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Quantitative assessment of sustainable city logistics

Rafael Grosso-delaVega[a,i] and Jesús Muñuzuri[a,ii]

[a] Dpto. de Organización Industrial y Gestión de Empresas II. ETSI. Universidad de Sevilla. Camino de los Descubrimientos, s/n. Isla de la Cartuja, 41092, Seville, Spain

[a,i] *rgrosso@us.es*

[a,ii] *munuzuri@etsi.us.es*

Abstract: The aim of this paper is to seek an answer to an specific question: how to make city logistics sustainable? This question in principle has no specific answer. By contrast, it could be answered in many and varied ways. Behind the search for some of these answers lies the development of a roadmap which this work aims to present. The research lines, the theoretical framework and methodology of the roadmap will be explained. Although the current status of the roadmap, its duration and timing still need to be completed, the main facts, as well as the results obtained to date and the expected results are here presented.

Key words: City logistic, Sustainable policies, Access time windows, Waste collection, Optimization.

1. Introduction

1.1. The paradigmatic framework

A multiplicity of different kinds of goods are constantly entering, transiting and leaving urban areas: consumer goods, building materials, waste, packaging and mailings, etc. (Dablanc, 2007). It is well known that the urban freight transport includes heterogeneous goods and different types of vehicles of different sizes. In addition, the movement urban goods has a direct and fundamental influence on economics (Muñuzuri *et al*., 2005) and is vital to industry performance. That is why urban freight management is a necessary challenge which nevertheless implies a high complexity. But goods are not only transported in urban environments, so the first problem which efficient management of urban freight transport finds is the very notion of transport itself and its variants (Figliozzi, 2012).

Traffic congestion has become a daily phenomenon due to the increasing amount of traffic and the limited capacity of the road network. And these growing delays are very costly for both private road users and logistics and distribution providers. This causes high economic costs to these providers, in an attempt to avoid possible delays in deliveries or collections to customers, by additional vehicles and its own drivers. In addition, violations of driving and traffic rules need close attention. Furthermore, it increases externalities related to the environment, such as emissions of CO_2.

Another important problem that urban freight transport has to face is the urban morphology. European cities have several common characteristics that influence directly their mobility and their businesses. Likewise it imposes some restrictions on the flow associated to the supply of goods. First, most of its city centers have a radial structure with a high concentration of shopping areas, restaurants and other centers of social attraction. This structure, which is inherited from the Middle Ages, generates asymmetric flows of people (going to work, to shop, to eat or to visit tourist attractions) with those flows associated with goods. Parking problems, which virtually exist at the center of all urban areas, increase in Europe due to its peculiar morphology consisting of alleys and narrow streets (Ligocki & Zonn, 1984; Muñuzuri *et al*., 2012b).

In addition, the road transport sector in Spain has not been considering City Logistics as an industrial subsector. Therefore, there are no databases showing the importance of this activity.

On the other hand, from the 90´s the concept of sustainable development has been attracting worldwide attention. Sustainable development has proven to be an enduring and compelling concept because it points towards a clear management policy. Also, it is also flexible enough to adapt to new challenges, technological and economic conditions and social aspirations. It appeals to the general public and the scientific community in particular, as it involves a systemic view of economy and ecology, and requires solutions that protect the interests of future generations (Goldman & Gorham, 2006).

Sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs. It is widely accepted that these needs include economic, social and environmental developments (see Figure 1).

This "triple" point of view understands that development should be bearable (socially and environmentally), fair (socially and economically) and viable (environmentally and economically) and, therefore, sustainable and durable. The representation of the "three pillars of sustainability" implies the fact that the concept of sustainability itself is the result of interactions between these three dimensions. That is the reason why they cannot, or rather should not, be analysed separately from each other (Rossi *et al*., 2012).

In response to the intersection of urban freight transport and the concept of sustainability, a holistic approach to globalize planning and urban management needs to be adopted (Robusté *et al*., 2000). Such a challenge needs to consider together all operations and services present in the city; special attention to the sustainability of the system should be paid. This new discipline, which aims at systemic or holistic optimization of city services, could be called Sustainable City Logistics.

