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Decision Support Platform for Urban Freight Transport

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Pedro David Gutierrez Quijano

Decision Support Platform for Urban Freight Transport



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Urban transport in cities is composed of many micro-transport systems. Each one of these has negative effect on the urban mobility. The study and analysis of one of these micro-transport systems is an effective way to understand the problem and consequently to propose new solutions, as well as a source of information to improve the urban transport system. In this paper we focus on the urban goods transport system that emerges from a particular supply chain, we support on a GIS (Geographic information system) computer simulation model to understand and analyze a case study. The simulation model developed is an example on how the abstraction approach of agent-based modeling (ABM) integrated with GIS can be used to represent the complexity inherent in the urban transport system. The novelty of our approach lies mainly in the fact of being able to analyze the combined effect between supply chain management and transportation system. The use of ABM allows us to model behaviors, negotiations and other social properties of the system's entities represented as agents, it can also help with understanding the emerging system's behaviors from an independent level. As a result of our study, the conceptual multi-agent model is presented and implemented in JAVA programming language, which is used for simulation experiments on the analysis of routing and departure time choice, with the goal to propose a plan to improve the micro-transport system under study.

Keywords: Supply Chain, Transport, Agent-based, GIS

1 Introduction

Today, 54 per cent of the world's population lives in urban areas, it is estimated that by 2050 two thirds of the world's population will live in cities. Projections show that urbanization combined with the overall growth of the world's population could add another 2.5 billion people to urban populations by 2050, United Nations Development Programme (2014). In a world of rapidly increasing urbanization, with an unprecedented transition from rural to urban areas, urban transport is at risk of collapsing in the next years, with a panorama that it can affect the quality of life of hundreds of thousands of citizen, it is not surprising that the urban transport must be high on the plans for politician, city planners and other specialists, as well as researchers.

Owing to their large and densely urban populations and widespread commercial activities, urban areas require the distribution and collection of large quantities of goods and the provision of a wide range of services for commercial and domestic use, resulting in considerable freight activity. However, in spite of its importance, lately politician and researchers have paid relatively very little attention to urban freight in contrast to passenger transport. Again like in the industrial revolution, urban freight transport pose us new logistical challenges, there is a need to contemplate how best to tackle urban freight transport logistics because it is vital to achieve the ultimate objective for urban areas: mobility and accessibility for both freight and passenger, efficiently supporting commercial transport with high quality of life for his citizens.

One approach regarding to the issue of urban freight that it has great potential despite still, it is in development process. It is related with the simulation models, decision makers trust on models, abstractions of the real world to test a number of scenarios before implementing a chosen scenario in practice. It make sense because, it is excessively costly and risky to perform scenarios in reality, it may then sound evident that, if the models are used to test decisions that will have an impact on the real world, they should be good representations and precise reflections of that same real world for which the decisions are intended. Unfortunately, transport models are more often than not poor representations. Consequently, they result in bad.

There have been numerous attempts to improve the performance of urban freight while simultaneously reducing its negative environmental impacts. The results, however, have been disappointing, and most pilot projects have not survived. This may be due to the fact that the solutions have been designed and evaluated without taking into account the particular characteristics of different city areas. A supply chain management approach may be applied to urban freight transport where the complete process is taken into consideration, emphasizing the role of customers as well as transport suppliers.

In contrast, we propose a model for urban freight transport, in which the behavior of freight agents and their relationship in supply chains are integrated, the model covering all links in the supply chain from supply through production up to the distribution and his transport until the final consumer. The approach aims assess the isolated impact of one supply chain on the urban transport.

This document summarizes the work done by the authors during three year, it aims to propose a decision support platform for urban freight transport and to show his application to analyze the urban freight movement in the Palmira city area. In the next pages, a brief introduction to simulation and agent-based modeling (ABMS), the main concepts and application areas are illustrated, a review of some previous work on the subject is done, and a review is made of existing methodologies to model agent-based systems. The proposed platform is discussed and the details on model formulations are provided. A practical application around the modeling and simulation based on agents (ABMS) in the supply chain related to the baker sector of the city of Palmira, Valle Colombia. The final section provides conclusions and recommendations on the proposed model.

2 Agent-based modeling (ABM)

Agent-based simulation has proven to be a very useful technique for modeling complex systems, especially social systems, Gilbert (2004). Using agent-based simulation, the modeler explicitly recognized the actors that make up complex systems, and in particular the social relationships between these, which are the product of individual behaviors and their interactions. The main difference between the agents and other modeling techniques-based simulation is the way to build the abstraction of the real system and consequently, the formal model is built.

