy. The authors led the Channel-MOR workpackage which was about promoting the sector's opportunities to SMEs and providing recommendations to regions about facilitating and stimulating regional transitions towards the energy sector. Channel MOR was a very large 11 partner project with a total budget of €1 million, and our workpackage involved extensive data collection, interactive workshops, and promotion events. It provided the authors with a genuine immersive experience with the sector and the opportunity to meet with all stakeholders. Data collection included a global survey of industry experts asking them to rank through an Analytical Hierarchy Process (AHP) key strategic factors that could lead a region to become a global player in the industry. The survey results were then used as an input for strategic analysis workshops to produce a mapping of all 8 participating regions onto a grand strategy matrix. Each of these workshops included local stakeholder participations. Finally, further workshops were organised for each region to produce scenarios of regional transitions to join the offshore renewable sector.

5.3 Data Analysis

A presentation of all the detailed data (e.g. survey results) is not possible given the quantity of data involved. Data from the Kent project can be found in Leseure et al. (2014) and the Channel-MOR findings in Channelmorenergy.eu (2014). This data forms the body of evidence from which we can assess the support for the 3 propositions formulated in the previous section. The method of data analysis is as follows:

1) Extract from each project's final report key observations and conclusions about (i) the context of operations of the offshore wind supply chain, (ii) the perception of the characteristics of this supply chain, and (iii) commonly shared beliefs about market structure and conduct.
2) Map the support that these observations/conclusions provide for each proposition.
3) Tally the overall amount of support for each proposition.

This process can be illustrated with one of the findings from the Kent project. To understand the lack of engagement of local businesses with the sector, an interactive workshop including 50 participants was organised. Participants were asked in groups to produce a cause and effect diagram of the root causes of barriers to engagement. In all groups, perception of high uncertainty about the future of the sector were identified as a reason to 'wait and see' rather than to proactively engage. The workshop was repeated at an international conference with 25 participants from industry in Cherbourg during the Channel-MOR project and produced similar conclusions. The high visibility of the sector in the press, which is based on numerous controversies (social acceptance, impact on cost of electricity, level of subsidies, low capacity factors, unproven technologies, etc.), means that businesses are reluctant to consider the (high) cost/risk of transitioning to this sector.

The next step is to question how this conclusion aligns with the three propositions. If the ongoing search, i.e. the policy makers' push for the sector, was based on the exploitative idea of generating short terms jobs linked to the construction projects, one would expect clear communications being made in this regard. Policy statements would stress the short term orientation of the search and clearly indicate to potential entrants that the long term future of the sector is not an issue, i.e. the aim is 'make money whilst we are building wind farms'. This is not the case as policy documentation (e.g. the *Offshore Wind Industrial Strategy*; HM Government, 2013) very clearly states that offshore wind is an exciting sector to invest in, and in the long run. Thus, we can conclude that our observations of the perception of high uncertainty does not support proposition 1.

Most business participants in our workshop were seduced by offshore wind but unconvinced by the opportunity and this because of their perception of uncertainty and high cost for establishing a competitive presence. One would expect that if proposition 3 were true (search for follower advantage), much of the policy voice would acknowledge this uncertainty as benefitting from follower advantage is by its very nature an uncertain business. A search of the *Offshore Wind Industrial Strategy* report reveals that uncertainty is only mentioned once, when discussing the challenge of raising finance. This gap between portrayed uncertainty (policy) and perceived uncertainty (actors) lead us to the conclusion we find no support for the third proposition. High uncertainty supports proposition 2 though, i.e. the idea that the current search is a case of escalation of commitment. For a rational decision maker, the persistence of the cause (uncertainty) of the setback (no spillovers) should reduce the perception of future outcomes (Staw, 1981). When it does not and investments in a prior course of action intensifies, this is a case of escalation of commitment.

This process of analysis is repeated for the 10 key conclusions from our three projects.

Table 1 – Support for the Three Propositions

	Proposition 1: Offset Subsidies - focus on S/T job prospect	Proposition 2: Escalation of Commitment	Proposition 3: Search for follower advantage
High perception of uncertainty		X	
Not acknowledging the challenge of competing with existing and mature agglomeration economies		X	
Lack of co-ordination at an early growth stage		X	
Idealisation		X	
Limited entrepreneurial knowledge, very dispersed		X	
Cognitive tie between production and use	X	X	
Lack of strategic option thinking	X	X	
Local, not global aspirations	X	X	
Overestimation of S/T job prospects and economic benefits	X	X	
Offshore wind, not energy	X	X	
Support for Propositions	5	10	0

6 Findings

Table 1 displays the results of the process described above, and is followed by a discussion of each row. Table 1 shows that we find no support for the idea that the current offshore wind industrial strategy is a consciously articulated case of searching for followers' advantage. We find only moderate support for the idea that it is about generating short term gains (job creation). We do find strong support for proposition 2, i.e. that UK offshore wind industrial policy is a case of escalation of commitment.

6.1 Not acknowledging the challenge of competing with existing clusters, Lack of Co-Ordination at an Early Growth Stage

Many of our interviewees and participants were fully aware of the level of competitiveness of first-movers (e.g. Germany and Denmark) and also of the long, often tedious, technology development processes that competitors from these countries have gone through. Very much in line with the title, participants were sceptical that the UK could, from a void, overtake the outcome of 30 years of R&D and TIS dynamics (Bergek and Jacobson, 2013; Jacobson and Lauber, 2006). In contrast, the policy stance is uncompromising: there is no reason why the oil and gas benchmark of 70% cannot be matched. This is an important issue as it means that policy ignores the anchor tenant's hypothesis, i.e. the fact that a local large R&D firm (in our case, first mover turbine manufacturer) stimulates the creation of a cluster and of spillovers (Agrawal and Cockburn, 2003). It is at an early stage that the anchor tenant recruits entrepreneurial partners and structures knowledge flow and activities. In the specific case of turbines, there is no anchor tenant in the UK and although structuring activities exist, they are being implemented at a very late stage of the TIS dynamics. Many of the small businesses that we interviewed and that participated in workshops also stressed the very high transaction costs and entry barriers associated with the sector today, which they compared to a 'gentleman's club'. It is very likely that these transaction costs were lower in the early growth stage.

6.2 Idealisation

Through the Channel MOR project, we observed a slight bias in the recruitment of our participants. All of them were very positive about the principle of renewable energy, in fact too positive. This can be described by idealisation, the process of over-valuing and augmenting a value or idea to the extent that it cannot possibly be challenged (Brown and Starkey, 2000). After the survey, we asked each region to perform the traditional stages of a SWOT analysis and we mapped the strategic positions of each region onto a grand strategy matrix. 7 out of 8 regions self-rated themselves as possessing top strengths and as being faced with outstanding opportunities, when common sense suggested that this could not be the case. After moderation of the strategic mapping, it turned out that only 1 region out of 8 was indeed in this area of the grand strategy matrix. One participant called for an end to the 'gold rush' mentality that surrounds offshore wind and for more a realistic assessment of the challenges and likely outcomes. It is difficult to provide more support to the proposition of escalation of commitment than this!

6.3 Limited Entrepreneurial Knowledge

A key challenge to achieve the spontaneous dynamics of smart specialisation is the dispersion and fragmentation of entrepreneurial knowledge, and when this challenge is too extreme, policy support will be required (for example by creating learning networks; Foray, 2014). There are a number of bodies (*UK Renewables Catapult*) and initiatives (*Offshore: Grow Wind*) that exemplify this type of support and these are successful. It is in fact very likely that all entrepreneurs with a genuine experience and interest in offshore wind are in contact or are being supported by these. In some areas of the supply chain (e.g. cables) where several UK players exist, there may be the required critical mass to create a cluster. However, when it comes to turbines, and therefore the bulk of the value chain, there are simply not enough potential entrants.

6.4 Cognitive Tie Between Production and Use, and Local, not Global aspirations

The behavioural theory of the firm tells us that both cognitive (forward looking) and experiential (backward looking) thought processes, and the balance between the two, will shape the direction of searches (Gavetti and Levinthal, 2000). Our research showed a strong cognitive tie between the erection of a wind farm and the development of a supply chain, and this for all participants (regional officers, businesses, etc.). It is true that this was the case of all first-mover turbine manufacturers and it is also true that in their early phases of growth they benefited from local content requirements (Lewis and Wiser, 2007). As these manufacturers grew this use-production tie disappeared. For example, the industry leader, Vestas, now exports 99% of its production (Lewis and Wiser, 2007). However, it is the account of the early growth stage that has been strongly imprinted in policy makers. In our survey of experts, construction and operations opportunities (i.e. those associated with projects) were rated as more valuable than investments in R&D. When asked to rate the key strengths of a global player in the renewable energy sector, weather, expertise, and policy support were rated equally. This means that policy makers have created an odd tale of wind farms that spontaneously bring factories on shore. The fact that the demand created by one wind farm project is not a sustainable demand base for these factories is rarely discussed and gladly avoided. In the Channel-MOR project, we witnessed the creation of this cognitive tie at work in the marketing of offshore wind farms in northern France, which are almost always associated with the promise of a factory in a local port.

6.5 Lack of Strategic Option Thinking, Overestimation of Short Term Job Prospects and Economic Benefits

This finding came from the Channel-MOR phase of the project when we asked the different regions to formulate scenarios for their transition towards the renewable energy sector. They confirmed the cognitive tie between production and use as many regions only presented scenarios of planned wind farm construction, making the implicit assumption that a local supply chain would naturally follow. This phase also revealed a lack of strategic opting thinking. Before the scenario planning stage, each region was provided with their moderated strategic positions, and most regions had moderate strengths (typically in the maritime and offshore sectors) and faced more threats than opportunities. Strategic options reasoning (Trigeorgis and Reuer, 2017) would recommend considering learning (e.g. partnering) options or waiting options, or in the case of regions with neither strengths nor opportunities, abandonment options. Clearly articulating these options would be the starting point of seeking follower advantage (Cottrell and Sick, 2002). The majority of regions formulated standard growth strategies in their scenarios, and this, despite (i) the fact that their strategic mapping suggested that they should not and (ii) the fact that these regions could

Table 2 – Industry Comparison

	Investment (£b) Capital Expenditure	Employees	Purchasing, Operations, and Maintenance budget p.a. (£m)
Large offshore wind farms (600MW)	1.91	90	76.40
Two UK automotive assembly plants	2.1	3800	1047.2

benefit from the lessons learned from more experienced regions in the project team. These (illusory) growth strategies are the outcome of the enduring policy promotion messages stressing the expected growth of the sector and the number of jobs that will be created. In a workshop in France, we compared the purchasing expenditures and permanent jobs created in the construction and operation phases of a wind farm with an automotive assembly factory, as shown in Table 2. Upon seeing the table, a representative of a French developer came to us at the end of the presentation and told us that we should urgently remove this table from our presentation as it was inconsistent with national policy statements.

6.6 Offshore Wind, not Energy

The vast majority of our participants were interested in offshore wind and more generally, offshore renewable energy. They generally had little knowledge and interest in the overall energy sector. This is counter to the strong knowledge exchange dynamics that one would expect to see in smart specialisation. In fact, the only region in the Channel MOR project that was in a position to adopt growth strategies (and had already done so) was the East of England (Norfolk and Suffolk). It not only benefited from their oil and gas experience but also from their very proactive all-energy interest group, EEEGR (East of England Energy Group) that perfectly matches the description of a smart specialisation learning network. This region is a successful case study of first tier market entry in the installation, servicing, and maintenance areas.

7 Conclusion & Implications for Policy

Our conclusion is that the Supply Chain Plan is a case of escalation to commitment that fails to recognise geo-political supply chain and industry dynamics which are at the heart of research on smart specialisation and technology innovation systems. The argument of Lewis and Wiser (2007) is based on the business history of first-movers and we find no evidence that it can be extended to seeking follower advantage in this sector. We question whether initiatives like the Supply Chain Plan are really desirable when they risk displacing investment and motivation in more balanced (exploration/exploitation) policies. Instead vertical policy support favouring R&D and structuring entrepreneurial discoveries in 'new spaces' connected to the offshore wind sector as identified in the Channel-MOR project (tidal, wave, energy storage, condition monitoring, subsea connectors, and smart transmission) would seem to be much more promising avenues with long term growth potential.

These findings have wider implications as the UK develops its Industrial Strategy underpinned by regional and national Science and Innovation Audits, founded on principles of smart specialisation. Many of these emphasise the importance of developing regional supply chains, although it is not always clear what the existing basis for this is. Our work also re-emphasises the importance of first mover advantage and establishing regional demand. In some areas of the Industrial Strategy it might be argued that first mover advantage has already been taken, e.g. with battery technologies.

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The Future of Temporal Supply Chain Networks

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Abstract

Prior research highlights how successful collaborative initiatives between supply chains members could lead to sustained differentiated performance. However, inter-organisational collaboration often fails due to misalignment of incentives and strategies. Whilst management research tackles this issue in the Relational View theoretical perspective, however, usually in contexts where the supply chain is a well-established network and overlooks a long-term time horizon. Considering the recent technological advancements and the rapid digital transformation of supply chains, it becomes pertinent to investigate the co-generation of competitive advantages in temporal contexts. As such, we can better understand and realistically manage supply chains against periods of uncertainty, while not compromising on the theoretical soundness. The present research investigates the interplay between supply chain relationships, collaborative strategies and performance. Employing a case study in industrial projects-based supply chains, the research touches upon the feasibility of achieving supply chain alignment, and reflects on the appropriateness of the relational view in temporal contexts

Keywords: Supply Chain Management, Relational View, Inter-organisational Collaboration, Alignment, Competitive Advantages, Introduction

1 Introduction

Supply chain management practices are viewed by many practitioners as an important source for developing competitive advantages (Capgemini, 2012). The findings presented in recent literature (see e.g. Melnyk et al., 2014, Sabri et al., 2017) suggest several elements embedded in the firm's internal and external environment that affect the management and the performance of supply chains (Lapide, 2006, Corominas et al., 2015). These elements are related to the implemented strategies, operational practices, or supply chain design and relationships.

Management research has explained this phenomenon through the relational view theoretical perspective (Dyer and Singh, 1998; Lavie, 2006), which suggests that there are certain resources that belong to the network of interconnected firms. Therefore, in a networked-firms context, leveraging the competitiveness of firms, and enhancing their performance, largely depends on exploiting the network's entire resources. Resulting in co-generation of competitive advantage through inter-organisational collaboration. This line of thinking proposes that the performance of a supply chain could be a determinant of the strategies followed on the firm – and the corporate – levels of the chain's members.

This research acknowledges that one of the main challenges facing supply chain researchers and practitioners nowadays is how to align inter-organisational collaboration practices with the corporate – and the supply chain – strategies to achieve a superior performance. Not only the existence of collaboration strategies is important, but, the alignment between these strategies becomes crucial for a successful inter-organisational collaboration (Dyer and Singh, 1998). As such, the performance of individual firms becomes not as pertinent as their relational performance (i.e. the performance that indicates the network's performance) (Mesquita et al., 2008).

Although the relational view perspective is well-established in management literature (e.g. Dyer and Nobeoka, 2000; Gulati et al., 2000, Lavie, 2006), however, it involves research on inter-organisational relationships overlooking a long-term time horizon. Alternative contexts that reflect real-life relationships, that are, temporal supply chains with shorter-term time horizons, are under-researched topic so far.

To this end, the purpose of this paper is to empirically explore how supply chain relationships could be employed for the survival of lower performing firms through co-generation of competitive advantages. More specifically, the present research investigates the interplay between supply chain strategy, inter-organisational collaboration, supply and distribution networks design, and, performance. The research touches upon the feasibility of achieving supply chain alignment, and reflects on the suitability of the relational view in temporal contexts.

2 Theoretical Background

2.1 Supply Chain Collaboration

Inter-organisational collaboration is defined in the supply chain context as "the ability to work across organisational boundaries to build and manage unique value-adding process to better meet customer needs" (Fawcett et al., 2008, p. 93). The outlined definition suggests that inter-organisational collaboration is sought after, given three conditions are satisfied; (a) there is a common objective or goal, (b) this objective cannot be properly achieved through individual firm efforts, and, (c) the value (i.e. benefits) of such collaboration should exceed the incurred costs.

The notion of supply chain collaboration emerged (Lamming ,1993; Simatupang and Sridharan, 2002), and has over the past decade been reinforced, due to the need to respond to customer demands (see e.g. Adams et al., 2014, Kumar et al., 2016). Furthermore, collaboration helps in risk mitigation through sharing the risk (and the rewards) among supply chain members, leading to an environment of openness and trust and yielding to building competitive advantages (Soosay et al., 2008). Therefore, in a collaborative supply chain, the members share their resources, capabilities, and also risks, so as to cogenerate a value (benefit) that was not possible to be achieved depending on an individual firm's efforts (Simatupang and Sridharan, 2002).

There is a well-addressed paradox in building an interconnected network's (e.g. supply chain's) competitive advantages, through exploiting the linkages of value co-generation between the network's members. On the one hand, individual firms are encouraged to collaborate, to cogenerate value, and to transfer their knowledge to their network members so as to reach a differentiated performance (Dyer and Singh, 1998). On the other hand, individual firms need to be certain that this knowledge spill-over is not going to negatively affect their individual performance. As such, firms put great deal of effort in ensuring the exclusivity of the collaboration benefits to the network, not to the individual firm, whether the firm is the supplier or the buyer (Mesquita et al., 2008).

Collaboration is being advocated in supply chain literature due to its impact on performance, and on building competitive advantages, through effectively matching the demand with the supply

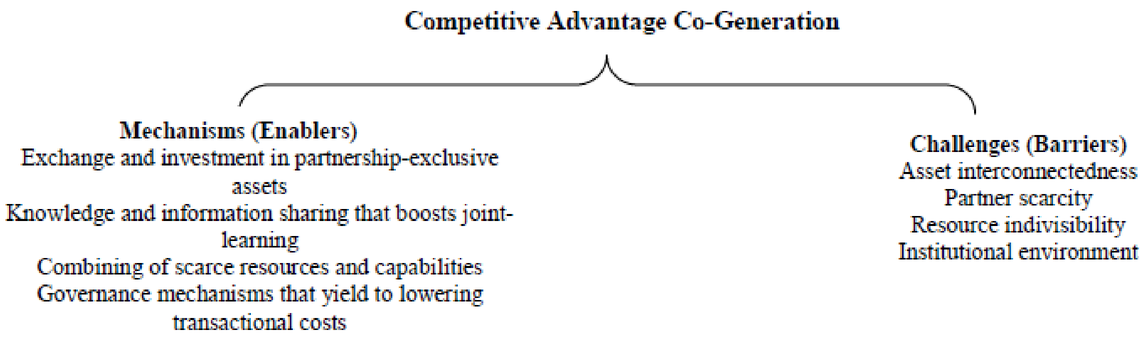

Figure 1 – Competitive Advantage Generating Mechanisms and Challenges from a relational view perspective (source Dyer and Singh (1998) and Touboulic and Walker (2015)

(Simatupang and Sridharan, 2002). However, to achieve a successful inter-organisational collaboration, alignment of the incentives of the network partners is needed (Dyer and Singh, 1998). Alignment is a rich topic in supply chain literature. Although there is lack of a clear definition of alignment, however, there are two noticeable scopes of the alignment notion in the management domain. In strategic management literature, strategic alignment is concerned with aligning the strategies and the resources of the network members to the contextual environment (Miles and Snow, 1978; Zajac et al., 2000). Organisational management literature sheds light on the notion of structural alignment, which mainly relates to aligning the organisation’s structure to its contextual environment, whether this environment is internal or external (Lawrence and Lorch, 1967; Khandwalla, 1972; Mintzberg, 1979).

Evidently, inter-organisational collaboration is not always a success story (Adams et al., 2014). Collaboration between organisations often fail to achieve its anticipated value. Fawcett et al. (2015) shine some light on the central reasons behind inter-organisational collaboration failures. First, Organisational reasons. In their research, Fawcett et al. (2015) find that organisations that are designed (structured) for cost minimisation, might not be as effective as in managing collaborative strategies. Second, for Sociological reasons, this is related to the rigidity of some decision-makers in accepting and/or managing the change process. Third, Structural reasons, where older and better-established organisational structures are more prone to resist the change. The outlined discussion on collaboration failure takes us back to the alignment notion, and the paramount importance of investigating the feasibility of achieving supply chain alignment when implementing supply chain collaborative strategies.

2.2 The Relational View: A Temporality Perspective?

In light of the above discussion, the relational perspective, therefore, could provide a theoretical lens for a better explication of the multifaceted phenomenon of inter-organisational strategic collaboration (Touboulic and Walker, 2015). The central theory of the relational view suggests that performance could be bolstered through the exploitation of resources that belong to the inter-organisational relations (Dyer and Singh, 1998). In contrast to the resources-based view of the firm, the resources and capabilities in the relational perspective could be a property of the network not of the individual firm, therefore, the unit of analysis is the relationship between firms.

Dyer and Singh (1998) identify four categories for generating competitive advantages through partnerships and alliances and four main challenges (identified by Touboulic and Walker, (2015) as ‘enablers’ and ‘barriers’ respectively), as depicted in Figure 1.

There is a significant growing body of supply chain research that embraces the relational view theory (see e.g. Wieland and Wallenburg, 2013; Walker et al., 2013; Touboulic and Walker, 2015). Yet, noticeably most of these papers examine the inter-organisational relationships in well-established networks, or relationships that are formed over a long-term time horizon.

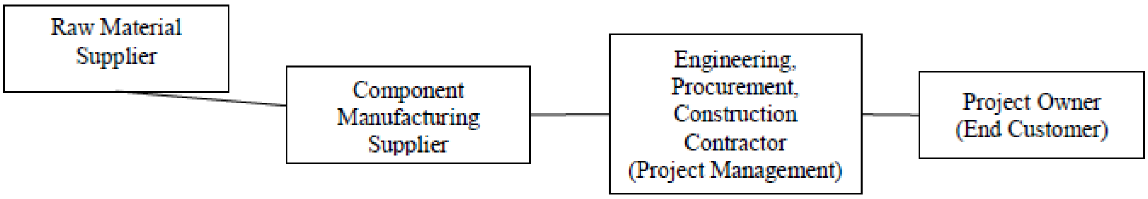

Figure 2 – Industrial Projects-Based Supply Chain

Little is known, thus far, on the appropriateness of the relational view in supply chains within temporal contexts. On the one hand, the manager in these firms still need to attain high levels of inter-organisational collaboration and alignment to face global competition, yet on the other hand the temporality dimension might hinder the managers' efforts in adjusting to Dyer and Singh's four mechanisms (enablers) of co-generating competitive advantage. Then: what do these firms do? how they accommodate the temporality in managing their supply chain strategic relationships? Can firms in such contexts reach superior performance, and if so, how researchers can transfer this knowledge to draw a potential survival map for lower performing firms? In the next section, we attempt to respond to these research curiosities.

3 Research Design

3.1 A Unique Context: Industrial Projects-Based Supply Chains

Although supply chain management is a research domain that receives great deal of attention from researchers, specifically in the last two decades (Giunipero et al, 2008, Chicksand et al., 2012). Yet, some contexts are still under-researched topics.

The present research explores industrial projects-based supply chain (Figure 2), which is considered to be a temporary networked organisation (Turner and Müller, 2003). Industrial projects are non-repetitive infrastructure mega-projects, for example as in the water treatment, nuclear, or oil & gas plants (Turner, 2014). Industrial projects can be of strategic, national and international importance (for example the cross-continental oil & gas pipelines). The project procurement is a complex process that involves a rigorous tendering procedures to ensure high technical capacity and delivering with minimum latency with respect to a mostly-rigid scheduling project plan. As such, the project owners (end customers) put importance to interpersonal relationship to ensure higher levels of trust and openness. Higher levels of collaboration and effective stakeholders' management is essential for delivering the project successfully.

The research team carefully selected this research context (i.e. projects-based supply chains) as it is best suited to explore co-generation of value and competitive advantages in a temporal context with a relatively short/medium-term time horizon.

4 Methodology

This research follows a multiple case study research strategy that respects the context sensitivity of the supply chain (Yin, 2014), as such, it allows the research team to access data from the actual decision makers.

Data are collected through structured and semi-structured interviews from 12 supplier firms located in Italy. Case selection was performed following these criteria: (1) the findings of the conceptual development phase of the research (presented in the Theoretical Background section), (2) the idiosyncrasy of the projects temporal context as highlighted above, (4) Expert opinion, and (4), the geographical approximately to the research team.

Based on these criteria, industrial projects supply chains are deemed as a proper empirical context that corresponds to the findings of the theoretical framework. We sought after supply chains that achieve a differentiated performance. Therefore, we decided to interview high

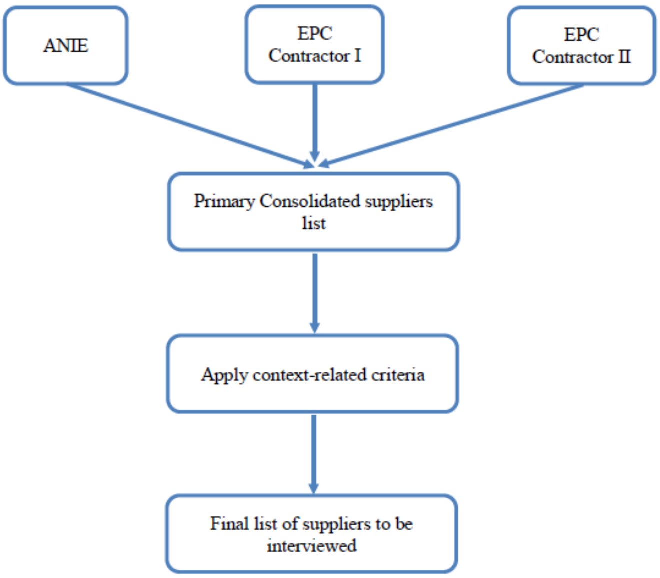

Figure 3 – case selection

performers, which provides beneficial insights on whether or not they cogenerated competitive advantage with their supply chain members, and if not then how they managed the challenges.

As outlined in Figure 3, the first step in identifying the case firms was contacting ANIE (The Italian National Federation of Electrical and Electronic Companies) and two main EPC (Engineering, construction and procurement) contractors were contacted to identify their best-in-class manufacturing supplier firms. The different lists generated based on these experts opinion were afterwards cross-examined and then consolidated in one list of 12 supplier firms.

Second, the research team discussed the compliance of the individual firms to the above outlined theoretical framework. The discussion resulted in exclusion of 3 firms which we deemed not to be consistent with the homogeneity of the sample, for the following reasons: the three firms are huge multinational manufacturers (in terms of size, turnover, and market share), which detaches them from the Italian context where the majority of the manufacturers are small and medium family-owned enterprises. Moreover, being well-established firms could have contributed in providing these firms with advanced value creation capabilities. Therefore, the decision was to interview these firms to have general knowledge on their operations and strategies, but to exclude the data collected from these firms from the cross-case comparison as they don't fully comply with the theoretical framework.

Data are collected on the corporate and/or firm strategy, providing a longitudinal view on their performance strategies, the relationships between these firms, their raw material suppliers, customers (EPC contractors), and end-users (project owners). Furthermore, their collaboration and information sharing practices implemented in the supply chain, the products characteristics, the main performance measures they employ in their operations, capacities within their facilities, and, supply and distribution channel design. Secondary data are also collected from reports provided by the national Italian associations gathering the Italian engineering, contracting and plant components suppliers, and Italian federation of National Associations of Mechanical and Engineering Industries. The interviews data were recorded and then transcribed by members of the research team. The collected data were analysed by following a coding process to identify matching patterns of similarity/difference, frequency and sequence (Saldaňa, 2012), yielding to identification of theoretical themes. Afterwards, the data were reflected on the mechanisms and challenges as identified by Dyer and Singh (1998).

Table 1 – Descriptive statistics table

Supplier Code	Size (no. of employees)	Turnover (Mln Euro)	Product-Related Turnover (%)	International Production Facilities (No. of)	Italian Production Facilities (No. of)	Belongs to a corporate group? (Yes/No)
S1	25	5	50%	1	1	No
S2	240	45	25%	2	2	No
S3	100	20-30	N.D.	2	2	No
S4	160	35	20%	2	1	Yes
S5	150	23	15-20%	1	1	Yes
S6	170	N.D.	N.D.	1	1	Yes
S7	300	40	N.D.	2	2	No
S8	58	20-40	100%	1	1	No
S9	150	30	N.D.	1	1	Yes

N.D. = Not Disclosed

5 Findings

The preliminary findings of this ongoing research indicate that high performing firms widely implement inter-organisational collaboration practices, in the context of industrial projects-based supply chains. In the industrial projects context, although the supply chains are temporary, however, the supply chain members are keen on keep their relationships well-established. The relationships, therefore, are not as temporal as the supply chain itself.

Supplier certification is key criteria in supplier selection, therefore, when these firms collaborate with the EPC contractors it enables small and medium sized supplier firms to access international markets without incurring huge investment risks "This kind of strong and direct access to the end users can be achieved through strong investments, lobbying for example, sending people there, basically networking and establishing connection". Most interviewed managers expressed their willingness to collaborate so as to be able to penetrate unexplored markets. "The EPC, thus, became a means of communication that the average Italian small business could use to get in touch with those new markets.". Inter-organisational collaboration also enables these small firms to win the tenders and to have access to the vendors list to the end users (or project owners)

Table 2 and Table 3 respectively depict the mechanisms and barriers of competitive advantage co-generation (X = not implemented, √ = implemented/exists, P=partially implemented). In table 2, regulatory mechanisms and paying respect to the legal enforcements (whether they are formal or informal, stemming from a partner's requirement or from a third-party requirements, e.g. national legislations) top the list of implemented collaboration mechanisms. This is followed by information sharing mechanisms and to a lesser extent site-specifity. It was found that some of the interviewed firms they put long-term investment in relocating or establishing a branch of their facilities so as to be geographically closer to their end customers, and to be 'visible in the market'. From their experience, it is very difficult to penetrate an international market that they don't have physical branch there that serves the end users. Know-how transfer, cogeneration of ideas and innovations and human asset specifity comes later in the priority. This can be interpreted by the response of one manager, as he puts it "[collaboration] needs a long-term commitment…it is very difficult".

In Table 3. Legal restrictions, organisational restrictions and country-specific (cultural) restrictions are the main barriers existing to implement inter-organisational collaboration. Forming long term collaboration in such context is quite challenging due to organisational barriers and misalignment of strategies "[forming alliance] it is very difficult…difficulties are related to the meeting between two different types of company management, two different management." There are many challenges associated with inter-organisational collaboration, some relate to national/cultural traits "this [Collaboration Failure] was probably caused by excessive individualism characteristic of Italian companies."

Table 2 – Mechanisms (Enablers) Analysis

		S1	S2	S3	S4	S5	S6	S7	S8	S9	SC implementing mechanism (No. of)
Exchange and investment in partnership-exclusive assets	*Site Specifity (localisation / geographical approximation of assets)*	X	√	X	√	X	√	√	√	X	5
	Physical Asset Specifity (capital investments in equipment/tools)	X	X	X	X	X	X	X	X	X	0
	Human Asset Specifity (know-how transfer through human resources)	√	√	X	X	X	√	X	X	X	3
Knowledge and information sharing that boosts joint-learning	*Cogeneration of new ideas and innovation*	X	X	√	X	√	√	X	X	√	4
	Information sharing mechanisms	X	√	√	√	√	√	√	√	√	8
	Know-how transfer mechanisms	X	P	X	X	√	√	√	X	X	4
Combining of scarce resources and capabilities	*shared equipment*	X	X	X	X	X	X	X	X	X	0
	shared facilities	X	X	X	X	X	X	X	X	X	0
	shared warehouse	X	X	X	X	X	X	X	X	X	0
	shared know-how resources	X	X	X	X	X	X	X	X	X	0
Governance mechanisms that yield to lowering transactional costs	*Third-Party enforcement*	√	√	√	√	√	√	√	√	√	9
	Formal Self-enforcing Agreements	√	√	√	√	√	√	√	√	√	9
	Informal Self-enforcing Agreements	√	X	√	X	X	√	√	X	X	4
	total mechanisms implemented	4	6	5	4	5	8	6	4	4	

Table 3 – Challenges (Barriers) Analysis

		S1	S2	S3	S4	S5	S6	S7	S8	S9	SC having barrier (No. of)
Asset interconnecte dness	*Cumulative bundles of joint investment decisions*	X	X	X	X	X	X	X	X	X	9
Partner scarcity	*Easiness of finding a partner*	X	X	X	X	X	X	√	X	√	7
	Willingness of the partner	√	√	X	X	X	P	√	X	√	4
	Experience in collaboration	√	√	X	√	√	√	√	√	√	1
Resource indivisibility	*loss of control over the firm's capabilities and resources*	√	X	√	√	X	X	X	X	X	2
	difficulty in redeploying resources due to collaboration restrictions	√	√	X	√	X	X	X	X	X	3
	loss of flexibility due to long-term collaboration	√	X	X	√	X	X	X	X	X	2
Institutional environment	*legal restrictions*	√	√	√	√	√	√	√	√	√	9
	organisational restrictions	√	√	√	√	√	√	√	√	√	9
	Country-specific (cultural)restrictions	√	√	√	√	√	√	√	√	√	9
	total barriers existing	8	6	4	7	4	4	6	4	6	

6 Discussion

Collaboration is employed as a strategy that provides means to survive the market competition, through exploiting the resources available in the network. Inter-organisational collaboration could enable interconnected firms in the supply chain to build a preparedness capability to overcome the uncertainty pertaining to globally spread supply chains. Moreover, inter-organisational collaboration was found to be a key influencer in the successful launching of new products and enhancing the innovation capability. However, there is still lack of implemented procedures on how to align the operational (firm-level) and the corporate strategies to the supply chain collaboration practices.

There are certain implications that result because of the particularity of the industrial projects-based supply chains context. The difficulty faced by small and medium manufacturing suppliers to get certified and appear on the project owner verified vendors list, force them to establish partnerships with the EPC companies. The EPC contractors in that case becomes a gatekeeper. Thus, the power structure and the potential opportunistic behaviour of some EPC contractors hinders trust and efforts for long-term collaboration. Furthermore, regulations and the restrictions imposed by legal agreements arise as a significant influencer on the co-generation of value. For example, due to the end customer (project owner) requirements of having a certain percentage of 'local content' of the components of the plants, somehow makes the collaboration a 'forced' strategy. Local content requirement also forces some of the small suppliers to invest in partnership-exclusive asset specifity, since the components need to be locally manufactured (country-specific barriers). It is noticeable that most of these supply chains have much better collaboration and relationship on the upstream side (1st and 2nd tier suppliers), as compared to the downstream side (EPC contractors and the end customer) and this could be explained with the existence of a rigid power structure of such kind of supply chains.

