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Interactive simulation for collective decision making in city logistics

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Abstract

For a given problem in city logistics, diversity of the stakeholders makes it difficult to consider everyone's objectives and constraints. Therefore, it is hard to anticipate the impacts of a new regulation. The proposed methodology is based on participatory modelling, where stakeholders share their expertise in order to build a common representation of the problem. In the proposed use case, discussion groups are asked to estimate regulatory impacts on two types of carriers. Following the objective to involve people unfamiliar with modelling techniques, the experimentation aims at testing if interactivity with the model helps as support for discussion.

Keywords: city logistics; simulation; interactive; participatory modelling; collaborative decision making; geographic information system

1. Introduction

1.1. Modelling city logistics

A complex system is a system composed by many components interacting which each other. Cities are complex systems where stakeholders are components. Therefore, the action (or reaction) of one stakeholder can have a global effect on the system. This phenomenon, called emergence, is hard to capture when modelling a complex system. Sometimes stakeholders are not aware of their relationships with other actors. Therefore, in order to assess a global solution, there is a need to exhaustively qualify and quantify such relationships in order to weight the benefits and costs for everyone. When a solution is proposed for a given City Logistics problem its impacts are usually estimated with simulations, called "UGM modeling frameworks" or "Decision Support Systems - DSS" (Comi and Rosati, 2015;

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Grzybowska and Barceló, 2012; Perboli et al., 2015; Routhier et al., 2014). The involvement of the stakeholders in these tools is not central in the modeling process, although it is possible and it has been done in some cases.

However, the outcomes and success of a given solution will largely depend on the modelling of the problem at hand (Anand et al., 2012a), hence relevant stakeholders' involvement is fundamental. By extension, if one stakeholder is not convinced, the solution will not be implemented as planned and failure becomes more and more likely (Holguín-Veras et al., 2018). Even in an optimistic scenario where all stakeholders are cooperating to reach a consensual solution, clear communication between stakeholders is essential. In other words, everyone should be able to express their opinions and to understand others.

1.2. Modelling and objectivity

A model is a tool to predict the global behaviour of the system after a change of some of its components. In city logistics, regulations are potentially changing interactions inside the system. Regulation is not only disrupting stakeholders' activities but also the activities of their clients, suppliers, and carriers. These indirect impacts are harder to anticipate, this calls for discussion between stakeholders. The objective is to create a model representing a "shared reality" among them. This representation can be divided in two parts. First, the model should be a common vision of the problem. Second, common objectives at a system level should be defined. The strategy is to involve diverse profiles in the modelling process in order to gain objectivity.

One approach is to use a so-called open model in participatory modelling. They are open in the sense of open source. People can have access to their code or a detailed description. The main characteristic of open models is to only address questions that we can answer with enough confidence. Simon (1990) states that modelling efforts should focus, as much as possible, on the questions that one can answer more or less definitively. The reasoning is that a complex system is chaotic: a slight mistake in the model will certainly lead to a wrong prediction or prescription. For Simon, a model giving almost definitive answer can usually fit on the back of an envelope. This apparent simplicity of the model can be seen as a fortunate consequence: the model is easier to understand and to interact with. As Cathy O'Neil puts it, "At its core, the point of open models is this: you don't really know what a model does until you can interact with it" (O'Neil, 2013). This observation echoes with Heuer (1999) definition of how to reach objectivity. He states that objectivity is achieved by making basic assumptions and reasoning as explicit as possible so that they can be challenged by others and analysts can, themselves, examine their validity. Open models can be the tools to support discussions between stakeholders to converge towards an objective model.

1.3. Research proposition

Per definition, stakeholders have different objectives, constraints, scope, business models and policies. These differences are likely to create frictions during a decision process. This research proposes a process of participatory modelling divided in two parts: (i) the problem modelling, and (ii) the solution design. This paper focuses on the first phase, where the goal is to identify parameters and quantify their relationships to create a model of the problem. In the second phase, the goal is to create consensual solution to a shared problem.

The concept of participatory modelling has already been developed in city logistics. Literature (Morana et al., 2014; Quak et al., 2016; Yearley et al., 2003) acknowledges the value in the diversity of stakeholders experience for model validation. They propose methods to collect (e.g. GIS maps or serious game) opinions and how to use them. Anand et al., (2016) and Inturri et al. (2017) applied the concept for validation of agent-based simulations. The literature focuses on the validation of models rather than their creation.

