Travel behaviour applied in freight transportation using intelligent products

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***Abstract*—[1] The route planning problem for an order in freight transportation involves the selection of the best route for its transportation given a set of options that the network can offer. In its adaptive (or dynamic) version, the problem deals with the planning of a new route for an order while it is actually in transit typically because part or all of its pre-selected route is blocked or disrupted. In the intelligent product approach we are proposing, an order would be capable of identifying and evaluating such new routes in an automated manner and choosing the most preferable one without the intervention of humans. Because such approaches seek to mirror (and then automate) human decision making, in this paper we seek to identify new ways for dynamic route planning in industrial logistics inspired by the way people make similar decisions about their journey when they travel in multi-modal networks. We propose a new simulation game as a methodological tool for capturing their travel behaviour and we use it in this study. The results show that a simulation game can be used for capturing strategies and tactics of travellers and that intelligent products can provide a proper platform for the usage of such strategies in freight logistics.**

I. Introduction

Unexpected events and the disruptions they normally cause in business operations have led researchers and practitioners to search for new ways to overcome them. As a matter of fact, risk management was placed second among the most important challenges faced by 400 supply chain executives in a recent industrial study [1]. Although most of the executives stated that they have yet to focus their interest on event management to monitor disruptions the study reveals that this interest will increase for 35–50% in the next 3 years.

In logistics and transportation, the routing of an order in a multi-modal or intermodal network is an operation where systems able to monitor and manage unexpected disruptions could offer significant help [2]. In this direction, the concept of product intelligence could be used as a platform for the implementation of such systems [3]. However, the decision making capabilities of the intelligent products (tactics, strategies, and more general the decision making process) in these systems have yet to be studied and tested for their applicability and performance. In this study we aim to identify such capabilities by studying the way people manage the disruptions they face while travelling in multi-modal networks as well as the way their tactics can be replicated and applied in freight logistics using an intelligent product approach.

Since people have to face situations of unexpected disruptions in their everyday life, we believe that the way their intelligence is being used in their decision making process in such cases could reveal useful techniques on how an intelligent product should handle similar situations. In order to study these decisions and the way they are being made, we design a new simulation game representing scenarios of unexpected events in multi-modal journeys as well as a study that uses it.

II. Literature Review

This literature review is divided into three sections: we begin with the routing problem in logistics, we then discuss how intelligent products can facilitate its adaptive routing version and we finish with a short review on simulation games.

A. The Routing Problem in Logistics

In an intermodal network the routing problem requires the identification and choice of the best route for the transportation of an order given a set of available options that the transportation network can offer [4]. This routing problem is close to the mathematical *shortest path problem* and multiple algorithms have been proposed for its solution [4], [5]. Although the term *dynamic routing* in logistics usually refers to the re-routing of vehicles in order to satisfy requirements that change while the vehicles are away from their stations, in this paper we focus on the routing of an order from the perspective of the order itself. In other words, we deal with the selection of the best way for an order to re-route itself in a network caused by unexpected disruptions that prevents it from using its initial route as well as the underlying system that can support this process (the reader is referred to [3] for more information on the characteristics of the problem).

[1]This is a machine-readable rendering of a working paper draft that led to a publication. The publication should always be cited in preference to this draft using the following reference:

- Kola, D., Giannikas, V. & McFarlane, D. (2012), "Travel behaviour applied in freight transportation using intelligent products", in *2nd International Conference on Communications, Computing and Control Applications*, Marseilles, France.

B. Adaptive Routing using Intelligent Products

During the last years, several researchers have recognised the opportunity for improved dynamic routing that product intelligence can offer [3], [6]. However, most of the available studies deal with the issue product re-routing in Flexible Manufacturing Systems (FMS) rather than in logistics ones [7], [8]. Although these studies show that intelligent products can be used to develop systems that can handle disturbances more effectively, they are not able to show how these systems could operate and perform in a logistics environment where information sharing among different organisations face significant difficulties. Thus, approaches using pheromone-based self-routing techniques [7], [8] or other solutions that take advantage of information sharing among products [9] have to be re-evaluated in terms of their applicability and practical implementation in transportation scenarios.