On formal models built using agent-based simulation, the basic components of the real system are explicitly and individually represented in the model, Edmonds (2001). In this sense the organizational boundaries that

define the fundamental components of the real system correspond to the boundaries of the model agents and interactions that take place among the fundamental components of the real system correspond to the interactions that take place between the agents of the model. In this sense the organizational boundaries that define the fundamental components of the real system correspond to the boundaries of the model agents and interactions that take place among the fundamental components of the real system correspond to the interactions that take place between the agents of the model. This direct correspondence is precisely the main attraction of the agents modeling since it is capable of increasing the realism and the scientific rigor of formal models thus constructed.

Agent-based systems are characterized by understanding various agents that are in greater or lesser degree heterogeneous, autonomous and independent, showing everyone their own goals and objectives, and are generally able to interact among themselves and with their environment, Torsun (2010). Often, but not always, they are systems characterized by the existence of large numbers of relatively simple agents, which can evolve over time to adapt to new conditions or new goals. In particular, agent-based simulation is particularly important in complex systems with the following characteristics:

- Systems in which the geographical space can have a significant influence. In many systems, the fact that two individuals are separated in space means a probability of lower interaction. Agent-based modeling facilitates the representation of physical space in which they move and interact agents.

- Systems where there is social interaction networks. Interactions between system components can be influenced by several factors in addition to the physical space. Agent-based modeling facilitates social interaction networks that are not necessarily structured spatially explicit representation.
- Systems in which the individual components of the system are able to learn, and it is convenient to represent explicitly and individually each component of the system.

Agents-based methodology has been widely used to model systems in a wide range of scientific disciplines: for example, economy, Tesfation (2002), finances Lebaron (2000), management of natural resources Bousquet (2004), political sciences Axelrod (1997), anthropology Kohler (2000), sociology Conte (1997), biology Paton (2004), supply chain and medicine Mansury (2002), where on the basis of rules which determine the individual behavior of the agents intends to infer the global properties of the entire system. Agents-based methods facilitate the study and modeling of complex systems from the units that compose them, allowing us to build experimental models of reality from a different from the traditional point of view: from the most simple to the complex, from the particular to the more general.

Since the emphasis on agent-based simulation is to find appropriate abstractions that describe the basic components of the system and their interactions, rather than seeking abstractions that handled directly on the global dynamics of the system, this modeling technique is particularly useful to model macroscopic processes that arise from interactions between actors in a system.

There are various research contributions that seek to assess the true value of the application of this approach in decentralized supply chains around the theme of ABMS, Borshchev and Filippov (2004) explains that the ABMS is by nature decentralized, since the overall behavior of the system is never defined, on the other hand the model defines individual behaviors allowing the behavior of the global system to emerge from individuals, also known as simulation, Arango Serna, Serna Uran, and Alvarez Uribe (2012), in decentralized chains however the overall behavior of the system is difficult to measure, because of the dispersion in terms of topological, functional, administrative, etc., of different organizations.

2.1 Methodologies

In the context of the ABMS have been proposed different methodologies, however very few focus on the supply chain (SC), Hernández, Alemany, Lario, and Poler (2009), some of these appear in the review made by Labarthe, Espinasse, Ferrarini, and Montreuil (2007) where needs to incorporate elements of complexity to modelling and go into detail on specific methodological elements are explicit. For the development of this work, three contributions were taken into account in particular:

Initially, Labarthe, Espinasse, Ferrarini, and Montreuil (2007) it proposes a methodology based on agents applied to the case of a SC of the industry of golf clubs, includes an experimental analysis by means of simulation, the authors propose a methodology comprised of three levels (i) a conceptual level, in which the real SC is modelled by means of domains and then reformulated to agents approach resulting in a conceptual model, (ii) an

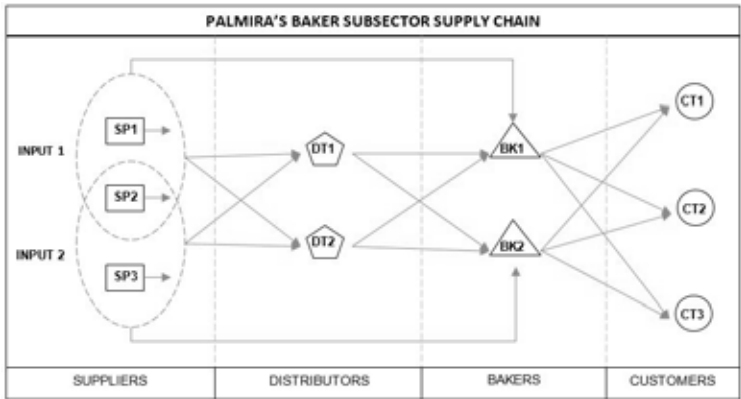


Figure 1 Palmira's baker supply chain

operational level which is developed a computational model known as operational model, (iii) a level of exploitation, in which the simulation is carried out based on scenarios.