Quak et al. (2016) adapted the concept of Shared Situational Awareness (SSA) to city logistics. This term characterizes the capacity for a stakeholder to understand its environment and to react accordingly. It emphasizes that one actor cannot understand the situation in its entirety, the actor has to share expertise with the others. Participatory modelling aims to involve as many people as possible. However, Gaudron et al. (2018) showed difficulties to create simulation models with a public unfamiliar to modelling, and proposed the use open models and interactivity to help participants. The present work differs from Guerlain et al. (2016) in that proposes an interactive and tangible medium where the model is considered as valid. Here, the methodology proposes to use the validation process undertaken by participants to collect information from different perspectives in order to improve the model. As we are strongly focusing on the model, we consider the MAMCA methodology as a complementary that focuses on building consensus on potential decisions.

In the paradigm of participatory modelling, this paper proposes a methodology to use interactive simulation to study a specific problem with the stakeholders. During a workshop, participants will be asked to study a use case comparing two different types of carriers (e-commerce and restaurant deliveries). This experiment will be carried out to test if interactivity of the simulation and group discussion improves participants' understanding of the model.

2. Methodology

A city logistics problem should gather the expertise of several stakeholders to reach a global solution. For that purpose, the methodology relies on the capacity of stakeholders to share a common vision of the problem at hand. Consensus is a fundamental component of the methodology. All stakeholders have to agree on the model, it shall not be imposed by an expert. Building a common model, or common language, is the necessary condition to reach a global solution. Indeed, if two stakeholders strongly disagree on the solution impacts, the solution is not likely to be implemented later.

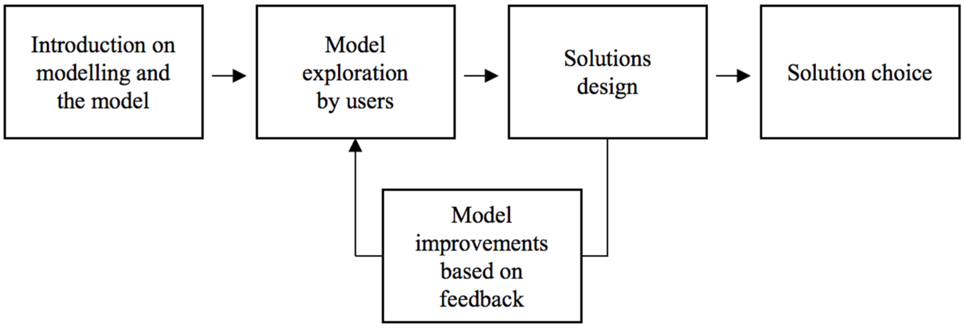

Fig. 1. Methodology for collective decision making using interactive simulator

Previous experiments with this type of tool showed that when users are not comfortable with modelling notions, this leads to later difficulties (Gaudron et al., 2018). Therefore, participants should be taught the basic ideas behind modelling. As shown in Fig. 1, our co-construction process starts with a model created by an expert. The model is explored by participants thanks to the interactive simulation. It relies on the interactivity and clear visualization of the simulation parameters and outputs. Quantification of the impacts is seen as powerful tool to support discussion towards a consensual solution. Participants should be able to explore the model, assess its validity, design different solutions, and assess their impacts. It is likely that the model would need improvements to create and to test new scenarios (e.g. add new parameters, constraints and/or objective functions). In the case of a model too far from the reality, insights from the discussion can be used by the expert to propose a new model for the next group discussion in another meeting. Ultimately all participants should have agreed on the model and a chosen solution.

The objective is to collect the expertise from different stakeholders, and synthesize them in one coherent model. Therefore, discussions between participants is essential. For that reason, a facilitator should moderate the discussion and guide participants through the different steps. He/she creates a scenario illustrating the problem at hand in order to engage participants with the tool and to initiate interactions. Just as a brainstorming session, he/she has to guarantee the opportunity for everyone to speak. The facilitator also has to clarify propositions, organize discussion about the propositions, and manage time.