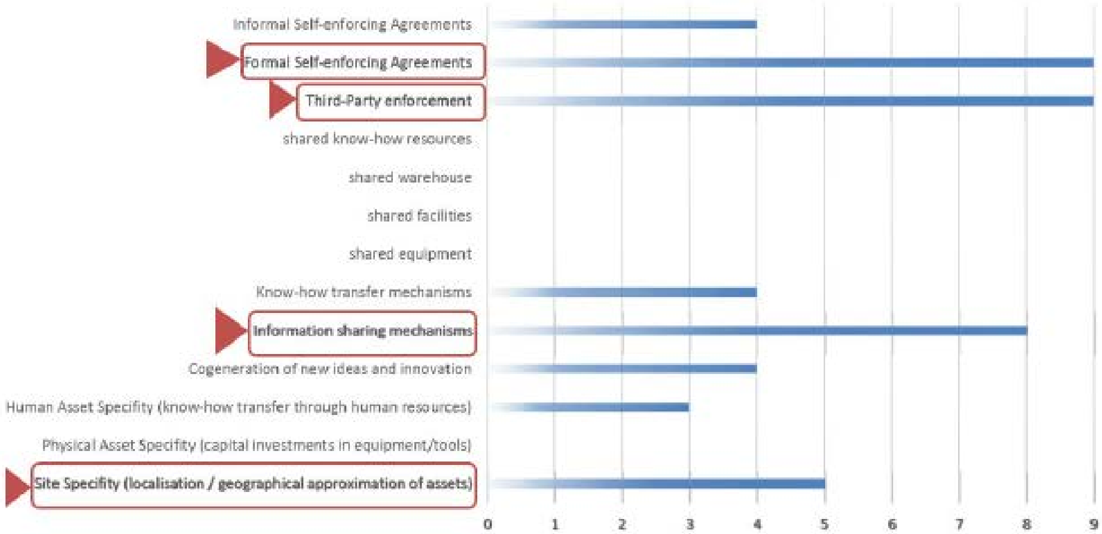

Figure 4 – Most significant mechanisms for value co-generation

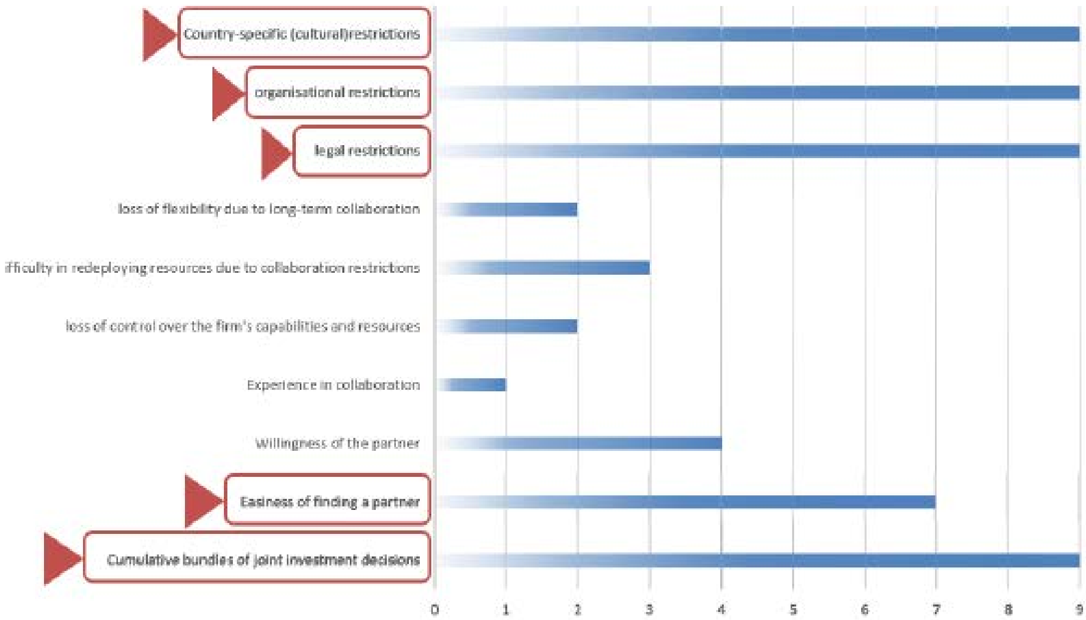

Figure 5 – Most significant barriers of value co-generation

Not only the power structure, but since these small and medium manufacturing suppliers operate globally, communication and language skills becomes a barrier to penetrate foreign markets, to showcase their innovation capability, or to establish long-term partnership or agreements. Other barriers related to the size of the suppliers, also are related to the context where many of these suppliers are family-run enterprises with different generations involved in the management.

7 Conclusion

This research investigates the inter-organisational collaboration practices in industrial projects-based supply chains, which is a rarely researched context in the supply chain research domain. The data collected from the case study provide in-depth analyses of the strategies implemented in temporary networked environments that enable firms to reach a differentiated performance.

Furthermore, the temporal nature of the industrial projects allowed the research team to develop a guiding framework for applying the collaboration mechanisms and managing certain barriers in rapidly changing environments.

7.1 Limitations and future research

The limitations of this research relate to the context of application. Most of the findings and their interpretation are dependent on the temporal projects based supply chains of Italian small and medium suppliers. However, the analyses in the paper could be analytically transferred and reflected upon in other contexts. Furthermore, this paper is part of an ongoing research project. The analyses provided are neither exhaustive nor conclusive. In the future, further collected data will be added to refine the value co-generation framework.

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The Internet of Things' potential to achieve supply chain integration: a case study

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Abstract

Construction industry has a lower productivity if compared to manufacturing and several researchers related the issues of productivity to the low levels of supply chain integration. Internet of Things (IoT) recently emerged as a promising solution for the achievement of higher levels of supply chain integration. However, the link between IoT and supply chain integration has not been adequately investigated, and a comprehensive analysis of the mechanisms enabling higher levels of integration is missing. In the light if this gap, this paper explores the potential of Internet of Things for the achievement of supply chain integration, assuming a supply chain perspective. The results of an in depth case study in an infrastructure firm show that the full exploitation of the potential of IoT at a supply chain level requires the proper implementation of the key supply chain management principles

1 Introduction

In the UK the Construction sector provides a significant contribution to the growth of the Gross Domestic Product, accounting for nearly 7% of the value added and 10% of total employment (HM Government, 2013). The activities of the sector include the planning, regulation, design, manufacture, construction and maintenance of buildings and other structures (Ireland, 2004). All these activities are conditioned by the project-based nature (Eriksson, 2015) of the industry: the final customer can heavily influence the design parameters of the deliverables (Akintoye et al., 2000) and the demand is generally discontinuous, fluctuating and project-specific for both products and services(Hartmann & Caerteling, 2010). Moreover, different projects employ different supply networks, even with the same first tier contractor.

A typical construction supply chain includes multiple actors such as clients, designers, primary contractors and suppliers (Aloini et al., 2012), connected in complex networks (Bankvall et al., 2010) and involved in the management of complex flows of information, materials, products, and funds. The vertical integration of construction supply chains is generally low with a huge reliance on a fragmented and subcontracted workforce. A 'typical' large building project (£20-25 million) can involve around 70 sub-contracts, mainly SMEs (HM Government, 2013).

The performance of the construction sector is lower if compared to the manufacturing sector (Bankvall et al., 2010; Harty, 2008; Segerstedt & Olofsson, 2010) and the causes of the poor performance include market fluctuation, regulatory changes, poor contractor management, material procurement problems, poor technical ability and escalation of material prices (Meng, 2012).

Several researchers and practitioners highlighted how higher levels of supply chain integration are essential for the solution of the abovementioned challenges. Potential approaches for the achievement of higher levels of supply chain integration are, for instance, batching the different processes within the project or keeping the SC together for different projects (Kelly et al., 2002). However, implementing these approaches in the construction sector seems particularly challenging (Briscoe & Dainty, 2005).

Internet of Things (IoT) recently emerged as a promising solution for the achievement of higher levels of supply chain integration. IoT can be defined as "a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual 'Things' have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network" (Ref in Xu 2014). IoT can improve supply chain integration because of its impact on the information management process. However, the link between IoT and supply chain integration has not been adequately investigated, and a comprehensive analysis of the mechanisms enabling higher levels of integration is missing. In the light of this gap, this paper explores the mechanisms promoting higher levels of integration in construction Supply Chains adopting IoT.

The paper is structured as follows. The second section summarises the relevant literature and proposes a framework describing the impact of IoT on Supply Chain integration. The third section outlines the research objectives and the research methodology. The fourth section presents the results. The fifth section proposes a short analysis of the results and the last section takes some conclusions.

2 Literature review

This literature review is structured into three parts. The first part introduces the concept of supply chain integration; the second part introduces the key enablers to SC alignment in construction, the third part introduces IoT and its role in the achievement of SC integration.

2.1 Supply Chain Integration

The concept of supply chain integration is often embedded in the definition of supply chain management (Bagchi et al., 2005) and it currently vague, since researchers and practitioners do not agree on what supply chain integration is and therefore they proposed different alternative definitions (Alfalla-Luque et al., 2013).

Lawrence and Lorsch (1967) initially described integration as an internal process consisting in a collaboration between departments of a company. From a company perspective, Stevens and Johnson (2016) explain integration as the coordination and alignment of processes, information and strategies. Frohlich and Westbrook (2001) focus on the supply chains and define integration as the level of engagement with suppliers and customers. Alfalla-Luque et al.(2013) synthesize existing definitions of supply chain integration and argue that it "implies collaborative inter- and intra-organisational management on the strategic, tactical and operational levels of activities that, starting with raw materials suppliers, add value to the product to satisfy the needs of the final customer at the lowest cost and the greatest speed".

Leuschner et al. (2013) define Supply Chain Integration as the scope and strength of linkages in supply chain processes across firms. They detail how the scope of integration can be internal, external (suppliers and/or customers), or both. The strength of linkages can be identified through three dimensions: information integration, operational integration, and relational integration.

Godsell (2008) observe that supply chain integration is not always desirable since it can hinder the achievement of structural flexibility (Christopher & Holweg, 2011). Therefore, she suggests that an ideal supply chain configuration should achieves the same objectives of integration but in a temporary and flexible way, and she calls this configuration “alignment”.

In this study we argue that construction industry supply chains should seek alignment rather than integration (Godsell, 2008), but we will use the term integration for simplicity.

2.2 Barriers to Supply Chain alignment

Current studies list a multitude of enablers and inhibitors for supply chain integration. Table 1 presents a summary and synthesis of the barriers to supply chain alignment identified in the literature and groups them according to the level and the dimensions they refer to.

2.3 Internet of Things as an enabler to improved alignment

Internet of Things (IoT) is a recent concept and different researchers tried to characterise it through definitions or theoretical frameworks.

The first definitions simply characterised IoT as addition of radio-frequency identification and other sensors to everyday objects (see e.g. Ashton, 2009; Santucci, 2009).

Welbourne et al. (2009) analysed the opportunity to bind information at each physical object and defined IoT as a RFID system in which each physical object has a corresponding virtual object, which is globally accessible. In this context, the virtual object embeds both historical and general information on the physical object such as origin, ownership, and sensory contexts. Recently, the term IoT assumed different meanings based on the application field. IoT can be referred to the supporting technologies, to the networks of interconnected smart objects, or to the applications and services (Miroandi, et al, 2012). Yang (2014) uses these different meanings to define the different “levels” that characterise IoT, namely the technology level, the communication/network level, and the intelligence level.

In line with this definition, Xu, He and Li (2013) describe an IoT architecture considering four layers: the sensing layer, the network layer, the Service layer, and the interface layer. The sensing layer focuses on data sensing/acquisition via smart objects containing technologies and devices such as RFID tags (Radio Frequency Identification), intelligent sensors, RFID readers, BLE (Bluetooth Low Energy) devices and WSNs (Wireless Sensor Networks). The network layer involves networks of smart object linked by communication and interaction among themselves and with the environment. The Service layer focuses on functionalities and functionally-defined systems such as Enterprise Resource Systems, Decision Systems etc. At this layer, functions can be decomposed and combined/recombined based on what the businesses intend to achieve (the business logics). The interface layer, focuses on the applications and interface with end users and other applications, in particular when considering composition across organisational boundaries.

Pang et al (2015) employed SOA for the development of a knowledge-based value-centric framework for IoT applications (Table 2).

In this framework, Pang et al. (2015) attempted to address the challenge of identifying, discovering, combining and processing data in order to deliver services and support decision-making (human or automated) at the intelligence level for SOA (Yang, 2014). Pang et al. (2015) stress that their framework is value centric rather than technology centric. The key principle for this design framework is based on the match between what information is essential from business point-of-view and what and how information should be delivered by technology based on the agreed values to be created. However, what is essential and what should be shared may differ across organisations. Moreover, a mechanism for achieving the agreement of value is needed. Without a single organisation or an explicit market in information and services, this mechanism cannot be

Table 1 – Barriers to SC Alignment in Construction

Level	*Dimensions*	*Barrier*	*Supporting references*
Industry environment	Processes	Complexity of processes and documentation	Akintoye *et al*.(2000)
		Lack of effective ICT	Bankvall *et al*. (2010); Briscoe & Dainty (2005)
	End-product demand	Lack of regular, continuous demand	Gosling *et al*.(2015); Ireland (2004)
	Culture	Uncertainty of payment (for SMEs)	`HM Government (2013)
		Lowest-price, competitive tendering culture	Dainty *et al*. (2001); Wolstenholme *et al*. (2009); Egan (1998),
		Change inertia	Kumaraswamy *et al*. (2005)
		Poor understanding of SCM theory and scepticism	Akintoye *et al*. (2000); Dainty *et al*.(2001)
Supply Chain	Governance structure	Reliance on fragmented sub-contracted supply-base	Briscoe and Dainty (2005); Wolstenholme *et al*. (2009)
	Relationships	Short-term relationships and different teams for a series of projects	Briscoe and Dainty (2005); Wolstenholme *et al*. (2009)
		Arms-length, power relationships	Briscoe and Dainty (2005); Gosling *et al*.(2015)
	Contracts	Lack of incentives for suppliers to innovate	Wolstenholme *et al*. (2009)
		Lack of financial incentives for suppliers	Lavikka *et al*. (2015); Wolstenholme *et al*. (2009)
		Contractual clauses	Briscoe and Dainty (2005)
		Lack of shared risks and rewards	Lavikka *et al*. (2015)
	Processes	Poor knowledge of client's processes by all partners	Briscoe and Dainty (2005); Wolstenholme *et al*. (2009)
		Planning horizon	Briscoe and Dainty (2005); Saad *et al*. (2002)
	Behaviours	Selection of partners that are not willing and competent for a collaboration	Wathne and Heide (2004)
		Opportunism	Cox and Thompson (1997)
Individual	Top management	Lack Commitment and support	Akintoye *et al*.(2000)
		Lack of engagement of the public and the key stakeholders about the 'new value' the built environment brings	Wolstenholme *et al*. (2009)
		Lack of engagement of employees to deliver necessary changes	Wolstenholme *et al*. (2009)
	Employees	Lack of talented and skill people for a wider pool	Wolstenholme *et al*. (2009)
		Lack of education and training to promote holistic learning across disciplines	Dainty *et al*.(2001); Wolstenholme *et al*. (2009)

developed. Indeed, the system perspective on IoT (Ng and Wakenshaw, 2017) might provide a way to address these issues. This framework is value centric rather than technology centric (Pang et al., 2015). The knowledge exchange between business applications and technology exploration are interfaced through information requirements and information delivery. On the business side, based on the need for value creation, information requirements could be derived. Information requirements could generate sensor portfolios and information fusion algorithm in the technical side. Information fusion algorithm would generate information delivery in the technical side. Information delivery would be evaluated by value assessment in the business side (Pang et al., 2015).

Mariani et al. (2015) adopt a different perspective and define IoT through the "Information's Value Loop". The Information's "value loop" consists of stages enabled by specific technologies and creating information related value. The loop of stages starts with an act, followed by the creation, communication, aggregation and analysis of information. The technologies that allow the stages are sensors, networks, standards, augmented intelligence and augmented behaviour. Magnitude, time, and risk determine the value of the information content within a supply chain. In a typical process, a sensor monitors an act and creates information. The information passes through a

Table 2 – SOA application (Source: Pang et al., 2015).

Layer (Xu et al, 2013)	**Level (Pang *et al.*, 2015)**	**Description**
Interface layer	Business level	Behaviour observation, business process representation, business logic model, performance evaluation etc
Service layer	Application level	Supply chain automation, documentation system, expert system, decision support system, enterprise information system, enterprise resource planning system
Communication and Networking layer	Data management level	Data collection, transmission, processing, information sharing, information fusion, middleware etc.
Sensing layer	Device level	RFID, WSN, machine-to-machine, human machine interaction; other embedded smart devices

network and it is communicated. Standards allow that information to be aggregated and augmented intelligence allows the information to be analysed. Finally, augmented behaviour technologies allow an improved new act that generates a new cycle.

Mariani's model is particularly useful in a supply chain management context because it follows the evolution of the information management process and information is one of the key flows in a supply chain. In particular, the three dimensions determining the value of the information content within a supply chain - Magnitude, time, and risk – can be used to characterise the impact of IoT on Supply Chains, in terms of improved efficiency, responsiveness, and trust. A theoretical framework summarising the impact of IoT on Supply Chains and inspired by the model of Mariani et al. (2015) is proposed in Figure 1.

3 Objective and Methodology

The empirical work addressed the following research questions in the context of the construction industry:

1. What are the current barriers to supply chain integration?
2. How can Internet of Things improve supply chain integration?

The methodology adopted to answer the research questions consisted in a single instrumental case study (Stake, 1998). The case study company is an innovative Joint Venture (JV) in water infrastructure representative of the sector.

The study took the form of 26 semi-structured interviews (Table 3) and the analysis focused on a project representative of the typical managerial complexity that the company faces.

Each interview lasted about one hour and took place in the company premises. The interview schedule logged the interviewee, date, time, duration, supporting secondary documentation collected and the contact note number. The latter records were written within 24 hours of the interview. The contact notes were analysed by the authors, the themes identified and integrated in the results of the study.

4 Results and discussion

4.1 Mapping the Supply chain

The Supply Chain of the construction firm can be described by referring to the SCOR model (Figure 2). The "Source" activities are replaced by the more articulated "Procurement" activities, the "Make" process becomes the sum of the activities of "Design" and "Build", and the "Deliver" process is represented by the activities of "Commission and Handover". The activities covered by the "Plan" part of a manufacturing supply chain are split into the three different levels of "Supply Chain Planning", "Project Management" and "Programme Management". "Supply Chain Planning" includes most of the typical planning activities of a manufacturing context; project management ensures the coordination of supply chain activities and the specific project in which the company operates; programme management ensures the coordination among the different projects in which

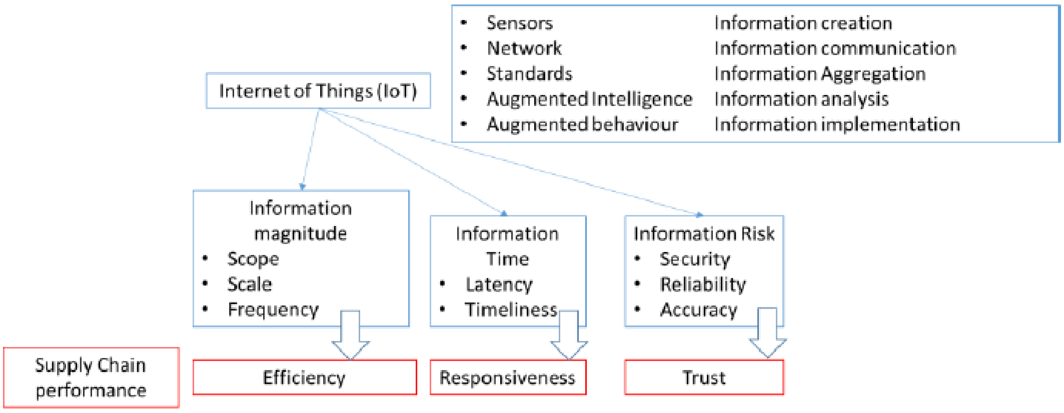

Figure 1 –Theoretical framework summarising the impact of IoT on Supply Chains

Table 3 –Interview Schedule

Interview Stage	Interviewee's Role
Scoping study	Head of Sector
	Head of JV
	Planning manager
	Supply chain Manager
	Delivery lead
	Head of Sector
Top team	Commercial head
	System Integration Manager
	Business Improvement Director
	Enterprise Architect and Programme Manager
	Director of Digital technology
	Group Infrastructure Manager
	Design Manager
	Advisory service manager
	Head of supply chain
	Efficiency lead
	MEICA lead
	Production manager
	HSE lead
	Project director
	Project director
	Procurement manager
	Supply Chain Manager (alliance)
Basingstoke Project	Project manager
	Planner
	MEICA lead engineer
Customer	Alliance SC hub manager

the company is involved. In the upstream side of the supply chain it is necessary to consider both suppliers and subcontractors, which play a decisive role.

4.2 Barriers to supply chain integration

The levels of supply chain integration are generally low. The supply chain manager mentioned the need of working in collaboration with the supplier and involving them in the early stages of design. There are several barriers hindering supply chain integration. The key ones are listed in this section, while Table 4 provides a comprehensive framework.

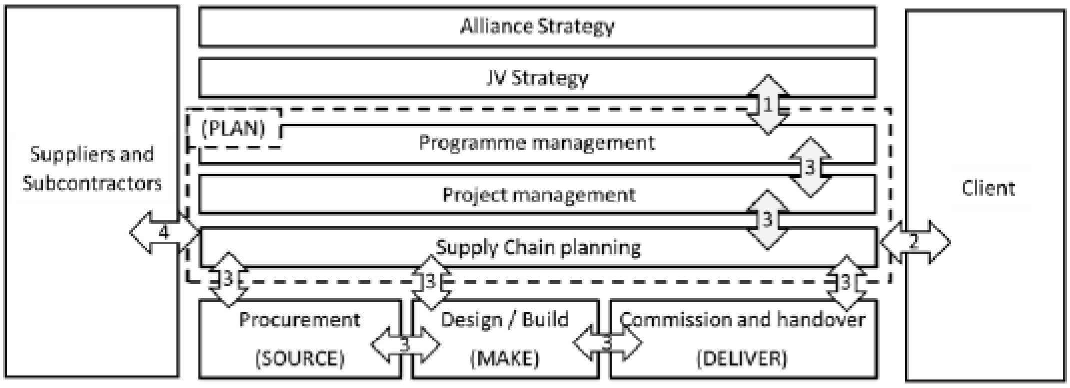

Figure 2 – Supply Chain of the construction firm

Lack of shared risks and rewards. The SC manager explained how the current tendering process is not effective because suppliers "have been asked to quote for the same thing again and again", without having certainty of actually getting the job. The commercial lead remarked that in this situation the suppliers tend to distrust the contractor because all the risk is passed down to the supply chain.

Reliance on fragmented supply-base. The SC hub manager highlighted how the current supply base is excessively fragmented and he suggested that the overall number of suppliers should decrease.

Planning horizon and lack of regular demand. The suppliers do not have an adequate visibility of demand. The head of JV explained how they could potentially create a 5-year demand plan, but how the current visibility of demand for suppliers varies between 3 and 6 months because of a continuous reprioritisation of the projects. The Head of JV also explained that the suppliers should be involved as early as possible in the design process. Similarly, the procurement manager indicated that the suppliers can give a contribution in the preliminary stages of design, and he recognises that the current way of involving suppliers is not adequate.

The interviews highlighted how the company faces several barriers to supply chain integration. The main barriers are discussed in the following section, while Table 4 provides a comprehensive list.

Contractual clauses. The Case Company generally uses standard NEC contracts with its suppliers. However, the different actors involved in the contracting process added a set of clauses that are unrealistic for the suppliers. Therefore, the suppliers try to renegotiate the unrealistic clauses and this causes long delays, frustration, and damaged supplier trust.

Planning horizon. The Case Company has a 5-year business plan. However, the planners often have to reprioritise work because of requests from the client and therefore the actual view of future demand is of only 6 months. The Company lacks the supply chain planning knowledge and discipline to make use of the business plan to drive a longer-term forecast, and drive some stability in the plan.

Tendering culture: The organisational culture that has been defined by the commercial lead as reactive to contract management. In this context, the supply chain focus becomes getting the contract out at the cheapest price, delay the payment as much as possible, and repeat the process for new projects. The reason for this tendering culture is that many people are stuck in this mind-set, having managed contracts in tendering based way for their entire career.

Misunderstanding of Supply Chain Management: The employees of the construction firm perceive "Supply Chain Management" as supply-base management. Sales and Operations Planning processes are missing, and there is an overlap between the activities of the supply chain management function and the procurement function.

Table 4 – List of main barriers of supply chain integration

			Head of Sector	Head of	Planning	Supply	Delivery	Efficienc	Commer	MEICA	Producti	HSE	Project	Project	Procure	Supply	project	Planner	MEICA lead	Alliance SC hub
Ind. environment	Processes	Complexity of processes and documentation	x	x					x					x	x		x	x		x
		Lack of effective ICT system			x						x				x					
	Demand	Lack of regular, continuous demand		x	x	x	x		x			x		x	x	x				x
	Culture	Uncertainty of payment (for SMEs)																		
		Lowest-price, competitive tendering culture	x	x	x	x		x					x			x				x
		Change inertia						x					x							x
		Poor understanding of SCM theory and scepticism	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Supply Chain	Governance	Reliance on fragmented sub-contracted supply- base							x						x					
	Relationships	Short-term relationships and different teams for a series of projects					x		x				x							
		Arms-length, power relationships						x	x											x
	Contracts	Lack of incentives for suppliers to innovate																		
		Lack of financial incentives for suppliers					x		x											x
		Contractual Clauses	x	x	x	x	x	x	x											x
		Lack of shared risks and rewards		x		x	x	x	x							x				x
	Processes	Poor knowledge of client's processes by all partners	x						x	x		x		x	x	x	x	x	x	
		Planning horizon		x	x	x	x						x					x		x
	Behaviors	Selection of partners that are not willing and competent for a collaboration						x				x		x						
		Opportunism																		
Individual	Top. management	Lack of commitment and support																		
		Lack of engagement of the public and key stakeholders																		
		Lack of engagement of employees to deliver necessary changes																		
	Employees	Lack of talented and skill people	x														x		x	
		Lack of education and training																		

Complexity of processes: A major inhibitor of SC integration is the complexity of managing a supply chain with multiple partners with conflicting needs. The Head of JV explained that having a multi-partner alliance is "exponentially more complex" compared to traditional JVs involving 2-3 partners. Similarly, other interviewees with a project related role argued that the managerial complexity of the JV originates from the amount of required paperwork and approvals.

4.3 Supply Chain Information Flow Mapping

Having mapped the supply chain of the firm, the empirical analysis focused on the information flow and on the degree of implementation of IoT. The information flow is depicted in Figure 3 and the corresponding steps are explained in Table 5. The integration of information systems within the firm and within the supply chain is very low. For instance, different teams use different software and the information exchange between business functions is not effective. Similarly, the information exchange across supply chain is not effective and there are only some preliminary attempts of using technology for collaborative work between partners of the same project.

4.4 Current role of IoT in addressing these challenges

The managers are aware of the importance of achieving higher levels of integration, and they acknowledge the pivotal role that IoT can play. However, the implementation of IoT within the supply chain is still at an embryonic state. The company is trying to move to a digital version of the documents and to a more extensive use of Electronic Data Interchange with suppliers. However, the full digitization has not been achieved yet, and the workers often handwrite to record data, thus generating errors and lower efficiency in the processes. The move to a digital version of the documents aims at reducing the complexity of processes, related to the amount of required paperwork and approvals. The company is trying to increase the efficiency of document management by introducing digital documents. EDI data are the main type of data used for the coordination with suppliers. Summing up, the current effort in the implementation of IoT is focused on the digitalisation of documents and in the improvement of the efficiency of the IT system in general. This effort is relevant but it only targets some minor inhibitors of supply chain integration such as the complexity of processes, the poor knowledge of the client's processes by all partners, or the lack of effective ICT systems. The interviews highlighted however how IoT could allow the company to overcome major barriers to supply chain integration.

A key barrier is the planning horizon and lack of regular demand. Indeed, the higher visibility on material flows and the interoperability between systems that IoT allows would allow the company to aggregate the demand across different projects, this achieving a more stable demand signal. Moreover, the demand would be communicated in a timely manner to the entire supply chain. However, IoT can be an effective facilitator of this process only if coupled with appropriate supply chain management choices. Indeed, an effective aggregation of the demand is possible with a long term planning horizon, that the managers estimate of around 5 years, while the current planning horizon is of only 6 months, due to the continue reprioritization of the projects. Therefore, the managers highlighted the importance of IoT and at the same time the need of shifting to a loner term planning horizon.

A second barrier key is the lack of trust and several interviewees highlighted how IoT can facilitate the overcome of this barrier for several reasons. First, the higher security and reliability of information can facilitate the trust of suppliers. The interviewees highlighted how the incompatible information systems at the industry level, standards and operating procedures could affect the collaboration across independent enterprises. In IoT, the systems consist of a large number of hardware and cyber components created by many enterprises, which have to be integrated with each other and with legacy systems. The move away from proprietary solutions towards open or shared interfaces and platforms can be a key enabler of trust. Second, the IoT system demands clear

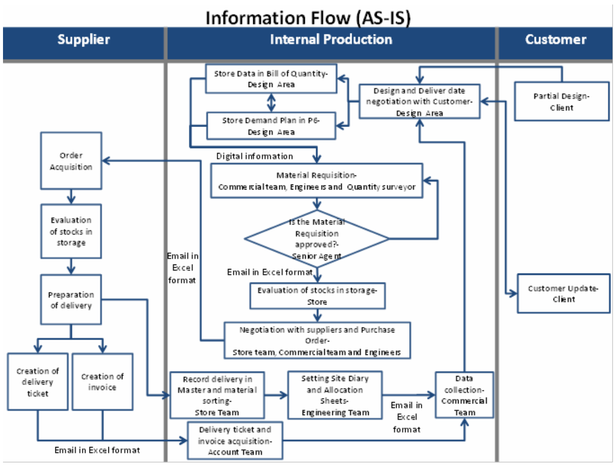

Figure 3– Information flow

Table 5 –Interview Schedule

Component	Description
Customer negotiation and design, demand forecasting	The Design team is responsible for the negotiation with customers. This team is composed of different roles (civil engineers, structural engineers and other specialists). The Design team receives a partial design from the customer and develops the design. P6 and Bill of Materials are updated and information such as plans, sections, elevations, construction drawings are available in a digital format.
Material requisition	Material requisition is produced using the negotiation information. This document includes specific aspects of the project, such as specifications, volume of aggregates, destination locations, any test requirements, certifications, material, etc. Commercial team, Civil Engineers and the Quantity surveyors work together to produce the best result. This document has to be accepted by a senior agent, and is shared by email in Excel format.
Stock evaluation:	Stores team receives Material requisition in Excel format by email, checks material in the store and creates an order. Moreover, the ordering information is recorded in Excel file.
Supplier negotiation:	This activity involves three different areas: Engineering team, Stores team and Commercial team, which deal with suppliers.
Replenishment	Company C and suppliers share material information (tracking) continuously by email. Moreover, suppliers send to Company C Account team also an Invoice and a Delivery ticket. Once the material arrives to Company C warehouse, the Stores manager produces a
Site Diary and allocation sheets	When material arrives on the site, engineers test the quality of materials and record this information with the work updates in the Site Diary and allocation sheets. These documents are unstructured handwritten Excel files and are sent to the Commercial
Delivery ticket and invoice acquisition	The Account team is responsible to manage these two documents, which they receive via email in Excel or PDF format. This information is collected and sent to the Commercial team.
Data collection	Commercial team collects incoming data from the Engineering team and the Account team in a single file. This file will be used to illustrate the deliverables reached.
Payments	Suppliers are often paid 30/60 days after the delivery.Company C is paid monthly on the basis of the deliverables reached.

shared goals at the service layer for planning, forecasting and replenishment. Partners have to achieve the shared goals and the rewards, costs and risks would also be jointly shared. Third, the uncertainty would be reduced by the increased transparency and visibility of the shared business processes. Moreover, an information that is relevant, accurate, sufficient and timely would enable the partners in the supply chain to see what others are doing, thus enhancing the trust between partners in the supply chain. However, also in this case IoT can foster trust in the supply chain but the managers highlighted that stronger IT security protocols can be effective if coupled with a move away from the tendering based relationship that characterises current buyer-supplier relationships.

5 Conclusions

Summing up, IoT can play a pivotal role in overcoming several barriers to supply chain integration. However, the facilitating role of IoT can fully express its potential if coupled with the right managerial attitude.

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International Supply Chain Resilience: a Big Data Perspective

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Abstract

It was not a natural disaster but terrorism (the September 9/11 attacks) that brought into question the transactional orthodoxy guiding the post-Cold War design configuration of international supply chains. The US government reaction was to put social pressure and introduce trade measures on multi-national enterprises (MNEs) that were importing manufactured products based on scale economies and low factor production costs. They were forced to self-police their supply chains and implement security measures. If they were be able to continue to have access to the US market. In order to reduce security risks they had to become involved in public/private partnerships, have C-TPAT accreditation, build up buffer "stock" and offer financial support to domestic manufacturers and logistic firms. This was perceived as a cost of production rather than a source of future capability. However security poses only one source of disruption and it became evident that there were many natural as well as man-made disasters confronting international supply chains. Therefore, by 2005, the work of MIT's Yossi Sheffi with his seminal book "The Resilient Enterprise" brought scholarly attention to the need for firms to have resilient supply chains. A chain robust enough to absorb disruption, keep functioning and return back to normal supply activity in as short a time as possible. In 2015, Sheffi re-emphasized the power of resilience in the supply chain through his latest book "The Power of Resilience: How the Best Companies Manage the Unexpected." This perceived resilience as a capability for building supply chain competitive advantage. Whilst supply chain resilience has grown as an important scholarly field, one area overlooked by scholars is the role to be played by big data technology. In this technical viewpoint we explore the role that big data could play in the supply chain, to improve its resilience and transform its operational capability. It acknowledges the reasons for the dearth of scholarship and also looks at the "dark side" of big data as well as highlighting the contribution that such technology might play in a radical revision of the resilience discourse. Finally, we propose an initial theoretical framework with examples of the type of operational capabilities that big data could bring with respect to international supply chain resilience.

1 Introduction

In the supply chain capitalism approach of Tsing (2009) international supply chain configuration decisions were simply a result of economic and exploitative determinants. Even though supply chains proved highly profitable for the multi-national enterprises (MNEs) orchestrating their design, they were also very much based on oversimplified analytics and limited data availability. Globalization exacerbates supply chain risks since the resulting dependencies might lead to risks on the demand side as well as the supply side (Thun and Hoening, 2011). It is thus based on the strategic importance of supply chains that disruptions and the associated operational and financial risks represent the most pressing concern facing firms that compete in today's global marketplace (Craighead et al., 2007). Extant research has confirmed the costly nature of supply chain disruptions, for example, during recent mega-disasters, such as the 2011 Great East Japan Earthquake and the 2011 Thailand floods, interdependencies in supply chains caused substantial economic damage (Haraguchi and Lall, 2015). More recently, the port explosions at Beijing's maritime gateway affected most of the 285 'Fortune Global 500' companies with offices in Tianjin, with the automobile sector taking the hardest hit (Mladenow et al., 2016). Therefore, in order to overcome their vulnerabilities, respond effectively to the negative effects of disturbances (Patil and Kant, 2016) and improve competitiveness (Pourhejazy et al., 2017) international supply chains must be resilient. A resilient international supply chain has adaptive capability to manage disruptions by enabling the supply chain to bend rather than to break and many authors agree that it is a property that increases the sustainable competitive advantage of firms (e.g., Ponis and Koronis, 2012; Melnyk, 2014; Ambulkar et al.,2015).

