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Data collection on Shipper's Preferences Using Simulation Games:

A Synchromodality Case Study

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Abstract.- The development of new more efficient freight transportation services requires in depth understanding of the engaged stakeholders behavior. Simulation Games (SG) have been used to study decisions and raise awareness over complex transport problems. This paper investigates the possibility of applying a simulation game as an innovative data collection tool for choices related to freight transport. Games sessions were organised with Dutch logistics managers and data on their choices for synchromodal services were collected. Model results revealed reliability, costs and reduced work load as key factors making shippers to opt for more synchromodal services.

Keywords: synchromodality, simulation games, behavioural data collection, service choice, multinomial choice model.

I. INTRODUCTION

Synchromodality is the "vision of a network of well organized and interconnected transport modes, which together cater for the aggregate transport demand and can dynamically adapt to the individual and instantaneous needs of freight transport users" [1]. The adoption of this innovative transport service is expected to increase the efficiency of freight transport. To adopt however, this innovative transportation solution a high horizontal and vertical coordination between the engaged stakeholder *(* [3], [4]*)* is necessary. On the other hand, the complex nature of freight transport which entails the interaction between numerous economic and political actors [2] hinders the orchestration of transport modes and services. Therefore, it is necessary to understand the behavior of the different actors in order to design effective policies [5].

The definition of Simulation Games (SG) is given by [6] as 'a conscious endeavour to reproduce the central characteristics of a system in order to understand, experiment with and/or predict the behaviour of that system' [7]. Participants in SGs take a specific role and react to different situations developed in a simulated environment. Therefore SG is considered an effective method for observing stakeholders behaviour and interactions in the context of organizational action, social change and technical development [8]. SG is applied in multi-disciplinary research since it permits the integration of different perspectives, concepts, theories, data, information, methods, techniques and tools [8]. This approach is particularly suited to transport applications where stakeholders with different perspectives, different information management regimes and conflicting interests are present.

Disaggregate behavioural freight transport data is difficult to obtain due to high data collection costs, time consuming surveys and confidentiality issues *[9]*. This paper addresses the aforementioned problem by applying a SG as disaggregated data collection tool. We apply a digital SG called MasterShipper that aims to raise the awareness of stakeholders on the advantages offered by synchromodality. Six MasterShipper gaming sessions with Dutch logistics managers were conducted in order to understand their preferences when choosing transport mode or service. The data are then applied to develop a Multinomial Logit Model (MNL) that quantifies the factors affecting shipper's mode and service choices. In the game we insert an innovative "synchromodal" service and via the model we are able to identify which ares the most important attributes of this new service.

The remainder of the paper is structured as follows. Section 2 presents the literature review while Section 3 describe the game. Section 4 presents and discusses the model results. Lastly, in Section 5 the concluding remarks and future research directions are made.

II. LITTERATURE REVIEW

The complex environment of freight transport is formed by various actors who have their own needs, objectives and frequently conflicting interests. The development of efficient services that can accommodate the increasing needs for reliable transport of goods require an in depth understanding of the mechanisms that influence transport related decisions. An increasing research interest on the factors that influence the preferences and the behaviour of the various stakeholders in urban freight can be observed ([10] [11] [12], [13], [16] [17] [18]). The majority of the aforementioned studies applies SP data to develop choice models [17]. SP surveys on freight transport preferences are usually very expensive and time-consuming to carry out, especially when combined with the collection of socioeconomic and Revealed Preference (RP) data. Respondents are reluctant to provide information and a low rate of response is frequently observed [18]. In addition, one of the biggest disadvantages of SP is the hypothetical design of experiments. Respondents are asked to make choices in

unfamiliar situations with limited information and understanding [19].
To deal with the aforementioned disadvantages of behavioural data collection we propose the application of SG. Innovative concepts such as synchromodality are expected to Simulation gaming is an evolving research method applied to study complex systems where multiple independent stakeholders are engaged [20], [21]). SG have the following characteristics that make them a method ideal for the research of complex multi-actors systems:

1. It is easier and cheaper to create gaming experiments that simulate a complex problem and different scenarios for its solution.
2. SG offer a strong potential as research method, as they are engaging in nature, can increase participation and are often digital permitting easier and more detailed data collection [22].
3. SG allow to get deeper insights in existing systems, enable players to become aware of certain challenges and problems [23] and enable the observation of player behaviour [24].