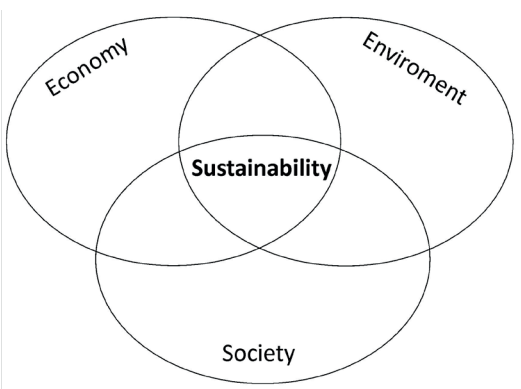

Figure 1. Schematic view of the "three pillars of sustainability".

1.2. Answering the questions

Therefore the question to answer in this roadmap is how to make city logistics sustainable. This question is very broad and covers many answers. That is why there has been an attempt at setting more specific objectives for our roadmap. Consquently, and for this purpose this work aims to solve two sub questions related to this capital aspect.

1.2.1. Are sustainability policies really sustainable?

The first sub question which is being addressed is about road freight transport. It is well known that road freight transport is causing a number of social, environmental and economic negative impacts in many cities around the world. Therefore sustainable city logistics must be the solution to the problems of urban centers, and researchers must have as their main objective to reduce these impacts without penalizing cities needs (Chang & Yen, 2012). Moreover, policy makers and decision makers aim at decreasing the above mentioned variety of negative social, environmental and economic impacts of urban freight transport. Because of this several initiatives and policies have been implemented to try reduce them (temporal regulation of access, promotion of cooperation between public and private sector, etc.). Some of the objectives of these policies are to improve the environment (air and noise quality), securing pedestrian's space and the prevention of accidents. They all have sustainability as the ultimate goal (Dalkmann & Brannigan, 2007).

In this situation, City Logistics researches, reflect upon the impact of these policies on the different areas and upon the interests of the different stakeholders involved in urban areas and its centers (citizens, residents, merchants, transporters, local authorities, etc.). This is a field that has been investigated in recent years (Quak & de Koster, 2009; Gonzalez-Feliu *et al*., 2012; Stathopoulos *et al*., 2012). Given the heterogeneity of the interests of these stakeholders, coordination becomes somewhat cumbersome, so they generally act independently and without any centralized control. But this paper seeks to answer a less particular issue; a question which captures the overall interests of all stakeholders involved (general interests should be above individuals): are sustainability policies really sustainable? Therefore, the first purpose of this work is to evaluate one of these policies in a quantitative way to answer the question (Muñuzur *et al*., 2013).

1.2.2. How to make urban fleets more sustainable?

The second sub-question that arises from the main one is about the urban fleets, more specifically about the fleet in charge of recyclable waste.

Trying to solve the problem of waste collection in cities is not a new problem. Back in the 70's, authors already addressed the problem, either from a mathematical point of view (Marks & Liebman, 1970), or by modeling and solving a vehicle routing problem (VRP) (Beltrami & Bodin, 1974; Turner & Hougland, 1975). This problem is not easy to solve since it falls under the classification of NP-hard.

The increased levels of consumption and the waste generation associated with it, the environmental considerations and the sustainability of cities have led to the emergence of new European and national policies regarding the management of municipal waste. An example of this is the National Integrated Waste Plan implemented in Spain in 2009, which is to continue the previous National Urban Waste Plan (PNRU). Among other things, it enforces municipalities over 5000 inhabitants to ensure proper separation for a selective collection of waste. Such measures imply the consideration of new challenges to municipalities, even more so in the economic recession framework in which we live. Different types of dumpsters, different types of waste, the location of dumpsters, pollution, energy consumption, cost reduction and the like, are some of these challenges. In this sense, authors address the problem from such perspectives as the consumption of fuel (Sonesson, 2000), or having in mind environmental and economic goals.