2 International Supply Chain Resilience

Whilst the evolution of resilience may have been plagued by competing definitions, there is general consensus that it is a multifaceted concept, which is increasingly being used as a metaphor in diverse fields of study to examine system propensity to adaptation (following a disturbance). According to the systematic review conducted by Annarelli and Nonino (2016), the main subfield of research has been international supply chain resilience.

Indeed, Papadopoulos et al. (2017) have acknowledged that supply chain networks resilience has become one of the most debated subjects among scholars in operations and supply chain field. The significance of international supply chain resilience is validated by the latest Gartner's Supply Chain Top 25 report (Hofman et al., 2011), in which authors identify *resilience* as being one of the four major themes for 2011 (Ponis and Koronis, 2012). So much importance is attached to resilience perhaps because it is often perceived as highly desirable given that it increases a firm's readiness in dealing with risks that can emerge from the customers' side, the suppliers' side, the internal processes adopted and the supply chain integration mechanisms employed (Purvis et al., 2016). It also often includes examining how a system can restore after a disruption, as opposed to only examining how to prevent disruptions (Taquechel, 2013).

Competing as the case may be, it seems that more recently some progress has been made in the direction of a mutually acceptable definition. Annarelli and Nonino (2016) have observed that the academic literature has reached a shared consensus on the definition of resilience. An examination of some of the definitions provided for international supply chain resilience seems to support the view that no conceptual differences between the definitions of the supply chain's *adaptive resilience capability* at the system level are currently apparent in the literature (Scholten et al., 2014). For example, Rajesh (2017) acknowledges resilience as the property of supply chains to handle impending vulnerabilities and potential disruptions, whereas to Kumar et al. (2010, p. 3721) *"resilient international supply chain networks need to be built having the ability to maintain, resume and restore operations after any disruption."* It can thus be thought of in terms of "*shock absorption*" between stages of the supply chain (Sheffi and Rice, 2005). In this work we adopt the following definition which seems to reconcile both the proactive and reactive view of resilience whilst emphasizing its strategic potential:

> *International supply chain resilience is the supply chain's ability to be prepared for unexpected risk events, responding and recovering quickly to potential disruptions to return to its original situation or grow by moving to a new, more desirable state in order to increase customer service, market share and financial performance* (Hohenstein et al. 2015, p. 108)

The importance of global supply chain management to a firm's bottom line has created the impetus for supply chain researchers to channel efforts in unpacking the factors that promote resilient capabilities. However, given the imprint of heterogeneity in its genealogy, the operationalization of international supply chain resilience has proven to be as elusive as its definition. For example, it has been suggested that the early conceptualisation of resilient capabilities was beset with vagueness, imprecision, as well as inconsistencies (Sahu et al., 2017). Furthermore, as Juttner and Maklan (2011) has rightly observed, the divergent concepts from theory building have led to an inconsistent use of terminologies in order to develop international supply chain resilience through antecedents, attributes, capabilities, elements and enhancers. Whilst authors such as Annarelli and Nonino as well as Juttner and Maklan are probably right about the mechanics of achieving resilience in practice, scholars seem to have settled on the formative elements of resilience. Increasingly, these formative resilience elements are being captured at a *capability level* (Ponomarov and Holcomb, 2009). Formative resilience capabilities are based on integrating and coordinating resources which often span functional areas and thus may become manifest in the supply chain processes. In the literature, a range of overlapping terminologies for these formative resilience capabilities is suggested (see Ponomarov and Holcomb, 2009 and Briano et al., 2009 for overviews). The four capabilities of flexibility, velocity, visibility and collaboration appear to be the most frequently mentioned and according to Juttner and Maklan (2011) they seem to capture the conceptual essence of all suggestions. In this work we maintain the same line reasoning and such being the case, the rest of this paper interrogates the utility of Big Data technologies in strengthening or developing supply chain resilience capabilities.

3 Big Data

Big Data can be defined as multimedia-rich and interactive low-cost information resulting If from mass communication (Zhan et al. 2016). It was initially characterized in terms of the high volume of data, the high velocity of nearly real-time or real-time data creation, and the high variety of data from different sources. More recently, Wamba and Akter (2015: 61) extended this original characterization by redefining Big Data as: "*a holistic approach to manage, process and analyse the 5Vs* (*volume, velocity, variety, veracity, and value) in order to create actionable insights for sustained value delivery, measuring performance and establishing competitive advantages*." This more contemporary definition is implicit in stressing that the value levers of big data are not inherent in the data per se but rather incumbent on how these are managed and embedded within extant organizational processes. The notion of embeddedness is in sympathy with the idea of resource reconfiguration or alternatively capability formation or renewal. Therefore, this bodes well with the notion that big data could be viewed as a critical building block of supply chain resilience capabilities and its eventual reconfiguration.

4 Big Data Analytics

Big Data analytics (BDA) is viewed as the vehicle that enables the extraction of value from big data. BDA is the process of using analysis algorithms running on powerful supporting platforms to uncover potentials concealed in big data, such as hidden patterns or unknown correlations (Hu et al., 2014). Hence, as Russom (2011) observes, BDA is really about two things - big data and analytics - plus how the two have teamed up to create one of the most profound trends in business intelligence (BI) today. Recognising their mutual interdependencies in supply chain management it is now common to speak in terms of Big Data and predictive analytics (Papadopoulos et al., 2017) as an all-encompassing term for techniques destined to handle Big Data. For instance, Markov chains, Markov decision processes (MDPs), queuing theory and discrete state models are widely used analytics, optimization and decision making tools.

5 Integrating Big Data with international supply chain resilience

Roberta-Pereira et al., (2014) have noted that scant attention has been paid to investigating relevant issues orientated to the enhancement of resilience in supply chains in spite of the efforts of some researchers to explore ways to better adapt to unforeseen disturbances. Perhaps what is even less forgiving, particularly in the context of the digital revolution era, is the serious lack of research efforts to examining the value digital information and communication technologies (DICT) brings to this debate. This is surprising given that the potential of DICT in enhancing supply chain resilience is widely recognised by SCM practitioners and commentators alike. For example, writing in Forbes, Culp (2013) acknowledges that when configured correctly, DICT can increase supply chain resilience through analytics, data and information sharing, scenario modeling, and pre-programmed responses. Of all the emerging and new DITCs, Big Data and predictive analytics (BDPA) appear to be the technology of choice for supply chain optimization.

There may be reasons for this lack of scholarly focus. Most works on big data have focused downstream on forecasting, market intelligence, last-mile logistics or on inventory management and process improvement. Therefore the focus has typically been with realising new market opportunities, efficiency or cost reduction. Another focus is with privacy and security issues and the risks to supply chain actor confidentiality of big data ("*dark side*"). Although big data has been glamorised as the information "*bloodstream*" or "*key strategic asset*" of future city design (smart cities) and connected car transport (i.e. mobility services) its social as well as economic value to society and citizens is not as well popularised. Certainly neither resilience nor supply chain resilience has been a key topic in "*big data*" strategy.

6 Big Data-Supply Chain Resilience Model

In beginning to answer the research question of how big data can be used to improve supply chain resilience we have opted for a capability approach. Based on a detailed review of relevant empirical literature we have developed the following framework that is presented in Figure 1. The framework is set up to demonstrate how big data could be leveraged to respond to the challenges of climate change, protectionism and sustainability.

Our analysis of the empirical work already conducted suggests that while companies do not set out to achieve supply chain resilience, the adoption of various big data technologies has inevitably led to the development of resilience capabilities along the supply chain. Drawing on the findings, scholars generally recognised that BDA could be leveraged in different parts of the supply chain in order to create value. In other words, there is widespread acceptance that BDA is valuable when it is used to create distinct capabilities as previously argued. In the main, the findings reveal that organizations are making use of the predictive proclivities of BDA to strengthen their decision making capabilities (Schoenherr & Speier-Pero, 2015) in a number of key supply chain activities. Some of these big-data enabled capabilities include market sensing (Chae, 2015; Lee, 2016; Li et al., 2015; Liu and Wang, 2016), planning and forecasting in different areas such as in logistics (Liu and Wang, 2016; Zhong et al., 2015) and demand and sales (Schoenherr and Speier-Pero, 2015), risk management (Papadopoulos et al., 2015; Wu et al., 2015; Zhao et al., 2015; Zou et al., 2016) and innovation (Tan et al., 2015) and most importantly visibility across the whole supply chain. Distinct capabilities often bestow performance advantages on the incumbent firms. The BDA-enabled performance advantages revealed by the findings include cost efficiencies (Bock & Isik, 2015; Hofmann, 2015; Li & Wang, 2015; Li et al., 2015; Liu et al., 2016; Schoenherr & Speier-Pero, 2015), enhanced customer services (Lee, 2016; Liu & Wang, 2016), agility, in terms of speed, flexibility and responsiveness (Giannakis & Louis, 2016; Kumar et al., 2016) and business growth (Chen et al., 2015). Based on these dynamics, it is quite clear that the BDA-enabled capabilities and performance outcomes speak to the four formative supply chain resilience elements of flexibility, velocity, visibility and collaboration. Thus, it may be argued that these findings do indeed concur that supply chain resilience and competitive advantage may well be two sides of the same coin.

Firms may also, for example, design their supply chain in order to take advantage of operational synergies and therefore plan their network to enhance individual capabilities by merging operations (Chae, 2015); to manage imbalances between supply and demand (Zhao et al., 2015); or to manage uncertainty of the supply of input resources (Liu and Wang, 2016).

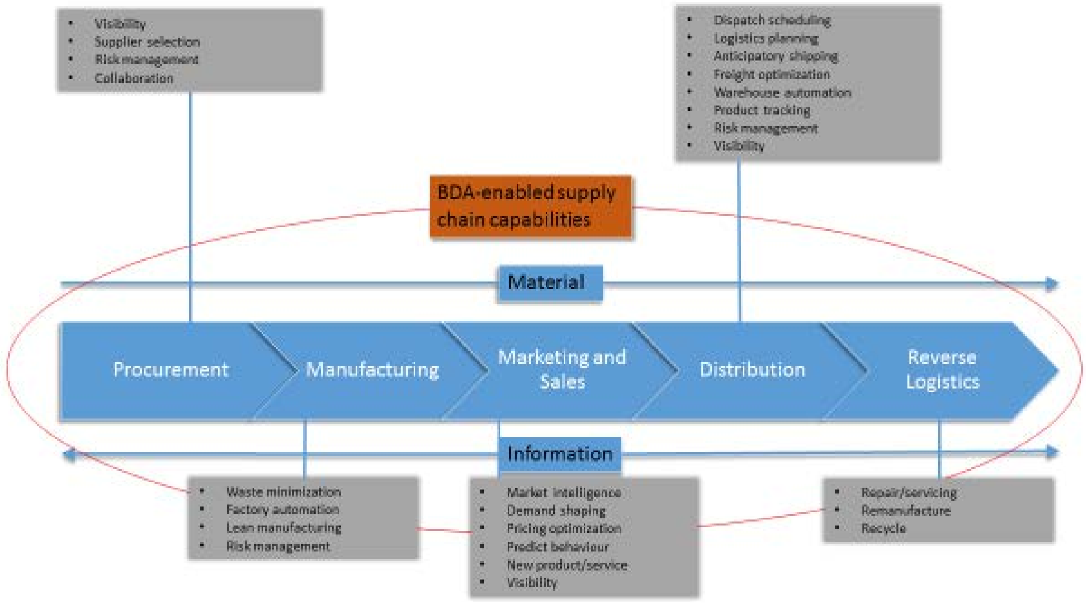

Figure 1 – Big Data Resilience Model

7 Reflective Summary

Adopting the global supply chain capitalism approach of Tsing (2009) or the transaction economics approach of Williamson (2010) big data would provide more sophisticated and enhanced resources for the international capitalist to squeeze even more value from chain configuration. It would provide far more superior optimization, accurate forecasting, track and trace capability and sophisticated means for accurately measuring the value contribution of each node (i.e. value added, efficiency and costs).

Running counter to the notion of a rampant supply chain capitalism piggy backing on the back of global free trade, there is evidence in the West of a more protectionist stance, in particular in the US, with the rise of President Donald Trump and in the UK with Brexit. Re-shoring, industrial strategy and localization of production is back on the political agenda in many Western economies as they seek to rebalance their financial and service driven economies and also strive to deal with an ever increasing productivity crisis and stagnant growth. As well as political pressure, new technologies are emerging which are facilitating less international production such as 3DP, additive manufacturing, robotics and drone technologies. Such technologies could facilitate shorter supply chains, with value pushed closer to the consumer and retained by the city where the goods are consumed rather than the value being globally diverted by the MNE's into a tax haven. Much shorter supply chains could by their nature be more resilient.

However if we take a more neutral capability approach (Teece, 2007) one can observe that driven by the needs to be efficient and scale economies, most global supply chains have been designed using economic and operational factors such as cost, quality, flexibility, speed and delivery. These configuration decisions were based on oversimplified analytics and limited data availability. The consequences of inaccurate data analysis meant a failure to fully optimize supply chain nodal capabilities. These capabilities are increasingly needed to deal with the rapidly increasing threat say of climate change and its negative performance impact. For instance, supply chain nodes being located in vulnerable areas (a decision based on cost not by climate vulnerability), the production technology misfit with product modularity, and the product not matching local customer expectations. Big data if managed carefully could be adopted to improve international supply chain configurations so that they are both resilient and economically viable.

Whilst growing attention in the supply chain discipline is now with the threat of "last mile" logistics to resilience: as firms seek to exploit digital economy technologies, gig workers (self-employed, freelanced, minimum wage rates) and deregulated city transportation policies. This is a short run phenomenon and the real long run threat is that of climate change and the need for resilience to permeate throughout the global supply chain. Big data could play a role in enabling supply chains to be configured by resilient capabilities rather by scale economies and the (low) costs of production/logistics. Rather than exploit workers in the last mile, digital technology can and should be used to improve: nodal location decisions; worker conditions; the carbon footprint, wastage and pollution. We need as supply chain scholars and practitioners to recognize that we are no longer in the 20th century design configuration era of "time-space" compression, but rather we are in a 21st century era of "big data-climate change". It is time to critically rethink our scholarship and offer 21st century resilient solutions for 21st century issues, challenges and problems.

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Digital open innovation and co-creation in service organisations: Enablers and barriers

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Abstract

The role of digitalisation in open innovation activities is increasingly attracting organisations. Digital platforms seem to enable multiple partners to co-create better services and customer outcomes, i.e., service innovations. However, it seems that organisations are facing challenges in adopting digital open innovation activities. This research aims to better understand the use of digital open innovation and co-creation activities. In this research, altogether 47 semi-structured interviews were accomplished in 8 service organisations. Early results of this research indicate that the organisations are aiming to increase digital open innovation and co-creation activities, and there seems to be certain enablers such as the need to effectively develop new services and barriers such as inadequate operating models. The final objective of this research project is to build a gamified roadmap that would support organisations in transforming their innovation models toward digital open innovation platforms enabling co-creation.

Keywords: Digital platforms, Digitalisation, Open Innovation, Co-creation, Service Innovation

1 Introduction

Digitalisation can be compared to an industrial revolution when looking at changes in organisations' and people's daily lives (Kenney et al., 2015). Digital technologies are expected to introduce disruptions in even the most traditional analogue markets (Soule et al., 2014). Moreover, digital technologies seem to have already changed organizations' innovation policy, and the role of digitalisation in open innovation activities is increasingly attracting organisations. Nevertheless, digitalisation seems to be quite unclear for organisations, and major players still find it difficult to draw up their digitalisation strategies (Rodrigues et al., 2011). Moreover, it seems that there is very little literature on digital open innovation among more traditional fields of business.

New disruptive technologies are changing the manner in which knowledge is managed within organisations, calling for a new and inventive knowledge management system and an open approach to foster knowledge flows (Santoro et al., 2017). Connecting technology with a user-centric perspective of open innovation allows unique opportunities for co-creation (Kohler et al., 2009). The interaction in digital environments has created a gigantic stream of behavioural data that provide novel research opportunities to move beyond traditional innovation activities (Brunswicker et al., 2015). Parmentier and Mangematin (2014) state that digital industries exemplify innovation processes where users bring new ideas and innovate directly with organisations. Individuals can use open, voluntary technology-enabled collectives to share data and knowledge and to co-create novel solutions for organisations (Brunswicker et al., 2015). There is a general feeling that communication and collaboration using technology can boost the innovation process with positive impacts on business indicators.

Digitalisation seems to enable open innovation platforms to co-create service innovations. Stakeholders are empowered with technology to co-create anytime and anywhere. Digitalisation opens possibilities for stakeholders to accomplish their aims together where individuals or organisations could not do it alone (Preece and Shneiderman, 2009). The advances in digital technologies are considered to form a megatrend with global impacts through international interconnectivity and the capability for real-time information sharing (Lee et al., 2012). For instance, social media enables constant hearing of users' voices instead of traditional customer satisfaction surveys and focus groups activities (Westerman et al., 2014; Buhalis and Law, 2008).

Furthermore, user participation with several stakeholders in the global context might be a challenge, but digital open innovation platforms can offer promising solutions (Friedrich, 2013). According to Mahr and Lievens (2012), virtual communities tend to propose solution-focused contributions, which provide greater value for organisations than more problem-focused traditional innovation activities. Moreover, digital platforms differ in terms of user purpose, but they have some common characteristics: for example, mass participation that allows greater intellectual capabilities and more ideas (Mačiulienė and Skaržauskienė, 2016), especially among external stakeholders (Hienerth, 2011). This allows organisations to advance new opportunities by harnessing users' innovation capabilities by integrating them into a service innovation process (Hienerth, 2011). However, digital open innovation and co-creation activities are not often used because when digital technology services are offered by external companies, organisations might not find them reliable enough (Mačiulienė and Skaržauskienė, 2016). Moreover, organisations face the challenge that there is often not enough time to evaluate the reliability of a technology (Chesbrough, 2006). Apart from this knowledge, there seems to be very little information on other barriers related to digital open innovation and co-creation.

Based on the literature, it seems that an increasing body of literature exists around digitalisation, open innovation and co-creation. However, there seems to be a very little empirical research on digital open innovation and co-creation. Thus, this research aims to better understand the use of digital open innovation and co-creation activities. Furthermore, it aims to better understand enablers and barriers of digital open innovation and co-creation. As this research is exploratory, using an abductive approach, this paper first only briefly discusses digitalisation, open innovation and co-creation to demonstrate the definitions of these phenomena, i.e., to demonstrate how digitalisation, open innovation and co-creation are understood in this research. Secondly, the abductive approach and methods used in this research are introduced. Thirdly, the findings of this research are introduced. Finally, conclusions, limitations, and future research are presented.

2 Digitalisation

As noted in the introduction, digital technologies seem to create new possibilities for open innovation and co-creation activities. Moreover, digitalisation has some distinct characteristics that have fundamental implications for open innovation (Nylen, 2015).

There seems to be no uniform definition for the concept of digitalisation, and in research articles digitalisation is often bound to a certain field of business or to an individual process (Ligthart et al., 2016). Definitions range from digitalisation as a global megatrend (Lee et al., 2012, 818-819) to the much narrower "digital representation of signals, information, and objects in binary code" (Stein, 2015, 2). Ilmarinen and Koskela (2012) note that instead of defining the concept of digitalisation itself, it is often described through examples.

The research literature also use the terms "digitalisation" and "digitisation" interchangeably and give both a number of definitions. Lipiäinen (2014, 20) defines the term "digitisation" as a social phenomenon in which everyday communication channels are pivoting from traditional forms towards their digital counterparts. While Lipiäinen (2014) refers to digitisation in the context of communications, the focus of the definition is on the social phenomena, not on the technical process of transforming information to a binary form. Tilson et al. (2010, 749) take a contradicting stance in stating that digitisation refers to a technical process, whereas digitalisation would be the proper term to use when the context is more of a social nature.

Definitions of both digitisation and digitalisation feature the same key component of transition from analogue to digital. Digitisation, defined as the conversion from analogue to digital, is identified as a key driver for enhancing digitalisation (Ilmarinen and Koskela, 2015, 21). Aside from a transformation from analogue to digital, the definition of the term appears to be highly contextual. Gartner's IT glossary (2016) defines digitalisation on a broad level and adopts a business transformation viewpoint: "Digitalisation is the use of digital technologies to change a business model and provide new revenue and value-producing opportunities; it is the process of moving to a digital business". While research in digitalisation is available in vast quantities, the numerous ways digitalisation is defined and interchanged with the term digitisation sets requirements to understand in which context the term is presented in research articles.

To conclude, this paper looks at digitalisation from an open innovation and co-creation point of view, seeing it as a transformation from analogue (i.e. face-to-face communication) to digital communication through digital platforms and a social phenomenon that can involve a large number of stakeholders

3 Open Innovation and co-creation

It seems that open innovation and co-creation have some overlapping characteristics. According to Chesbrough (2003), open innovation can be defined as the intentional use of inputs and outputs of knowledge to accelerate internal innovation and expand market possibilities for the use of these innovations. Open innovation is based on utilizing both external and internal ideas and open channels for accessing and employing knowledge and solutions. Marilungo et al. (2016) states that open innovation refers to a process in which external partners are involved in the development process. This means that an organisation's external stakeholders are well-recognised as a valuable source for innovation (Von Hippel, 2001). It should be noted that there are many intelligent people outside the organisation (Aas and Pedersen, 2016). Therefore, open innovation can generate substantial benefits for organisations, such as the introduction of an external perspective (Gassmann et al., 2010).

On the other hand, co-creation is understood as a powerful approach to foster innovations (e.g. Ramaswamy and Gouillart, 2010). The power of co-creation in innovation is its capability to combine the knowledge of stakeholders from different perspectives (Keränen, 2015). Grönroos and Voima (2013, 141) see that interactions "form a platform for co-creation of value", meaning that there needs to be a certain kind of interaction to co-create value. Keränen (2015, 218) introduces a co-creation framework that focuses on face-to-face and B2B co-creation in service companies, and she goes on to state that there are certain kinds of characteristics in co-creation which she calls pre-conditions and co-design manners. Moreover, Keränen (2015) indicates that co-creation creates a certain potentiality for strategic thinking and that triggers are needed to enhance co-creation activities. Co-creation can be seen as a learning process of creating new knowledge/solutions for the stakeholders involved (Keränen, 2015).

The number and type of different partners with which an organisation collaborates with can demonstrate the organisation's openness to innovation. The larger the number of partners, the more open the innovation process seems to be (Lazzarotti and Manzini, 2013). Sivard et al. (2014) mention that most innovations occur through a learning process where various actors, individuals as well as organisations, take part. Thus, organisations would not have to rely entirely on their internal research, but should open the innovation process to all employees, suppliers and customers i.e. the main stakeholders of the organisation. Open innovation is based on co-creative activities where stakeholders jointly create value to develop better or new service innovations (Carbone et al., 2012). It has received substantial business attention as a means of providing organisations with the ability to co-create new products and services in hyper-competitive environments (Almirall et al., 2014).

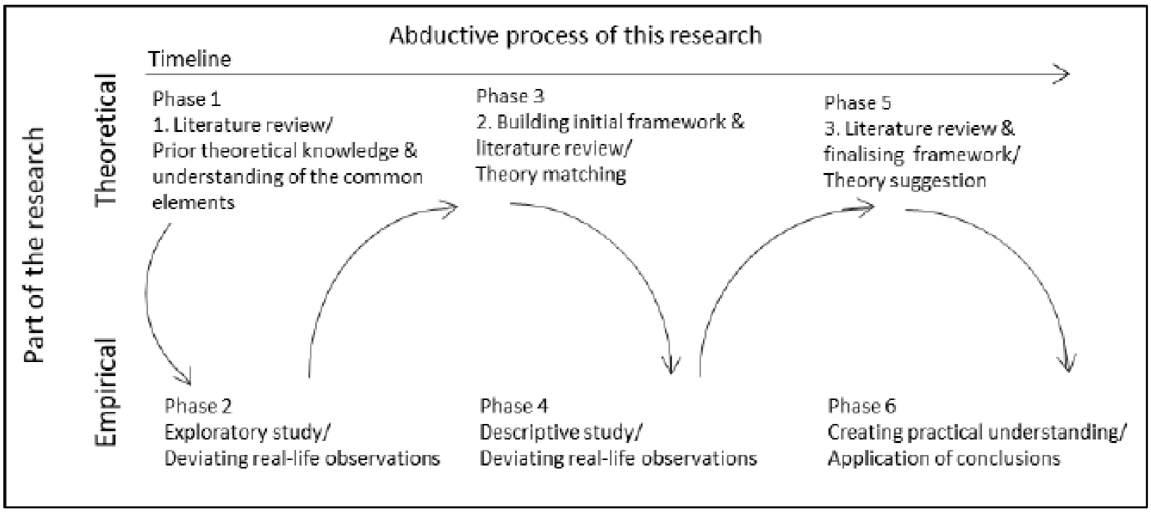

Figure 1 – The abductive process of this rese

One of the key elements in innovation is the use of technology (Saguy, 2011). Fostering new opportunities using technology is vital for organisations in today's global market (Rabelo & Bernus, 2015). However, most competitive organisations are no longer proud to say that their technology was "developed in-house", because the results of this open environment tend to be better (Burcharth et al., 2014). No organization or institution has reached a leading position in the development of technology by accumulating all their knowledge in isolation, but they have achieved this through co-creation activities in a collaborative environment and the rapid spread and transmission of knowledge (Van Vrande et al., 2009).

To conclude, open innovation in this research is understood as the intentional use of both external and internal inputs and outputs of knowledge to accelerate internal innovation and expend market possibilities (Chesbrough, 2003). On the other hand, co-creation can be defined in the following way: co-creation is a joint value creation process (Grönroos & Voima, 2013) of developing solutions (e.g. Aarikka-Stenroos & Jaakkola, 2012; Hakanen & Jaakkola, 2012), facilitating innovations (e.g. Kristensson et al., 2008), and creating strategic potentiality through co-design manners for the stakeholders involved (Keränen 2015, 222). Hence, this research sees open innovation as a platform of sharing knowledge where an organisation's external and internal stakeholders co-create solutions that facilitate innovations for the stakeholders involved. The platform itself can contain both digitally enabled co-creation activities and/or face-to-face activities.

4 Research Method

This qualitative research was carried out using the abductive research approach. And the nature of this phase was explorative, as we wanted to better understand digital open innovation, which seems to be an unexplored phenomenon. The core idea of the abductive approach (see Figure 1) is that the researcher moves between the theoretical and empirical worlds and accepts the incompleteness of thoughts, taking non-linear approaches throughout the research to deepen both theoretical and empirical understanding (Dubois & Gadde, 2002). This can also be called "systematic creativity" (Kovács & Spens, 2005). The abductive approach is to an extent inductive in attempting to theorise the knowledge gained through empirical enquiry rather than deductively testing the theory. However, the abductive approach attempts to understand the theory related to the topic to gain pre-understanding and to generate an understanding of the common elements of the research which can lead to an understanding of the phenomenon in a new way (Kovács & Spens, 2005). This research moves up to Phase 3 as it attempts to build an initial model based on the empirical findings of the exploratory study.

Table 1 – Cases and the service sectors of this research

Organisation	Service sector
O1	Retail
O2	HR services
O3	Taxation
O4	Insurance
O5	Consultation
O6	Finance and banking
O7	Insurance
O8	Property management

Table 2 – The levels of adaptation of open innovation and co-creation activities

Level of adaptation	Description
High	Open innovation/co-creation activities are regularly used in the organisation's operations and they are embedded in the organisation's main processes
Moderate	Open innovation/co-creation activities are used in the organisation's operations but they are not embedded in the organisation's main processes
Low	Open innovation/ co-creation activities have been used couple of times in the organisation's operations
None	Open innovation/ co-creation activities have not been used in the organisation's operations

To gain a better understanding, not just from one organisation but from multiple organisations, this research was carried out as a multiple-case study design where the units of analysis were eight service organisations located in Finland (Yin, 2009).

The cases were chosen to have a wide collection of different kinds of organisations. Organisations also varied in size; three organisations were small- or medium-sized organisations, and five were large organisations. The organisations operated in the following service sectors: finance and banking, taxation, insurance, retail, property management, consultation and HR services (Table 1).

The data was collected from 47 semi-structured interviews among eight organisations between April and August 2016. Interviewees were managers and specialists. Each interview was 45 to 90 minutes long. After conducting the interviews, the data was transcribed and analysed.

In this phase, data was analysed first based on the level of adaptation of open innovation and co-creation practices (see Table 2). Next to be analysed were the enablers and barriers related to adopting digital open innovation and co-creation activities. Finally, the results were presented to the organisations which, after an initial model, moved towards open innovation and co-creation activities.

5 Findings

In this paragraph, we demonstrate the data and findings of this research. First, we mapped the level of adaptation of open innovation and co-creation. Secondly, we looked at enablers and barriers in open innovation and co-creation.

The evidence from the analysed data pointed out that none of the organisations were adopting co-creation activities or open innovation activities on a high level. At this point, the data also revealed that neither digital nor face-to-face open innovation and co-creation activities were extensively adopted in these organisations.

Table 3 – Level of open innovation and co-creation adaptation among organisations

Level of adaptation / Organisation	Open innovation High	Co-creation High	Open innovation Moderate	Co-creation Moderate	Open innovation Low	Co-creation Low	Open innovation None	Co-creation None
O1					x	x		
O2					x	x		
O3			x	x				
O4					x	x		
O5			x	x				
O6			x	x				
O7							x	x
O8					x	x		

Table 4 – Open innovation and co-creation enablers

Enablers	Enablers to open innovation	Enablers to co-creation
E1. A need to effectively develop new services	O1 O2 O3 O4 O5 O6 O7 O8	O1 O2 O3 O4 O5 O6 O7 O8
E2. Systematic process	O1 O2 O3 O4 O5 O6 O7 O8	O1 O2 O4 O5 O7 O8
E3. Regular activity with customer	O3 O5	O2 O3 O5 O6 O8
E4. Regular collaboration among personnel		O2 O3 O6 O7
E5. Person responsible for the process	O7 O8	O8
E6. Piloting	O1 O8	O3
E7. Encouraging organisation culture	O3 O4	O2
E8. Process transparency	O6 O8	
E9. Rewarding those involved in process	O2 O7	
E10. Digitalisation		O1
E11. Workshops		O1
E12. Tools		O8
E13. Consultants and other external support	O6	

For the moderate-level organisations, O3, O5, and O6 were mapped to have moderate open innovation and co-creation activities. Four organisations have been testing open innovation or co-creation activities (using them a couple of times): O1, O2, O4, and O8. Organisation O7 had not been using any open innovation and co-creation activities so far. Here it should be noted that all organisations have digital services for their customers, but open innovation and co-creation seem to be new activities for them (Table 3).

Next we looked at open innovation and co-creation enablers within these organisations. We were able to map altogether 13 enablers (see Table 4). The most common enabler among all organisations was a need to effectively develop new services (E1). This enabler would occur as an

Table 5 – Open innovation and co-creation barriers

Barriers	Barriers to open innovation	Barriers to co-creation
B1. Traditional operating model/ closed organisation culture	O1 O2 O3 O4 O5 O6 O7 O8	O1 O2 O3 O4 O5 O6 07 O8
B2. Not enough resources, not enough time	O5 O8	O3 O8
B3. Short projects not ongoing activity	O6	O6 O8
B4. Organisation's capability to react fast enough to changes	O1 O2 O7	O2
B5. No knowledge how to interact deeply with customer		O1 O2 O4 O5
B6. No knowledge on how to interact deeply with personnel	O2	O2
B7. Too many ideas – choosing the most innovative is challenging	O3 O5	
B8. Management is passive		O3

enabler for both open innovation and co-creation. The organisations generally brought up the need for a systematic process (E2), meaning that there is a need for a systematic process to be open innovative and co-creative. For co-creation, it seems that there is a need for regular activity with customers (E3) and regular collaboration among personnel (E4). This would mean, for example, regular steering group meetings with customers, regular workshops or other regular activities. Moreover, organisation O3 and O5 brought up that regular activities with customers (E2) would also enable open-innovation activities. It also seems that for a few organisations, it is important to have a person who would be responsible (E5) for co-creation (O8) and open innovation activities (O7, O8). Case O3 proposed that piloting (E6) would enable co-creation activities, and cases O1 and O8 made proposals from the open-innovation point of view. Here piloting would mean short pilot projects that would enable organisations to test new approaches like open innovation and co-creation. Cases O3 and O4 from open innovation point of view and O2 from co-creation point of view brought up that encouraging organisation culture is an important enabler. More over process transparency (E8), rewarding those involved in the process (E9) and consultants and other external support (E12) could enable open innovation activities. On the other hand, case O1 indicated that digitalisation (E10) and workshops (E11) and case O8 indicated that tools enable co-creation activities.

After mapping the enablers, we looked at open innovation and co-creation barriers within these organisations. We were able to map altogether 8 barriers enablers (see Table 5). The most common barrier, both for open innovation and co-creation among all organisations, was the traditional operating-model/closed-organisation culture (B1). With a traditional operating-model/ closed-organisation culture, we mean a model in which the organisation is hierarchical, focusing on its own competences, resources, processes, and technologies, and an outsider's access to the organisation's information is very limited. Next, we found that in some organisations (O5, O3, O8), it seems that there is not enough resources and time (B2) to accomplish open innovation and co-creation activities. Moreover, it seems that some organisations stated that open innovation and co-creation activities are carried out within short projects, but they are not embedded in the organisation's ongoing activity (B3). This means that open innovation (O6) and co-creation (O6, O8) are seen as an extra activity. Barrier B4 (an organisation's capability to react fast enough to changes) was related to open innovation in three organisations (O1, O2, O7) and to co-creation in only one organisation (O2). Barrier B5 (no knowledge on how to interact deeply with the customer) divided organisations, as no one saw this as a barrier to open innovation while four organisations (O1, O2, O4, O5) saw this as a barrier to co-creation. Barrier B6 (no knowledge on how to interact deeply with personnel) was seen

Figure 2 – An initial model of moving toward open innovation and co-creation activities

as a barrier in organisation O2. Organisations O3 and O5 brought up that open innovation activities might cause too many ideas and it might be difficult to choose the most innovative ones (B7). Organisation O3 saw passive management as a barrier to co-creation activities.

In conclusion, the evidence from the analysed data pointed out that none of the organisations were adopting neither co-creation activities nor open innovation activities on a high level. Thus, it can be said that none of the organisations have extensive experience in open innovation or in co-creation. Seven out of eight organisations have been open innovating and co-creating at least a couple of times. However, it seems that these organisations are highly interested in learning how to adopt open innovation and co-creation activities, but they brought up that they need a road map on how to shift toward open innovation and co-creation activities. It should be noted here that although we were initially looking at digital open innovation and co-creation activities, we did not find any. And these organisations did not seem to view digitalisation as an enabler as only one organisation brought it up (O1). As said earlier, these organisations are offering digital services for their customers, but they seem not to have any digital activities related to open innovation or co-creation.

Hence, based on this empirical evidence, our attempt is to build a first draft to best describe the journey from a non-open innovative and non-co-creative organisation to an organisation where open innovation/co-creation activities are regularly used in the organisation's operations and they are embedded in the organisation's main processes (see Figure 2).