C. Simulation Games

A simulation game is "an exercise that possesses the essential characteristics of both games (competition and rules) and simulations (ongoing representation of real-life)." [10, p.16]. In other words, simulation games try to replicate situations and activities from real life in a form of a game for education, exploration, assessment or research purposes [11]. In operations management simulation games have been used mainly for learning and educational purposes [12] with the *Beer Distribution Game* being perhaps the most popular one [13]. To the best of our knowledge, there are no studies that use simulation games as a methodological tool in operations management, although this is not the case for travel behaviour research [14], [15].

III. Methodology

The research method applied to this project is exploratory since its main objective was to provide an insight into an area that literature is scant rather than to prove a hypothesis or provide causal knowledge. This choice was strengthened by the fact that there were no models or frameworks the researchers could rely on in order to conduct this study. Thus, the study was mainly oriented towards the answering of "why" and "how" questions as well as the investigation of strategies and tactics that people to monitor disruptions. In the next sections we discuss the applicability of a simulation game as a methodological tool for this research study and describe its design details as well as the way it was used during this study.

A. Simulation Games as a Research Tool

Three methodological tools were reviewed in terms of their suitability to meet the objectives of this study: *a*) *a participant-observer method (or field experiment)* [16] — here a number of participants are asked to move from a city X to another city Y given certain available funds and time. The participants are then interviewed on their experience during the trip; *b*) *personal interviews* [16] — a number of scenarios are presented to the participants by the researcher and they are asked to make plasmatic decisions and discuss their decision making process; and *c*) *a simulation game* [17], [18] as described in detail in this paper. Table I summarises the benefits (+) and drawbacks (−) of each tool based on eight criteria, which are relevant to the objectives and limitations of this study.

TABLE I
Comparison of different methodological tools

Criterion	Methodological tools		
	Field experiment	**Interviews**	**Simulation game**
Close to reality	+	−	+
Applicable for research with limited previous data	+	−	+
Entertaining for participants	+	−	+
Study scenarios with specific characteristics	−	+	+
Track down the decision making process of participants	−	+	+
Cost	−	+	+
Participants' familiarisation with the tool	+/−	+	−
Ease of designing the study	−	+/−	−

The main advantage of field experiments over the other tools is that they offer the researcher the opportunity to study the real system in real travel-hehaviour scenarios. which is particularly useful in exploratory research studies. Moreover, since the sample participates in real cases, it is much easier for them to understand the different factors affecting their decisions and the process of making these decisions. On the contrary, the nature of this tool prevents the researchers from studying scenarios with specific characteristics. As an example, it is very possible that during a trip from London to Paris, no disruptions will happen to a traveller and as a result the data gathered will be very limited. This factor along with the fact that such methods can be very expensive and time consuming led the researchers to not use this tool.

Interviews, on the other hand, do not face the problems of field experiments since they are relatively easy to be organised and not as expensive to be designed. At the same time, several scenarios with multiple characteristics and different levels of information availability can be formed and researched. However, an interview would not "lead" the participants to make real decisions as they tend to think what they "would" do instead of what they "will" do in case of disruptions introducing some bias in the study. Also, since data from previous studies are not available in the literature and the type of the results of such a study cannot be predicted in advance, it could be hard to decide which questions should be asked.

A simulation game overcomes the main difficulties that field experiments and interviews face while at the same time the researcher can track down the decision making process of the participants more easily since he is physically with them during the study. Regarding the drawbacks of simulation games we consider the low level of familiarisation of the participants with it as well as its difficulty to be designed.

B. Research Methodology Steps

The study which would implement and use a simulation game (depicted in Fig. 1) was designed and executed. The goal of the *design phase* was to define the way the game should be designed and used in the study. The criteria that the game should meet were identified based on literature reviews on the adaptive route planning problem in logistics, travel behaviour and simulation games, followed by interviews and brainstorming sessions with people who have enough experience in travelling long distances. This led to a first version of the game along with the identification of the specific scenarios to be studied. Note here that most of the key decisions regarding the game and the characteristics of the scenarios were made based on the review on freight transportation. In this way, we can make sure that the scenarios represent cases in freight transportation and that the findings of this study can be also used in industrial cases. The initial version was evaluated with a small number of participants and the game was redesigned based on their feedback.