Nowadays the emergence of new technologies and the drop in their price allow researchers to find new tools to solve this problem. Examples of these new technologies are, among others, the Geographic Information System (GIS), volumetric sensors, or radio frequency identification (RFID). By using this technology, some issues may be addressed. These include eliminating unnecessary stops, fleet reduction and balancing according to demand, pollution impact reduction, operating costs reduction, etc. These issues are actually the basis of some research projects undertaken in recent years (Chang, Lu, & Wei, 1997; Nuortio *et al*., 2006) . Needlles to say that all these new lines of reseach offer a great potential for future work.

It is in this direction that this work moves. This part of the project addresses the problem of waste disposal in urban areas with the real-time level data of the dumpsters. In particular, the work focuses on the collection of glass containers. A more sustainable collect policy is present and compared with other classical optimization algorithms (Grosso-delaVega *et al*., 2014).

2. Proposed Solutions

The objectives of the roadmap will focus on:

- Characterize and analyse the situation of city logistics and characterize and analyze the situation of recyclable waste collection in the European Union and Spain.
- Study the existing scientific literature on city logistics and recyclable waste collection, especially in the field of sustainability and city centers.
- Study of the determining factors for sustainable development of city logistics in centers in European and the particularly factors in Spanish cities.
- Design optimization models for sustainable city logistics improvement and for better understanding and analysis.
- Development of a simulation environment, using heuristics and metaheuristics, specifically designed for City Logistic problems in city centers.
- Validation of the models proposed in the simulation environment.

As already mentioned above, the proposed methodology focuses on optimization algorithms. Also, also solutions need to found in a relatively short time; in this way fast optimization mechanisms such as metaheuristics, heuristics and techniques are implemented. These will be compared with existing techniques in order to be able to verify the hypothesis.

The work has been divided into four stages, which be conducted sequentially:

1. Study of the history of freight transport in Europe and the state of the art in terms of optimization of urban transport routes and its sustainability.
2. Development of a simulation environment in which to test the heuristics and metaheuristics.
3. Development and codification of the different heuristics and metaheuristics are considered to solve the said problems.

4. Analysis of heuristics raised. Study and comparison of the results obtained. Analysis of the improvements that the system would provide in a real environment.

3. Expected and existent contributions

This roadmap project was initiated in September 2012. Since then there have been many experiments and some intermediate results have been obtained. There are still results to be complete, however, although some of the responses to the issues raised have been published in the following papers derived from the roadmap: Grosso-delaVega *et al.* (2014) and Muñuzuri *et al.* (2013).

Other published works related to the main theme of the roadmap are: Muñuzuri *et al*. (2012a) and Muñuzuri *et al*. (2011).

In their paper, Muñuzuri *et al*., (2013) developed a model based on VRP logic called Vehicle Routing Problem with Access Time Windows (VRPATW). This model was solved using genetic algorithms. They provided conclusive results, about the sustainability of the policies adopted in the city centers. Following the line of research initiated earlier, the autors are currently working on the development and resolution of the model. It is intended to solve as a mathematical model and using a Greedy heuristic. In this way the model would be solved by mathematical programming, using a metaheuristic and also a heuristic. The aims are:

- To be able to answer the questions raised in a more precise way.
- Perform a comparison of the different techniques used in terms of methodology. This comparison is intended be accomplished in terms of:
    - Proximity to the optimal solution
    - Size of the problem that can be solved with each technique
    - Solving times.

At present, this research project is at the design of the experiment phase stage. These experiments must be designed in order to be solved by means of the three techniques. It must be said that the greedy heuristic is being tested so that it solves the problem satisfactorily. With respect to the line of garbage collection, this research project is currently trying to improve the resolution algorithm in order to to improve the results.

At the time that this work was written had another year and a half to the end of the stipulated period of time for the finalization of the roadmap. Given the published results and the results that could be obtained, it is expected that two publications can be submitted in the period of time left.

Aditionally, potential contributions of the roadmap might include the following:

- A move from the theoretical level to the practical level and transfer the results of this roadmap to local authorities.
- Continue developing as a scientist.

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