During the interviews, we noticed that many of the interviewees spoke about a cultural change and an iterative process where the stakeholders of the process would have a chance to learn while moving toward more active open innovation and co-creation activities. Thus, the initial draft of the model demonstrates the journey as an iterative process where enablers are currently arranged to the best to our knowledge and where barriers are turned into enablers. To give an example, barrier B8 (management is passive) is demonstrated as an active management in the model, and B2 (not enough resources, not enough time) is demonstrated as adding resources.

Moreover, the data indicated that there has to be some kind of trigger or a need for organisations to show an interest in open innovation and co-creation. In this case, the trigger seems to be a need to effectively develop new services.

To conclude, the data demonstrated that organisations have a little experience in open innovating and co-creating with their stakeholders. However, they seem to be highly interested in learning how to open innovate and co-create, but there needs to be trigger/need which will activate organisation to pilot open innovation and co-creation activities. Nevertheless, they seem to lack knowledge on how to open innovate and co-create. Thus, we created an initial model that serve as a road map for organisations for their journey from a non-open innovative and non-co-creative organisation to a highly open innovative and co-creative organisation. As this result is based on empirical data, the next step needs to deepen the current theoretical aspects of open innovation and co-creation in order to build an initial framework to better understand the phenomena.

6 Conclusion

In this research, altogether 47 semi-structured interviews were taken in eight service organisations. This research initially aimed to better understand the use of digital open innovation and co-creation activities. Furthermore, it aimed to better understand enablers and barriers to digital open innovation and co-creation. As this research is exploratory, using an abductive approach, this paper first only briefly discussed digitalisation, open innovation and co-creation to demonstrate the definitions of these phenomena. Secondly, the abductive approach and methods used in this research were introduced. Thirdly, the findings of this research were introduced. Next we discuss the conclusions, limitations, and future research.

As we stated earlier, our starting point for this research was to better understand digital open innovation and co-creation activities. However, we quickly understood that organisations did not seem to have much experience in both open innovation and co-creation activities, either on the digital level or face-to-face. Nonetheless, the results of this research make us better understand that there are some enablers and some barriers related to open innovation and co-creation activities. Moreover, early results of this research indicated that the organisations are aiming to increase digital open innovation and co-creation activities but there needs to be certain triggers or a need to effectively adopt open innovation and co-creation activities, and organisations need a road map on how to approach open innovation and co-creation activities.

We presented an initial model (see Figure 2) that introduces an iterative journey moving toward a systematic process of open innovating and co-creating among an organisation's stakeholders. This model might support theorising on open innovation and co-creation phenomena, as in the next phase the results of this study are compared with existing knowledge. Moreover, this model might support organisations in their journey toward a highly open innovative and co-creative organisation, which according to current literature, would bring new aspects into their innovation process and competitive advantage.

This paper suffers from some limitations that need to be addressed in future research. First, the data was collected without an extensive literature review. Thus, it might be that the literature already demonstrates similar results. However, digitalisation seems to be a new research topic, and when combined with open innovation and co-creation, the initial literature research did not reveal any studies. Secondly, the initial model has not been tested yet in practice in any organisations; thus, we do not know how generalisable our findings are. Furthermore, the model needs to be designed in a more coherent way.

To conclude, as this research is part of a larger research project where the final objective is to build a gamified roadmap. The purpose of the roadmap would be to support organisations in transforming their innovation models toward digital open innovation and co-creation platforms. Hence, we will continue this research in strengthening the theory and testing the model and letting the theory and testing take us to the next research steps.

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Modelling Performance Landscape in Digital Manufacturing (DM) firm

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Abstract

In Digital Manufacturing (DM) context, additive manufacturing (AM) is expected to transform the traditional manufacturing paradigm. AM would open various avenues and develop strategic options for the modern firms to position and compete. This might tempt firms to compete on multiple dimensions of competitive priorities and evade their strategic focus. Present literature needs the insights on how to leverage AM practices to develop effective manufacturing capabilities. The proposed research is aimed to contribute to this literature gap. The purpose of this paper is to evaluate strategic options based on the fitness of the firm. We develop Grey-DEMATEL-NK fitness approach to evaluate fitness landscape of the firm with case illustrations in Digital manufacturing firm in India. Further, we establish the linkage of fitness and performance of the firm.

Keywords: Performance Landscape, Digital manufacturing, NK model, Positioning, Grey-DEMATEL-NK

1 Introduction

Positioning is the central concern of the manufacturing strategy research (Sarmiento, Sarkis, and Byrne, 2010; Skinner, 1974, 1996). It deals how a firm competes in the market. Past studies show that positioning has rarely been the focus of analytical research (Adner, Csaszar, and Zemsky, 2014). This work initiates efforts towards this research need.

We consider the strategy modeling and performance modeling as two facets of positioning. Strategy modeling mainly concerns with modeling the way firm chooses its position in the market. Performance modeling includes consideration of developing manufacturing capabilities once the strategy is formulated. We restrict the scope this work to performance modeling considering three aspects- a) What are the strategic options available for the firm to develop its manufacturing capabilities. b) How to evaluate these strategic options? c) How to plot the development pathway to develop the capabilities of the firm.

We develop Grey-DEMATEL-NK method to model the performance of digital manufacturing firm. We specifically select digital (or additive) manufacturing context as it is claimed to transform the traditional manufacturing paradigm. AM would open various avenues and develop strategic options for the modern firms to position and compete. This might tempt firms to compete on multiple dimensions of competitive priorities and evade their strategic focus. Present literature needs the insights on how to leverage AM practices to develop effective manufacturing capabilities.

The purpose of the proposed work would be to evaluate strategic options emerged with AM practices. Further, it would model an implementation path for AM practices in manufacturing firm considering its fitness landscape.

Firms perform internally (i.e. changes in performance over the time) as well as externally (against industry and competition levels). Modelling Performance of firm requires the consideration of both these facets (Sarmiento et al., 2010; Sarmiento, Shukla, and Izar-Landeta, 2013). Taking this point forward, we identify two distinct approaches that illustrate Positioning-Performance relationship. - i) Industrial Organization (IO) approach ii) Evolutionary theory approach.

IO approach concerns mainly with the external performance (Porter, 1996; Sarmiento et al., 2010, 2013). The evolutionary theory deals with the internal performance of the firm. The position of the firm is represented as the vector of policies and decisions, that determine the overall fitness value in NK model (Adner et al., 2014; Ghemawat and Levinthal, 2008; Levinthal, 1997). The fitness landscape is the surface in which fitness values for strategic alternatives are plotted. This is used to show the development of the internal performance of the firm. Celo et al., (2015), Ganco and Hoetker (2009), Ghemawat and Levinthal (2008), Levinthal (1997), McCarthy (2004), Rivkin (2000) demonstrated the application of NK model through fitness landscape.

Existing NK models use fitness values are generated with a random number of uniform distribution ranging from 0 to 1. Despite increasing significance of NK model in strategy domain, previous research has not focused on the elimination of the need for random fitness generation. Thus, fitness landscape remains theoretical landscape based on random fitness values (Bai, Kusi-Sarpong, and Sarkis, 2017). Furthermore, this theoretical fitness landscape lacks the linkage with the external performance measure. This has seriously impacted the theoretical development of performance modeling literature. We initiate the foundation of this work to address this research gap with following objectives-

- To update the existing NK based random fitness generation considering manufacturing strategy elements and their interactions.
- To establish the linkage of internal performance and external performance.

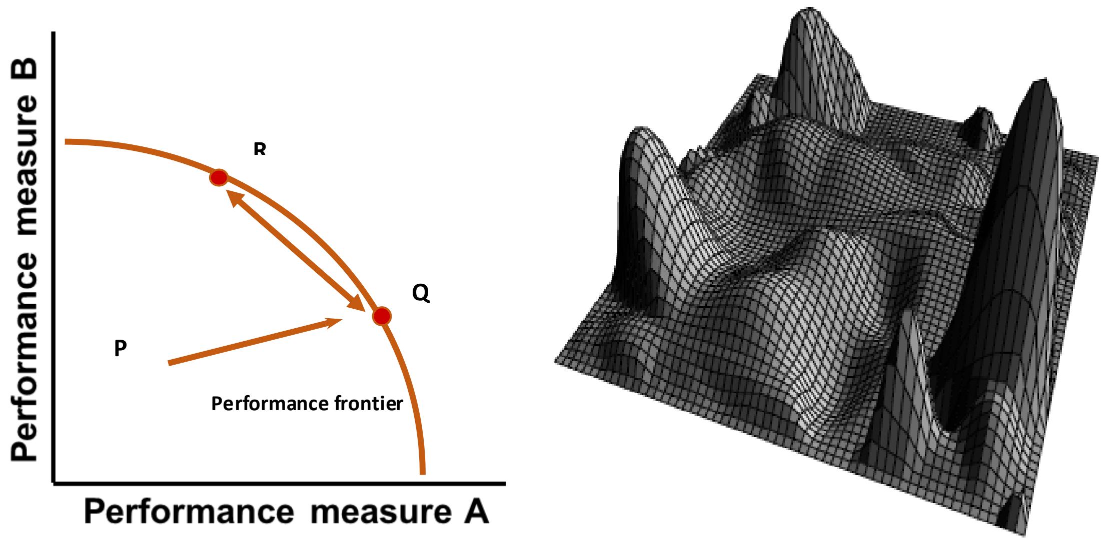
In consideration of first research objectives, we developed Grey-DEMATEL-NK fitness model considering the interactions among manufacturing strategy elements- cost, quality, delivery, and flexibility. Further, we use response surface method to establish the linkage among the internal and external performance of the firm. We consider the strategy modeling and performance modeling as two facets of positioning. Strategy modeling mainly concerns with modeling the way firm chooses its position in the market. Performance modeling includes consideration of developing manufacturing capabilities once the strategy is formulated. We restrict the scope this work to performance modeling considering three aspects- a) What are the strategic options available for the firm to develop its manufacturing capabilities. b) How to evaluate these strategic options? c) How to plot the development pathway to develop the capabilities of the firm.

2 Literature Review

Positioning is the first and most critical phase of strategy formulation. Sarmiento et al. (2010,2013) highlight the need for a distinction between internal and external performance while consideration of positioning and performance relation. We identify two distinct approaches that illustrate positioning-firm performance relationship. - i) Industrial Organisation (IO) approach ii) Evolutionary theory approach.

2.1 Industrial Organisation (IO) Approach

IO approach represents the position of firms with respect to performance frontier curve. These representations mainly signify the external performance of firm against its competitors (Porter, 1996; Sarmiento et al., 2010, 2013). In performance frontier, the firm position is represented as the point in two-dimensional space (Figure 1a). This representation considers the smooth trade-off between two performance dimensions. Firms that are positioned inside the performance frontier



(a) (b)

Figure 1 – Performance frontier on Industrial Organization (a); Performance landscape on basis of Evolutionary theory(b)

can be considered as the inefficient and firm can improve on both performance dimensions (From P to Q).

MS research have considered 2d performance frontier representation extensively (Cai and Yang, 2014; Clark, 1996; Da Silveira, 2005; Lapre and Scudder, 2004; Porter, 1996; Sarmiento, 2010; Sarmiento and Shukla, 2010; Sarmiento, Thurer, and Whelan, 2016; Schmenner and Swink, 1998a; Vastag, 2000). However, the important limitation of performance frontier representation is lack of linkage with manufacturing decisions that are required to occupy given position. In other words, MS decisions enabling internal performance improvement cannot be depicted with performance frontier approach.

Many firms have several factory within factory (FWFs) and compete on the multi-attribute space with heterogenous customer (Adner et al., 2014; K Ferdows and De Meyer, 1990; Kasra Ferdows and Thurnheer, 2011; Flynn, Schroeder, Flynn, Sakakibara, and Bates, 1997). Firms represented in performance frontiers models are assumed to face a smooth trade-off, which is conflicting with traditional IO research (Adner et al., 2014). Manufacturing capabilities development is multi-dimensional and can be achieved with both through trade-off and cumulative capabilities approach. Hence, the 2-dimensional frontier representation may remain inadequate to track the internal manufacturing capabilities development across four dimensions of manufacturing performance- i.e. cost, quality, delivery, and flexibility.

2.2 Evolutionary theory

Firms evolve as the biological systems with multiple interacting elements. In performance landscapes (Figure 1b), firm positions can be represented as the vector of policies and decisions, that determine the overall fitness value in NK model (Adner et al., 2014; Ghemawat and Levinthal, 2008; Levinthal, 1997). This approach considers strategy as the complex system with higher interdependence among its decisions. Firm performance is attributed to the interdependence among decisions. The greater number of interdependencies show, the more rugged surface with more number of local peaks. Strategy research acknowledged NK based performance landscape to explore interdependence among strategic decisions (Celo et al.,2015, Ganco and Hoetker 2009, Ghemawat and Levinthal 2008, Levinthal 1997, Rivkin 2000).

The mathematical model of the manufacturing firm as the complex adaptive system (CAS) begins with NK (C) models of Kauffman's class. McCarthy (2004); McCarthy and Tan (2000) and Tan (2001) established the relevance of fitness landscape theory with manufacturing strategy. But since then,

Table 1 - Three strategic verticals of ABC company and their performance (Source: Company website)

	ABC Vertical	Scope	Strategic Focus	Strategic Approach	Performance Outreach
Complimenting views	**Eng. Services**	Rapid prototyping of engineering applications in aerospace, automotive industry	Design and development of existing products	Supporting tool based subtractive manufacturing through faster and cheaper pre-production and post production	500 prototypes/month with more than 50 technologies
Alternative views	**Jewellery**	Jewellery and art work replacing existing manual artisan craftwork with digital crafting	Cost competitive digital crafting	Providing open source digital platform to leverage cost competitive digital crafting for replacing existing jewellery artisan	1600 designs brought every day for 3500 customers
Breakthrough view	**Medical**	Human skeletal organ manufacturing	Co-creation with Surgeons	Impacting lives with patient specific solutions.	500 lives impacted with association of 50 doctors

there is a paucity of research in relating MS with performance landscapes. We found the rationales towards inadequacy of NK models in decision making and attempt to address issues in the application of NK model in developing fitness landscape. We develop Grey-NK-DEMATEL approach and with the illustrative case in the digital manufacturing domain. The next section details the case and developed approach.

3 Research Methodology

3.1 Case Study

Case study approach focuses on understanding the dynamics present within single settings. Case study combines data collection methods such as archives, interviews, questionnaires and observations, which can be used to propose, develop or to test theory (Eisenhardt, 1989; Yin, 2009).

The key purpose of this case study is to evaluate strategy alternatives Digital manufacturing firm-ABC have. On the backdrop of nascent research in digital manufacturing domain, we purposefully select ABC-company for the investigation. Following are the explicit rationales to select of ABC-Company for our investigation- i) Firm operates in three views- complimentary, Replacement and Innovative views (Sonar, Kulkarni, Khanzode, and Akarte, 2017) and engages itself in catering to Engineering Services, Jewellery, and Medical. ii) MD and CEO have participated in earlier phases of this research. He was already aware of this research and its scope. Hence, it was easier to get relevant data access for the required work. iii) ABC-company strives to maintain strategic consensus across its three domains. Strategic consensus denotes the coherent level of agreement between senior level executives and manufacturing managers on the strategic importance and interrelationship. This reduces the possibilities of variations in responses at strategic and operational levels. iv) Presence of company in digital manufacturing domain for more than 5 years. v) Well known competitive position recognized by the global customers across three verticals.

3.2 Case Profile

ABC company is the pioneering firm in Digital manufacturing in India, that has evolved with the extensive application of 3D printing technology. ABC company serves more than 4000 customers with the production of 2500 parts every day. Following Table 1 summarises three operation strategy levels and their respective strategic approaches.

3.3 Case Scenario

The key purpose of this case study is to evaluate various strategy alternatives Digital manufacturing firm-ABC have. We develop Grey-DEMATEL-NK-fitness landscape model based on the strategic importance given by ABC-company and to model, how internal decisions cost, quality, delivery, and flexibility affect the fitness of the firm. We now brief about NK model and illustrate the need of updating existing NK method.

3.4 *Concept of Fitness*

The objective of MS is to create to operationally significant elements of manufacturing capabilities such as cost, quality, delivery and flexibility (Ian P. McCarthy, 2004; Tan, 2001). Tan (2001) defined manufacturing fitness as- "The ability of the firm to increase their survivability and competitiveness in the manufacturing environment through inheriting, imitating and searching for manufacturing capabilities such as cost, quality, delivery, and flexibility."

With this definition, the performance of the firm depends on the manufacturing capabilities developed by the firm alone. Traditional strategy research adopts NK fitness landscape model, that specifically concern with developing manufacturing capabilities as the internal performance of the firm. In NK model, N as elements of manufacturing capabilities (i.e. cost, quality, delivery, and flexibility), while k states the level of complexity. The complexity and structure of manufacturing strategy configuration are captured in number and pattern of interdependent decisions. With each configuration, firm achieves a certain level of fitness. The mapping of all possible strategy options for all firm decisions onto corresponding fitness level is used to plot the fitness or performance landscape. Earlier NK research studies adopt uniform random function generation U(0,1) for the evaluation of fitness contribution of individual configuration (Billinger, Stieglitz, and Schumacher, 2014; Celo et al., 2015; Ganco and Hoetker, 2009; Giannoccaro, 2011).

3.5 *Need of Updating NK method*

Existing NK method is insufficient to capture the complete effect of positioning of the firm (Adner et al., 2014). There are two primary issues in existing NK method: a) It lacks the connect of elements and their interactions with fitness values due to uniform random generations of fitness. b) It requires extensive computational support to establish between strategy configurations and its associated fitness values. In this work, we argue that fitness landscape is required to develop considering- i) Number of elements (N) ii) Interaction among these elements (K) iii) the Strategic importance of each element iv) Relative interactions among these elements. However, capturing interrelationships among strategy elements requires to address two challenges- a) How to capture the strategic interrelationship. b) How to address the uncertainty and inadequate information regarding interrelationship among strategy elements.

We use DEMATEL as the visualization method for building and analyzing a structural model of complicated causal relationships between its component. We further integrate grey system theory to build grey relative relationship model for the elements and extract the strategic importance of each strategy element. Grey system theory is used to solve the uncertainty problem with discrete data and incomplete information (Bai et al., 2017; Bai and Sarkis, 2010, 2011). Annexure 1 introduces some notations and operations relevant to our application based on the earlier grey system studies such as Bai et al.,(2017); Bai and Sarkis, (2010, 2011); Liu, Forrest, and Yang (2011). We develop the stepwise Grey-DEMATEL-NK method (Figure 3) to evaluate the strategic options available to develop manufacturing capabilities.

3.6 *Data Collection Method*

The unit of analysis for this case study is firm level. To represent, firm level, data is collected from MD and CEO of the ABC-company, as he is responsible for strategy and performance of all three verticals. We also supported these data collection interviews with the Gemba walks. This has helped us to understand the day-to-day operations. Data collection is done two phases- A) The initial phase of the detailed semi-structured interview B) Pairwise Interrelation among elements of manufacturing capabilities.

A) Semi structured Interview: Semi-structured interview on MD and CEO as a strategy maker of ABC-Company. This task has helped us to understand the digital manufacturing, its context,

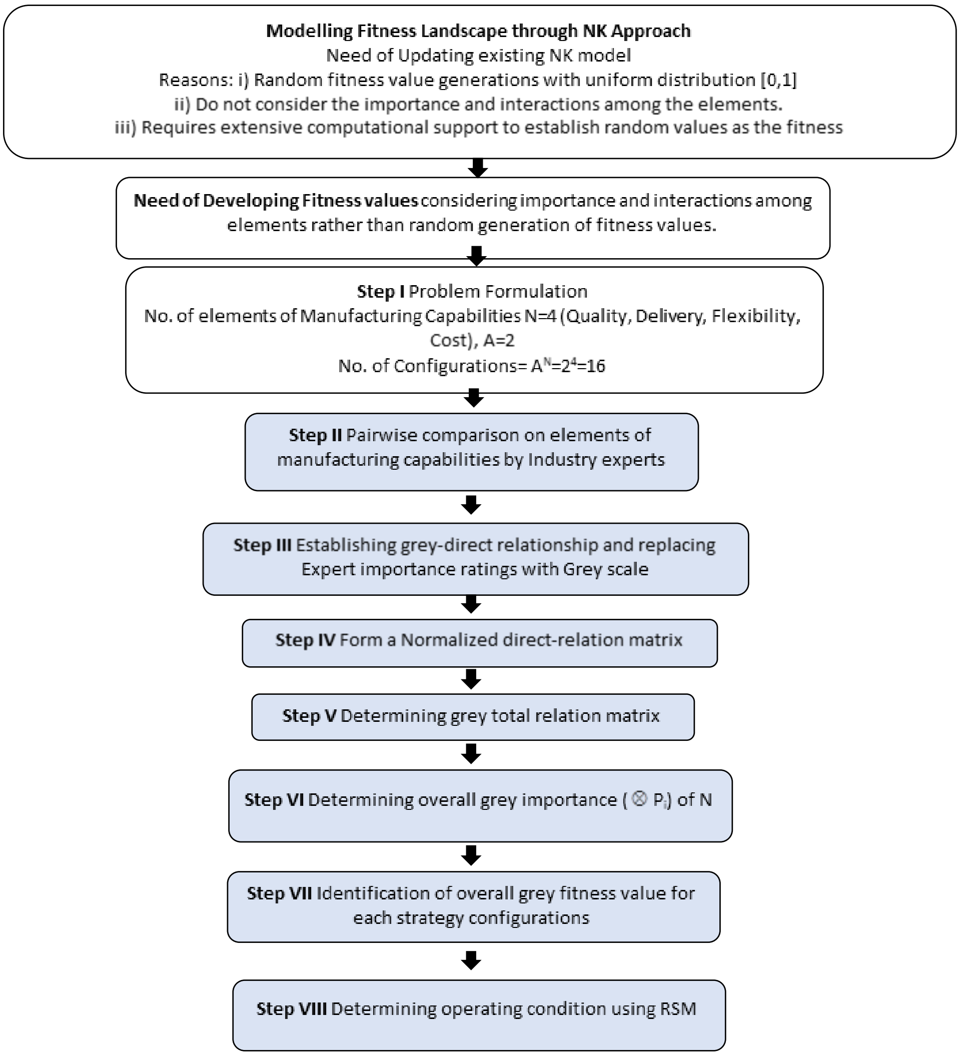


Figure 3 – Grey-DEMATEL-NK method

competitive positioning and related investment decisions, operational policies, and routines firm. We avoid the detailed discussion of results considering the research scope.

B) Pairwise Interrelation among elements of manufacturing capabilities: We consider manufacturing capabilities as the strategy elements for the sake of landscape modeling. These include cost, quality, delivery, and flexibility. The strategic importance of the element refers to the key impact of these elements on the performance of the firm. We take firm level strategic importance on the linguistic scale according to MD and CEO of the firm as the key strategic decision maker.

In general, it is difficult for the decision maker to accurately assign relative strategic importance by considering all of them simultaneously. The pairwise comparison method can reduce above difficulty, gives more reliable and consistent weights (Lekurwale, Akarte, and Raut, 2015).The relative weights are assigned to the elements of manufacturing capabilities using grey based importance scale from N (0.0) to Vh (1.0). N indicates the no importance of interrelation among two criteria while Vh indicates very high importance in the fitness of the firm. Table 2 details the pairwise interrelation among elements of manufacturing capabilities.

4 Grey-DEMATEL-NK method and Illustration

We now illustrate the stepwise procedure of Grey-DEMATEL-NK method (figure 3) in digital manufacturing firm-ABC company.

Table 2 - Pairwise interrelation among elements of manufacturing capabilities

ABC Company	Quality	Delivery	Flexibility	Cost
Quality	N	L	Vh	Vh
Delivery	L	N	L	L
Flexibility	Vh	L	N	Vl
Cost	H	L	Vl	N

4.1 Step I Problem Formulation:

Assumptions:

1. N=4 (Strategy elements- Quality, Delivery, Flexibility, and Cost)
2. A=2 (Levels of individual strategy elements- Absent (0) or Present (1))
3. The level [Vh] as the outstanding level or market leading level of performance with coded value as [1]. (ii) [H, L and Vl] being mediocre performance levels of manufacturing capabilities with coded value [0].
4. Total Number of Strategy configurations on landscape=AN= 24 = 16
5. A firm with complete strategic consensus with absolute fit among designed strategy elements and realized elements at the operational level (Schoenherr and Narasimhan, 2012).
6. Firm is positioned away from the performance frontier and does not experience trade-off (Sarmiento et al., 2010; Schmenner and Swink, 1998b; Vastag, 2000).
7. Quality is the basis for continual improvement in the manufacturing firm.

4.2 Step II and Step III Pairwise comparison among manufacturing capabilities and Establishing the grey direct -relation matrix

To measure grey interdependencies between MS components $c=\{c_i, i=1,2,3,..,n\}$, the grey numbers for five linguistic term explained earlier in Table 2. We introduce grey pairwise influence relationships among elements of manufacturing capabilities. Initially, we set grey interrelation among MS elements to N [0,0]. Further, pair wise interrelations are taken from strategy experts of ABC firm as depicted in table 3.

Table 4 illustrates grey direct interrelationships among strategy elements. We use this matrix (***M***) for further understanding of strategy elements and their interactions.

4.3 Step IV Normalising the grey direct-relation matrix

Based on the grey direct interrelationship among strategy elements, the normalized matrix N is obtained by the following equation

$$\boldsymbol{N} = s\boldsymbol{M} = \left(s \times m_{ij}, s \times \overline{m}_{ij}\right) \qquad (1)$$

where

$\overline{m}_{ij}, m_{ij}$: upper and lower values

$s = \frac{1}{max \sum_{j=1}^{n} m_{ij}}$ $\quad i, j = 1,2,3, \dots n$

Table 5 shows the normalised grey direction matrix.

4.4 Step V Determining grey total relation matrix

The grey total relation matrix (T) is determined by the following expression

$$\boldsymbol{T} = \left(\underline{\boldsymbol{T}}, \overline{\boldsymbol{T}}\right) = \left(\underline{\boldsymbol{N}}\left(\boldsymbol{I} - \overline{\boldsymbol{N}}\right)^{-1}, \overline{\boldsymbol{N}}\left(1 - \overline{N}\right)^{-1}\right) \qquad (2)$$

In which ***I*** represent a $n \times n$ identity matrix. Table 6 shows grey total relation matrix.

Table 3 - Grey direct relationship among elements of manufacturing capabilities

ABC Company	Quality	Delivery	Flexibility	Cost
Quality	N [0,0]	L [0.25,0.5]	Vh [0.75,1]	Vh [0.75,1]
Delivery	L [0.25,0.5]	N [0,0]	L [0.25,0.5]	L [0.25,0.5]
Flexibility	Vh [0.75,1]	L [0.25,0.5]	N [0,0]	Vl [0,0.25]
Cost	H [0.5,0.75]	L [0.25,0.5]	Vl [0,0.25]	N [0,0]

Table 4 - Grey Direct interrelationship among strategy elements

ABC Company	Quality		Delivery		Flexibility		Cost	
	Lower value	Upper Value	Lower value	Upper Value	Lower value	Upper Value	Lower value	Upper Value
Quality	0	0	0.25	0.5	0.75	1	0.75	1
Delivery	0.25	0.5	0	0	0.25	0.5	0.25	0.5
Flexibility	0.75	1	0.25	0.5	0	0	0	0.25
Cost	0.5	0.75	0.25	0.5	0	0.25	0	0

4.5 Step VI Determining the overall grey importance ($\otimes P_i$) of manufacturing capabilities elements

Determine the overall grey importance ($\otimes$ P_i) of MS elements. The values ($\otimes$ P_i) shows total net cause and effect index.

$$\otimes P_i = \{\otimes R_j + \otimes D_j; i = j\} \tag{3}$$

where $\otimes R_j$ represents the sum of influence by the strategy element i, on other strategy elements, and $\otimes D_j$ represents sum of direct and indirect influence that decision component is affected by the other elements. Table 7 details the overall grey importance ($\otimes P_i$).

4.6 Step VII Identification of overall grey fitness value for each strategy configurations

Each MS strategy element can have its fitness value. The objective now is to find overall grey fitness value for the various configurations on the landscape. The overall fitness value $\otimes F$ of the system is the sum of values assigned to each strategy element (c_i) and the interdependencies with other components c_j, that are also selected ($c_j = 1$).

$$\otimes F(\{c_i; c_i = 1\}) = \sum_{i\in\{i;c_i=1\}}\left(\otimes P_i + \sum_{j\in\{j;c_j=1;j\leq k\}} \otimes t_{ij} \otimes P_i\right) \qquad i \neq j \tag{4}$$

In which $\{c_i; c_i = 1\}$ represent the configuration of components ($c_i = 1$).

For example, if the only quality is present, then the overall fitness value is F = [2.215,6.918]. If flexibility is present separately, the fitness value would be F = [1.576, 5.641] which is equal to $\otimes$ P_f. If firm develops joint configuration of quality and flexibility strategy, the strategic configuration would be represented as C [0,1,0,1] and fitness value is [2.215,6.918] + [1.576, 5.641] = [3.791, 12.560]. In this case, we consider the only direct effect on strategy elements, however, neglect the interaction effect among two strategy elements, and assume t_{ij}=0. Fitness values for each manufacturing strategy are computed following the procedure explained. Table 8 summarises the overall fitness values for 16 manufacturing strategy configurations.

4.7 Step VIII Determining Operating Condition using RSM

From table 8, the fitness of firm is influenced by the several variables such as manufacturing capabilities in terms of cost, quality, delivery, and flexibility. We now use, response surface methodology (RSM). In RSM, by careful design of experiments (DOE), the objective is to optimise the response (output variable), which is influenced by independent variables (input variables).

Table 5 - Normalized grey direct relation matrix

ABC Company	Quality		Delivery		Flexibility		Cost		
	Lower value	Upper Value	Lower value	Upper Value	Lower value	Upper Value	Lower value	Upper Value	
Quality	0	0	0.25	0.5	0.75	1	0.75	1	2.5
Delivery	0.25	0.5	0	0	0.25	0.5	0.25	0.5	1.5
Flexibility	0.75	1	0.25	0.5	0	0	0	0.25	1.75
Cost	0.5	0.75	0.25	0.5	0	0.25	0	0	1.5
								s	0.4

Table 6 - Grey Total relation matrix

ABC Company	Quality		Delivery		Flexibility		Cost		⊗ Rj	
	L	U	L	U	L	U	L	U	L	U
Quality	0.2114	0.8468	0.1978	0.7658	0.3832	0.991	0.3832	0.991	1.1756	3.5946
Delivery	0.1854	0.7207	0.0507	0.3964	0.1607	0.6306	0.1607	0.6306	0.5575	2.3783
Flexibility	0.382	0.9623	0.1644	0.6429	0.131	0.5807	0.131	0.6716	0.8084	2.8575
Cost	0.2608	0.7944	0.1446	0.5733	0.0927	0.5815	0.0927	0.4906	0.5908	2.4398
⊗ D_j	1.0396	3.3242	0.5575	2.3784	0.7676	2.7838	0.7676	2.7838		

In this case, the fitness of the firm can be represented as the function of independent manufacturing capabilities in terms of cost, quality, delivery, and flexibility. Mathematically, output fitness variable (y) can be given as

$$y = \Psi(\text{cost, quality, delivery, flexibility}) + \epsilon \quad (5)$$

We use RSM as the sequential procedure, to plot the fitness landscapes using fitness values obtained in stage VII. The eventual objectives set is to determine the optimum fitness condition for the system. Frequently, the initial estimate of optimum operating conditions is far away from the actual optimum. In certain conditions, the firm intends to move rapidly to the general vicinity of the optimum. Mayers and Montgomery (1995) suggested the method of steepest ascent can be applied for moving sequentially to the maximum of fitness. We develop second-order response model for the fitness values using RSM of Minitab 17. Table 9 details the second order response model for three fitness values- i) Higher ii) Average and iii) Lower.

Table 10 shows the statistical significance of the developed model. P values for the linear model for lower, average and higher fitness values are statistically significant. However, there is no indication of interactive effect.

The probable rationales for the statistical insignificant of the interactive effects can be- We take strategic importance and pairwise of the elements of manufacturing capabilities with the fitness as perceived by the strategy designer of the ABC-company. We are considering tangible measures of manufacturing performance such as Quality (scrape/defect rate), Delivery (manufacturing lead time), Flexibility (number of products introduced) and Cost (manufacturing cost as the percentage of sales cost) and establish its linkage with TPF. Results of this research are excluded considering present research scope.

4.8 Adaptive Walk of the Firm on Fitness landscape

Firms attempt to search better fitness value than its existing fitness value. In NK modeling, this process is known as the adaptive walk in which firms move in search of peaks. We explore the best theoretical sequential path with following the stepwise rule:

Table 7 - Overall Grey importance of MS elements

ABC Company	Quality		Delivery		Flexibility		Cost		Rj		($Rj+D_j$)	
	L	U	L	U	L	U	L	U	L	U	L	U
Quality	0.211	0.8468	0.197	0.765	0.383	0.991	0.383	0.991	1.175	3.594	2.215	6.918
Delivery	0.1854	0.7207	0.050	0.396	0.160	0.630	0.160	0.630	0.557	2.378	1.115	4.756
Flexibility	0.382	0.9623	0.164	0.642	0.131	0.580	0.131	0.671	0.808	2.857	1.576	5.641
Cost	0.2608	0.7944	0.144	0.573	0.092	0.581	0.092	0.490	0.590	2.439	1.358	5.223
D_j	1.0396	3.3242	0.557	2.378	0.76	2.783	0.767	2.783				

Table 8 - The overall fitness values for manufacturing strategy configurations

C	F	D	Q	Lower	Upper	Average
0	0	0	0	0	0	0
0	0	0	1	2.2152	6.9188	4.567
0	0	1	0	1.115	4.7567	2.93585
0	1	0	0	1.576	5.6413	3.60865
1	0	0	0	1.3584	5.2236	3.291
0	0	1	1	3.3302	11.6755	7.50285
0	1	0	1	3.7912	12.5601	8.17565
1	0	0	1	2.9344	10.8649	6.89965
0	1	1	0	2.691	10.398	6.5445
1	0	1	0	2.4734	9.9803	6.22685
1	1	0	0	2.9344	10.8649	6.89965
0	1	1	1	4.9062	17.3168	11.1115
1	1	0	1	5.1496	17.7837	11.46665
1	0	1	1	4.6886	16.8991	10.79385
1	1	1	0	4.0494	15.6216	9.8355
1	1	1	1	6.2646	22.5404	14.4025

1. Consider, the firm starts from the origin with fitness value 0, it means firm does not possess capability in any of manufacturing strategy element. Initially, we set the sequential path (Sqp) = π. In the end, Sqp would be the order of strategy elements (1,1,1,1).
2. Select strategy element i, which has maximum grey fitness value and let c_i=1 into Sqp using following equation: $\max(\otimes F(sqp + c_i))$ then $c_i \Rightarrow sqp$
3. Keep circulating the second step, until all the strategy elements are selected into Sqp at all c_i = 1. Then the sequence of selected strategy element into Spq may be the sequential path in search of the better fitness value by any firm.

In our illustrative case, the firm starts with ci=0 with initial fitness value 0, indicating the firm does not possess capability in strategy element. At first step, ABC would have options for capability development is cost, quality, delivery, and flexibility. Considering the focussed factory concept, firm cannot achieve market leading performance in all dimensions and attain strategy configuration of [1,1,1,1] directly. Hence firm should focus and develop its capabilities sequentially one-by-one. The grey fitness values [1,0,0,0] < [0,1,0,0,0] < [0,0,1,0] < [0,0,0,1] using definition II and equation 5 of Annexure 1. This directs ABC should develop its capabilities in Quality. Further, firm can develop flexibility and attain its configuration as [0,1,0,1] with grey fitness value [3.7912,12.5601].