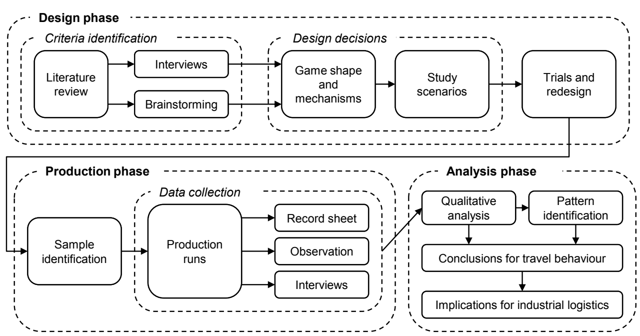

Fig. 1. Research methodology

In the *production phase*, the game was played by the participants while they were completing record sheets (see Table II for an example) about their decisions and their decision making process especially when unexpected events took place. Also, the participants were asked to write down the route they decided to follow before the beginning of the game so that it can be compared with their actual route after they reach their destination. During the game the facilitator was collecting notes based on the observation of the participants. Finally, the participants were asked to answer a small number of open questions which aimed to give more insight in dimensions and issues that were not captured during the game. Finally, in the *analysis phase* the data gathered were qualitatively analysed and patterns in the decision making process of the participants were identified. These formed the conclusions of the study on travel behaviour and its implications for freight logistics and transportation.

C. Description of the Simulation Game

The game represents an intermodal transportation network where each player has to travel through several terminals before he can reach his final destination. Fig. 2 depicts the

TABLE II
RECORD SHEET

Route you plan to take to reach destination: Example 1…A…2…T…
Route initial plan: …………………

Day	Pre-booked tickets	Events	Normal tickets	Current location	Notes
1	Ship from 1 to 2: £25	Closed terminal 2 for 3 days	Ship from 1 to 6: £20	1a6	I did not want to wait for 3 days so I decided to buy the cheapest available ticket
2	-	-	-	1b6	

layout of the game where the players have to move from the top left to the bottom right terminal. The larger, light blue circles on the board represent terminals while the smaller ones are used to represent days of travel of different modes between terminals. Each round in the game represents one day, whilst the points represent the cost of transport between terminals and vary depending on the trip duration and the mode of transport chosen. The players are given the option to pre-book (purchase before the event takes place) their tickets with some discount.

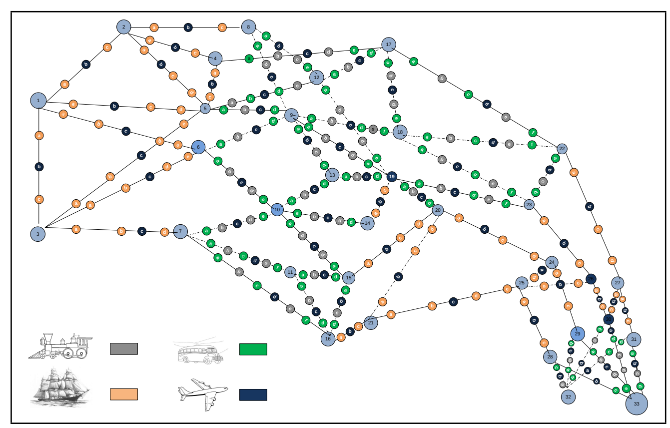

Fig. 2. Layout of the game

The players' journeys may be disrupted by random unexpected events while they are in a terminal or while they are in transit. In such cases each player has to make a new decision on how to deal with these disruptions deciding between waiting in the same terminal or booking a ticket to another destination. Some examples of events are closed terminals due to severe weather conditions, broken tracks on railways and strikes in ports. These events are introduced in the game by randomly picking an *event card* from a larger stack of cards (one stack per terminal and one stack for 'in-transit' events). Note that 'in-transit' events can only happen one day before a player reaches a terminal. Each disruption has a certain duration defined by the roll of a die. In Fig. 3 a simple flow chart illustrates the process that each player has to follow each time it is his turn to play. The decision nodes in dashed line represent decisions made by a player whereas the ones in straight line represent random events.