Hernández, Alemany, Lario, and Poler (2009) presents the implementation in a case study on one car CS, proposes a nine phased methodology that considers the modeling AB and linear to support programming operational planning in SC nine phrases are developed through three blocks of action that are similar to those proposed by Labarthe, Espinasse, Ferrarini, and Montreuil (2007): (i) conceptualization that corresponds to the identification of the problem, conceptualization, and obtain parameters, (ii) modeling AB: beginning with the identification of main and intermediate agents representation of behaviors and the conceptual model AB, (iii) the application considers the development of the application and the final validation.

Finally, Ivanov, Sokolov, and Kaeschel (2010) combined application of the control theory, operations research and modeling AB on a methodology for Adaptive SC. The authors consider different types of structures for decision-making in the SC: products, functions, organization, technology, topology, information and finances, the importance of this approach is the identify relationships in operations resulting from the different types of structures. The authors also present a methodology based on three phases: conceptual modeling, mathematical modelling and validation in simulation environment.

3 Case Study

The case study that analyzed in this work is composed of 80 companies in the planning sector of the city of Palmira, Valle. The characterization of this supply chain was carried out by members of the Group SEPRO (Society Economy and Productivity) in previous stages of the research. Below I present a summary of the current situation of these previous research-based supply chain.

3.1 Description

Following is the supply chain based from three points of view, as it proposes, (Cardenas, 2013) in its methodology.

3.1.1 Normative View

Organizational structure: From the raw material production to the final consumption, the Palmira's baker subsector supply chain is composed of

four levels: Supply, Distribution, Manufacture and Consumption; each level conformed by only one actor (Figure 1), these actors interact with each other with the goal to transform the resources into goods, and finally, distribute them to consumers.

Functional Structure: Based to the SCOR model the functional structure of Palmira’s baker subsector supply chain is illustrated in the (Figure2), the production process is simple, initially the suppliers supplied the input materials to produce the bread, this materials are dealer to the distribution centers, later the bakeries buy these materials to the distribution centers or directly to the suppliers, and then the bakers make bread and await that the customers will buy bread.

Decisional Structure: In accordance with the classification of Chu and Leon (2008), the Palmira’s baker subsector supply chain is a “private information

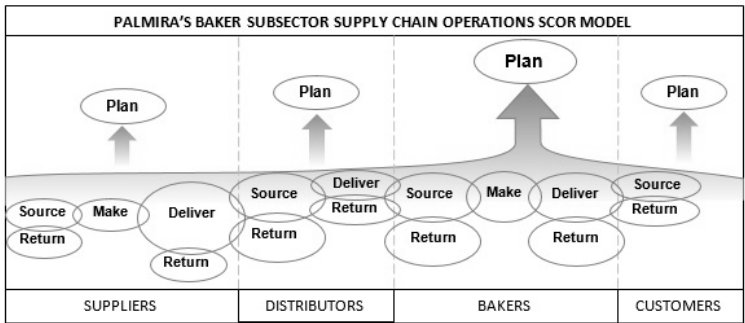


Figure 2 SCOR Model

system” in other words a system where the decision-making authority is “decentralized” since no actor has authority to make decision for other actors in the system, and the access to information is “partial” because the decision-makers has access to only limited information of the system (private information). In this case there are no any decision structure, the decisions are taken individually by each actor of the supply chain, and the particular benefit governs the system. This is related to the fact that neither exists any informational structure.

General Politics: Although the decisions are taken individually by each actor of the supply chain, the suppliers have more influence than all other actors in the chain, because of them depends the supply of raw materials to the other actors.

Applicable laws: The main control institution is the Secretary of Health, who is responsible to inspect, evaluate and enforce the GMP (Good Manufacturing Practice) based on the decree 3075 of 1997.

3.1.2 Infrastructure View

The study area is located in Palmira, it is a city and municipality in southwestern Colombia in the Valle del Cauca Department, located about 30 km east from Cali, the department's capital. The city covers an area of 1.160 square meters, and have about of 296.200 habitants, Chamber of Commerce (2011) distributed on 16 comunas of which 7 comunas are located in the urban area. According to the official data supply by the Palmira's Chamber of Commerce, the city have 204 bakeries of which 80 bakeries participated in the study. We have the geographic position of each of the bakeries.