Hence, the rationale is to leverage the advantages of SGs and apply them in the context of transport. In literature SGs have been already applied but mostly for passenger transport ([25] [26], [27], [28], [29]), while the freight transport examples remain limited ([30], [31], [32], [33], [34]. In previous work [32] discuss the use of games for the governance of the transport system in a whole, and to create awareness for sycnhromodal transport solutions in particular. In [35]students were given the role of economic agents that interacted with truckers to study the formation of the truck tour. Finally, in [36] simulation gaming is applied to model the participation of actors in reverse logistics.
This paper serves as a first effort to substitute long, time consuming and expensive SP questionnaire surveys with a SG that can simulate the environment ask players to make choices in this simulated environment.

III. THE MASTER SHIPPER GAME

The MasterShipper Game to raise awareness about the advantages offered by synchromodal services to shippers. The game simulates the office and the job of a logistics planner in a company selling electronic products. Players undertake the role of the and have to make sure that all types of products are delivered from their producers on time. Shipments have three levels of priortity:1) low priority for goods that take limited space and their delivery is not urgent, 2) medium priority for larger products such as washing machines which should be delivered with medium urgency and 3) high priority for valuable products such as cell phones that present high levels of demand and should be delivered without delays.
The player has in front of him/her a screen where the various orders are placed. In the screen he/she also has an overview of the status of the order and the available transport services he can use to get the products from the supplier. He/she can also get informed about possible delays and disruptions in the network. The player is asked to plan each order using one of the available modes.
For each mode the following characteristics are available: Pick-up day, duration of trips, route (south or north), cost.
The player can add some extra services such as track and trace, can choose to include last mile delivery and can take insurance insure for late delivery the shipments. All these services are added with an extra price. The player also receives some orders and instructions from the CEO of the company with which he/she has to comply.
The players have to book the transportation of electronic products (medium, high and low priority) using the different modes service packages available by different service providers. Disruptions happen in the network and players have to change the services they chose to deliver on time.
In addition, the player is given the alternative of synchromodal service. This service is usually offered in a higher cost, the players does not know which mode of transport is used and in case disruption changes are made by the service provider. This decreases the workload of the player significantly.

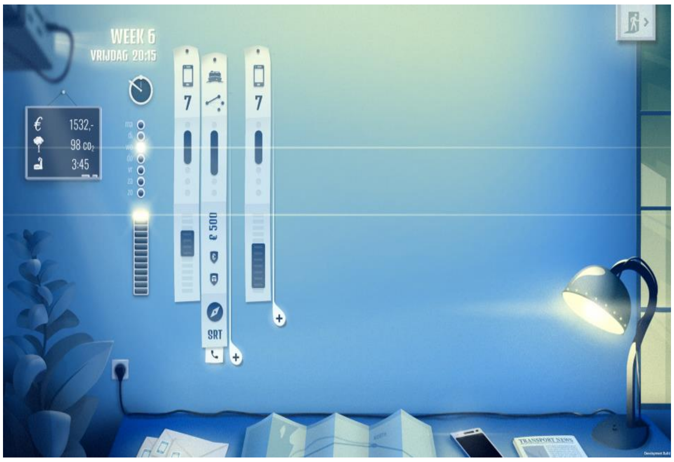

FIGURE 1. THE PLAYERS DISPLAY

FIGURE 2. ORDERS AND SERVICES

The player is assessed based on the number of delayed shipments, the number of products he/she managed to deliver on time, the workload for organising the transport and the emissions generate by the transport design. Workload is one of the main advantages of synchromodality because in case of disruption the transport service provider takes care to make changes in the services.