ABC company should develop its cost capability as fitness values for other configurations is less. For instance, [0,1,1,1] < [1,1,1,0]. ABC company can develop its delivery capability. These fitness values imply that ABC company should adopt Q-F-C-D as the best implementation strategy configuration sequence.

5 Results and Discussions

We consider total factor productivity as the ratio of profitability to operating expenses for two years 2014-2015 and 2015-2016 as the measure of firm performance. Table 11 summarises the comparative of performance the growth of ABC company.

Table 9 - second order response model for the fitness

Fitness (Higher)	-0.11 + 5.11 Cost + 7.37 Flexibility + 6.49 Delivery + 5.61 Quality - 2.80 Cost*Flexibility - 2.80 Cost*Delivery + 2.80 Cost*Quality + 0.42 Flexibility*Delivery - 0.42 Flexibility*Quality - 0.42 Delivery*Quality
Fitness (Average)	-0.08 + 3.20 Cost + 4.75 Flexibility + 4.08 Delivery + 3.74 Quality - 1.79 Cost*Flexibility - 1.79 Cost*Delivery + 1.79 Cost*Quality + 0.32 Flexibility*Delivery - 0.32 Flexibility*Quality - 0.32 Delivery*Quality
Fitness (Lower)	-0.054 + 1.298 Cost + 2.130 Flexibility + 1.669 Delivery + 1.876 Quality - 0.772 Cost*Flexibility - 0.772 Cost*Delivery + 0.772 Cost*Quality + 0.214 Flexibility*Delivery - 0.214 Flexibility*Quality - 0.214 Delivery*Quality

Table 10 - Second order response model and its statistical significance

Source	Degree of Freedom	Adj SS	Adj MS	F-value	P-value
Model (Higher)	10	498.751	49.875	6.94	0.023*
Linear (Higher)	4	474.656	118.664	16.51	0.004*
2-way interaction (Higher)	6	24.095	4.016	0.56	0.751
Model (Average)	10	205.870	20.5870	6.85	0.023*
Linear (Average)	4	195.985	48.9963	16.31	0.004*
2-way interaction (Average)	6	9.885	1.6474	0.55	0.757
Model (Lower)	10	40.7632	4.0763	6.57	0.025*
Linear (Lower)	4	38.8390	9.70	15.65	0.005*
2-way interactions (Lower)	6	1.9242	0.3207	0.52	0.778

* P < 0.05

In the year 2014-2015, strategic focus the firm is to develop its "Quality" with strategy configuration of [Vh, L, H, L] i.e. [1,0,0,0] with corresponding fitness value [2.2152, 6.9188]. A firm with deliberately attempting to improve its scrap rate and controls its operating expenses. However, profit levels show the negative trends. TPF ratio recorded to -0.0044. In 2015-2016, the firm operates with the strategy configuration as [Vh, H, Vh, H]. Given strategy configuration of firm can be [1,0,1,1] with corresponding grey fitness [3.7912, 12.5601]. The corresponding TPF slowly improves to 0.019.

The critical questions now, whether firm should improve on its delivery [1,1,1,0] or cost [1,1,1,0]. The corresponding grey values are [4.9062, 17.3168] and [5.1496, 17.7837]. If we consider the steepest ascent method, the firm may choose to improve upon its Cost, as the corresponding fitness values are greater. Presently, it seems the direct relationship with fitness and TPF.

The firm performance is not only dependent on the developed manufacturing capabilities but the environment in which firm operates. This would significantly impact the relationship between fitness and the performance of the firm. Future research requires further investigation the relating fitness and performance of the firm considering market context.

Developing manufacturing capabilities is no more linear but complex. So, the mechanistic approach of modeling linear system is inadequate to model performance of any manufacturing firm. We develop performance landscape using Grey-DEMATEL-NK approach to capture complex interactions among elements of manufacturing capabilities.

We now state key limitations of this work to improve this work further- i) We restrict the research scope to a single case from digital manufacturing domain. There would be contextual variations in the strategic importance of elements and their interrelationships. ii) In Grey-DEMATEL based fitness value generation, we consider only the main effects of strategy element and neglected the interaction effects among these elements. iii) We assume, the firm is positioned away from the performance frontier and does not experience trade-off (Sarmiento et al., 2010; Schmenner and Swink, 1998b; Vastag, 2000). The firm follows the sand cone model of cumulative capabilities and assumes cost, quality, delivery, and flexibility can be improved cumulatively. Hence, we consider the

Table 11 - Growth of ABC company (Source: CMIE, database)

	2014-2015	2015-2016
Manufacturing strategy configuration	**[1,0,0,0]**	**[1,0,1,0]**
Grey Fitness value	**[2.2152, 6.9188]**	**[3.7912, 12.5601]**
Profit (in Rs. million)	-1	5.9
Operating Expenses (in Rs. million)	225.1	300.5
Total Factor Productivity (TPF)	-0.00444247	0.019633943

pairwise interactions with non-negative terms. Future work may consider the trade-off relationship and execute the pair-wise interaction accordingly. iv) The focus of research is to develop performance landscape model. Future work may be developed to identify the optimal search strategy for the firm. Specifically, the application of optimisation techniques can help the firm to explore the quickest way towards manufacturing strategy configurations.

Apart from this, future research requires further investigation on the relationship between fitness and performance. One of the important extension of this work would be to plot the respective positions of SBUs/FWFs on firm's landscape to understand the variations strategic configurations. This would help strategy designers and managers to monitor, evaluate and synchronize their manufacturing strategy with corporate goals.

6 Conclusions

Many firms aspire to become 'world class', 'lean' and 'flexible'; but often fail in midway. The reason is not always- they loose the track. Most of the times, firms miss out the strategic approach to enable their capabilities to differentiate in the market. These capabilities do not come by chance or intuitive decisions but require structured and enlightened strategic approach to manufacturing (Brown, 2000, 2012). Performance modeling concerns with evaluating strategic options of manufacturing capabilities development. Despite performance being the central concern in strategy literature, Performance landscape modeling has rarely been the focus of analytical research (Adner et al., 2014). This research attempts to contribute towards this theoretical need in strategy domain.

6.1 Theoretical Contributions

The purpose of this work is to address the limitation of traditional NK model and make two specific contributions- i) We develop Grey-DEMATEL-NK based fitness approach to generate fitness values based on strategic importance and interactions among elements of manufacturing capabilities. ii) Further, we develop response surface method model to establish the linkage of the internal and external performance of the firm. We take case study approach to illustrate the developed approach.

6.2 Managerial Implications

Modeling performance landscape can assist in identifying the current position of firm its performance landscape. This would help managers to evaluate the strategic options created by AM practices. Relating current position with performance landscape further can be linked with the improvement trajectories of the firm focusing on-

a) Where does plant need to be? (Position of performance landscape and available strategic choices)

b) How to develop strategies to move from where plant is to where it needs to be (Implementation of MS decisions and derive reliable action plans and improvement practices to outreach performance Optima)

With broadening the scope of manufacturing, firms need to scale up their manufacturing capabilities with advancing technology as well as market requirements. It is essential to know there is no single generic and superior strategy to satisfy the need for all firms. Firms within the same industry frequently prefer to use several functional strategies. Some of these may perform very well or fairly. Hence it is imperative for the firm to evaluate the strategic options available for the firm and align its strategy suitably with competitive priorities and operational plans. Performance landscape study can offer the way to evaluate strategic options and develop operational plans AM practices in a digital era.

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Annexure 1

Definition I: Let x denote a closed and bounded set of real numbers. A grey number , is defined as an interval with known upper and lower bounds but unknown distribution information for x (Liu et al., 2011). That is, $\otimes x = [\underline{\otimes}x, \overline{\otimes}x] = [x' \in x \mid \underline{\otimes}x \le x' \le \overline{\otimes}x]$ where $\underline{\otimes}x$ and $\overline{\otimes}x$ are the lower and upper bounds of $\otimes x$, respectively.

Definition II: Let $\otimes x_1 = [\underline{x}_1, \overline{x}_1]$ and $\otimes x_2 = [\underline{x}_2, \overline{x}_2]$ be the two grey numbers. Generally, some basic grey number mathematical operations are represented by the following relationships (expressions (A.1-A.4)):

$$\otimes x_1 + \otimes x_2 = [\underline{x}_1 + \underline{x}_2, \overline{x}_1 + \overline{x}_2] \quad \text{(A.1)}$$

$$\otimes x_1 - \otimes x_2 = [\underline{x}_1 - \overline{x}_2, \overline{x}_1 - \underline{x}_2] \quad \text{(A.2)}$$

$$\otimes x_1 \times \otimes x_2 = [\min(\underline{x}_1\underline{x}_2, \underline{x}_1\overline{x}_2, \overline{x}_1\underline{x}_2, \overline{x}_1\overline{x}_2),\ \max(\underline{x}_1\underline{x}_2, \underline{x}_1\overline{x}_2, \overline{x}_1\underline{x}_2, \overline{x}_1\overline{x}_2)] \quad \text{(A.3)}$$

$$\otimes x_1 \div \otimes x_2 = [\underline{x}_1, \overline{x}_1] \times [\frac{1}{\underline{x}_2}, \frac{1}{\overline{x}_2}] \quad \text{(A.4)}$$

Definition III: Let $\otimes x_1 = [\underline{x}_1, \overline{x}_1]$ and $\otimes x_2 = [\underline{x}_2, \overline{x}_2]$ be the two grey numbers, $l(\otimes x_1) = \overline{x_1} - \underline{x_1}$ and $l(\otimes x_2) = \overline{x_2} - \underline{x_2}$. The Possibility degree, larger value of two numbers can be defined as $P(\otimes x_1 \ge \otimes x_2)$ and be expressed mathematically as,

$$P(\otimes x_1 \ge \otimes x_2) = \begin{cases} 1; \underline{x_1} \ge x_2 \\ \dfrac{\overline{x_1} - \underline{x_2}}{l(\otimes x_1) + l(\otimes x_2)}; \overline{x_1} \ge \underline{x_2} \wedge \underline{x_1} < \overline{x_1} \\ 0; \overline{x_1} \le \underline{x_2} \end{cases} \quad \text{(A.5)}$$

Where, the possibility value of grey number $\otimes x_1$ is grey number $\otimes x_2$. 0.5≤ $P(\otimes x_1 \ge \otimes x_2)$ ≤1 indicates $\otimes x_1$ dominates $\otimes x_2$. This relationship is denoted by $\otimes x_1$ D $\otimes x_2$. These basic operations and possibility degree is utilised in the fitness evaluations to advance NK model considering the importance of strategy elements.

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Impact of Additive Manufacturing on Supply Chain

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Abstract

The research in additive manufacturing is limited to an engineering discipline, and management of additive manufacturing is a less explored domain. This work is aimed at examining select papers in the management of additive manufacturing (AM) and its impact on the supply chain in recent past. The papers are classified as conceptual, exploratory, empirical and review papers, and prevailing issues are identified. To further probe in understanding impact of AM, we analyse supply chains considering Upstream, Process and Downstream aspects along with three primary flows- Goods and services, funds and information. We propose the need for developing Additive Manufacturing strategy for the competitiveness of the firm.

Keywords: Additive Manufacturing, Manufacturing Systems, Additive Manufacturing Strategy, Supply Chain Management, Literature review

1 Introduction

Additive manufacturing (AM) denotes the family of manufacturing techniques that allows layered production using digital inputs. AM enables the remote production of parts/products without scrap or wastage (Gibson et al., 2010). AM is most widely used in applications with low production volumes, small part sizes, and complex designs in the applications like aerospace, biomedical, jewellery, sculpture, rapid designs (Deradjat and Minshall, 2017; Holmstrom et al., 2016). In 2013, AM market grew to $3.07 billion with compound annual growth rate (CAGR) of 34.9% and is expected to grow up to $10.8 billion by 2021 (Thiesse et al., 2015). Despite overwhelming economic potential and increasing technology expectations, research on AM is limited to engineering discipline focusing on methods and materials of the additive manufacturing process (Chen et al., 2015; Deradjat and Minshall, 2017; Thiesse et al., 2015). The research stream focusing on the management of AM is still in nascent stage.

Although AM revolutionises manufacturing technology, firms tend to adopt it with caution. AM displays some advantages over the conventional manufacturing technology, company managers still should pay attention to their supply chain circumstances when they would like to adopt AM. Currently, the biggest challenge in supply chain management is the need to efficiently and

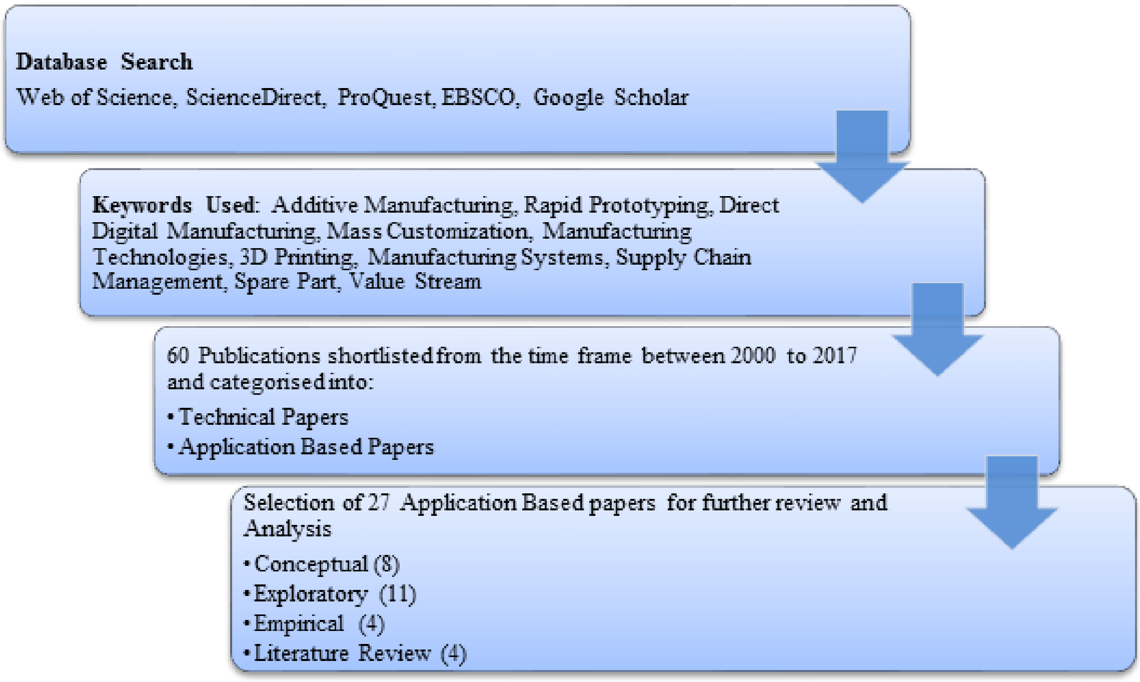


Figure 1 – Literature Search Strategy

effectively deliver ever more valuable products and services to customers (Holmström et al., 2010a). Now, the emergence of AM technology further creates an opportunity to improve supply chain dynamics (Liu et al. 2014). The supply chain management is also digitized for effective inventory and producing customized products (Kumari et al., 2017).

The purpose of this work is to examine recent relevant literature in AM domain and its impact on SCM to find out possible future directions. For this, we use systematic literature search strategy to select the papers for consideration. On careful examination of the selected papers, we suggest three prominent research directions for future work in developing Additive manufacturing strategy: (i) Impact of AM on value stream (ii) Positioning AM on volume-variety matrix. (iii) Impact of AM on Business Performance

The rest of the paper is organised as follows: In the following section, we provide details of literature search method and classification scheme. Then, we discuss conceptual, exploratory, empirical and review papers on AM and SCM and then identify prevailing issues. Finally, we propose the future research directions in the AM-SCM domain.

2 Method

The purpose of this paper is to examine select papers on the impact of AM on the supply chain. We have used Additive Manufacturing and Supply Chain Management as two important domains for this work. The literature search strategy was adopted from similar previous studies (for example, Kulkarni et al., 2016). This included identifying relevant data sources and keywords. The detailed search strategy is depicted in Figure 1.

Multiple journal databases are used (for example, Google Scholar, ScienceDirect, ProQuest, EBSCO, Web of Science). The scope of the literature search is restricted to recent academic research (between 2000 and 2017) in AM and supply chain management of spare parts. A set of 60 publications was shortlisted. These publications are categorised into two types, technology-based and application based. As the focus of this paper is to explore the impact of AM on the supply chain, we selected 27 papers for further analysis. These papers are classified as per the taxonomy of Dangayach and Deshmukh (2001) as: conceptual (8), exploratory cases (11), empirical studies (4) and review (4).

Table 1 – Selected conceptual papers on AM applications

Author(s)	Key Findings
Berman (2012)	Examination of characteristic and application of 3D printing and comparison with mass customisation
Conner et al. (2014)	Reference system for 3D product development from manufacturability standpoint considering- customisation, production volume and complexity
Holweg (2015)	Delineating limits of AM and future avenues to implement AM, complementing traditional manufacturing
Thiesse et al. (2015)	Commentary on the economic implication of AM and initiate the discussion of impact of manufacturing system
Sasson and Johnson (2016)	Introduced an alternative where DDM coexists with and complements traditional mass production.
Holmstrom et al. (2016)	Future research agenda in operation, supply chain and operation strategy issues of AM.
Jaime Bonnín Roca et al. (2017)	Commenting on application of AM with near-term expectations and examination of AM hypes
Durão et al. (2017)	Scenario Analysis for distributed production of spare parts.

3 Results and discussion

Due to advancements in materials and methods of AM technologies, applications of AM are significantly increasing (Mellor et al., 2014). However, research in management of AM and its impact on supply chain management is in nascent stage (Holmstrom et al., 2016; Khorram Niaki and Nonino, 2017b; Weller et al., 2015). AM has several advantages over the traditional manufacturing technology, managers still have to pay attention to their supply chain conditions when they would like to adopt AM (Li et al., 2017). We classify select papers in - a) Additive manufacturing management b) AM and its impact on Supply chain

3.1 Additive Manufacturing (AM) Management

Additive manufacturing (AM) denotes the family of manufacturing techniques that allows layered production using digital inputs. Most common advantages of AM are a) time-to market speed increase b) prototyping cost reduction c) complex customization d) inventory reduction. Efficacious applications of AM are among the reasons some firms are looking to AM to gain a competitive advantage. A set of 20 papers on AM are classified as: conceptual, exploratory cases, empirical studies and literature review.

Conceptual Papers: Table 1 summarizes select conceptual papers on AM applications, that are primarily discussing the key characteristics and application of AM in manufacturing paradigm. Holmström et al. (2010) enlist benefits of AM technology as: (i) Reduction in production lead time with minimal tooling requirements, (ii) Feasible and economic smaller batch production enabling higher variety, (iii) Rapid design changes allowing customized designs, and (iv) Simplified supply chains and lower inventories. Conner et al. (2014) argue that AM can be more cost effective than traditional manufacturing at higher complexity levels. Holmstrom et al. (2016) argue that AM may not completely replace traditional manufacturing, rather both can be used in synergy. However, present conceptual research lacks the insights on how this synergy can be achieved. The literature is also silent on how and when traditional manufacturing firm should initiate implementing AM. Berman (2012), Conner et al. (2014) emphasis on applications of AM in mass customisation. Further, exploratory case based studies have investigated the AM implementation as an enabler of mass customisation.

Exploratory Papers: Table 2 depicts select exploratory papers on AM applications, focusing on the case based investigation of AM. As the AM research is in a nascent stage, case studies are used as preferred methods of investigation (Mellor et al., 2014) with an objective to understand AM implementation process. These studies are from diverse industries like aerospace and aviation (Khajavi et al., 2014; Mellor et al., 2014; Tuck et al., 2008; Wagner and Walton, 2016), medical and dental (Deradjat and Minshall, 2017; Eyers and Dotchev, 2010; Khorram Niaki and Nonino, 2017a), electronics (Achillas et al., 2015; Khorram Niaki and Nonino, 2017a). However, there are limited cross-

Table 2 – Selected exploratory case study papers on AM applications

Author (s)	Key Findings	Industry Sector
Tuck et al., 2008	Case illustration of AM facilitating cost-effective customisation	Aircraft
Holmström et al., 2010	Potential approaches to introduce AM in spare parts supply chain	Aircraft
Mellor et al., 2014	Structured model of implementation factors related to AM technology, operations, strategy and supply chain	Aerospace
Khajavi et al., 2014	Detailed case-based investigation of the impact of AM improvements in the aerospace supply chain.	Aircraft
Rylands et al., 2016	Cross case illustration to explore the process of AM within manufacturing systems and impact on business performance	Filters and Wallpapers industry
Sirichakwal and Conner, 2016	Examines how AM affects the management of spare parts inventory. The AM implementation impacts on inventory strategies, potential applications and current shortcomings are also discussed.	Aircraft
Oettmeier and Hofmann, 2016	Systematic analysis of the effects of AM technology adoption on SCM processes and SCM components in an engineer-to-order environment.	Hearing systems industry
Wagner and Walton, 2016	Current and future trends of AM in aviation supply chain	Aviation
Khorram Niaki and Nonino, 2017b	Case-based study on the impact of business strategy, AM and firm performance.	Multi-sectorial cases
Deradjat and Minshall, 2017	Framework for implementation of AM enabling mass customisation using a case study from the dental sector.	Dental
Li et al., 2017	Explores the impact of AM on supply chain performance and quantitatively examines the superiority of utilising AM in the spare parts supply chain.	Spare part manufacturing

case comparison studies to explore industry-specific variations in AM implementation (Khorram Niaki and Nonino, 2017b). As an exception, Khorram Niaki & Nonino (2017b) and Rylands et al. (2016) examine AM implementation across sectors viz. textile, furniture, aerospace, automotive, medical, electronics.

Empirical Papers: Table 3 states select empirical papers on AM applications dedicated to the quantitative modelling of AM and its applications. Empirical studies in AM domain are sparse. Achillas et al. (2015) propose the decision-making framework for selection of effective production strategy using multi-criteria decision aid (MCDA) and DEA. Weller et al. (2015) investigate economic and technological characteristics of AM at firm and industry level. Future research in AM needs to be focused on the development of empirical models in different contexts.

Review Papers: Table 4 states select literature review on AM applications focusing on the investigating research avenues in AM management such as AM and mass customization, AM-SCM. Eyers and Dotchev (2010) review various AM technologies to discuss opportunities and challenges of mass customization. This study also signifies the importance of evaluation of AM process towards mass customization with a case study. Holmstrom et al. (2016) present the agenda for future research at the factory, supply chain and operation strategy levels. Khorram Niaki and Nonino (2017) present the systematic and quantitative analysis of literature in management of AM and elaborate research in eight domains of AM: (i) Technology selection, (ii) Supply chain, (iii) Product design and production cost models, (iv) Environmental aspects, (v) Strategic challenges, (vi) Manufacturing systems, (vii) Open-source innovation, (viii) Business models and economics. Jin et al. (2017) entails the scientometric review exploring hotspots and emerging trends of AM.

3.2 Supply Chain Management (SCM)

Supply chain management (SCM) is the management of the flow of goods and services, involves the movement and storage of raw materials, of work-in-process inventory, and of finished goods from one point to another. A set of 7 papers on AM-SCM are classified as: conceptual (2), exploratory cases (4), empirical studies (1) and literature review (1).

Conceptual Papers: Additive Manufacturing is perceived as disrupting technology of the entire manufacturing economy or simply allowing innovative production scenario (Sasson and Johnson, 2016). This paper qualitatively evaluates potential supply chain reconfigurations. The analysis shows that firms will develop AM capabilities to isolate disruptive, low-volume production from scalable mass production. The distributed manufacturing of spare parts in locations closer to the final user

Table 3 – Selected empirical papers on AM applications

Author (s)	Key Findings
Chen et al. (2015)	Demonstrates the implication of AM with sustainability. Highlights the analysis of AM with craft production, mass production, mass customisation.
Achillas et al. (2015)	Decision-making framework for selection of effective production strategy using multi-criteria decision aid and data envelopment analysis
Weller et al. (2015)	Economic and technological characteristics of AM at firm and industry level.
Knofius et al. (2016)	Identification of economically valuable and technologically feasible after sales parts manufacturing by AM

Table 4 – Selected Literature Review papers on AM applications

Author (s)	Key Findings
Eyers and Dotchev, (2010)	AM technology as enabler of mass customisation
Rogers et al. (2016)	To identify 3D printing services, with the scope of determining the potential implications on the supply chains of manufacturing firms and creating a research agenda for future studies.
Jin et al. (2017)	Explores hotspots and emerging trends of AM through detailed scientometric review
Khorram Niaki and Nonino (2017a)	Themes of AM management research- AM technology selection, supply chain, product design and production cost models, environmental aspects, strategic challenges, manufacturing systems, open-source innovation and business models and economics.

has several advantages, such as reduced delivery lead times and reduced logistics costs (Durão et al., 2017).

Exploratory Papers: The impact of AM on the spare parts supply chain is investigated by Li et al., 2017 in the three scenarios: a) conventional supply chain, b) centralized AM-based supply chain and c) distributed AM-based supply chain. These three scenarios are compared using system dynamics model which shows that supply chain utilizing AM is more beneficial than traditional SC configuration. Rylands et al., 2016 explored the adoption process of AM within a manufacturing system and its impact on business. The results showed that the implementation of AM caused a shift in value propositions and the creation of additional value streams (VSs) for the case study companies. AM VSs would rather strengthen the traditional manufacturing VSs instead of completely replacing them. Systematic analysis is provided by Oettmeier and Hofmann (2016) about the effects of AM technology adoption on supply chain management (SCM) processes and SCM components in an engineer-to-order environment. Two explorative case studies are used for investigation of the impact of AM technology adoption on SCM process and its components. However, there is lack of studies available in the literature which analyses the consequences of AM adoption from supply chain standpoint.

Empirical Papers: Knofius et al. (2016) discussed the possible reasons for the value of AM for after-sales service logistics and to develop a method to simplify the identification of economically valuable and technologically feasible business cases. The approach is based on the analytic hierarchy process (AHP) and then sensitivity analyses explain the robustness of the approach. Further, this work illustrates the flexibility of applying the method in practice. Apart from this study, we see a serious void in the empirical investigations of the impact of AM on SCM.

Review Papers: Rogers et al., (2016) identified the AM services, with the scope of determining the potential consequences on the supply chains of manufacturing firms and creating a research agenda for future studies. AM services may complement, replace or even create entirely new supply configurations, offering extraordinary flexibility in terms of production volume, production location, product customization and product complexity. But further studies are required to authenticate the results.

3.3 Impact of AM on SCM

The biggest challenge in supply chain management is the need to efficiently and effectively deliver ever more valuable products and services to customers (Holmström et al., 2010a). Additive manufacturing with a digital link enables to maintain digital models of the spare parts. This reduces the expenses of physical warehousing and increases the availability of parts at the point of use. By manufacturing items closer to the end destination, we reduce logistical costs and environmental impact. Furthermore, successful implementation of AM processes relies on the intersection of two supply chains: the supply chain of a machine and materials vendor and the supply chain of the company intending to purchase the tools that allow them to 3D print products (Mellor et al., 2014). Therefore, the continuous development of AM offers OEMs the opportunity to change their manufacturing operations and their supply chain configurations.

Present AM research lacks insights on the linkage of AM with firms' competitiveness and how AM technology will significantly improve supply chain dynamics. Although AM revolutionises manufacturing technology, firms tend to adopt it with caution. Additive Manufacturing Strategy needs to evolve, which may help practitioners in following ways: 1) To develop competing priorities, 2) To assist in structural and infrastructural decision choices, 3) To develop manufacturing capabilities which differentiate a firm. However, past literature lacks the systematic way of understanding the impact of AM supply chain.

Researchers analyse supply chains considering Upstream, Process and Downstream aspects along with three primary flows- Goods and services, funds and information. The upstream supply chain includes suppliers and raw material producers. The downstream supply chain includes distribution network including retailers. AM is said to be transforming the traditional manufacturing and supply chain paradigm (Holmstrom et al., 2016; Holmström et al., 2010b). Hence, we need to explore the relationship between AM and traditional SCM. Therefore, we map the research issues found in the AM-SCM domain in the following matrix (Table 5).

3.4 Impact of AM on Upstream SC

These studies discuss various approaches to introduce AM in the spare parts supply chain. Present research requires further insights on the challenges pertaining to inventory and material management models, location and distribution networks of suppliers, raw material quality inspection and standards. We also see a dearth of studies in funding and information related issues despite the hype of Industry 4.0.

3.5 Impact of AM on Process

This stream has received the significant research attention in the recent past. The rationale for the extensive research is attributed to the potential impact of AM on the traditional manufacturing. We analyse these research attempts classifying manufacturing decisions as structural and infrastructural decisions. Structural decisions include long term, capital intensive policy decisions such as facility, capacity, location, layout, process and technology. Infrastructure decisions include routine operating decisions PPC, Quality systems, organisation design (Hayes and Wheelwright, 1979; Kulkarni et al., 2016). The introduction of AM would impact manufacturing decisions in both structural as well as infrastructural levels.

The studies focusing on impact of AM on structural manufacturing decisions include location (Durão et al., 2017), Make or buy decision (Mellor et al., 2014; Ruffo et al., 2007), Vertical integration (Sasson and Johnson, 2016), Technology and Process (Eyers and Dotchev, 2010), Manufacturing system design (Holmstrom et al., 2016; Khorram Niaki and Nonino, 2017a; Rylands et al., 2016; Thiesse et al., 2015).

The potential of AM as the enabler of mass customisation is the most popular research stream in AM management domain. Past studies such as Chen et al., (2015); Deradjat and Minshall, (2017); Eyers and Dotchev, (2010); Khorram Niaki and Nonino, (2017b); Tuck et al., (2008) devote the discussion on the AM as the enabler to mass customisation.

With these extensive research efforts, the positioning of AM on volume-variety matrix depicting how AM can affect the trade-off among cost and variety is an emerging interest to AM-SCM researchers. This may develop Additive Manufacturing Strategy as the new avenue for the AM management research like operation strategy issues given by Holmstrom et al., (2016).

Table 5 – Understanding Impact of AM on Supply chain

Flow	Upstream	Process	Dowstream
Goods and Services	• Supplier relationship management (Lambert, 2014; Oettmeier and Hofmann, 2016b) • Upstream supply chain dynamics (Li et al., 2017b) • Approaches for introducing AM in spare parts SC (Holmstrom et al., 2016; Khajavi et al., 2014)	• Location of near to the downstream to cater the ultimate need of the end user. • Significant reduction in lead time and logistics cost (Durão et al., 2017) • Need of manufacturing super centre and supply chain reconfigurations (Sasson and Johnson, 2016) • AM for production of customised parts (Berman, 2012; Chen et al., 2015; Deradjat and Minshall, 2017; Eyers and Dotchev, 2010; Tuck et al., 2008) • Manufacturing flow management (Lambert, 2014; Oettmeier and Hofmann, 2016b) • Multi-criteria Decision aid framework for production strategy selection (Achillas et al., 2015) • Make or buy decisions (Mellor et al., 2014; Ruffo et al., 2007) • Complimenting AM with traditional manufacturing (Holmstrom et al., 2016; Holweg, 2015) • Reduction in holding cost and production lead time (Sirichakwal and Conner, 2016b)	• After sales service logistics of AM parts (Knofius et al., 2016) • Customer relationship and service management (Lambert, 2014; Oettmeier and Hofmann, 2016b) • Returns management (Lambert, 2014; Oettmeier and Hofmann, 2016b) • 3D printing services on supply chain of manufacturing firms (Rogers, Baricz and Pawar, 2016) • Distributed Supply chain of spare parts (Durão et al., 2017) • Implications of AM for spare parts inventory (Sirichakwal and Conner, 2016b)
Information	• Development of heterogeneous bill of material (Sasson and Johnson, 2016)	• Challenges of information exchange, communications and control among production sites (Durão et al., 2017) • Lack of experience with the technology (Berman, 2012; Hopkinson et al., 2006)	• Enhancing profit margins and customer satisfaction (Mellor et al., 2014)
Fund		• Economically feasible production to smaller production lot size (Berman, 2012) • Economic and technological characteristics of AM (Weller et al., 2015) • Impact of AM on manufacturing system and business performance (Holmstrom et al., 2016; Khorram Niaki and Nonino, 2017a; Rylands et al., 2016; Thiesse et al., 2015) • Reduction in downtime cost (Khajavi et al., 2014) • Cost-benefit analysis for AM adoption (Malte Schrödera, Björn Falka, 2015; Sasson and Johnson, 2016; Yao et al., 2016) • Cost effective customisation (Tuck et al., 2008) • Costs of the AM (N Hopkinson and P Dickens, 2003; Ruffo et al., 2006) • High printer acquisition cost (Berman, 2012; Hopkinson et al., 2006)	

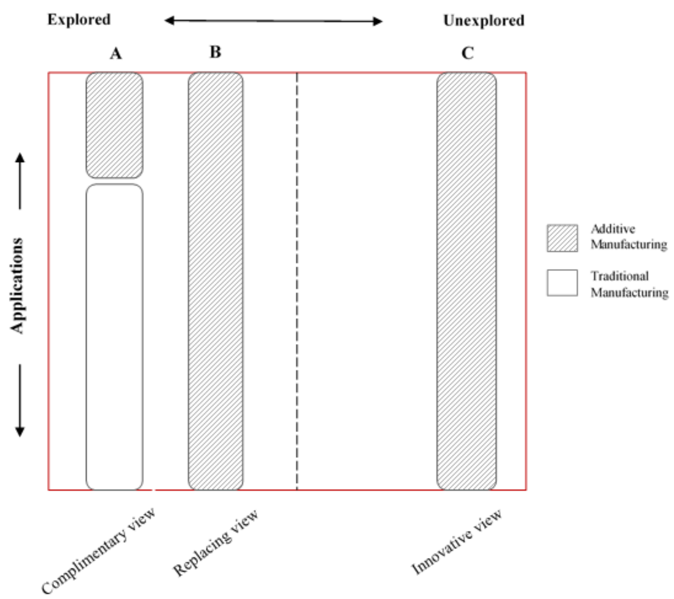


Figure 2 – Additive manufacturing and its application with respect to traditional manufacturing

To initiate the discussion on Additive manufacturing strategy, we highlight possible research directions- a) Impact of AM on value stream b) Positioning of AM on volume variety matrix c) Impact of AM on business performance. We discussed these research directions in the next section.

3.6 Impact of AM on Downstream SC

The downstream SC primarily focuses on the dynamics in spare part management (Durão et al., 2017; Lambert, 2014; Li et al., 2017a; Oettmeier and Hofmann, 2016b; Sirichakwal and Conner, 2016b). Present AM-SCM domain has acknowledged research in after sales service logistics (Knofius et al., 2016), customer relation and service management (Lambert, 2014; Oettmeier and Hofmann, 2016b), return management (Lambert, 2014; Oettmeier and Hofmann, 2016b), spare parts inventory at dealers (Sirichakwal and Conner, 2016b). The research on the impact of AM on downstream SC requires the specific guidelines on the assessment of the impact of AM on customer satisfaction, service time, maintenance down time.