The winner is the player who manages to use the fewest points (spend the less money) and arrive at the destination

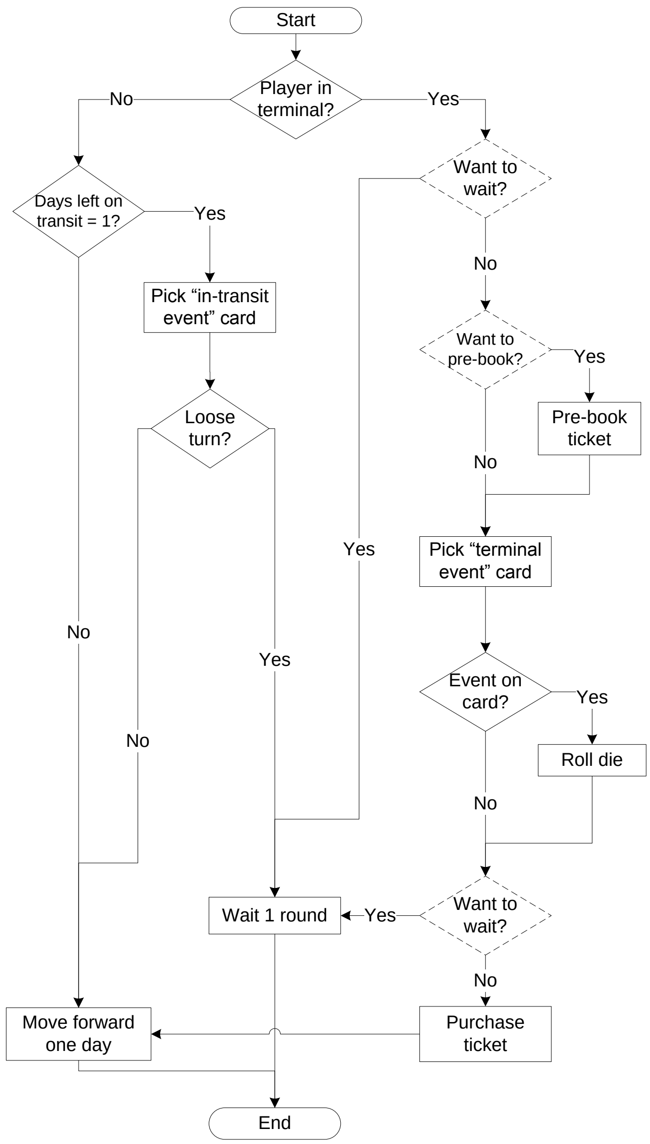

Fig. 3. Process followed by the players in each turn

terminal by a certain deadline. Later in this paper we will present in more detail the strategies of the players that used the most or the fewest points during the game (see Table V).

IV. Analysis and Results

In this section we provide an analysis of the data gathered during the production runs of the game. A factual summary of the game's results is presented in Table III. Note here that the purpose of the analysis is not to compare and define winning and losing strategies/decisions but to identify those strategies and tactics that were followed during the game and use those that can be replicated in industrial scenarios. We begin with a general analysis of all the players and then we deep into the specific tactics followed by the players with the best and worst scores (See Section III-C for details regarding the calculation of these scores). We finally link the results of this study with freight logistics and intelligent products.

TABLE III
Factual Summary

Statistic	**Value**
Pilot runs/Production runs	4/6
# of players	20 (in groups of 2)
# of 'event' cards/'in-transit' cards	459/58
Probability of unexpected event	60-90%
Percentage of players reaching destination on time	75%
Average trip duration/cost/# of unexpected events per player	28 days/£146/5 events

A. General Analysis

In terms of general strategy, all the players tried to calculate their *shortest path* before the beginning of their trip. However, since the problem was to complex to be handled by a human without the help of a computer, the players chose to calculate their shortest path based on the number of terminals visited rather than on the total cost or days of travel. Also, some players decided to avoid specific terminals which they were thought to be riskier than others due to the low number of alternative options provided in case of a disruption. For example, a terminal with only one outbound connection with another terminal could be very risky in case the latter terminal gets closed. Finally, there were some players who tried to define 2–3 alternative strategies before they started the game based on worst, normal and best-case scenarios so that they will be ready to cope with unexpected problems.

The complexity of the problem, the fact that the players could not predict the unexpected events as well as the fact that they were competing each other led some players to define a strategy to control their speed and cost of travelling. Thus, there were players that tried to spend money and move fast in the beginning so they can save money in the end, and players that did the exact opposite. Both strategies gave them the flexibility to change their initial plan based on status of the game rather than stick to a-priori calculations.