IV. MODEL ESTIMATION

A starting point for the proposed methodology is to treat the game play results as SP data. In every gaming session 4 or 5 logistics managers participated. Each player played three consecutive rounds and the synchromodality option was available in all of them. At the end of each round the players could compare their results with their "opponents". At the end of session the winner is the one who has managed to deliver more shipments (earn more points) with less workload. In the gaming sessions we did not focus so much in the environmental performance of the players. We then apply the game data to develop a choice model between different modes (truck, rail, barge) and the synchromodal service.
In Figure 3, ellipses represent the utility of the modes chosen by the participants while rectangles stand for explanatory variables such as the cost, reliability or desk time. The choices made on the simulated environment of the serious are considered as Stated Preference (SP) data and we apply the framework developed in [37].

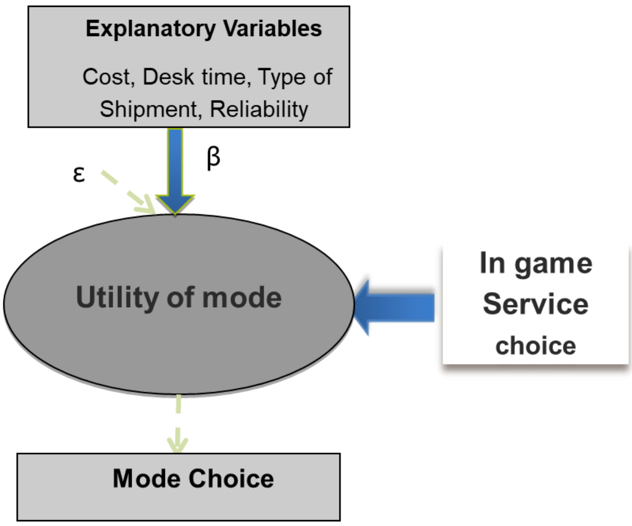

FIGURE 3 METHODOLOGICAL FRAMEWORK

SAMPLE CHARACTERISTICS

The data used in this paper are taken from six gaming sessions played with logistics managers from the Netherlands logistics sector. The game is digital so data are stored simultaneously. The output of the game is a series of txt files which are then cleaned and consolidated to one database. The sample consists of 28 respondents who completed on average 3 game rounds each. In each round between 6 to 8 shipments are being scheduled. Totally, **532 observations (choices)** were included in the database.
For each shipment the player can choice between the truck service, the barge services and the synchromodal service. From the available data we expect that choices were influenced by the following parameters:

1. The cost of each alternative.
2. The travel time.
3. The reliability of each alternative, hence the probability that each alternative has to be delayed.
4. The workload calculated in time. The workload is defined as the amount of type the player spends to schedule a shipment.
5. We also test the existence of possible differentiation between the different types of shipments (high, medium and low priority)
6. The score on the CO_2 emissions per type.

Table 1 summarizes the characteristics of the sample.

TABLE 1 Sample characteristics

Variable name	
Cost	470, 4 euros (mean)
Travel time	2,2 days (mean)
Reliability	28,5% (mean)
Workload	125,8 seconds (mean)
Emissions	210,71 (gCO_2)
Sample size	**532 observations**
Truck	26%
Barge	16%
Synchromodality	43%
Rail	15%

In general the travel cost is 470 euros per shipment and mean travel time is 2 days. The players spend on average 2 minutes to schedule each shipment. Half of the sample are planners 25.75% work in the sale department and the rest hold a managerial position. Emissions are 210 g CO_2. The majority of choices were for synchromodal transport while rail and barge have the same low market share.

MODEL SPECIFICATION `

In order to define the probability of the player to choose a service we develop a Multinomial Logit Model (MNL). Let i denote a service and n represent a choice between services. Our objective is to model the the utility of a player to make a choice i. We define X_n as the matrix with as many rows as choices, where Xin corresponds to the ith row of X_n . $\boldsymbol{X_{in}}$ is a row vector that contains the explanatory variables. We define $F(i| X_n; \beta)$ as a function that predicts the probability that a player n will make a choice i where β is a vector of unknown parameters. The number of the different possible choices is denoted as J.
We assume that the player chooses the service with the highest utility. The utility a player n to make a choice i is:

$$U_{in} = X_{in} \cdot \beta + \varepsilon_{in} \quad (1)$$

where ε_{in} is an error term that accounts for measurement errors. The explanatory variables are inserted in the model through a linear relationship $X_{in}\beta$. The error terms, ε_{in}, $i=1,$ ....., J, are assumed to be independently and identically distributed (i.i.d.)

standard random variables ([38], [37]).

