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ScienceDirect

Procedia Engineering 178 (2017) 569 – 578

Procedia Engineering

www.elsevier.com/locate/procedia

16th Conference on Reliability and Statistics in Transportation and Communication, RelStat'2016, 19-22 October, 2016, Riga, Latvia

Simulation Techniques for Evaluating Smart Logistics Solutions for Sustainable Urban Distribution

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Abstract

Smart logistics solutions have been developed in order to alleviate the adverse impacts of increasing goods' transport in urban areas. However, the outcome can be questioned, unless proper assessment is conducted to compare impacts during or after implementing these solutions. Simulation has been proved as valuable tool to assess impacts of the logistics solutions, before their actual implementation in the field, and support the decision making process. This study contributes in presenting the current state of practice in modeling smart logistics solutions, provides a roadmap in simulation techniques for urban freight transport solutions and improves the knowledge around the patterns currently followed.

Peer-review under responsibility of the scientific committee of the International Conference on Reliability and Statistics in Transportation and Communication

Keywords: city logistics, smart logistics solutions, simulation, last mile distribution, evaluation

1. Introduction

Urban distribution of goods is a main component of sustainable transport networks and one of the main contributors on traffic congestion and environmental pollution in the cities. Urbanization, consumerism, technological blooming and international competition cause a vast demand of products and services and make the

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Peer-review under responsibility of the scientific committee of the International Conference on Reliability and Statistics in Transportation and Communication
doi:10.1016/j.proeng.2017.01.110

distribution of goods within urban areas an essential priority for public authorities. The ever growing demand in transport of goods renders the upkeep of a high traffic and living quality in cities a challenging process.

Over the last decades, many smart logistics solutions have been developed to allay cities' problems related to distribution of goods. These solutions complement conventional Urban Freight Transport (UFT) measures and policies, or replace them entirely. However, new approaches are always generated towards these smart solutions, rendering their implementation dreaded in terms of adequacy and sufficiency, due to the lack of past experience. Especially in a multi-dimensional environment as the urban environment, in combination with the multivariate nature of logistics measures, their implementation can bring adverse effects if all aspects are not considered carefully. To avoid such situations, modelling of the proposed solutions is advised, since it facilitates impact assessment and evaluation before their actual implementation in the field, and support the decision making process.

Several models, grouped mainly according to the scope they serve, have been applied to evaluate logistics measures. For example, Ambrosini *et al.* (2004) addressed two families of urban freight models: (a) the operational models for improving the flow management and (b) the systematic models for evaluating the impact of interventions made in a logistic system. Hicks (1999) under a different approach, grouped the models based on their utility into: (a) simulation models, (b) optimisation models and (c) simulation-optimisation models. Accordingly, Taniguchi *et al.* (2012) clustered models in: (a) optimisation models and (b) simulation models. Optimisation models are associated with the process of finding the best solution out of the number of alternatives the user has in his disposal, based on the objectives need to be achieved. Such optimization models have been used into the logistics field to address issues like sourcing decisions for minimization of total costs (Farahani and Elahipanah, 2008), risk management for coming up with strategies to minimize potential disruption (Gaonkar and Viswanadham, 2014), network design for determining the best network for efficient deliveries (Melo *et al.*, 2009) and other. Simulation models have as purpose to replicate adequately a working system in order to understand it better. Then, an adequately calibrated and validated model can be used as a test bed, where different scenarios and optimisation can be examined. Simulation models, frequently substitute optimisation models, since they can act as fancy manual calculators to test different scenarios and identify the best one, through the trial-and-error process.

In research, several models can be found that aim at the evaluation of the impacts of the concerned logistics solution in some or all four principal sustainability impact areas (economy, environment, transport, society) (Anderson *et al.*, 2005; UK Round Table on Sustainable Development, 1996; Behrends, 2011). This paper focuses on simulation models, and presents them, considering three simulation techniques: (a) Systems dynamics, (b) Multi-agent systems, (c) Traffic simulation (Taniguchi *et al.*, 2012).

2. Simulation models

2.1. Systems dynamics

Systems Dynamics (SD) is a computer-aided approach developed by Jay W. Forrester at MIT University during the 1950's. This approach aims to analyse and solve complex problems related to policy analysis and design by applying feedback control theory to simulation models of organisations (Forrester, 2003; Angehofer and Angelides, 2000). Forrester (1969) in his publication on Urban Dynamics, proposed a new approach for analysing urban related problems, which lays the fundamental grounding for the linkage of the urban dynamics with the decision-making process of urban areas. This approach was widely adopted in the following years, since many applications took place ever since in the area of logistics. Qui *et al.* (2015) describe a systems dynamic model for simulating the logistics demand dynamics in the city of Beijing, China. Teimoury *et al.* (2013) develop a SD simulation model to study the relationships and behaviours developed in the supply chain of perishable fruits and vegetables in Tehran, Iran, as well as to analyse the supply, demand and price interactions. Tako and Robinson (2012) reviewed the Discrete Event Simulation (DES) compared to SD as decision support tools and highlighted advantages and disadvantages in applied case studies. Poles (2013) model a production and inventory system for remanufacturing activities. Shouping *et al.* (2015) developed an SD model to evaluate the logistics system in the city of Guangzhou. Rasjidin *et al.* (2012) examined the aspect of weather conditions and energy supply's fluctuation in respect to minimization of energy retailer's cost.