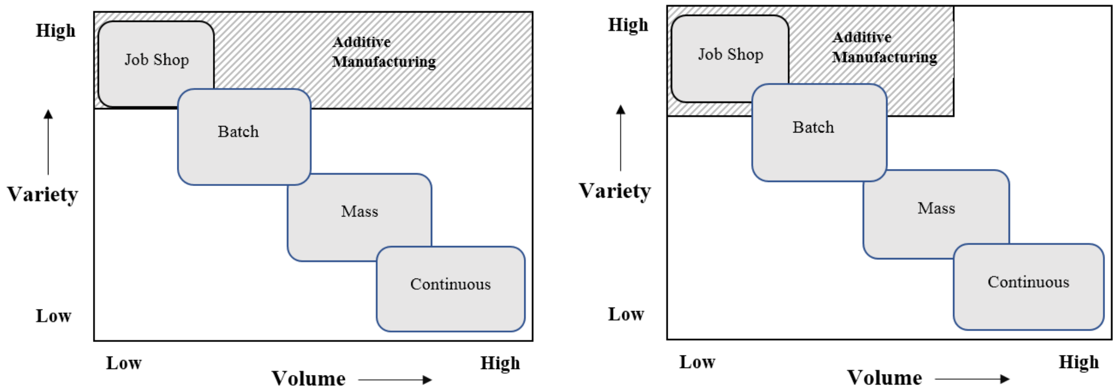
Holistically, by understanding the impact of AM on supply chain and how products, information and money flows through it, SC managers would be in good position to find several inefficiencies and figure out how to enhance their competitiveness. However, present AM-SCM research demands the significant contributions with respect to Fund and information flows across the supply chain. Material supplier chain and inventory management models, raw material handling and carrying patterns, the shelf life of the material, demand forecast uncertainty, Data and design sharing issues, scheduling are further operation management concern required to be pondered as the future research avenues across the value chain.

4 Future research directions

To initiate the discussion on Additive manufacturing strategy, we highlight possible research directions- a) Impact of AM on value stream b) Positioning of AM on volume variety matrix c) Impact of AM on business performance.

4.1 Impact on value stream

According to Chen et al., (2010) a value stream consists of all the materials and information required in the manufacturing of a particular product and how they flow through the manufacturing system. The AM research illustrates its potential impact on the shortening manufacturing lead time across the value stream (Deradjat and Minshall, 2017; Holmstrom et al., 2016; Mellor et al., 2014). AM may



a) According to Tuck et al., (2008)   b) According to Authors

Figure 3 – Positioning AM in volume-variety matrix

partially or fully replace traditional tool based subtractive manufacturing processes in the value stream. Figure 2 shows three possible ways in which AM may impact value stream: (i) Complimentary view (auto components - Khorram Niaki and Nonino (2017a), Rylands et al. (2016)), (ii) Replacement view (jewelry and art work - Tripathy et al. (2016)), and (iii) Innovation view (medical applications - Deradjat and Minshall (2017), Khorram Niaki and Nonino, (2017a)). This classification is equivalent to Holmstrom et al. (2016).

We find the complimentary view (Rapid prototyping and rapid tooling) and the replacement view (complete replacement of traditional manufacturing) prevalent in the literature. We also expect a strengthening of innovative view in near future, resulting in the manufacture of complex parts not amenable to traditional manufacturing. Researchers need to explore cases within and across these three verticals, investigating configurations and decision choices in AM implementation, similar to Choudhari et al. (2010, 2013).

4.2 Positioning AM in Volume-Variety Matrix

On the volume-variety matrix, Tuck et al (2008) position AM across the entire volume axis and higher side of the variety axis (Figure 3a). However, we argue that the scope of AM may be restricted to mid of mass production volume levels and may not reach to highest volume and highest variety region (Figure 3b). High volume and High variety region is considered as the manufacturing mirage (Hayes and Wheelwright, 1979). The hypothetical position at upper right portion of volume-variety would resolve the traditional trade-off between cost and differentiation. This would falsify the traditional strategy positioning theory (Porter, 1996). Additionally, this may nullify the requirement of mass continuous production systems. The mass produced make to stock (MTS) low-cost products such as soaps, pens, tyres, plastic parts, toys or in certain common products which do not require customisation would require continuing to produce with traditional manufacturing techniques. The impact of AM and its positioning on volume-variety may differ with given product context. This proposition, however, needs to be tested empirically.

4.3 Impact of AM on Business Performance

The primary focus of future investigation in AM, should be a focus on three critical questions as addressed in earlier works: i) How to leverage AM strategically? (Holmstrom et al., 2016) ii) What are the critical factors for AM implementation (Deradjat and Minshall, 2017; Mellor et al., 2014) iii) How to establish a relation between AM implementation and firm performance? (Holmstrom et al., 2016; Khorram Niaki and Nonino, 2017a).

On the backdrop of these critical questions, the central purpose of the AM management research would be establishing linkage of AM implementation and business performance. The impact of AM on value stream may vary with given industry sector. AM implementation may subject to critical

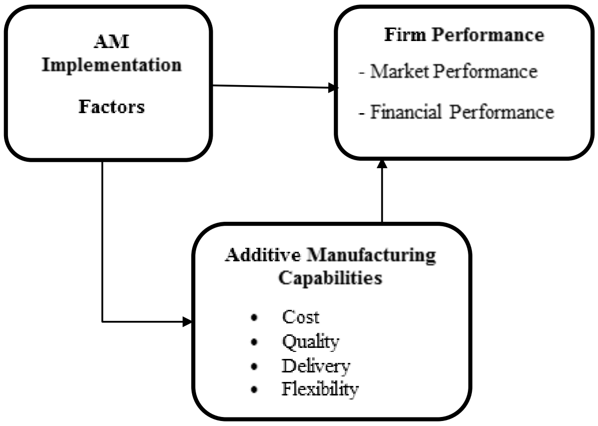


Figure 4 – Conceptual framework on relating AM with business performance

factors related to strategy, supply chain, technology, organization change (Deradjat and Minshall, 2017; Mellor et al., 2014). These factors are central to firm performance and competitiveness (Deradjat and Minshall, 2017; Khorram Niaki and Nonino, 2017b; Mellor et al., 2014; Weller et al., 2015).

Present AM research lacks the context specific study on the exploration of critical factors of AM implementation and their impact on the firm performance. We propose a conceptual framework (Figure 4) to develop study further. It contains three major constructs: a) AM implementation Factors b) Additive manufacturing capabilities in terms of cost, quality, delivery and flexibility c) Firm Performance. Future work may be developed as the context specification empirical investigation of present framework.

5 Conclusion

The biggest challenge in supply chain management is the need to efficiently and effectively deliver ever more valuable products and services to customers (Holmström et al., 2010a). The purpose of this paper is to examine select papers on the impact of AM on the supply chain. We review 27 select papers and investigated the research status in the AM-SCM domain. This study further analyses supply chains considering Upstream, Process and Downstream aspects along with three primary flows- Goods and services, funds and information. AM is said to be transforming the traditional manufacturing and supply chain paradigm (Holmstrom et al., 2016; Holmström et al., 2010b). Hence, we need to explore the relationship between AM and traditional SCM. Therefore, we map the research issues found in the AM-SCM domain in the following matrix.

5.1 Theoretical contributions

Multiple possibilities exist in future research directions in the AM-SCM domain. We initiate need of leveraging AM for the competitiveness with the need of developing additive manufacturing strategy. Along with these points, Customer engagement, mass customization aspects, and technology considerations are some of the relevant areas of future research in addition to the issues cited in this paper.

5.2 Managerial Implications

Present AM research lacks insights on the linkage of AM with firms' competitiveness and how AM technology will significantly improve supply chain dynamics. Although AM revolutionises manufacturing technology, firms tend to adopt it with caution. Additive Manufacturing Strategy needs to evolve, which may help practitioners in following ways: 1) To develop competing priorities, 2) To assist in structural and infrastructural decision choices, 3) To develop manufacturing capabilities which differentiate a firm. By understanding the impact of AM on supply chain and how products, information and money flows through it, SC managers would be in good position to find several inefficiencies and figure out how to enhance their competitiveness.

Despite these research directions, we state the following key limitations of this study- a) We restrict the scope of literature to the AM-SCM domain. The overlapping literature from manufacturing management or operation management literature is not included in the present literature analysis. b) The paper selection, classification and analysis is the manual process and may involve researchers' bias. Future work may involve bibliometric analysis of select research to understand various research themes, authors from the AM-SCM domain and their interrelation.

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Design of Operations in Digital Supply Chains: From Simulation Modelling to Real-world Intelligent Autonomous Vehicles

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Abstract

The aim of this research is to provide a framework for the complementary use of simulation software analysis along with emulation tools and real-world intelligent autonomous vehicles (IAVs) for exploring alternative designs for effective operations in digital supply chains. A major network design challenge considers the inability to predict the system's response to the "dynamics" of manufacturing and distribution operations. On the one hand, software simulation analysis provides a certain level of abstraction in order to identify key performance indices while simulation models often have a myopic focus on inventory control and intra-logistics operations without considering any practical and detailed operational challenges. On the other hand, emulation and use of physical IAVs is emerging in the supply chain management domain owing to their capabilities to gather real-time information about specific operations and develop interfaces for addressing interoperability issues between sensor-driven vehicles and the installed equipment at facilities. In this sense, the aim of the present study is twofold: (i) to discuss key challenges associated with the myopic use of either simulation or real-world IAVs in supply chains, and (ii) to provide a three-stage framework that motivates the integrated use of simulation modelling, emulation and physical application of IAVs for the effective design of value network operations in the today's digital era. More particularly, we firstly simulate IAVs' operations in a conceptual warehouse and we then develop a 3D validation and verification emulation software tool to represent the actual operations of an IAV. Finally, we explore software interfaces of a commercial depth sensor (i.e. Microsoft Kinect sensor). The results indicate that simulation modelling should be initially used to examine overarching supply chains' operations performance while emulation tools and real-world IAVs are eminent, in advanced design stages of operations in digital supply chains, to effectively tackle practical and operational challenges.

Keywords: Digital supply chains, Design of dynamic operations, Intelligent Autonomous Vehicles, Simulation modelling, Emulation tools, Depth sensor.

1 Introduction

The digital manufacturing discourse motivates advancements in intelligent vehicles (Scarinci, Hegyi and Heydecker, 2017) and further fuels opportunities stemming from the utilization of autonomous production and distribution systems across supply chain operations (Bechtsis, Tsolakis, Vlachos et al., 2017). However, the decision-making process related to the selection and implementation of Intelligent Autonomous Vehicles (IAVs) could be challenging owing to the involved operational complexities and financial considerations (Chen, Ardila-Gomez and Frame, 2017). To that end, general purpose and off-the-self software tools enable discrete-event simulation of facility layouts, involved entities, and manufacturing and distribution processes. Nevertheless, simulation analysis cannot capture detailed operational aspects, hence motivating the development of three-dimensional (3D) validation and verification emulations which are used to "mirror" the utilization of IAVs in manufacturing and distribution operations (Sharif and Sadeghi-Niaraki, 2017). Despite the merits of simulation and emulation, the application of physical IAVs is essential to assess and validate the vehicles' appropriateness on each specific operational setting and justify the associated investments (Briggs et al., 2017).

Notwithstanding the bespoke need for rational investments in IAVs, simulation modelling and emulation of autonomous systems, prior to their real-world implementation, is neglected due to either the lack of specific knowledge over existing capabilities and requirements or the misconception of quickly gaining competitive advantages by adopting such technologically advanced applications. The limited volume of the related published literature (Briggs et al., 2017), especially over autonomous applications in the non-automotive sector, highlights the underlining ambiguity and complexity of the issue under study.

The on-going research presents a theoretically and empirically derived three-stage methodological framework for the integrated use of: (i) simulation modelling, (ii) emulation tools' development, and (iii) physical deployment of automated vehicles, for the efficient incorporation of IAVs in value network operations. In particular, the aim of the present research is to exemplify critical issues and guide academics and practitioners alike towards the effective and efficient use of vehicle automations in supply networks, by attempting to answer the following research questions (RQs):

- RQ1: What are the merits and disadvantages associated with the application of simulation modelling and real-word physical IAVs?
- RQ2: Which theoretical and empirical-driven methodological process could support the effective evaluation of alternative IAV technologies in digital supply chain operations?

The above RQs are critical to be addressed, since smart manufacturing and distribution systems are regarded as the ideal technological solutions in a range of network operations across diversified economic sectors (Bechtsis, Tsolakis, Vlachos et al., 2017); however, the appropriateness of such intelligent technological approaches for the effective design, planning and execution of supply chain operations has not been validated yet. Especially, the answer to RQ1 will compare the benefits and disadvantages related to simulation modelling and real-world applications. Following that, RQ2 will provide a theoretically and empirically derived three-stage process that guides the design and planning of operations in digital supply chains.

This paper follows a multi-method approach to answer the aforementioned questions. More specifically, literature findings along with our empirical evidence and experimental results are utilized to address both RQ1 and RQ2. Following that, literature evidence, simulation modelling, emulation scenarios and real-world application of a commercial depth sensor (i.e. Microsoft Kinect sensor) yield useful findings which provide answers to the enunciated RQs and unveil a plethora of future research potentials.

The remainder of the paper is structured as follows. In Section 2 we describe the advantages and drawbacks associated to the myopic use of only simulation or physical autonomous vehicles in a supply chain context. In this regard, we explore the synergistic value of these analysis approaches by systematically investigating simulation, emulation and real-world implementation methods of incorporating IAVs to a SC ecosystem in Section 3. In Section 4, we propose a three-stage framework for the integrated use of simulation, emulation and real-world application of IAVs on the design and planning of operations in digital supply chains. The framework is driven by both theoretical evidence and our empirical and experimental research related to autonomous vehicles. Conclusions, limitations and future research potentials are discussed in the final Section 5.

Table 1 – Simulation modelling of IAVs in supply chain operations

Advantages	Disadvantages
1. Enables rapid understanding about IAV's operations, under limited data availability	1. Provides limited flexibility in accurately capturing actual IAVs' operations
2. Allows for an IAV's feasibility assessment at a strategic/tactical/operational horizon	2. Provides limited capability to model novel IAVs in detail
3. Assesses an IAV's performance under alternative operational settings	3. Fails to accurately capture actual IAVs' drive cycles
4. Determines the optimum facility layout configuration accommodating IAVs	4. Demonstrates technical difficulties in modelling multi-scale operations in time
5. Reduces development time and cost of an IAV	5. Requires significant computational/processing power
6. Minimizes potential IAV operational risks	

2 Intelligent Autonomous Vehicles: A Research Dichotomy

The incorporation of IAVs in a digital manufacturing context is a complex process and demands the support of manual calculations, general discrete-event simulation modelling and 3D validation and verification emulation tools in order to assess the resulting performance at strategic, tactical and operational levels. Following that, physical IAV prototyping and testing could be used to validate the simulation results and ensure the interoperability of the vehicles with the existing infrastructure, information systems and communication protocols.

2.1 Simulation modelling

In a manufacturing context, simulation modelling and analysis is defined as: "the process of creating and experimenting with a computerised mathematical model of a physical system" (Chung, 2004). Especially, in today's digital epoch, simulation-based analysis approaches are a focal point in terms of experimentation, validation and verification of manufacturing and distribution systems' configurations (Mourtzis, Doukas and Bernidaki, 2014) .

At preliminary stages of an IAV's operations analysis, simulation modelling allows for the fast representation of the physical counterpart (Briggs et al., 2017), under limited data availability, that can support the often time and funding-constrained decision-making process (Table 1). In this sense, simulation allows for the assessment of an IAV's feasibility in a strategic/tactical/operational horizon under risk management, cost estimation, and manufacturing and distribution planning considerations (Uzzafer, 2013). Simulation can also assist in capturing an intelligent vehicle's efficiency in terms of mean values of selected key performance indicators (KPIs) (Bietresato, Friso and Sartori, 2012) with regards to alternative manufacturing and distribution operations (Schmidt et al., 2015). In case of intra-logistics operations, simulation results can indicate the optimal facility layout configuration in terms of accomplishing certain objectives (e.g. minimum operational cost) for a specified intelligent fleet capacity (Cardona et al., 2015). A key contribution of simulating IAV operations in a manufacturing and distribution system refers to the resulting reduction in the vehicle's development time and cost while identifying and eliminating any detrimental conflicts, deadlocks and integration risks (Hsueh, 2010).

Despite simulation enabling the facile representation and analysis of manufacturing and distribution systems, commercial off-the-shelf software often provide limited flexibility in developing accurate and customized models of the corresponding IAVs' operations. Moreover, commercial software packages contain inbuilt libraries of components (Briggs et al., 2017) that might be either outdated, meaning that they provide databases of obsolete equipment, or limited in terms of range of covered equipment. Consequently, modelling novel IAVs is challenging, typically governed by a magnitude of non-realistic assumptions. In addition, particularly for

Table 2 – Physical application of IAVs in supply chain operations

Advantages	Disadvantages
1. Requires reduced human intervention and labour cost	1. Requires significant capital investment on vehicles' development/purchase
2. Requires minimum vehicle maintenance cost	2. Requires capital expenditure on supporting infrastructure development and maintenance
3. Ensures increased safety	3. Requires modifications in the hoisting facility layout
4. Ensures increased accuracy and productivity	

distribution operations, simulation drive cycles do not include hoisting, tilting and lifting operations that impact the performance of the entire supply system (Briggs et al., 2017). In this regard, simulation models cannot capture the majority of dynamic operating conditions (Wu et al., 2008), like for example fuel cell consumption in electric vehicles (Schell et al., 2005) or a driver's response to disruptions during material handling and navigation operations (Seelinger and Yoder, 2006). Additionally, individual simulation modelling approaches cannot capture the different time-scales of operations across a supply system to inform precise IAVs' operations schedules (Garcia and You, 2015). From a technical viewpoint, computational/processing power could be a constraint (Mourtzis, Doukas and Bernidaki, 2014).

2.2 *From emulation to physical entities' application*

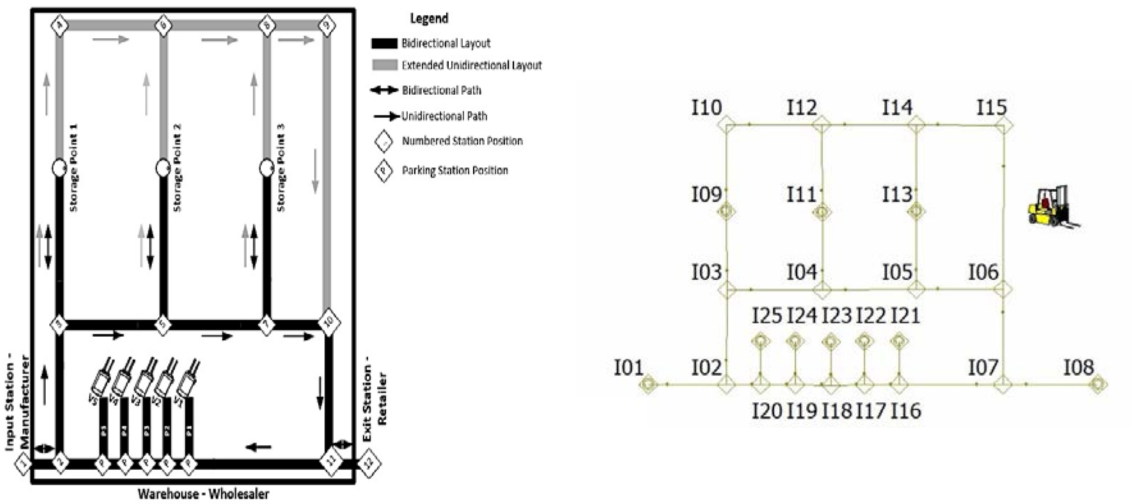
Although simulation tools have reached an adequate maturity level and can even be used, at an advanced stage, to emulate 3D real-world robotic/machinery functionalities, the physical IAV's experience is indispensable in most manufacturing and distribution environments. Basically, a physical vehicle's testing allows four key functions under complex environmental conditions (Kim and Kim, 2017), namely: (i) sense, (ii) perception, (iii) cognition, and (iv) behaviour (Table 2).

In general, IAVs can operate on a 24/7 basis without human intervention, thus promoting labour cost savings, while they have lower maintenance cost compared to conventional vehicles (Bechtsis, Tsolakis, Vlachos et al., 2017). Furthermore, IAVs provide increased safety levels in a workplace, that might be challenging to simulate under dynamic working conditions, especially for the case of hazardous environments (Vale et al., 2017). Nevertheless, the emerging adoption trend towards IAVs in supply chains is mainly motivated by the associated increased accuracy and productivity they offer (Lu et al., 2017).

The capital expenditure required to develop/acquire, install and operate IAVs is a significant cost factor that greatly impacts the total cost of a facility (Kavakeb et al., 2015), at least for heavy duty and customized vehicles designed to perform specialized logistics operations. In this vein, installation and standardisation of supporting facility infrastructure (e.g. charging stations, communication centres) could have practical along with capital and maintenance cost ramifications (Chen, Kockelman and Hanna, 2016), especially for the case of an electric vehicle fleet. In addition, the actual navigation of an intelligent vehicle, considering its dimensional specifications, along with possible carrying load volumes, allows the identification of required modifications in a workplace's layout to further allow the realization of necessary routing trajectories (Martínez-Barberá and Herrero-Pérez, 2010).

3 Experimental Evidence: From Simulation Modelling to Physical Application

Considering the myopic and disintegrated approach towards the adoption of IAVs in supply chain ecosystems, as previously discussed, we apply simulation modelling along with emulation and real-world deployment of a physical sensor to investigate and promote the synergistic value of these analysis approaches. Our aim is to contribute to the gradual transition towards the digital



(a) *(b)*

Figure 1 – Graphical representation of the warehouse facility layout (a); Simulation model of the warehouse facility layout (b)

manufacturing era. In this context, we initially identified a conceptual industrial warehouse facility (Figure 1a), which is adopted by Bechtsis, Tsolakis, Vouzas et al. (2017), that acts as a testbed with the scope of monitoring and optimizing the associated material handling operations performed by an IAV.

Based on our work with leading digital manufacturing and smart distribution systems' business and academic stakeholders, we initially performed manual calculations, considering alternative market demand scenarios, in order to determine the number of required intelligent vehicles that could serve the conceptual facility. Determining the number of operational IAV units allows stakeholders to provide a logical reasoning about the necessity of an associated investment. Following the simple calculations, we developed a corresponding mixed-integer linear programming model to derive optimal values about basic system's elements, namely: (i) number of IAVs for a certain facility layout, (ii) number of facility navigation paths (i.e. unidirectional, bidirectional), and (iii) allocation of parking/charging stations along with the vehicles' starting, ending and pick-up/drop-off points. Following these initial modelling efforts, we proceeded to more sophisticated analysis approaches as general solvers usually provide numerical results; however, graphical interpretation of a mathematical model's output can provide better insights into the installation prerequisites and operational performance of IAVs.

3.1 Simulation findings

In order to develop a comprehensive analysis approach for IAVs, that could be applied independently from complex mathematical equations, we firstly leveraged the ARENA® Simulation Software, a commercial discrete-event simulation software, to model (Figure 1b) and simulate material handling operations in the conceptual warehouse under study. Simulation outputs include: (i) optimal fleet size, (ii) capacity and bottlenecks of the facility layout, (iii) service level of the warehouse, and (iv) sustainability performance of the intra-logistics system.

Following the simulation modelling with the commercial software, we developed a custom software simulation tool by using the Microsoft Visual C# 2010 programming environment. The model building module of the tool allows the representation of a customized facility by manually determining the layout parameters including: entry points, storage separators (walls), recharging stations and exit points (Figure 2). This first pilot edition of the tool includes only manual controls for the vehicle's movements while the vehicle management component's interface allows the real-

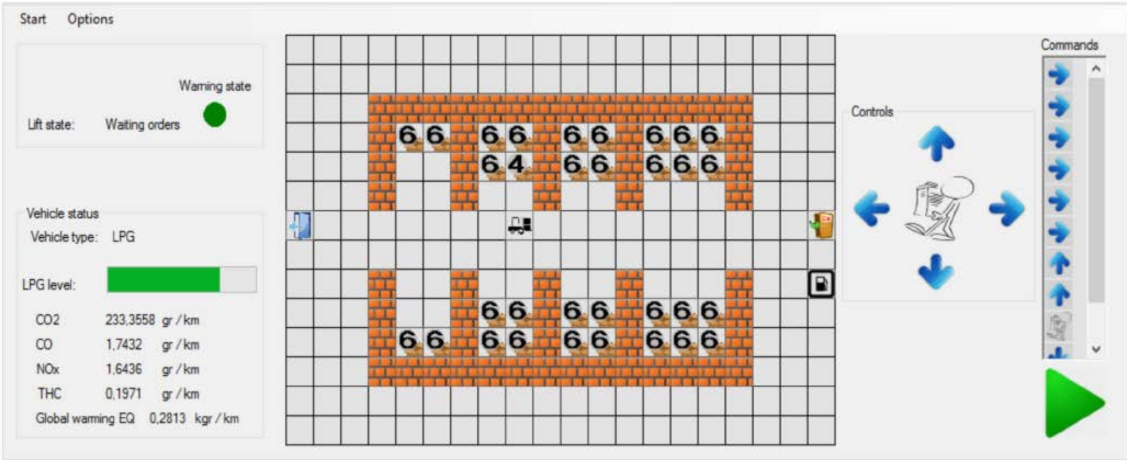


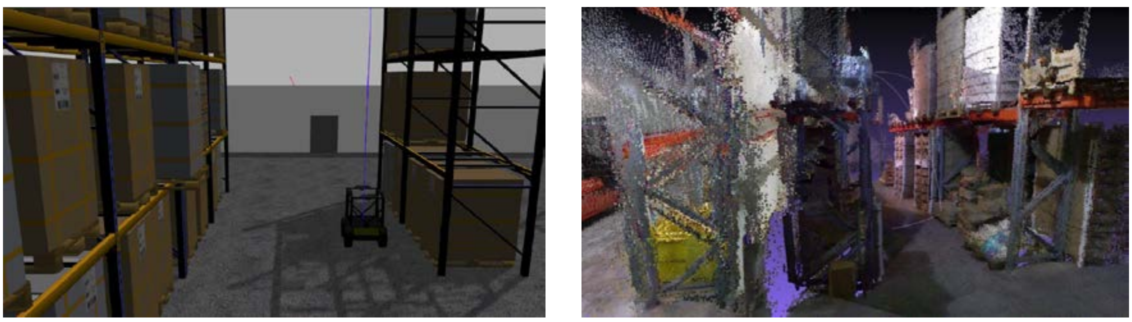
Figure 2 – Custom build simulation tool: Sustainable intra-logistics vehicle management

time reporting of the IAV's sustainability performance through reporting the resulting environmental sustainability impact.

3.2 Physical system emulation and application

The simulation approach presented in subsection 3.1 provides detailed vehicle schedules, vehicle utilization, service level and sustainability performance information, but lacks the illustration of useful operational details as well as a near to the real-world facility layout representation. To this end, 3D validation and verification emulation software tools could be utilized to represent the actual operations of intelligent vehicles, provide practical insights and verify any obtained simulation results (Moisiadis et al., 2017). Notably, emulation tools are often used in tandem with real-world physical applications.

Emulation tools can implement multiple interfaces to replicate the functionality and interaction of physical machinery/equipment to the operations environment. More specifically, we emulated the Husky autonomous vehicle at the identified experimental warehouse and we further added a commercial depth sensor on the vehicle (Figure 3a). The emulation model records a set of specific interfaces including scanning capability, colour image attributes and depth attributes. Following that, we tested the corresponding physical depth sensor Microsoft Kinect to explore the emulation interfaces of the physical depth sensor and apprehend the real-world environmental perception of the hardware. The Microsoft Kinect sensor was selected as it is commonly used in autonomous vehicles (Hedenberg and Åstrand, 2016) and it is further accompanied/supported by a well-



(a) *(b)*

Figure 3 – Warehouse emulated environment (a); Depth sensor captured image (b)

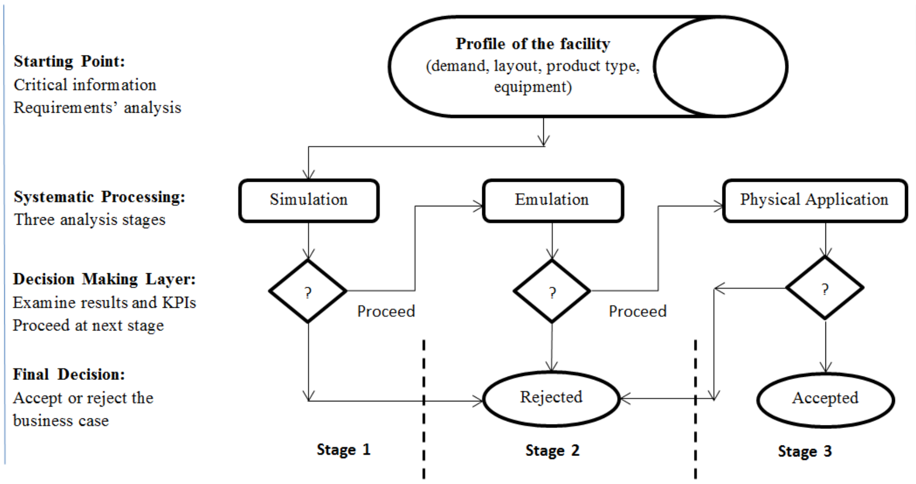


Figure 4 – Methodological framework for integrating IAVs in digital supply chain

established digital model. The sensor provides information about the environment and samples its behaviour on different lighting scenes, textures, scanning angles and environmental conditions (Figure 3b). As expected, the retrieved interfaces outnumbered the simulation interfaces providing detailed manipulation functions.

The results clearly indicate that the emulation software interfaces are limited while the physical device provides a complete list of features which outperform the emulation analogue. To that end, emulation oriented steps should be initially used to capture specific facility conditions and IAV's operations, while the need for real-world physical hardware is eminent in advanced research stages to tackle specific technical and operational challenges.

4 Bridging the Dichotomy: An Integration Framework

Considering that alternative digital supply chain designs entail diverse uncertainty types across spatial and temporal scales, we recommend the adoption of a hybrid approach for the effective design and assessment of future supply chains. The hybrid approach should comprise of three analysis stages: (i) simulation modelling, (ii) emulation, and (iii) physical IAVs' application to allow for adaptive collaborative decision-making. Figure 4 depicts the proposed methodological framework for fostering the effective integration of IAVs in digital supply chains

5 Conclusions

This research sets out the process for the systematic development of tools supporting digital transformations in supply chains. A three-stage methodological framework is proposed beginning with simulation modelling of IAVs in supply chain operations, progressing to emulation and physical application of autonomous vehicles in a customized operations environment. The proposed methodological framework assists in enabling digital supply network transformations (Srai, 2017). More specifically, the simulation modelling and emulation tool developed in this research can be useful for the effective design of specific supply chain operations in diversified sectors. As part of our on-going research we particularly investigate the case of precision agriculture operations performed by IAVs.

Commercial simulation packages provide limited modelling capabilities towards creating bespoke models of complex manufacturing and distribution systems, while the development of customized simulation models is time consuming, expensive and requires competent modelling skills and capabilities. Especially for distribution operations, a major challenge associates to the congruence of the simulation model and the corresponding real-world system (Ottemöller and Friedrich, 2017). In this regard, emulation environments could replicate, monitor and optimize real-world processes and capture unpredictable risks in order to proactively assess the impact of the external and internal environments of a manufacturing and distribution system, and provide insights for increased efficiency (Weyer et al., 2016). However, only the real-world application of a physical IAV enables consideration of both temporal and spatial environmental dynamics.

In conducting this study, some limitations are evident which, however, provide interesting grounds for expanding our research horizons. Firstly, the provided analysis framework was developed using literature evidence and our research experience, without consulting any experts. Secondly, this study was developed based on a single physical device (i.e. Microsoft Kinect sensor) and should be further enriched with the use of a physical IAV in an industrial warehouse.

With respect to future scientific directions, we aim to demonstrate the applicability of the proposed methodological framework on real-world settings. The case of the pharmaceutical industry is paramount for understanding and designing automated operations of the respective end-to-end supply networks, with specific focus on supporting more participative healthcare through responsive digital manufacturing models and more patient-centric delivery models. Moreover, the framework could be applicable to the case of networks defined by renewable chemical feedstocks, which are characterized by diverse and volatile physico-chemical quality specifications, to address emerging supply chain management challenges and market dynamics.

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Lean activity transfer to other industry – Cases of agriculture businesses

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Abstract

This paper discusses agri-products manufacturing operations and its typical management problem caused by waste are examined on the lean platform. This subject consists of two types of lean activity transfer, transfer from manufacturing industry to agri-industry as an inter-industry transfer, and R&D-based business model development by focusing on loss zero-tisation, which is considered as a business functional transfer. Case investigation is essential for learning from the problem, model building and analysis

Keywords: Lean management, Agri-businesses, Knowledge/technology transfer, Case study, Muri (Strain), Mura (Fluctuation), Muda (Waste)

1 Introduction

Transfer activities of lean management and technology have been conducted by Japanese industrial professionals over the world even before the publication of The machine that changed the world (Womack et al., 1990). Pattern of transfer consists of three issues, i.e. horizontal transfer that includes transfer from domestic factories to offshore factories, mutual transfer among offshore factories within the same country and also among the countries, functional transfer including from manufacturing sites to other business functions and inter-industry transfer, namely from manufacturing industry to other industries such as agriculture, commerce, transportation, public service and also inter-transfer among these industries (Katayama, 1999; 2000; 2005; Murata et al, 2012; 2015; Sato, et al, 2017; Takeyama et al., 2016). Contents of this paper concerns the second and third category of transfer, i.e. R&D function and agri-businesses (Katayama et al, 2004).

Agri-industry in Japan has been struggling with tough business environment such as severe competition with imported products, increasing average age of concerned workers, decreasing the number of farmers that causes shrinking national self-sufficiency rate of products (Chiyoma et al, 2014)(Ito, 2006). As a countermeasure of these obstacles, national government introduced revised agricultural land law in 2009 that permits to join this sector of business from other industries such as manufacturing (Ministry of Agriculture, Forestry and Fisheries; 2015). Effects of this encouragement come up slowly in the early stage followed by rapid increase on the number of companies launching their owned agri-business units. They are trying to implement lean management, e.g. TPS (Toyota Production System) (Uchiyamada, 2008; Monden, 1993), TPM (Total Productive Maintenance and Management) (JIPM Solutions, 2007; Katayama, et al, 2003, 2005; Nakano, 2005)(Suzuki et al, 2001; Suzuki, 2006; 2015) born in Japanese manufacturing sector, for better performance. However, agri-business has distinctive features such as production processes in natural environment, enormous waste caused by low yield rate, products perishability, volatility of demand and also weak leadership of managers, employees' understanding, intuitions and skills. These obstacles must be mitigated as the products are the necessaries of life.

Based on the above recognition, agri-products manufacturing operations and its typical management problem caused by waste are examined on the lean platform (Katayama et al, 1996, 1997; 1999; Katayama, 1998; 2001; 2006; 2007a; 2007b). Namely, the subject consists of two types of lean activity transfer, transfer from manufacturing industry to agri-industry as an inter-industry transfer, and R&D-based business model development by focusing on loss zero-tisation, which is considered as a business functional transfer.