The probability for a player n to choose a service i is given by the following equations.

$$P_n(\boldsymbol{i}) = \frac{e^{V_{in}}}{\sum j \in C_n e^{V_{jn}}} \quad (2)$$

where C_n is the feasible choice set given in each player; and :

$V_{in} = U_{in} + \varepsilon_{in}$ (3)

The final specification of the MNL model utilities are presented below:

$U_{truck} = \beta_1 + \beta_{tc} * Cost1 + \beta_{desk} * Desk1 + \varepsilon_1$ (4)

$U_{barge} = \beta_2 + \beta_{tc} * Cost2 + \beta_{reliability} * Reliability2 + \varepsilon_2$ (5)

$U_{rail} = \beta_3 + \beta_{tc} * Cost3 + \beta_{reliability} * Reliability3 + \varepsilon_3$ (6)

$U_{synchr} = \beta_4 + \beta_{tc} * Cost4 + \beta_{reliability} * Reliability + \beta_{desk} * Desk4 + \varepsilon_4$ (7)

where:

$\beta_1, \beta_2, \beta_3, \beta_4$ = the alternative specific constants

$\varepsilon_1, \varepsilon_2, \varepsilon_3, \varepsilon_3$ = the error terms

β_{tc} = the generic coefficient for cost

Cost= the cost for each service

$\beta_{reliability}$ = the generic coefficient for reliability

Reliability= a continuous variable denoting the percentage probability of a service to be delayed.

B_{desk} = the generic coefficient for workload

Desk= a continuous variable denoting the amount of time necessary to schedule a shipment

The next section presents the model results.

V. RESULTS

The model was estimated using the BIOGEME software [39]. The coefficients included are statistically significant in the 95% confidence interval and intuitively correct. Alternative specific models were developed, meaning that for every alternative different model coefficients were estimated. Table 2 presents the estimated values of the model coefficients. The coefficients that are not presented in the table were found statistically insignificant and we did not include them in the model.

TABLE 1 Model Estimation Results.

Coef.	Values	T-stat
β_1	0	0
β_2	-1.42	8.21
B_3	0.378	5.21
B_4	-0.687	4.34
B_{tc}	-0.937	-2.89
$B_{reliability}$	-0.0937	-3.37
$B_{workload}$	0.0729	2.41
Sample size	532	
Rho-squared	0.213	

The signs of the alternative specific constants the preference towards solutions that give more mode flexibility to the LSPs. The higher the workload the lower the higher the utility of the service. Workload is important for synchromodality and the truck services that are more flexible and require less time to handle. Reliability is important for all modes and it is negative correlated to utility. The same is also for costs with higher the cost the lower the utility. Emissions were not found significant probably because during the sessions it was not a main point of focus. Finally, we did not observe differentiation between the different types of shipments.

VI. CONCLUSIONS.

This paper serves as a first effort of applying SG games to replace SP experiments in the collection of choice related data. For this purpose a digital SG, MasterShipper was played in sessions with Dutch logistics managers. MasterShipper aims to raise awareness on synchromodality and to identify the factors that influence the choice of actors for synchromodal services. An MNL model is estimated using game data. The reduced workload offered by synchromodal services is important for the choice of this services. As expected travel cost reduces the utility of each alternative while environmental benefits do not influence the choice. Promoting therefore the reduced effort and the flexibility and resilience to disruptions attributed to synchromodality can help to increase the market share of this service.

On a more methodological note this work explores the practical implementation of SG techniques as a survey instrument in the area of freight transportation. We proved that SG , if designed correctly, can work as a way to replace classic SP experiments and could potentially increase the response rate especially freight surveys since we were able to develop an informative model for synchromodal services. Logistics managers participated willingly in the survey and where able to relate to the simulated environment they were presented during game play. The limits however imposed by the game itself did not permit more variability in the choices of the respondents. Adjusting the game to a menu based questionnaire would provide us with rich information. Future work includes the design of a SG on the preferences of shippers and the development of a methodological framework on how games could be applied as an alternative to SP. Finally, we also aim to collect more data and experiment with more coplicated model structures.

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