3. Use case

3.1. Problematic

Cities face complex problems when dealing with regulations. The use case focuses on possible regulations related to carriers. Two types of activities are considered: e-commerce and restaurants deliveries. An imaginary city has five options for regulations, the objective of the interactive simulation is to estimate how regulations will differently impact different types of carriers. The goal is to see if participants can agree on the impacts on the operation of the two carriers. The chosen regulations are:

- Vehicle size: trucks are forbidden.
- Time windows: deliveries are only allowed between 9:00 and 11:30 am.
- Land reserved for logistics: the warehouse is far from the logistic demand.
- Vehicle ban: only EURO 5 and 6 vehicles are allowed.
- Sustainable development: clients are encouraged to reduce their consumption.

3.2. Group animation

During model exploration, participants get familiar with the model. A model is already proposed for the two companies (e-commerce and restaurant deliveries). Users can play with the model to get a sense of how decision variables impact the KPIs. Next, regulation models are proposed by the facilitator. Participants have to imagine the decision taken by the companies regarding to each type of regulation. Those decisions are taken from the perspective of the carrier. They can be driven by cost, quality of service or even brand image.

First, interactions will be based on discussions relative to different drivers of the decisions. For example, what would be an acceptable financial loss if carrier improves its brand image by using cleaner vehicles? Secondly, participants will be asked to compare how decisions differ between the two companies. Participants will be asked to define together if a regulation is more likely to impact one type of carrier or the other. Here, a scale from 1 to 5 will be used: (1) the regulation only impacts the e-commerce carrier, and (5) the regulation only impacts the food carrier. Thirdly, interactions will focus on model improvements for a future meeting. The facilitator will keep a record of the discussion.

3.3. Model proposition

The idea is to start with a simple model that could represent “a” reality (objectives, decision variables, constraints) of a carrier in different activities. The authors, based on the literature relative to operations research and city logistics, have created a first version of the model. Models are usually based on the Vehicle Routing Problem, where the travel distance for distribution has to be minimized. Most models in the literature also add constraints on the capacity and the time windows. These constraints have significant impacts on operational decisions (Jlassi et al., 2017). The model proposed for the workshop is a Capacitated Vehicle Routing Problem. As we consider decisions at the strategic level, where carriers with an infinite fleet is a reasonable assumption – the market is stable and predictable over a year. The model uses Geographic Information System (based on OpenStreetMaps) containing the roads, locations of the clients and the warehouse.

The optimization model has three decision variables. The first decision variable is the warehouse location. The first choice is in Montrouge is just outside the ring road around Paris. The second choice is in Rungis (15 km from Paris), an industrial and commercial zone well connected to Paris by highways but further away. The second decision variable is the number of clients. Each client has a specific location, they are all inside Paris. The third decision variable is the vehicle capacity. The optimization aims to minimize the total distance driven by the fleet.

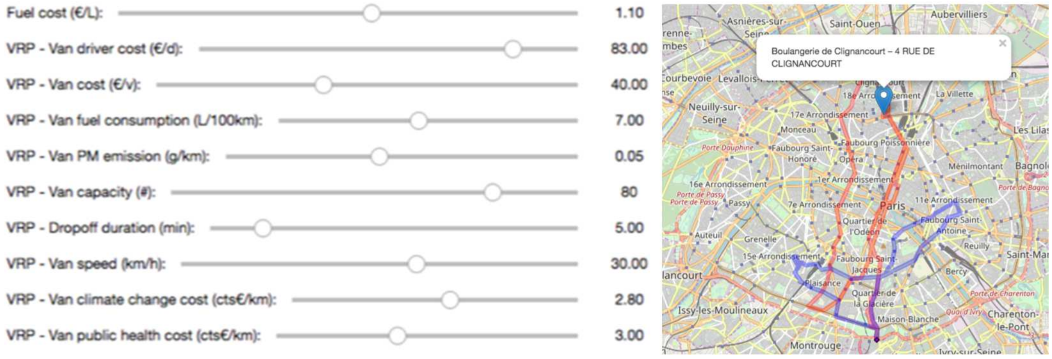

Fig. 2. On the left, simulator parameters are easily customizable using sliders. On the right, vehicles itineraries are plotted on a real map.

Capacity has been directly added as a constraint in the optimization model. The constraint on capacity is viewed as the average number of orders that can fit into one vehicle. A choice of simplicity has been made on this constraint: weight or size of the orders are not considered. This offers flexibility to compare different activities within the same model. Indeed, some companies are limited by order weight (i.e. construction, food industry), while others are limited by order size (i.e. furniture delivery). Moreover, it obviously makes things easier to understand for the users. Anand et al, and Holguín-veras et al. (Anand et al., 2012b; Holguín-Veras et al., 2018) have shown the difficulty to model this constraint as goods can require different types of trucks. Of course, it shades the potential difficulties for companies having orders with different weights (and/or sizes) to optimize their vehicles loading plans. Finer modelling of this constraint could be a potential improvement to study the problem at an operational level in a future iteration.