The suppliers and the distributors have wineries where they stored his products; these wineries generally are leased by other people. The main transportation means used in the supply chain are bike and motorcycle however the suppliers and the big distributors use tucks.

Studied bakeries are located within the urban area of the city of Palmira, where 96% are in the lower middle strata (2 and 3) and plants which develop their activities are rented by 82%. However this sector providers, have different locations designated as local, regional and national. Transport of inputs and distribution of the finished products are made only by land; for the transport of inputs used bicycle, motorcycle and bike trailer for small distributors, while producers or larger distributors used vans for transportation of inputs. Used labor is essentially technical.

Information infrastructure is basic, is limited to the use of means of telephone communication between bread and distributors or producers, without registration or support of such communication, use of additional media such as the use of email, software or fax is not recorded.

Financial structure, within the supply chain transactions, there are basically two methods of payment. Cash payment and payment on credit, the latter with greater presence in the bakeries of small size. There is no evidence of electronic payments, or any other transaction.

3.1.3 Logistic View

Physical flow: The logistic flow from the raw materials to his transformation in final product, happens from suppliers to the customers (see Figure 1), the flow of raw materials begins with the producers, inputs flow water down

through dealers, to converge in bakeries, and finally reaching the final consumer in the form of cakes and pastries from this level. There is no surge while raw materials flow down the chain.

Information flow: The information flow about the logistic operation between actors of the chain supply is completely null, the only information that flows through the chain is related to the commercial exchange between the actors in the chain.

Financial flow: Opposite of logistic flow the financial flow happens from the customers to the suppliers, the flow of money begins with the commercial exchange between consumers and the bakery: consumers buy bread at the bakers products, then money flows between the bakery and the distributors and sometimes between bakeries and producers: bakeries use part of their profits in the purchase of the necessary inputs for manufacturing their products to distributors or directly to producers Finally the money flows between distributors and producers since distributors buy inputs to producers.

3.2 Results

The simulation platform is still a prototype. All the modules are programmed but still is phase of validation and verification. The next step is to compare the simulated trip patterns with actual data from field research. The results look very reasonable and promising. The model is capable of describing trip patterns, predicting route choice and calculating effects on accessibility and environment.

4 Computational Platform

In the last few years, the agent-based modeling (ABM) community has developed several practical agent based modeling platforms that enable individuals to understand each individual system separately supply chain or transport system. However, real life does not works in this way, our approach is develop a platform that enable to logistic analyst to understand the complete system.

4.1 Modeling

The platform proposed uses the multi-agent paradigm to model a supply chain and her emerging transport system, in order to apply multi-agent system tools to simulate supply chain management. A supply chain may be defined as an integrated process wherein a number of various business entities (suppliers, manufacturers, distributors, and retailers) work together in an effort to: (1) acquire raw materials, (2) convert these raw materials into specified final products, and (3) deliver these final products to retailers. Following, we describes each one of the agents proposed to model under study system.

4.1.1 Agent 1: Supplier

The objective of this agent is supply the demand of raw material of the producer's agents, it only have direct relation with agents type 2. With the idea of simplify the model, this agent is modelling like supplier with endless supplies.

4.1.2 Agent 2: Producer

The objective of this agent is supply the demand of final product efficiently, always with the idea of maximize its own profit, it is customer of agent 1 at the same time it is supplier of the agent 3.

4.1.3 Agent 3: Retailer

The objective of this agent is supply the demand efficiently, at the right time, in the required quantity and required quality. It is customer of agent 2 at the same time it is supplier of the agent 4.

4.1.4 Agent 3: Distributor

The objective of this agent is the keep finished product available for sale, while it has already set a frequency with which the batches of production will be carried out, must calculate how many products must be built and put on sale, why it should consider the expected demand, available inputs and the current inventory of finished product.

The assumptions that are handled for this agent are mainly three: (i) the agent has a daily frequency of fixed and known production, (ii) the production of finished products (breads) time is deterministic and known, (iii) the agent boasts a daily demand according to the day and month.