With regards to the players' pre-booking strategy, it was mainly driven by two factors: *a*) the price difference between the regular and the pre-booked ticket; and *b*) the number of events that disrupted their journey during the game. In other words, if the player felt that it was worth taking the risk for the discount given, he would pre-book a ticket for his journey. However, if a player was unlucky enough to see his pre-booked tickets being affected by unexpected events very often during the game, he usually shifted his strategy into a no pre-booking one. Note here that there were players who decided never to pre-book a ticket as this would significantly reduce their risk during their journey since there would be no cost to change an initial plan in case of disruptions. The reader is referred to Table IV for a more detailed analysis of the tactics followed after a disruption took place during the game.

B. Analysis of Strategies that Led to Best and Worst Scores

Even though the comparison among players is not feasible in all cases due to the different number and variability of

TABLE IV
SUMMARY OF DECISIONS IN UNEXPECTED EVENTS

Event	Tactics/Decisions
Closed destination terminal	Willing to wait if terminal is closed for few days and there was enough time left to reach their destination (more important in cases where players had pre booked tickets)
Pre-booking affected by an event	If the event is short and there was time left then wait or move with the cheapest mean. Otherwise move by using the fastest mean.
Mode of transport planning to take was not available (no pre-booking involved)	If there was time left then move with the next cheapest mean otherwise chose the fastest available
A terminal planning to visit later in the trip is affected by an event	Reconsider plan/strategy if the risk of the terminal been affected when they reach it is high
Events affecting terminals out of the plan	Majority of players did not absorb that information and did not consider it.
Events affecting modes that did not think to use	

unexpected events encountered to each one (especially when they were not competing in the same game session) there are some key points that can be drawn regarding their strategy and decisions. Table V presents the overall strategy of these players (as it was stated by them) and few comments based on the observation notes.

Starting with the players with the best score, both of them based their strategy in defining the shortest path in terms of terminals visited. Moreover, although they differed in terms of their initial preference on the pre-booking option, they both ended up eliminating the risk by not pre-booking and re-routing themselves when unexpected events took place. As regards the players with the worst score, a common pattern that can be derived is that they were usually more willing to wait in order to defend their pre-booked ticket and save cost feeling safe about the days left rather than re-route. The common mistake though was that they neglected the risk of a new event occurring.

C. Implications for Freight Logistics and Product Intelligence

We now seek to identify these scenarios in which the tactics and strategies presented in the previous section could be applied in freight transportation using the concept of product intelligence. Table VI outline a number of example scenarios that could be applicable both in people and freight transportation and we link the decision made by travellers with these that could be made by intelligent products.

In Table VI it is obvious that the way people overcome difficulties caused by disruptions in their journeys could provide useful input on how similar problems could be solved in freight transportation. We summarise the analysis of this table along with the analysis of the previous sections in the following suggestions for freight logistics:

- Dead time in terminals should be avoided (when it is not in the initial plan). This means that, when disruptions block the continuous movement of a freight in a network there should be alternatives that make sure the freight can use another route. As we showed in Section II-A the issue of adaptive route planning has yet to be extended for freight transportation in multi-modal networks.
- The risk of failure of a route/terminal/mode should be taken into account during the calculation of the best route for a freight. There are currently available algorithms in the literature that can be used for this reason, however, each organisation should obtain its own historical data in order to make the right predictions for its network.
- While choosing the best route for a freight, one should consider different points on the Pareto Frontier (formed based on cost and time of different routes) for different parts of the journey. Strategies like 'slow start-fast end' or the opposite should be also considered.
- A freight's owner (usually the customer) should be able to manage his freight while it is in transit in the same way people manage themselves. Although the forwarders and distributors of a freight may consider a set of different options in case of a disruption, the final choice should be made by the owner of the freight leading to a more