Time windows for carriers' operation are constrained by the working shift duration or city restriction (e.g. it is forbidden to delivery to the city centre between 8:00 am to 10:00 am). Time windows are fundamental, they help to understand carriers' operational, tactic and strategic decisions. Solving directly with the optimization engine only hides the importance of time windows. So, it has been decided not to integrate the constraint directly into the model. User swill have to optimize thier decision variables with respect to the time windows constraint.

After the presentation of the model, participants may call into question the model. In this example, the optimization strategy is to minimize the total driven distance. However, participants may think the cost, instead of distance, should be minimized. The facilitator could take the opportunity to use the interactive nature of the simulation. The group could run different scenarios to test how different optimization strategies would impact the chosen KPIs.

3.4. Key Performance Indicators

Three Key Performance Indicators (KPIs) have been chosen to model different objectives: financial (carrier perspective), time (carrier perspective) and pollution (city perspective). They have been chosen for their relative simplicity, their known influence on stakeholders (Holguín-Veras et al., 2018). The KPIs are computed based on optimization results (i.e. number of km) and customizable parameters (e.g. fuel cost, polluting emissions per km, delivery duration). Although both activities are sharing the same KPIs, their differences will lead to different decisions. For example, restaurant deliveries have a strong time constraint to operate before lunch (between 9am to 12am). If the vehicles are already at full capacity, there is no apparent incentive to improve their speed of delivery, as it is not possible to deliver after noon or use a bigger vehicle. On the contrary, for e-commerce deliveries that can be performed all day long, it may be easier to perform another delivery tour. Interactivity should help people with unfamiliar with logistics to discover these differences by themselves.

This example illustrates well that a common model for both different activities can help draw meaningful conclusions to explain their operational decisions. For this use case, the advantage is to be able to test one regulation on both activities at the same time, and have comparable indicators for the different activities. The limitation is that the KPIs may not be able to measure differences: one KPI may not be adapted to a certain type of activity (e.g. speed of delivery is less relevant when delivering to restaurants). Therefore, participants could suggest adding KPIs to improve the model. In this discussion, it seems important to point out increasing the level of detail will make the analysis more complex: the number of scenarios to test grows exponentially when adding parameters. The facilitator should lead the discussion towards the initial objective of the interactive simulation for this use case: create a understandable model to estimate the impacts of regulations on different activities. The model has to be understood by everyone to be able to reach consensus on the model and the estimation of the impacts.

3.5. Solutions design

In this use case, it is not really about designing solutions but rather imagining the decisions of the carriers consecutively to a new regulation. For example, participants have to predict the carrier's decision following the truck ban. This step can only be ended if consensus on the model has been reached. Participants have to validate the model: are the modelled carrier's operations representative of its activity? Are the KPIs meaningful? Are the KPIs providing enough information to predict the carrier's decision? If not, participants have to propose improvements to the model. Validation of the model by the participants is expected to be reached only after several iterations.

The concept of open models has to be emphasized for the model validation. The model has to be "simple" in order to be understood and to be usable by everyone. The goal is more about opening a group discussion about reality and not trying to mimic it perfectly. In other words, some concepts are so obvious (or easy to infer) for the participants that it may not be necessary to modify the model. For example, time windows are not a constraint in the optimization. It is easy for the participants to make the relevant decisions with respect to the constraint. This approach of learning-by-doing is seen as a powerful way to explain some logistics concepts. Moreover, the model is potentially easier to explain: there are less parameters and less constraints to take into consideration. Finally, if the model is general, it is more flexible to model new hypothesis (e.g. new activity types, unforeseen operational constraints).

All this effort for transparency is not only meant for validating the model. It also aims to help participants to analyze the results from the simulations. Previous experiments (Gaudron et al., 2018) showed the difficulties for participants unfamiliar with modelling over a short time span (half- day) to extract knowledge from the simulations. This is one of the main motivations to start with a model that can be seen as basic. This model can already answer questions even partially. Then, only when gaps are identified, the model is going to be improved. Otherwise, participants have to pay the price of complexity from the beginning: the model is not understandable and cannot be generalized to other scenarios.