2 Related Studies

Aoki, R. et al. (2017) proposed a procedure constructing level production and supply operations, that is called Heijunka (Katayama, 2016), for a case agri-products manufacturing process including four major operations, i.e. seeding, germination, harvesting and shipping. The steps of this procedure are summarised by two issues as illustrated in Figure 1. Elimination of causal elements of each operation's fluctuation for realising high and stable harvest quantity. Reduction of seeding interval and seeding quantity for improving WIP characteristics (Vassian, 1955) with stable products supply that is realised through continuous flow processing. Namely, Effort on Mura (Fluctuation) elimination first by activity followed by Muda (Chronic Waste) by activity. By this way, production speed and supply timing can be synchronised with demand speed. This two-step procedure enables to eliminate or mitigate Muri (Strain), which is inter-related mutual cause of Mura and Muda.
Meanwhile, waste reduction is one royal road for obtaining leanised performance and many industrial professionals/companies have been concerned this matter. One important approach among various IE methodologies (Murata, et al, 2007a; 2007b; 2010a; 2010b; 2013) is Material Flow Cost Accounting (MFCA) (Kunibe, 2008) that intends to measure the value of all the output, particularly focusing on waste which is considered to have certain negative value. This procedure provides the methodology to evaluate positive as well as negative outcomes, however it does not provide the way to turn the negative value to positive value.

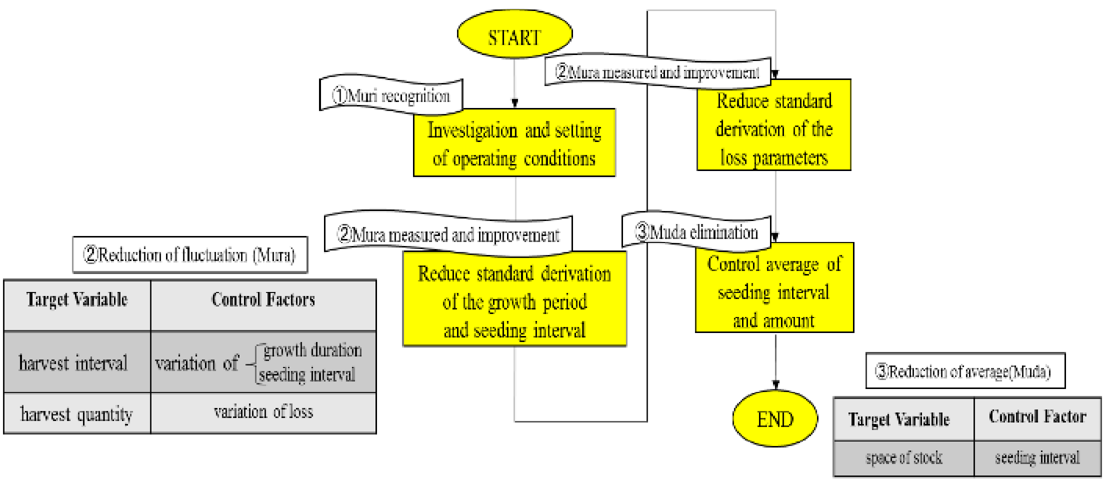

Figure 1 –A Heijunka Procedure of Harvest Quantity (Aoki, et al.; 2017)

3 Research Procedure

This paper provides following three step approach for examine the problem.

Step 1: Investigation of agri-product manufacturing process through collaboration with case commercial farms followed by model building. Medium size local farmer is selected which produces Brassica rapa var. perviridis (BRP).

Step 2: Performance analysis of the objective process by Heijunka procedure of harvest quantity. Performance of current process and Heijunka procedure assisted improved process is evaluated by simulation experiments, where entire process starts from seeding bound for delivery.

Step 3: Analysis and evaluation of proposed new business model that enable to develop new products by utilising disposed waste in the current operation. Development of new product, which is expected to have positive market value, is proposed by utilising waste (negative value) in the current process, then, overall business performance is evaluated by Portfolio graph.

4 Investigation of agri-product manufacturing process through collaboration with case commercial farms followed by model building (Step 1)

4.1 Investigation of agri-product manufacturing process

Brassica rapa var. perviridis (BRP), which is very popular vegetable among Japanese family, is selected as considered product and growing process, from seeding to delivery, is drawn as Figure 2 through interview candidate commercial farms.

From this figure, it is noticed that entire process consists of six sub-processes and four sub-process are sacrificed by turbulent factors such as germination rate, thinning rate, selection rate. Brief explanation of thinning sub-process is described here.

<Thinning operation>

Job: Removing some plants growing at crowded area

Purpose: ① Maintaining ventilation in order to protect diseases

② Concentrating sunshine and nutrition to superior plants

Expected result: Higher product quality → Better profit

4.2 Parameters of current process

Parameters affecting process performance as turbulent factors are listed here.

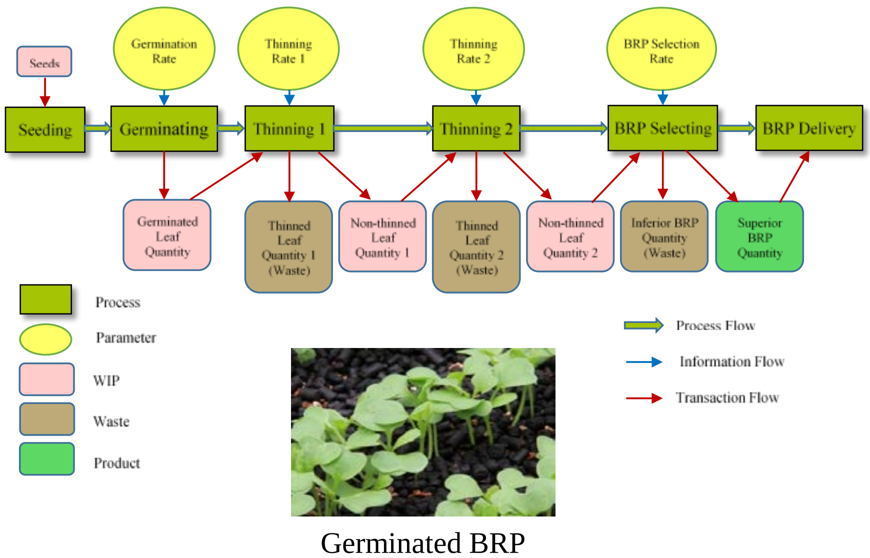

Figure 2 – BRP Production Process of the Case Company (Case: two times thinning)

α: Germination rate. Ratio of the number of germinated seeds to the number of seed scattered and its distribution is identified based on data investigation.

β_1: Thinning rate 1 (first thinning). Ratio of the number of thinned vegetable units to the number of those before thinning, where approximate seeding interval is 1 cm and new interval by thinning is roughly 3 cm. Its distribution is identified based on data investigation.

β_2: Thinning rate 2 (second thinning).Ratio of the number of thinned vegetable units to the number of those after the first thinning, where approximate interval between units is 3 cm as mentioned above and new interval by second thinning is about 5 cm. Its distribution is supposed by truncated normal distribution.

δ: BRP selection rate. Ratio of the number of delivery vegetable units to the number of those after the second thinning. Its distribution is supposed by truncated normal distribution.

5 Performance analysis of the objective process by Heijunka procedure of harvest quantity (Step 2)

Number of calculations were performed based on the Heijunka procedure described in Figure 1 and its effects were clearly observed which has the similar trend to the results in the previous paper (Katayama et al.. 2016).

Figure 3 shows an example performance of BRP production/delivery process when 10,000 seeds were scattered in the seeding phase. Obtained results provide the following suggestions.

① BRP delivery quantity, which has concrete positive market value, is only 12% of seeded quantity in average.

② One necessary countermeasure for revenue increase is growth of BRP.

③ Way of thinning must be reconsider as it eliminated amount of baby leaf.

6 Analysis and evaluation of proposed new business model that enable to develop new products by utilising disposed waste in the current operation (Step 3)

6.1 Reengineering of the agri-product manufacturing process

From the consideration of the last section, it is noticed that amount of BRP baby-leafs have been disposed. Ordinary approach in this situation will be reduction of baby-leaf waste through improvement of the way of thinning. It may contribute on reducing negative value if

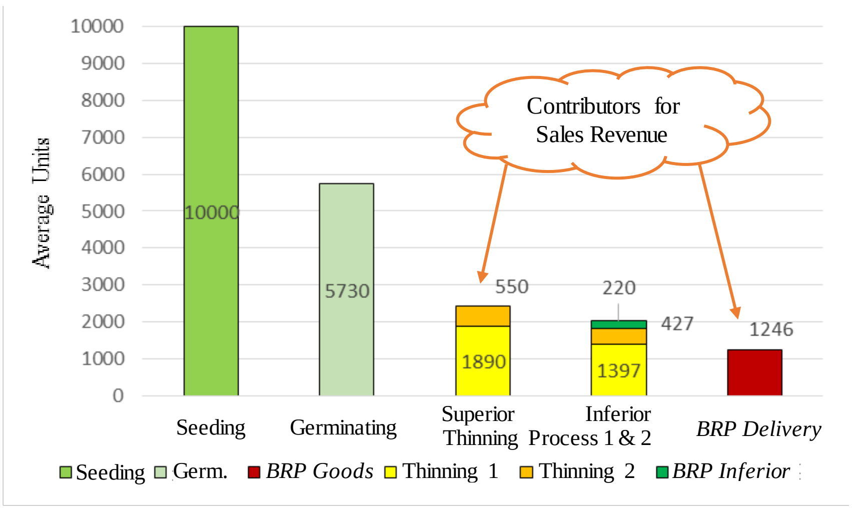

Figure 3 – Simulation Result of Production Process
(Case: New business model implementation for thinned leafs, two times thinning)

countermeasure works, however, negative value never turn to positive one. Bearing the most important lean way of thinking, the contradiction-driven approach (Katayama, 2010; 2011a; 2011b; 2012a; 2012b; 2014a; 2014b; 2015; 2017), in mind, it is a good chance for exercising aggressive thinking to change this business game (Nissan Motor Co. Ltd,; 2017).

A hopeful direction will be, seizing current prosperity of baby-leaf market world-wide (Hatake Company Co. Ltd.; 2016), imprementation of new business unit providing BRP baby-leaf to the objective market. This approach might be able to shift the waste, the negative issue, to a hopeful product that can provide positive value. Structure of the entire bisuness is drawn in Figure 4.

6.2 Parameters of objective process

Additional parameters affecting process performance as turbulent factors are listed here.

γ_1: Ratio of the number of delivery leaf units to the number of those after the first thinning. Its distribution is supposed by truncated normal distribution.

γ_2: Ratio of the number of delivery leaf units to the number of those after the second thinning. Its distribution is supposed by truncated normal distribution.

6.3 Evaluation of the new scheme

In this section, process performance of the following three cases are investigated for assuring whether aforementioned ideas are feasible and/or effective.

Case 0: No thinning operation is applied:

$$\beta_1 = 0,\ \beta_2 = 0,\ P_0 = 70,\ S_0 = 1{,}203[\times 10^3\ JPY]$$

Case 1: One thinning operation is applied:

$$\beta_1 = 0,\ 0.39 \le \beta_2 \le 0.41,\ P_1 = 100,\ p_2 = 10,\ S_1 = 1{,}083[\times 10^3\ JPY]$$

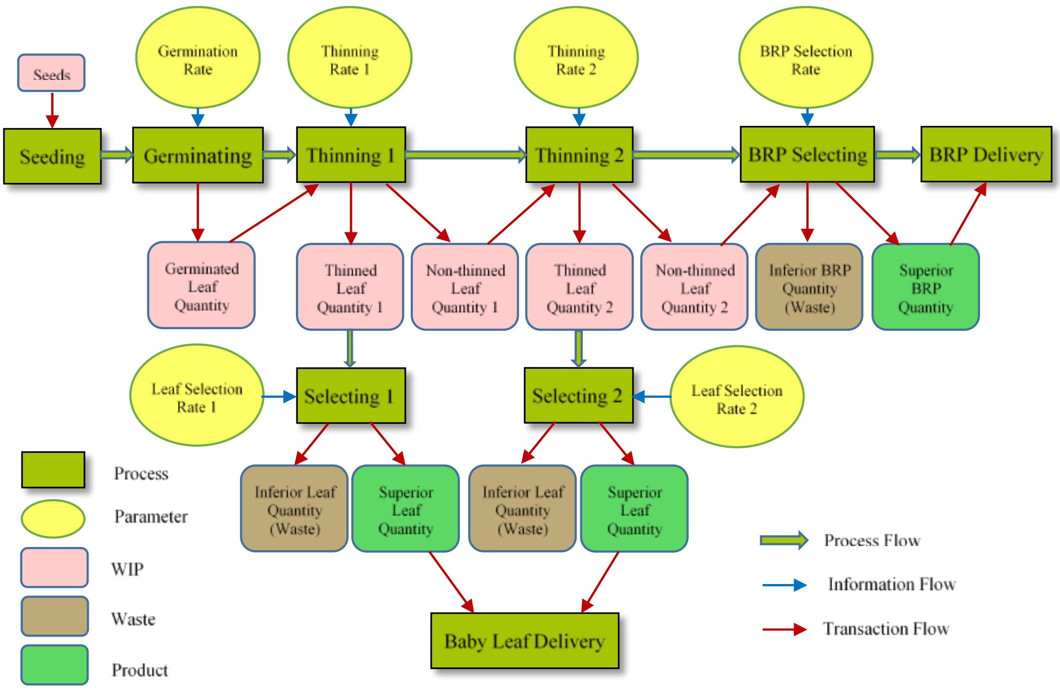

Figure 4 – BRP Production Process by the Proposed Business Model
(Case: New business model implementation for thinned leafs, 2 times thinning)

Case 2: Two thinning operations are applied

$$0.49 \le \beta_1 \le 0.66,\ 0.39 \le \beta_2 \le 0.41,\ P_2 = 120,\ p_1 = 3,\ p_2 = 10,\ S_2 = 1{,}607[\times 10^3\ JPY]$$

<Symbols>

S_i	:Expected sales revenue of Case *i*	P_n	:Unit Price of BRP
		p_m	:Unit Price of thinned baby-leaf
β_n	:Thinning rate of the *n-th* thinning ID number	*n, m*	:Thinning ID number

Where, unit price of each product was settled based on the current market.

Figure 5 illustrates Portfolio Graph of each case. Obtained results provide the following suggestions.

1. Current thinning policy, the case of two thinning operation, has the highest expected sales revenue, but it may be the most risky.
2. The case of one thinning operation is absorbed in the dominant area of the case of no thinning operation. Therefore, it has no reason to be a candidate.

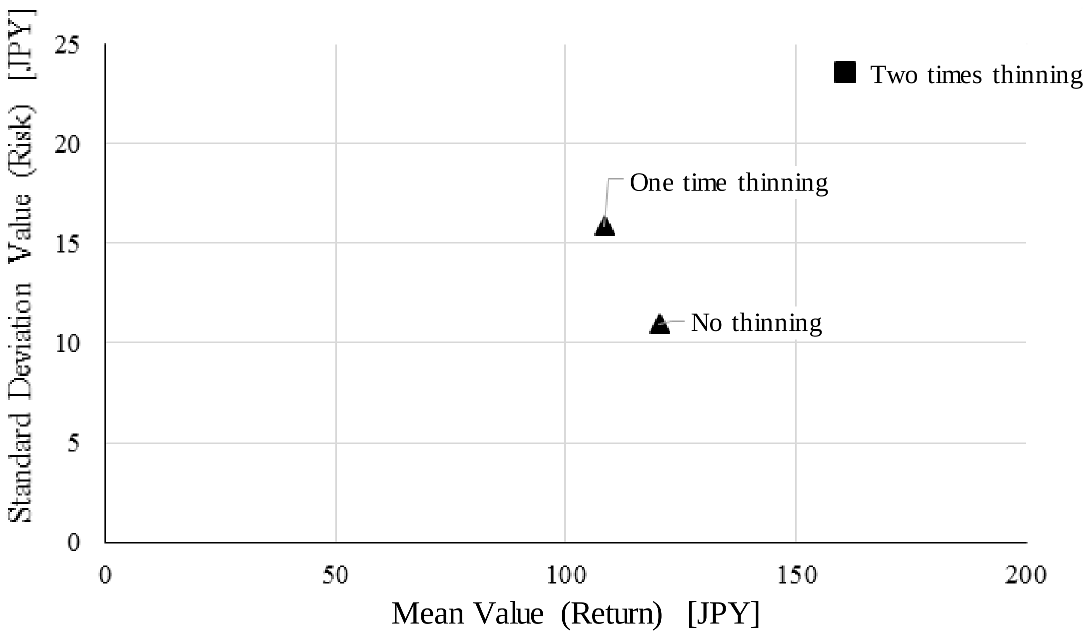

Figure 5 – Evaluation of Proposed Business Model with Thinning Policy by Portfolio Graph

7 Concluding Remarks

This paper, taking BRP production process as a case investigation, performance of agri-products manufacturing process was investigated through simulation experiments, Portfolio Graph and the concept of MFCA, where the last issue focuses on waste measurement and reduction. As waste is one of the material-originated major loss, this concept and method gets on along with lean management. By this experience, some aspects of relevant knowledge for agri-product production management is revealed. Further research topics might be evaluation of impacts of improving statistical characteristics toward overall process performance.

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How will big data and the internet of things transform distributed product-service systems in the automotive sector?

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Abstract

The connected car industry is rapidly evolving towards self-driving or autonomous vehicles. Such a rapid rate of innovation is accelerating the need for new business models, and those which are emerging are embedded in product and service innovation. The old capabilities and blueprints for competitive advantage, which were grounded in process (i.e. lean) and product innovation (i.e. design) have been radically disrupted by technological discontinuities in the form of "big data" and the "internet of things" (IoT). The purpose of this paper therefore is to explore how the global development of "connected vehicles" will lead to new product and service innovation, leveraging regional infrastructure with service delivery at the local level. A model is developed to identify the key distributed product and service innovation challenges being faced, by both incumbents and emerging actors, in the connected vehicle sector. The model is tested through primary and secondary exemplar cases. Our work is theoretically informed by transaction cost economics (TCE) and recent developments in distributed product-service systems. We make an important contribution to service innovation theory through our distributed systems focus

Keywords: Automotive; Distributed Product-Service Systems; Internet of Things, Big Data

1 Introduction

The motor vehicle of 2025 is expected to look and function quite different than it does today. It is suggested that cars will become a computer on wheels generating vast amounts of valuable data. The motor vehicle firm needs to have the infrastructure in place if it is to be able to process, analyse, and strategically learn from the data it collects. Forecasts estimate a market of 250 million connected cars on the road within the next eight years (Gissler, 2015). Consulting firm McKinsey estimates that connected car data and the new business models that emerge could be worth $1.5 trillion a year by 2030. A connected car denotes: "a vehicle equipped with Internet access, and usually also with a wireless local area network" (Swan, 2015, p. 3). There are a number of disruptive market and technological trends presumed to shape the future of cars, from a growing focus on service innovation to new patterns of ownership and the emergence of disruptive technologies (i.e. "big data" (BD) and the "internet of things" (IoT)) (Stawski, 2015).

Cars are no longer being solely manufactured for individual private ownership, but increasingly they are designed to be leased and shared between communities of users. The forecast growth in "model variants" and "personalized products" suggests a need for more user-focused innovation. However, the bulk of future market growth in the motor vehicle sector is forecasted to come from new data services, new offerings and new revenue streams rather than the traditional production and the physical design of the car itself (Swan, 2015). Janssen & den Hertog (2016) defines service innovation as follows: "… new service concepts; new forms of customer interaction; new business partners; new revenue models; a new delivery system from a market point of view; and a new delivery system from a technological point of view." (p. 99). Whilst the developments in IoT and big data[1] has created several market opportunities for incumbents, it is primarily the new entrants, such as Tesla which have seized the strategic initiative and built first mover advantage through their distinctive service innovation competences (Storey et al, 2015).

The purpose of this paper is to look at the interplay between three disruptive influences: first, the technology development of the connected car; second, the supporting regional infrastructure of "big data", "IoT" and the physical infrastructure; and third, the emergence of distributed localized services. Therefore, the connected vehicle is emerging within a distributed service model mixing global, regional and local influences and enabling factors. Furthermore, we sought to answer the research question of how these disruptive influences were impacting on the emergence of distributed service innovation within the connected car sector. To answer this question, we employ primary and secondary cases encompassing multiple tiers of the connected vehicle supply chain including: component suppliers to the incumbent manufacturer (OEM), the OEM itself and finally, its customers that provide sharing and distributed models of fleet management and autonomous vehicles. In essence, we investigated the connected motor vehicle from business–to-business (B2B) (i.e. Bosch, Tesla) and business-to-consumer (B2C) perspectives (i.e. Uber, Drive Now).

2 Theoretical Foundation

The theory underlying our approach leverages TCE (Williamson, 1981), where the most efficient interfirm contracting drives "make-buy" analysis. In situations of disruptive technological change, research has found that technology and information capabilities are positively correlated with radical innovation (Di Benedetto et al. 2008). More recent work by Williamson (2008) describes the TCE approach under non-equilibrium environments for products that are not mature, such as that faced by incumbent and emerging companies in the connected car segment. Under this view of TCE, hybrid contracting includes disequilibrium contracting in cases such as high technology innovations with few firms possessing necessary capabilities (Williamson, 2008), where in disequilibrium the TCE contracting focus is on adaptive efficacy, with the need to develop capabilities for real-time responsiveness via hybrid contracting to provide coordinated adaptation.

Coordinated adaption is necessary under increased complexity in outsourcing (Choi & Krause, 2006), where coevolution of needed capabilities arise in dynamic environments (Choi et al. 2001). In dynamic environments, network forms of organization may emerge (Powell, 1990), such as in the car manufacturing sector driving (traditional automotive) original equipment manufacturers (OEMs) into the more dynamic innovation realm of computers and high technology firms (Fine, 2000), which is a more natural realm for more recent entrants such as Tesla and Google's "Waymo project". Innovations arise with concomitant risks, and in many ways they are two sides of a coin, as risks pose opportunities where innovations may advance the state of the art in an industry. Many of the

[1] Essentially the IoT means that individual, man-made or natural, objects and interrelated collections of objects, such as in homes and cars, can be made uniquely identifiable by radio tags, sensors and actuators, and thereby become virtually represented in wireless and wired internet structures (Ashton, 2009). These services are made possible by a firm's capacity to capture and leverage high volumes of structurally diverse and high-speed data ("big data") generated by the sensors and embedded electronics of connected devices (McAfee & Brynjolfsson, 2012).

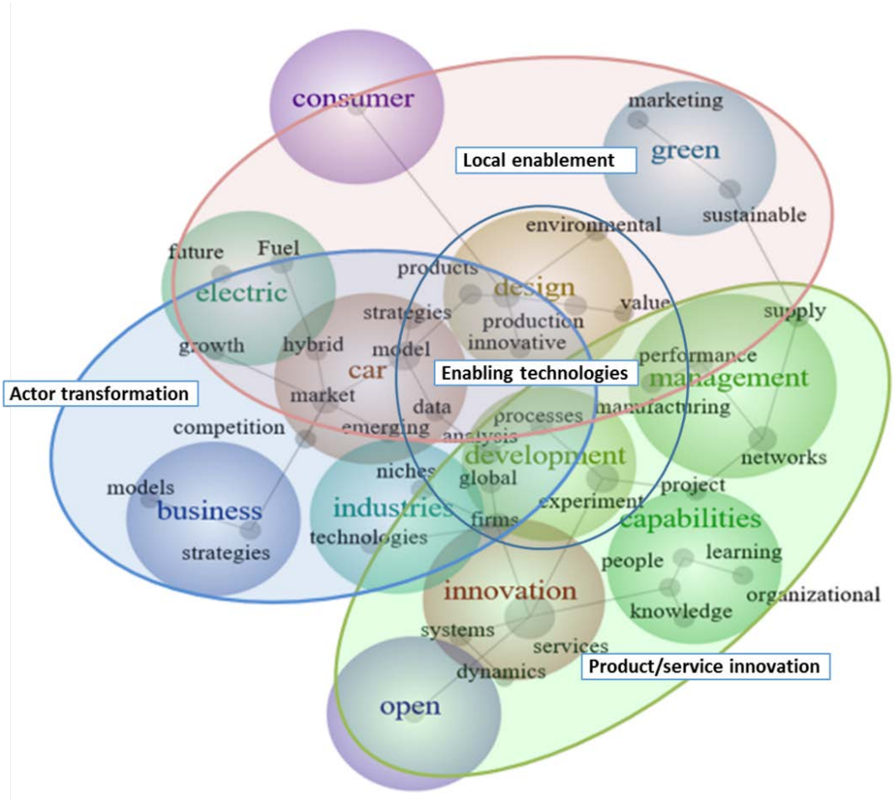

Figure 1 – Concept map identification of four literature categories

characteristics that underline TCE-related issues also provide a relevant description to the ongoing challenges confronting motor vehicle manufacturers. A recent study of key dimensions of risks in emerging industries and large scale systems (Burns, 2017) can be applied to innovation in connected cars. For example, as customer expectations and market needs evolve, the mission for incumbent and emerging firms changes to that of developing, or partnering via contracting, those capabilities needed for rapidly advancing software and hardware technology.

Perhaps a point that needs to be articulated more persistently here is that the essence of connected cars re-centres open innovation at the very soul of this movement. The traditional players are no longer the sole gatekeepers of the knowledge required for market success. By default, this new dynamic imposes on traditional manufacturers the imperatives of opening up their R&D. We take a wider view of opportunities to optimise cost structures and recognise the "economic value" of collaboration not only with economic entities such as firms but also to include consumers and the regulatory institutions for instance. We employ TCE in the context of disequilibrium (Williamson, 2008) to help illuminate the economic value of these entities to the connected cars business model while operating under market and technological uncertainty. The starting point for this discussion is how the shift in customer expectations and market needs drives the need for new business models driven by service innovation in a more open and collaborative model.

3 Topic Categorization

Using the Scopus database as a source of text files, 116 articles were uploaded into "Leximancer" (i.e. a text mining software). This software reduces article content into an interrelated "concept" map. This schematically links key "concepts" and "terms" together. This map is presented in Figure 1. The key concepts are presented at the centre of each circle. Each circle contains sub-category terms. These are all key terms linked to the top level concepts. Linkages (i.e. lines) are shown

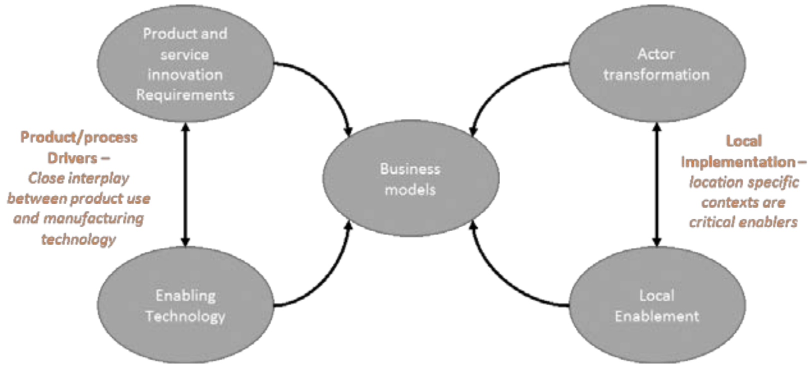

Figure 2 – Theoretical product/service innovation model for connected vehicles

between all concepts. As a rule of thumb the closer the concepts are together in the map the stronger are the linkages and the greater the likelihood that two concepts are connected together. For instance, the concepts termed: "car" and "design" had a likelihood probability of 86% of co-occurring together in the 116 articles. This likelihood of association can be used to cluster (into thematic categories) several concepts together (Roberts, 2000).

The emerging categories were cross-referenced with the distributed service modelling work of Srai et al. (2017). This confirmed the four model categories that they had previously identified whilst studying the impact of distributed services on the evolution of local production eco-systems.

4 The "2:1:2" Model

This first phase of our research resulted in the confirmation of four central model categories[2] (Srai et al. 2017). These categories included: product/service innovation, enabling technologies, actor transformation and local enablement. Furthermore, from our critical interrogation (i.e. content and thematic analysis) of the Scopus source literature, it became evident that "business models" acted as an integrative category between the four categories. Therefore, we conceptually extended the original "four category model" of Srai to five categories (which we now term the "2:1:2" model). The model is presented in Figure 2.

4.1 Product and Service Innovation Requirements

Consistent with TCE in disequilibrium environments, achieving adaptive efficacy in dynamic environments requires a strategic understanding of emerging product and service requirements from users, developers, and third parties, such as fleet services and cooperatives who are focusing on leveraging newly developed capabilities. Leveraging product and service innovation requires the recognition of shifts in incumbent and emerging player expectations, as well as user expectations, as the development of advanced automotive controls moves toward fully autonomous cars. As the level of technology increases, new technologies enable end users to move beyond infotainment – obtaining information and entertainment while driving – toward more advanced benefits such as: crash avoidance and insurance cost decreases, optimized travel routing, autonomous transport for condition based vehicle maintenance without the user driving to the repair shop, and self-parking cars after being dropped off at the airport. Users can also use travel time in a fully connected self-contained entertainment, akin to an office or entertainment centre on wheels, particularly for longer commutes and long distance driving.

[2] Hennelly et al. (2017) have also confirmed the Srai et al. model to be internally consistent, well tested and robust in digitally enhanced service contexts.

4.2 Enabling Technology

Adaptive efficacy in the connected car segment leans heavily on developing and advancing enabling technologies. Enabling technologies, such as big data, IoT and the cloud, are empowering companies to foster service innovation and evolve from goods based to solution companies. For example, IoT systems embedded in vehicles and along high volume routes enable advances on product and service capabilities, big data also enables the optimization of productive capacity with demand information (markets) (Emelogu, 2016). Technologies to balance congestion may include features already in use, such as real-time RFID scanning and rate charging for peak time premiums on local and toll roads, particularly in congested and more air-polluted urban areas, but with the ability to more accurately tune and optimize rates, with advanced over-the-air notice to end users. It also allows users of electric cars to arrive at work, plug into the smart electrical grid, and sell surplus stored energy to the grid at peak times and recharge during non-peak times at lower rates using optimization algorithms embedded across the client-server system.

4.3 Actor Transformation.

Actor transformation in disequilibrium environments is required to achieve adaptive efficacy because of the broad range of vehicle and control technologies that are necessary to develop connected cars and eventually evolve to autonomous vehicles. For example, once autonomous, OEMs are likely to work with new partners, who are new to the automotive industry, including companies such as Skype, Nintendo, Netflix, and Sky. Another example is Ford acquiring Chariot to start a bike sharing scheme that enables its customers to use multimodal transport. Today no single company possesses all the needed current and future technologies. The field includes incumbent car companies embracing advanced vehicular control and feature-driven technologies to develop future competitive advantages, while emerging technology companies boldly challenging their plans.

4.4 Local Enablement

Adaptive efficacy may also be driven to varying degrees by local enablement via consumer-driven or local government driven organizations. As innovation continues but standards begin to emerge, local enablement can then arise as an outcome of the co-evolutionary dynamics that drive differing benefits simultaneously to end users and local governments or regulatory agencies. One consumer-benefitting aspect of local enablement is that as connected cars emerge and continue to evolve into autonomous vehicles, the concept of vehicle ownership is likely to undergo significant transformation. Some users, for example may retain their own personal vehicles. Others may form ride sharing cooperatives, under which a set of users may co-own a vehicle and set up a daily time-sharing scheme, where users are on complimentary schedules such as working different shifts, or may have commonality in to-from transport points in morning and evening commutes for efficient ride sharing

4.5 Business Models

Each of these major themes identified in the study converges to influence new business models. Driven by the non-equilibrium dynamics that drive the strategic need for adaptive efficacy, we observe that business models of traditional car companies entering the connected car segment not only differ from the emergent technology driven entrants, but also from each other as their influences and decisions are driven by differing strategies, prior and current investments, and varying degrees of advances in each of the four themes. The emerging business models simultaneously influence and are influenced by their respective supply chain designs, approaches to product and service ownership models, cost models, and network partnerships, among other strategic influences.

5 Research Method

To test the "2:1:2" model empirically, a "multiple" case study design will be used in this research. Whilst not hugely popular, the case study, as a methodology is not uncommon in researching innovation in the automotive industry. For example, Cauchick and Pires (2006) investigated "modularity" regarding production and design in a company that produces trucks and bus chassis.

There were four steps in our data collection protocol. In Step One - three preliminary in-depth interviews were initially performed with the Director of Service Enablement and the Director of the IoT Cloud Platform and IoT Project Manager. This step was also supplemented with a review of 12 detailed reports on the challenges faced by Bosch and its actor network, in developing new or adapted business models. In Step Two – two focus group interviews were then conducted in 2016. The first focus group was conducted, in May, with eight IoT (Big Data) Project Managers and the second, in June, with seven IoT (Big Data) Engineers. The participants were working around the topics of: "IoT", "big data", "sensors and networks". Both groups had on average at least ten years of experience in innovative IT-projects for internal logistics, smart homes and connected cars. They were all interviewed for both their customer and business views.

For Step Three – using the KNIME analytics platform (https://www.knime.org) to support our qualitative coding analysis (QCA), we were able to identify and analyse over 4,000 tweets from Bosch, to expert actors (i.e. suppliers, dealers, trade press) participating in their immediate social network.

In Step Four – three exemplar cases of the connected car/service innovation concept were developed from secondary data sources. These cases were first reported in Graham et al. (2016) but have been significantly advanced in terms of their quality and reliability for this paper. This combined the analysis of 10 executive interview videos available on YouTube with the critical interrogation of 30 consultant and industry association reports (downloaded from the Web). The purpose of our analysis of these secondary case studies, were to broaden our insights on firms that were building their service innovation business models on connected vehicle technologies. This helped the authors to refine our initial generalisations from Bosch about connected cars and their implementation benefits.

We aimed to advance our knowledge of the constructs outlined in the model, through their thematic extension with primary and secondary data (Eisenhardt, 1989). Through the thematic interplay of data with theory we could now confirm, modify or reject parts or the whole model. The purpose of analysing the secondary case study was to draw additional insight on service innovation from broader real-world experiences. This helped the authors to refine their generalisations about service innovation and its implementation benefits. Together, the four cases represent a diversity of industries, products and market segments served.

The analysis of the case study borrowed the concepts of coding from the "grounded theory" as articulated by Strauss and Corbin (1990). Whilst machine assisted tools were used for the conceptual work, coding was conducted by hand under an overall thematic analysis umbrella. Rather than emergent phenomena the main value of the data analysis was to evidence the categories established a priori. Therefore, thematic analysis was used more as a confirmatory rather than exploratory tool. The steps described by Clarke & Braun (2013) was employed to conduct the thematic analyses and these included: (1) Familiarisation with the data; (2) Coding; (3) Searching for themes; (4) Reviewing themes; (5) Defining and naming themes; (6) Writing up.

6 Case Study Findings

We have primary and secondary case studies from our connected car research. The one we are focusing on in depth is Bosch because of its primary focus, while providing shorter insights in secondary case studies due to space limitations. The following section on the primary case reports the analysis of data collected from the company through the interviews and company documents together with external consultant reports and executive press releases (i.e. from their associated technology companies, suppliers, dealers and industry commentators).