4.2 Implementation

The computational framework for implementing the proposed strategy consists of the following components: the computation control module, the

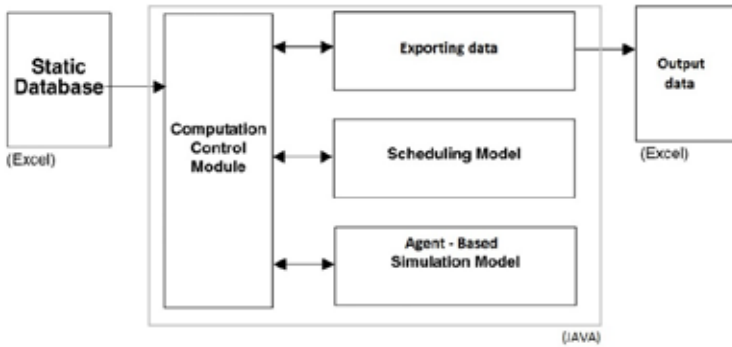


Figure 3 Computational components

three models for exporting, scheduling and simulation, and the static database feeds the system, as shown in (Figure 3). The computational control module provides centralized computation management and control of interactions with the other computational components. Its various functional roles include:

1. Generation of deterministic demand forecasts and demand scenarios.
2. Generating/updating and releasing commands for executing the planning, scheduling and simulation models.
3. Issuing commands for retrieving/recording in the databases.
4. Re-processing the outputs of planning and scheduling models as inputs to scheduling and simulation models respectively.
5. Reporting the computation results.

The static database contains the information defining the case problem. The data is saved in a Microsoft Excel Workbook file. One spreadsheets for agent and inside of each spreadsheets, the data is categorized based on

their relevance and saved in its corresponding spreadsheets. The categories of the static data are as follows:

1. Quantities related: number of agents of each type, number of product types, number of grades, number of packages, and number of processing units in each production facility, production capacities.
2. Time related: length of simulation horizon, length of the horizon and of each period in the planning and scheduling models.
3. Demand related: demand proportion of each product type, package ratio, proportion of regional demands, parameters for demand patterns of each product.
4. Analysis related: number of iterations for the outer optimization loop, convergence tolerance.
5. Extras: inventory cost, backlogging cost, safety stock shortage cost, transportation cost, transportation time, initial safety stock levels.

The output data records the computational results and provides the updated output data. The following summarizes the information kept in this the output database:

1. Current time related indices: current iteration number of the outer loop, current iteration number of the Monte Carlo loop, current simulation clock (date and time of the current point at a simulation).
2. State variables: on-hand inventory levels, WIP at each processing units at each agent, demands backlogged and products in transit,

which are updated at each scheduling time period as the simulation proceeds.

3. Demand data: the deterministic demand forecast and the demand scenarios.

The GIS and agent based simulation model is fully written in JAVA language and support by different open source frameworks.

5 Conclusion

Transport and urban development projects are often a source of major controversy, as they can generate significant benefits as well as difficulties for various local actors. Methodologies are needed that can incorporate different points of view in order to find sustainable solutions for transport, mobility and logistics. Computational models can be used in the context of complex transport-policy decisions, allowing all of the different stakeholder perspectives to be taken into account and structuring the discussion by assessing the relative weights of all the factors involved.

In urban contexts, freight transport is an important part of the local economy and employment and, at the same time, one link in a larger supply chain. It is therefore important to look for solutions that fit in with urban policy objectives and the commercial model of the supply chains. Therefore, solutions require a combination of local policy, new technology and varied logistics solutions.

There have been numerous attempts to improve the performance of urban freight while simultaneously reducing its negative environmental impacts. The results, however, have been disappointing, and most pilot projects

have not survived. This may be due to the fact that the solutions have been designed and evaluated without taking into account the particular characteristics of different city areas. A supply chain management approach may be applied to urban freight transport where the complete process is taken into consideration, emphasizing the role of customers as well as transport suppliers.

The proposed model is a comprehensive approach to model freight transportation in a way that systematically reflects the individual behavior of freight agents. The model incorporates individual behaviors by considering the largest influence of each freight agent at each stage. The model takes into account the fundamentals of goods transport, which is consequence of goods flowing through supply chains. Each agent is assumed to behave rationally in freight transport activities (such as goods purchasing, carrier and vehicle size selection, and vehicle routing) by trying to minimize his own total costs in each activity. The proposed model was applied to analyze the freight transport in the Palmira city area. The results of model application suggest the need follow working for models reflect reality more accurately, this concept is very promising.

The proposed model for vehicle routing is still rather simple and considers only the distribution purpose while pick-up purpose is not yet incorporated. Vehicle routing with time window constraint is also suggested for an improvement of the model. The variations in the pattern vehicle routing are needed to be considered in the future.

Multi Agent-based models in traffic and transport planning are still relatively new, but have proven to provide more accurate and richer result sets, although currently somewhat slower. That is, they are better reflections of

reality. Also, they are much more intuitive to understand and to validate, an aspect often over looked in evaluating the quality of a model's output.

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