TABLE V
STRATEGIES OF PLAYERS WITH THE BEST AND THE WORST SCORES

Score	Strategy	Other Comments
Best	"Choose the route that included the least number of stops/terminals and change my plan according to the particular situation"	This player was not willing to wait when an event affected his pre-book ticket and generally he was trying to move forward. Every time (even when a disruption changed his initial plan) his decision was based on the shortest path identification.
	"I initially wanted to take the route with the least amount of stops (in order to avoid events) trying to move fast at the beginning and save money at the end. During the game I realised that is less risky to find out about an event before spending money on a pre-booked ticket"	This player usually preferred to wait in order not to lose his pre-booked ticket in situations when the delay was very short. However, he reconsidered his strategy during the game and stopped pre-booking towards the end.
Worst	"My overall strategy was to spend as less as possible and that is why I was calculating the topical optimal solution. Then, I had to shift my strategy to a more greedy one as in my plan I did not initially take into account the events occurring."	The strategy of the player was to make decisions that would save him cost and that is why he was willing to wait for the event to end before he started moving again. However, this caused him to run out of time towards the end of the game forcing him to spend more to reach his destination.
	My strategy was to go through the faster route (in terms of number of terminals) to avoid the 'terminal events' as much as possible. At the end I had to change my strategy to avoid being late because so much time had been lost in waiting.	This player was pre-booking for most of the time and preferred to wait and use his ticket later in case of disruptions. The reason that this strategy failed was that he did not take into account the risk of additional events happening in terminals.

TABLE VI
APPLYING HUMAN DECISION MAKING IN INDUSTRIAL SCENARIOS

Scenario	Human's Decision	Intelligent Products
A certain node/ terminal that is planned to be visited during the journey is closed while the order is in previous terminals	If there is still enough time left to reach final destination wait until terminal re-opens	Monitor the condition of the product and if it is not close to the end of its lifecycle wait until the terminal re-opens making sure that lead time is respected.
Order contain products that require special maintenance conditions and thus have to reach their destination with the least number of stops possible	Choose the journey that requires fewer terminals to be visited	Calculate the 'shortest' path to reach destination by minimising the number of intermediate terminals in order to avoid potential events
Order is stuck in place where severe weather conditions prohibit the only mean that can be used towards the next terminal to depart	Prefer terminals with many edges so if something happens, more options in terms of available terminals and modes of transport will be available	While calculating the initial path, avoid those intermediate terminals that offer limited choices in terms of mode of transport that can travel from/towards them and neighbour terminals
National unrests completely prohibit any travel activity towards a terminal that an order is planned to visit later in its journey	Take into consideration events affecting terminals that I plan to visit in the future even if the event will be over by that time	Require information regarding the availability and condition of all terminals that are in the initial plan while an order is in transit and re-route if needed
The number of unexpected events happening in a terminal is high	Identify those terminals that are riskier than others and try to avoid them.	Based on historical data from previous orders, calculate the probability of an event to take place and take this information into account while defining your path

customer-oriented control system [19].

V. Conclusions and Discussion

In this paper we have shown how a simulation game can be used as an alternative methodological tool in operations management in order to capture people's decision making and apply these results in logistics using the concept of product intelligence. A main outcome that came out of the production runs was the importance of static planning before the beginning of a player's journey but more importantly the significance of a strategy to confront unexpected events and disruptions, e.g. by re-routing himself in the network. In freight transportation, similar strategies/tactics should be incorporated in the decision making capabilities of intelligent products so that they are able to manage disruptions during their transportation. Nevertheless, since products can not control themselves physically like people do in their trips (e.g. move from one place to the other in a terminal), we believe that a system using an intelligent product approach with the capabilities described in the previous section will be worthless without an operational process that can facilitate its utilisation.

We conclude with a series of limitations that should be considered in a future version of this game or another similar one:

1) Although the data collection mechanisms managed to capture the outcomes of the decisions made by the players during the game along with their overall strategies, they did not perform as well in capturing their decision making process. For this reason, additional mechanisms are required in order for the whole decision making process to be captured and replicated in industry through intelligent products.
2) The game managed to capture a wide range of travel behaviours but not winning and losing ones. In this direction a more detailed experiment should be designed before the game and more players should participate in the study. A computer-based version of the game might help to engage more participants in it.
3) The players could not have access to new information about the game (e.g. risk in a specific terminal) even if they wanted to. This means that industrial systems that can provide a company with more information, such as track and trace systems, could not be evaluated using the current version of the game.
4) The players did not play the game more than once. Thus, their learning experience could not be evaluated although in industrial logistics it is often the case that a customer has some knowledge about the transportation of his items based on previous shipments.

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