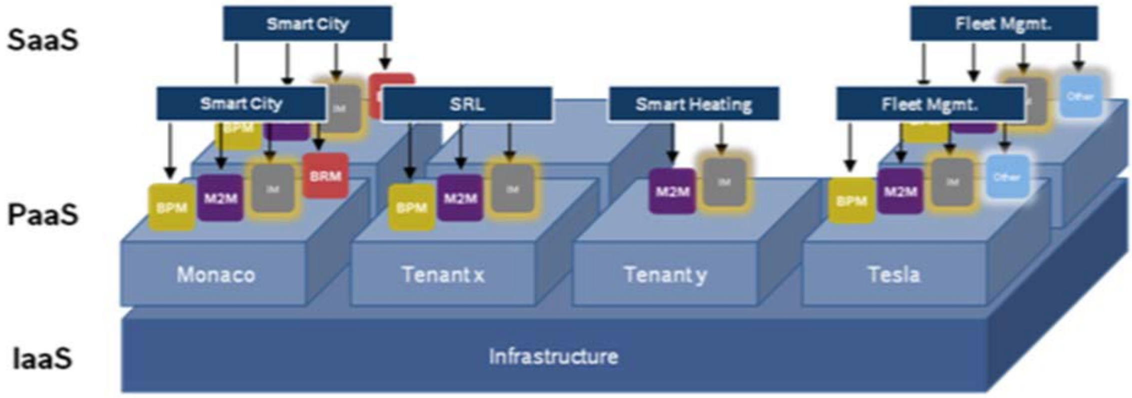

Figure 3 – BIC IoT Cloud platform

6.1 Primary Case: Robert Bosch

The Bosch Group is in the process of transition from being an automotive hardware and software supplier to becoming an IoT solutions company.

Enabling technology:

The Bosch IoT Cloud (BIC) is a project, based on the idea to provide a common platform for all Bosch products. The components provide multi-device and multi-service communication in real-time and secured access. Users pick (and pay) per service used, and the availability does not dictate that everyone has to use these services. The only exception is a common identity management component that is required to achieve a single sign on for all customers across the services operated on the BIC. It provides the following services, which are assumed to be broadly reusable when implementing IoT solutions (Robert Bosch, 2015):

- Identity Management (IM) is a component that provides the ability to manage users, their roles, relations and authorizations within multiple tenants within BIC. It provides access control and authorization to users based on their identity.
- Device Management (DM) seamlessly integrates devices with IT services based on an event-driven architecture. Devices can be integrated simply into a network, structured to form virtual systems and controlled and managed with flexibility, security, and transparency[3].
- Big Data Processing (BDP) supports the exploration and exploitation of large data sets and provides common mining, reporting and Extract-Transform-Load (ETL) functionalities.
- User Interface Management helps to create a unified look & feel for web-based user interfaces and provides lightweight integration capabilities.

Each solution can profit from the already available functionality provided by the software components (PaaS) that the BIC provides. For example, an IoT solution can choose the component to manage a complex system of things or it can be used for the purpose of provisioning updates and security patches (please refer to Figure 3). The key characteristics that differentiate the BIC from a generic Cloud Computing platform are provided by the software components. These are the fundamental for building IoT services. In the context of BIC system actors can interact directly with BIC via the public Internet, while (business) customers can access the BIC with the same "single sign on" account. Services hosted by the BIC are used by Bosch customers, suppliers and partners directly, using separate identity and access management infrastructures. From the perspective of the IoT Cloud the connections are not generally available, but limited to individual tenants, where

[3] Further details on device integration are available on the Bosch blog (blog.bosch-si.com, 2016, p.1). Please refer to the following it-sp.eu (2015) for more in depth details on IoT solutions.

Bosch itself is just one of many actors renting virtual space as a tenant beside each other tenant's in the BIC.

Product-Service Requirements:

While the business outlook for the new IoT solutions is very optimistic, it includes significant key challenges for Bosch:

- IoT solutions generate large quantities of data that need to be processed and analysed in real time .
- The Cloud is deployed and operated by customers outside the Bosch communication network (Robert Bosch, 2015). This can lead to enhanced security and privacy challenges.
- Partners and end users bring their own identities that are typically not managed by Bosch. They often want to reuse these identities across different solutions. This can challenge and even undermine the firm's authentication and authorization protocols (Robert Bosch, 2015).
- A fast-moving market environment requires quick responses thereby minimizing time-to-market for new IoT solutions down to a few months.

Bosch have developed the BIC platform as an attempt to address these challenges, and to improve the lead time to market for their new IoT-service solutions. There was a consensus amongst the IoT Project Engineers, that the BIC is allowing Bosch to potentially monetise its entire IoT offering, through the adoption of block-chain transaction software (Blockchain, 2017). Each software solution is isolated from other solutions and bound to the tenant of each customer. This is also true when the very same solution (with a different configuration) is operated by another customer, such as illustrated by its smart city and fleet management solutions. Any software component obtained from third parties can also be operated by the BIC.

Actor Transformation

At a strategic level, Bosch recently announced a strategic collaboration with Mercedes to develop self-driving car systems. Such collaborations will enable the firm:

> "*... to develop new revenue streams from integrated services and shift our focus to creating long-term customer relationships and selling technology solutions*." (Director of the IoT Cloud).

Actor Transformation - Consumers' View

The usage of the BIC from a consumer perspective starts prior to purchasing the IoT solution. It is necessary that Bosch (or a contracted logistics service provider) uploads the latest software prior to shipment to make sure that the customer receives the latest version of the product. At this time, access to the BIC and the available services for the product are granted and made available to a customer to be ready for use when the device is installed by the user. Ownership "claiming" is the first personal interaction of a consumer with the BIC. It can be performed via the web or via a smart phone, e.g. by scanning a bar code and relates the Cloud with the end user and provides access to the services hosted by the BIC.

Local Enablement

The distributed service innovation model associated with Bosch's is focused on localizing production and the supply chain. For instance, service innovation based on relations between Bosch and Mercedes in Germany is very different say to that of Bosch with actors in India and with actors in the US such as: Chrysler, GM and Chevrolet. In other words, increasingly in the car industry service innovation modelling is configured geographically. Bosch have also been localizing its manufacturing production recently in North America and India. This is due to differences design and manufacturing role allocated by Bosch to local suppliers and/or mobility operators. The power given to local actors in the automotive supply chain impacts determines the level of distributed services provided by Bosch (Srai et al. 2017).

Business Models

The IOT project engineers showed a coherent view about the values for the Bosch as a whole company: "The merits of such a BIC would not only generate benefits for a single project, but for all parts of the organization". The group sees it as enabler for "true" Internet of Things instead of the several isolated solutions that are currently built in single projects without reusability and standardization. They argued with a "common space" where products can be connected across business sectors through a single BIC. The group members actively started to create and discuss useful combinations for BIC and its benefits. They were searching for a use case, which could connect several Bosch products. Typical observations included the following:

> "*The connected car (Bosch Automotive Sector) can inform a smart home (Bosch Consumer Products) solution that you are about to arrive. The smart home solution turns up the heating (Bosch Household appliances) at home and communicates with the block heating solution which is installed in the community so that another home will start consuming a certain amount of heat energy in the next 20 minutes. This message is used for production planning by the block heating solution*." (IoT Project Manager)

6.2 Secondary Case Studies

Table 3 illustrates the interface between service innovation characteristics of the emerging business models across the three cases. In the case of Tesla, the service operations output is multi-faceted because Tesla provides a service offering based on a product, namely the vehicle that is sold directly to the customer with no intermediaries (i.e. dealers). Tesla's service uses big data to understand, maintain and also improve vehicle functionality in line with customer expectations. It maintains vehicle functionality by collecting diagnostic data on individual vehicles, and it improves vehicle functionality by aggregating driving data to understand driving conditions and vehicle performance, optimal locations are for charging stations. These cases illustrate the importance of on-going relationships with customers, rather than ending the transactional interaction at the point of sale.

In terms of enabling technologies these are software-based, they are not constrained by time and space in the same way as a tangible product. Updates to the service can easily be applied without physical presence or a mutually agreed time. One particularly noticeable trend across the three secondary case studies is therefore that of producing minimum viable products. This means that instead of delivering perfected products and services to customers, the company determines what is the minimum viable level for the service to work, produces that and then tweaks and perfects its service offering based on how it is going to be used and perceived by customers.

The concept of actor transformation is evident with Tesla allowing its customers to use unfinished products is novel in the automotive industry. With feedback loops and real-time monitoring enabled by big data, the customer becomes part of the service improvement process. It enables companies eventually to deliver exactly what the customers want. Tesla is a key example of this. Its major software updates (new, improved features) are released on a yearly basis, while minor updates (bug fixes) are released on average every month.

For Uber, flexible capacity is achieved by not employing its drivers or owning a fleet of vehicles. Demand and supply are managed by "surge pricing". For DriveNow, service capacity is constrained by the size and functionality of the fleet; if customers do not find a car available in a suitably close location, the service is of no value. Flexible service provision is therefore enabled by deploying a large fleet and a small team of service agents who check tyre pressures, clean the cars and move them to more popular locations if necessary. Supply and demand are managed through incentives for customers to park in optimal locations and incur fixed pricing. For Tesla's service delivery, flexible capacity is configured by designing the vehicle from the ground up to ensure that features can be updated safely via software updates over time. However, Tesla also has to manage the constraints of producing hard products vehicles and is constrained in the usual way for the manufacturing side of its product-service systems.

Table 3 - A comparison of the three cases across the different model categories

Category	Tesla	Uber	DriveNow
Business Model	Luxury high performance electric vehicles and high quality service.	Mobility service in urban environments.	Self-distributing vehicle hire and rental car sharing service.
Product/ service requirements	Direct service to the customer. Application upgrades and system monitoring.	Digital ride hailing taxi service. Flexible price system. Drivers and riders have account profiles so that potential partners can view reviews and feedback. Real-time data usage	Business users niche segment – private/public multi-format city mobility. Efficient premium vehicles and comprehensive service.
Enabling Technology	Electric vehicles serviced by Private Tesla cloud. It brings vehicle analytics and all front- and back-office functions into a single platform Tesla is able to monitor the car's critical system components and pre-emptively alert drivers to maintenance issues. Quality QA and R&D/open source technology	A more sophisticated algorithm than its rivals that provides better driver/ customer matching system and mileage/fare calculation that yields consistently positive user experiences. Uber keeps launching new features, including Uber pool, enabling booking or large cars, etc, which has been blindly followed by many of its competitors.	DriveNow application on smartphone, tablet or computer to locate and reserve a vehicle. Each vehicle is equipped with an embedded SIM that transmits key vehicle data to DriveNow's back office systems. The data from each car are small in size and transmission only requires 3G and 2G networks. Not only does the 'service area' map show currently available cars, but also cars that are becoming available shortly.
Local enablement	Service capacity is managed locally by Tesla and is based on city demand-led requests for service, giving the local dealer more control over its fleet.	The localized application integrates the smartphones' GPS locations with 3G or 4G cellular network so that a suitably located driver can be requested for a ride by the potential rider.	Fleet of over 4,000 locally based vehicles in 15 countries.
Actor transformation	Direct to consumer – Tesla allows customer to buy a car over the web CAAS model, and save time and money by skipping the middleman. Simple application updates – Customers can treat a Tesla car as an App that can be upgraded on the fly when bug or better algorithms are found. Personalization – Customized experience for different drivers with car seat, climate control, and other features etc.	Outsourced fleet of drivers (using their own vehicles) managed through a real-time digital platform. Uber's marketing strategy has always been innovative and closely related to popular culture,	Vehicles may be hired and dropped off wherever the customer needs them, thus clearly differentiating DriveNow from products offered by other competitors. Integrated intermodal software format enabling consumers to switch to public transport or other car sharing services depending on traffic situations (i.e. in Copenhagen, the DriveNow service is integrated into the public transport app - Rejseplanen.

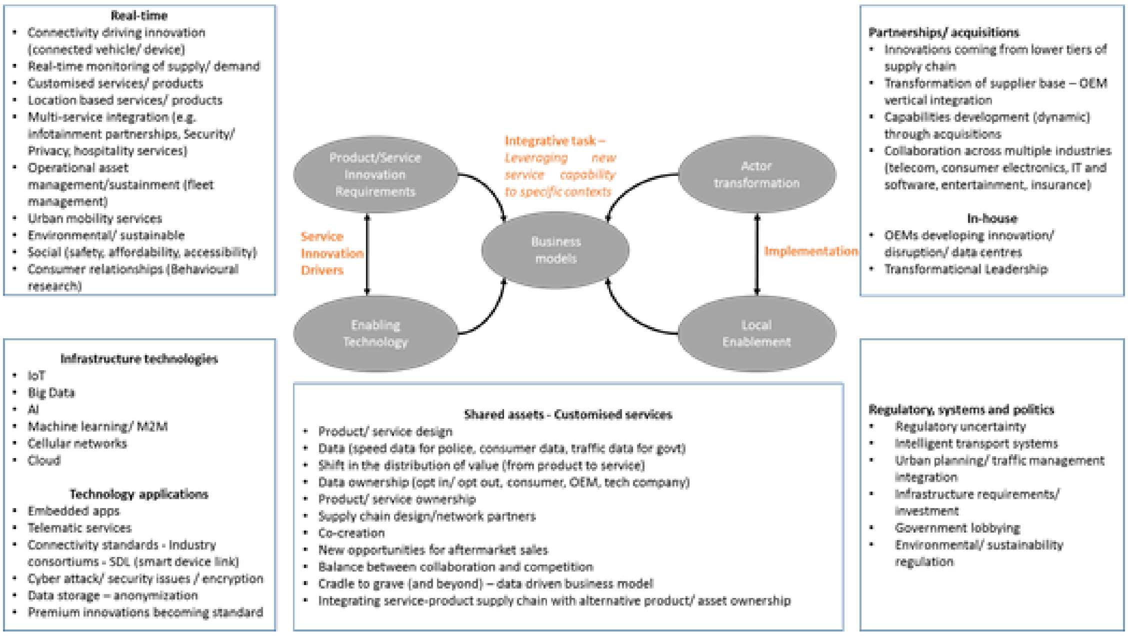

Figure 4 – Advanced product/service innovation model for connected vehicles

7 Discussion and Advancement of the Model

Figure 4 below summarises the insights from our case observations. The analysis builds on the categorisation of service innovation drivers and enablers emerging from thematic text analysis following the systematic review of the literature (Figure 1). Each of the category constructs are summarised (text boxes in Figure 2) and suggest the generalisability of the case and literature observations. For brevity, we do not repeat here in the paper but rather comment on the interrelationships between the five constructs.

Firstly, we observe that the connectedness of service and technology constructs is evident and suggest that service-product technology developments must be undertaken jointly, often at specialised centres of expertise, far from being dispersed activities. For example, the integration with smartphones is becoming key to offering infotainment value services to the consumer.

Secondly, we observe that service innovation requires transformational leadership roles married closely with both hard and soft infrastructure development. The need for incumbent OEMs to partner with new firms from a variety of sectors, to provide new services to the consumer is inevitable. Furthermore, for urban mobility a progressive institutional environment is essential to realise the potential of the connected car. i.e., having city regulation permissions processes speeded up to enable efficient car sharing.

Finally, execution in the field requires the development of the Advanced product/service innovation model for connected vehicles. Where integration of service-product technology, local hard/soft infrastructure and institution capability and capacity building requires a significant level of whole system integration. For example, in Figure 4, the DM business model represents the integrative task leveraging new capabilities, often developed at specialised centres, with specific contexts providing a distributed execution capability.

8 Conclusion

The purpose of this paper was to develop and test a distributed product-service model pointing at key challenges for incumbent OEMs in the car manufacturing sector. The research presents a detailed in-depth primary case which explored the impact of the emerging service innovation ecosystem in the car industry, along with supporting secondary case studies. Based on this research, it is argued that for an IoT, big data-enabled service innovation to develop, such as Bosch's BIC, there needs to be overlapping processes and integration between networks that previously had little or no interaction.

8.1 Theoretical and Managerial Contributions

Our main theoretical contribution comes from the focus on distributed product-service innovation at the OEM level. We have advanced and tested an initial categorization model proposed by Srai et al. (2017). The analysis demonstrates the challenges facing automotive OEMS of the need to take global concepts such as the connected car and implement them at the local level (Gissler, 2015).

We contend that the service innovation discipline needs to re-orientate its focus from global organizational perspectives (Kang & Kang, 2009; Lichtenthaler, 2013 Randhawa et al. 2016) towards the local enablement of distributed service concepts (Srai et al. 2017). The car industry demonstrates that local OEMs and suppliers are increasingly pressurizing the automotive MNCs (multi-national corporations) for autonomy in service innovation and product development at the city and town levels of production (Swan, 2015).

This paper demonstrates that the rapid rate of innovation cannot be solely captured by any one organization (Janssen et al. 2015; Perks et al. 2012). Since the industry is currently in disequilibrium due to the pace of innovation we have provided evidence supporting Williamson's (2008) argument that organizations employ adaptive efficacy as the dominant mode of TCE during dynamic environmental conditions. This way of thinking paved the way for us to rethink the "boundary of the firm" in the context of connected cars and allowed us to conceptualize a business model that draws on TCE under high degrees of environmental uncertainty.

This study revealed that one of the key managerial challenges is that the IoT/ Big Data is often treated as "knowledge" when in fact there are transformative processes and advanced data analytics that are required to make this data "useful". The capabilities of organisations in extracting knowledge and intelligence from raw IoT Data will increasingly become a core competence for organisations.

8.2 Future Research Directions

Much research remains to be done in service innovation in emerging and complex supply chains., and three types of research are particularly required. Firstly, more research is needed to develop and validate the model to link IoT with changes in service innovation models in different types of organisations. This will require both theoretical and empirical research.

Secondly, new research is particularly needed to gather detailed evidence on real life examples and industry best practices of using the IoT to enable the transformation of existing operations models and the development of new operations models in different sectors and domains, and explore lessons that can be learnt from such cases. This will enable us to develop deeper understanding of the opportunities and challenges involved, and use emerging new capabilities of the IoT to facilitate transformational changes in operations models; and articulate and measure the strategic values that can be derived from such changes.

Finally, the risks involved in emerging and complex supply chains - the dark side of IoT service innovation - should also be systematically examined. This research area to date has received sparse attention from the academic literature

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Exploring actors, coalitions and institutions influences for developing supply network capabilities

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Abstract

The purpose of this paper is to explore the influences existing within the supply network relating to policy interventions and capabilities. In the study, we have investigated the relationship between supply network capabilities and government policy interventions under the bi-directional influences existing within the network. The multidisciplinary nature of the study, drawing on previous work from diverse fields of knowledge, including manufacturing and policy, provides new perspectives on the relationship between supply network strategic design and policy interventions development. The study addresses a significant gap in manufacturing theory and practice, specifically the development of government policy interventions through supply network actor coalitions in the context of actor influences. The key question is how policy interventions and network capabilities are linked to actor and institutional influences? Case study approach is developed and multiple respondents from government, industry and business coalitions are interviewed conducted in different countries. Result involving cross-case analysis is done that exploring policy interventions and their implications on supply network capabilities. It was found out that there is a significant presence of bi-directional influences existing amongst supply network actors and related institutions. These influences results in policy intervention design and developing network capabilities.

Keywords: Supply Network, Influences, Policy, Capabilities

1 Introduction

Actors and coalitions exist in policy sub-systems that shape the policy outcomes (Sabatier & Jenkins-Smith, 1993). The coalitions are formed across the industrial structures based on shared policy goals. Much of the literature on coalitions from a policy perspective is available in the political economics. Governments often tend to classify industrial actors based on several indicators such as value chain, firm size, technology levels, location, etc. Value chain analysis is used in classifying the sub-sectors in the industry (Kaplinsky, 2000; Gereffi & Memedovic, 2003). Actors, especially those within the supply network, often involve in exchange, co-development or sharing of capital, technology, assets and other expertise and resources with other companies (Harrigan, 1988). From a strategic perspective an 'alliance' or 'coalition' is usually formed to formalise the relationship between actors. Strategic management literature considers 'firm resources' and 'network resources' for the aims of coalition formation. (Gulati, 1999; Eisenhardt & Schoonhoven, 1996; Chung et al, 2000; Ellram & Cooper, 1990). Gulati (1999) specifically compared network resources and alliance formation among network actors.

Table 1 - Policy Interventions (adapted from Ghani and Srai, 2016)

Policy Interventions Categories	Evidence from Theory	Evidence from Practice
Education, Information, and Awareness	Cimoli et al. (2009); Lall (1992)	• India • Bangladesh • Vietnam • Mexico • Germany • United Kingdom
Institutional Collaborations	Rodrik (2008); Keele (2007)	
Improving Productivity and Competitiveness	Kurgman (1994); Rodrik (2004); OECD (2010).	
Regulations, Deregulations and Liberalisation	Lall (2004); Gupta (1983); Gunningham et al. (1997); Lenox (2006)	
Natural Resource Exploitation	Hart (1995); Asiedu (2006)	
Technology Upgradation and Innovation	Branscomb (1995); Narula (2014)	
Establishing Macro-Economic Stability	Rodrik (2008); Suzigan (2006)	
Attracting Foreign Direct Investment	Branstetter (2006); UNCTAD (2011)	
International Trade Facilitation	Leonidou (1995); Bhagwati (1998)	
Infrastructure and Capacity Enhancement	Porter (1998); Rodrik (2008)	
Compliance and Sustainability	Hall (1993); Weiss (2000); Ahamed (2013)	
SME and Regional Development	Ceglie (1999); Irwin et al. (2010)	

There are different kinds of interplays within the relational framework of coalitions and institutions. Building new capabilities or enhancing existing ones are the primary objectives for the existence of such influences in the network landscape. Dependence of state institutions for large network actors and coalition for insight into resources and network-based learning is significant for designing policy interventions. This phemnonemn is explained by (Czinkota, 2000) and also in policy literature as a case of 'knowledge spill-overs effect'. The interaction of network actors and state institutions becomes important especially from smaller actors. This is where 'infant-industry support' argument is presented by several economists and industrial policy experts. These actors rely on government policy support. However, limited resources and sub-optimal relational capabilities serve as barriers in connecting with the government (Hadjikhani & Ghauri, 2001). Therefore, coalition approach is preferred by small supply network actors.

2 Approach

The level of supply network actor relationships with policy institution can be an influencing type (Morash & Lynch, 2002). These relationships can be proactive or reactive. Partnering and interdependence is a proactive approach (Freeman, 1998). Pekkanen et al. (2014) presented proactive advocacy as to enact a new policy, while arguing that the reactive one should be adopted in stopping or modifying a government policy. It will be interesting to see how influences are related to policy and supply network capabilities. The focus here is on an 'industrial policy' that impacts network capabilities. Therefore, it is essential to have a broad set of network capabilities that are significant to firms and the government. This selection process is done through literature and an in-depth exploratory study. The key supply network capabilities, used for investigation are Supply Network Connectivity (Bauer et al., 2001; Barratt, 2007), Total Network Efficiency (Kavanagh, 2002), Supply Chain Process Improvement (Rich, 1997; Bititci 1997) Product and Service Enhancement [PSE] (Szakonyi, 1994). There are different institutional mechanisms and processes to develop policy for the industry. An attempt to categorise policy interventions are made by several policy advocacy bodies and practitioners. However, an attempt to categorise policy intervention was made by Ghani and Srai (2016) into 12 categories (Table 1).

3 Case Investigations

In-depth investigations were conducted in Pakistan's textile industry (Table 2). This was a particular case where the dimensions of enquiry, (both on policy system and supply network), are not captured by any existing frameworks. 'Influence mechanism' is defined as the unit of analysis of the research

Table 2 - Cases

Actors/Coalitions	Type
A	Ginning company, BCI compliant
B	One of the largest synthetic fibre manufacturer in Pakistan
C	Among the largest textile composite groups
D	Among the top 3 largest composite groups in Pakistan
E	Among the top five largest textile groups in Pakistan
F	Oldest and among top five textile groups in Pakistan
G	Top garment manufacturer in Pakistan
H	The largest domestic market textile company to Pakistan
I	Largest garment company and supplier to UK/USA markets
J	Among the top five garment companies to serving UK/USA markets
K	Textile service providers and supplier, (machinery, consultancy, and chemicals)
L	Largest garment manufacturers association representing > 1000 companies
M	The largest textile association, representing spinners and weavers > 400 business groups
N	An association representing ginning industry

and applied to the policy system and the supply network. Insights gained through fieldwork, interacting with policy practitioners and direct observations of policy development processes were used in the investigation. Both, Pakistan's first and second national textile policies were particularly investigated. Case interviews were held with CEOs of top textile firms and head of business/trade associations. A panel study was also conducted with leading policymakers at Cambridge to capture policy-related challenges and processes. The capability development initiatives CDIs are captured from the policy interventions relating to the textile industry.

A comparison of supply network capabilities and policy intervention about the CDIs is given in Table 3. The shaded cells in the table give the 'Significant Capability Development Region' against a policy intervention category. Investigating actors coalition and their influences for the CDIs, a comparison is developed between the influences and supply network capabilities and is shown in Table 4. The CDIs are ranked to their importance across various dimensions of the policy system.

4 Discussions

The Supply Network Capability that is related to Government Proactive influence is the Product Service Enhancement. This observation reveals that network actors are not sufficiently investing in new Product and Service Enhancement, including R&D Efficiencies and New Product Development, without a proactive government support. Internal network mechanisms as argued by several authors such as Ucler (2017), Hong and Hartley (2011) and Choi and Hong (2002) may not be significant in this case in product service enhancement. Macroeconomic policies often play significant part in financial and banking sector (c.f. Lindgren et al., 1996), however, from a supply network perspective, it is insightful to understand how different economic instruments and levers shapes the level of product and services. The capabilities development initiatives under the policy intervention category of Establishing Macro-Economic Stability mostly relates to providing fiscal support and tariff protection to firms. Perhaps, these measures enhance liquidity, which may allow firms to improve their product and services further as argued by Fagiolo and Luzzi (2006) for Italy and Ojeka (2011) for Nigeria. However, such policies, if not formulated appropriately at a Network level, may have a significant impact on market price distortion of the product as evident during the case of R&D support mechanism on textile industry in Pakistan. It is also noted that the Government proactively supports Supply Chain Process Improvement while supply network actors are rather reactive to such a policy influence. The reactive nature corresponds to issues revolving around the Network transparency.

Table 3 - Policy and Supply Network Capabilities (continues)

Policy Intervention Categories	**Supply Network Capabilities**			
	Product Service Enhancement	**Supply Chain Process Improvement**	**Supply Network Connectivity**	**Total Network Efficiency**
Education, Information and Awareness	Upgradation of technical training and engineering, design and fashion institutes	Policy Information dissemination: workshops, printing and seminars throughout the country.	Government consultations with industrial coalitions on zero-rating of exports.	Financial support in hiring of foreign teaching/research staff and foreign consultants
Institutional Collaborations			Market-related interventions for Man Made Fibre manufacturing	Consultations with trade associations for Man Made Fibre supply. Consultation with trade associations for tariff rationalisation
Improving Productivity and Competitiveness	developing strategies to enable the technological shift from traditional looms to high-speed weaving machines		Establishing protocols for the servitization of Ginning sub-sector	
Regulations, Deregulations and Liberalisation	Enforcement of Cotton Control Act and Cotton Standardization Ordinance		Public-private partnership in the infrastructure development of textile industrial hubs Zero rating of exports and drawback of local taxes for exports orientated manufacturing	Analysing regulatory bottleneck faced by the industry across the value chain
Natural Resource Exploitation	Increase cultivation of BT-Cotton in targeted regions Encourage Organic Cotton Cultivation			Strengthening existing Cotton Grading system through institutional mechanisms Encourage product diversification using natural fibres
Technology Upgradation and Innovation	Upgradation of outdated Ginning Machines Specifying machine types for new investment in fabric manufacturing R&D support to universities and research centres in new product development	Establishing of e-commerce platform for textiles		Technology upgradation scheme for existing manufacturing setups
Establishing Macro-Economic Stability	Rationalisation of tariff structure. Refund of R&D support claims. Monetisation of PTA.		Export refinance scheme	Zero-rating of exports Restructuring of long-term loans Drawbacks of local taxes
Attracting Foreign Direct Investment	Incentivising foreign direct investment in BT cotton and organic cotton production		Incentivising merger and acquisition Incentivising joint ventures in textile industries	
International Trade Facilitation	R&D scheme on export		Initiation of free trade agreements and preferential trade agreements in the major markets	Reimbursement on local taxes for export products

Policy Intervention Categories	Supply Network Capabilities			
	Product Service Enhancement	Supply Chain Process Improvement	Supply Network Connectivity	Total Network Efficiency
			Support for branding, grading and labelling of value-added products Marketing insurance scheme	
Infrastructure and Capacity Enhancement	Developing new technical training institutes through public-private partnerships	Schemes for warehousing, storage and marketing Establishment of Textile and Garment Parks/Cities Establishment of a new Ginning Institute and strengthening of research centres		
Compliance and Sustainability			Support for international social and environmental compliance certifications and audits for firms	
SME and Regional Development	R&D support and establishment of product development in carpet manufacturing	Women employment support programme Support for companies employing disabled people.	Incentivising joint ventures in allied industries: machinery, dyes/chemicals and accessories	

Table 4 - Supply Network Capabilities and Influences

Supply Network Capabilities	Government Reactive – Industry Proactive	Managed	Government Proactive – Industry Reactive
Product Service Enhancement	Upgradation of technical training and engineering, design and fashion institutes Supporting narrow-width processing and knit dyeing Rationalisation of tariff structure Refund of R&D support claims Monetization of PTA R&D scheme on export	R&D support to universities and research centres in new product development	developing strategies to enable the technological shift from traditional looms to high-speed weaving machines Enforcement of Cotton Control Act and Cotton Standardization Ordinance Increase cultivation of BT-Cotton in targeted regions Encourage Organic Cotton Cultivation Upgradation of outdated Ginning Machines Specifying machine types for new investment in fabric manufacturing Incentivising foreign direct investment in BT cotton and organic cotton production R&D support and establishment of product development in carpet manufacturing
Supply Chain Process Improvement	Schemes for warehousing, storage and marketing Establishment of Textile and Garment Parks/Cities		Policy Information dissemination: workshops, printing and seminars throughout the country. Establishing of e-commerce platform for textiles Establishment of a new Ginning Institute and strengthening of research centres Women employment support programme Support for companies employing disabled people.
Supply Network Connectivity	Market-related interventions for Man Made Fibre manufacturing Public-private partnership in the infrastructure development of textile industrial hubs Zero rating of exports and drawback of local taxes for exports orientated manufacturing Export refinance scheme Initiation of free trade agreements and preferential trade agreements in the major markets Support for branding, grading and labelling of value-added products Support for international social and environmental compliance certifications and audits for firms Incentivising joint ventures in allied industries: machinery, dyes/chemicals and accessories.	Establishing protocols for the servitization of Ginning sub-sector	Government consultations with industrial coalitions on zero-rating of exports. Incentivising merger and acquisition Incentivising joint ventures in textile industries Marketing insurance scheme
Total Network Efficiency	Consultations with trade associations for Man Made Fibre supply Consultation with trade associations for tariff rationalisation Specifying high productivity spinning machines in the Technology Upgradation Scheme. Analysing regulatory bottleneck faced by the industry across the value chain Zero-rating of exports Restructuring of long-term loans Drawbacks of local taxes Reimbursement on local taxes for export products	Financial support in hiring of foreign teaching/research staff and foreign consultants Strengthening existing Cotton Grading system through institutional mechanisms	Encourage product diversification using natural fibres Technology upgradation scheme for existing manufacturing setups

It is also observed that, the most significant interventions under Supply Chain Process Improvement relates to Infrastructure and Capacity Enhancement, and are promoted by the industry. Infrastructure projects such as establishing economic development zones and industrial cities, significantly enhance manufacturing capacities and enable economies of scale. Such economies of scale are discussed from an industrial organisational (Ellram, 1991), process (Shah, 2005) and risk (Chopra and Sodhi, 2004). This investigation explores the significance of infrastructure development from supply network capability perspective. Both network capabilities relating to Supply Network Connectivity and Total Network Efficiency exhibit Industry Proactive influence. However, many initiatives under Network Efficiency are 'Managed'. The significant intervention category relating to the capability cluster of Supply Network Connectivity is the International Trade Facilitation. The key Capability development factor involves the initiation of free trade agreements or preferential trade agreements with other countries, supporting technology spill-over through incentivising M&A, financing exports on easy terms, etc. Total Network Efficiency significantly relates to the intervention category of Establishing Macro-Economic Stability. Other key interventions involved in this capability include Natural Resource Exploitation and Institutional Collaborations. Analysing a particular case of Total Network Efficiency, it was evident through the case study that firms deploy supply-side measures (raw material and technology), demand-side measures (export financing and tariff rationalisation) and operational efficiencies (engaging consultant), to enhance product quality and lean process implementations. In a nutshell, supply-side measures are government proactive influenced.

It is observed that the network actors exhibit reactive policy influence on those supply network capabilities mostly related to functional level performances. Firms often hesitate to seek direct government support that risks their business confidentiality. Establishing trust through information security between government and industry plays a key role in this. The study research also shows that the established link between policy interventions and supply network capabilities may serves as a key informational resource for designing supply networks involving different policy systems i.e. involving different countries or regions.

5 Conclusions

This study draws on the literature of development studies and manufacturing to build investigative framework for a case study analysis. The case study is performed in textile sector industry due to its dynamic international supply chain with significant social, economic and environmental implications, particularly in developing countries demanding critical government policy considerations. Different industrial policies of countries including India, Pakistan, Bangladesh, Sri Lanka and Mexico are reviewed and policy interventions are categorised to compare with the supply network. A total of four network capabilities were selected for analysing the relationship with the policy. Case studies were carried out in Pakistan, selected as a country where textiles manufacturing is the most significant industrial sector of its economy, and is ranked amongst the leading textile manufacturing and exporting countries across multiple product categories. The information, gathered through primary and secondary sources include reports, policy documents and interviews from leading industry leaders, association heads and government policymakers. Each capability development initiatives identified through policy directives are analysed for their relationship to supply network capabilities, influences and government policy interventions.

The significance of actor coalitions and influences is evident whilst examining the relationship between supply network capabilities and policy interventions. Industrial actors proactively propose policy interventions and push through the policy system to attain specific supply network capabilities. Information on influences are captured and highlighted during the case studies for each capability development initiatives. Furthermore, a pattern emerging from tabulating the relationship between policy and supply network capabilities indicates a schema of the national industrial landscape in the context of building supply network capabilities. This result has two key implication both for network actors and the government. Firstly, it gives a strategic direction to the industrial coalitions engaging with the government to present policy proposals on enhancing supply network capabilities of the industry. Secondly, government policymakers could understand which policy interventions they can focus to enhance particular network capabilities of the industry.

The bi-directional in nature of influences of supply network actors and coalitions impacts policy system. Government policies can significantly impact the structure and capabilities of manufacturing supply networks. Equally network capabilities are linked to supply network actor coalitions, and their policy influencing dynamics are in-part determined by the given configuration structure in which they operate. The finding suggests that these bidirectional supply network – government influencing mechanisms can have profound implications for the strategic design of supply networks and policy interventions. Different Understanding such influences in the context of a policy system and network strategic design can lead to a focused policy development. Furthermore, the alignment of capability development initiatives on network capabilities can give a guiding principle to the government intervention mechanism for drafting an industrial policy.

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