4. Experimentation

An experiment is planned to estimate how participants' understanding of the model improves with interactivity. The experiment is planned to be replicated on two groups. The first group (neophyte group) will be composed of students. They have a variety of backgrounds (biology, architecture, engineering, etc.) and little knowledge about City Logistics, modelling, and operations research. The second group (expert group) will be composed of professionals close to the City Logistics issues – logistics managers, directors of operations.

The experiment will be composed of three phases. Each phase will be evaluated with the same survey in order to follow the potential evolution of their opinions. The survey will have a similar form to the one described in the methodology. In addition to the evaluation on the specificity of one regulation, participants will have to share a comment on their decision. Participants will also be asked to give a confidence grade about their opinions.

During the first phase, the group only has access to a description of the model. Participants will have to infer conclusions from the model, "in their heads". In the second phase, the group can use the interactive simulator, but they are not allowed interact with the other participants. In the third phase, group discussion will be moderated by the facilitator as proposed in the methodology. At the end of this last phase, participants have to propose a common answer for each regulation. However, if consensus cannot be reached, participants will give their own opinion in the survey. The group of experts will also be asked to model their activity (all or a part) and to define the model domain of validity.

Two observations are expected from the experiment. Firstly, confidence level in the problem analysis is expected to grow. Secondly, opinions in the neophyte group are expected to be dispersed and to converge more and more along the different phases of the experiment. In contrast to the expert group, where opinions are expected to be much more similar from the beginning thanks to their expertise. The experiment is unlikely to show if both improvements in confidence and consensus come from, (1) the additional time thinking about the problem, (2) interactions with the model or (3) interactions with the group. A qualitative survey will be done to gain feedback on their experience with the interactive simulator.

5. Conclusion

A methodology for collective decision making is proposed for the field of City Logistics. This methodology relies on an interactive simulator. It offers a common platform for everyone to express their opinion and listen to others. This tool is meant to be used during group discussions with shippers, carriers, and local authorities. The interface can be useful to help balance stakeholder's trade-offs. It can be used to show what is impossible or reasonable to ask from one stakeholder. Additionally, a stakeholder can discover value in a solution not fulfilling its main objective. For example, from a carrier perspective, low emission deliveries are more expensive, but they are good for communication purposes. Moreover, constant discussions about the solution should mitigate the risk to miss operational constraints. Therefore, it should help to come up with some well thought solution avoiding implementation problems in real life. If a proposition is unacceptable for a stakeholder, all the energy should be saved to explore a more consensual proposition. An experiment using the methodology will be conducting using two different groups: students and professionals close to city logistics issues. Ultimately, the tool should be used on a mixed group of professionals and local representatives. To that end, the multi-actor, multi-criteria analysis methodology (MAMCA) (Verlinde and Macharis, 2016) could be useful to help define a solution acceptable for different stakeholders.

Antoine de Saint-Exupéry said that, perfection is achieved, not when there is nothing more to add, but when there is nothing left to take away. The goal of a workshop using this methodology is not to come up with the perfect representation of reality. The goal is to bring into light the essence of the problem. Participants should not only master the specific issues studied in the workshop but also, they should be able to apply their knowledge to other issues.

Apparent simplicity and openness are sometimes view as a weakness in modelling. A usual critic is that people could cheat. However, people are likely to refrain their urge to cheat if everyone can see they are using the model to their advantage. Another common criticism is that open models lack the capacity to represent a system. On the contrary, we argue that the ability to gather a diverse panel of experts will help model construction and validation. Notably, agreeing on modelling social criteria –such as equity– may only be done by the collaboration of many disciplines (citizens, professionals, operations research practioners, researchers in social sciences, etc.). Finally, the interactive simulator is seen as a support for discussion, the model is here to help understand, to test hypotheses and to infer conclusions. Models do not necessarily need to depict exactly the problem at hand.

Today, experts build complex models (e.g. agent-based simulation) that only they or their peers can understand. In a near future, machine learning models may be used more and more, although today virtually no one could understand the logic of these models. One research perspective is to investigate how open models can be used in conjunction of these "complex" models in order to better explain them. Open models could be used in order to involve non-expert persons in modelling along the decision process or for validation of these "complex" models.

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