COLLABORATIVE AUTONOMOUS SYSTEMS IN MODELS OF URBAN LOGISTICS

SISTEMAS AUTÓNOMOS COLABORATIVOS EN MODELOS DE LOGÍSTICA URBANA

MARTÍN DARIO ARANGO SERNA

Ph.D. School of Mines. Universidad Nacional de Colombia. mdarango@unal.edu.co

CONRADO AUGUSTO SERNA URAN

M.Sc. Assistant Professor. Faculty of Engineering, Universidad San Buenaventura, Campus Medellín. sernauran@yahoo.com

KARLA CRISTINA ALVAREZ URIBE

IM.Sc. Universidad Nacional de Colombia. kcalvare@unal.edu.co

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ABSTRACT: Cities grow, and along with them, the exchange and distribution of goods and services has led in recent years to a greater increasing interest for the optimization of logistic processes carried out in urban areas. In this article, the main approaches and solutions which have been proposed from academic research will be described, focusing mainly on collaborative autonomic logistics, which is offered as an attractive solution to the urban goods distribution problems in complex cities.

KEY WORDS: Autonomous collaboration, city logistics, logistic models

RESUMEN: El crecimiento de las ciudades y con ellas el intercambio y distribución de bienes y servicios ha motivado en los últimos años un interés cada vez más creciente por la optimización de los procesos logísticos llevados a cabo en zonas urbanas. En este artículo, se caracterizan los principales enfoques y soluciones que se han propuesto desde la investigación académica, haciendo especial énfasis en la logística autónoma colaborativa, la cual se ofrece como una solución atractiva para los problemas que conlleva la distribución urbana de mercancías en ciudades complejas.

PALABRAS CLAVE: Colaboración autónoma, logística de ciudad, modelos logísticos

1. INTRODUCTION

Issues related to city logistics in the transportation of urban goods, have become a relevant topic in city planning. In recent years, both planners and experts in logistics have analyzed the challenges and problems of organizing the transportation of goods within the urban environment, analyzing the behavior of some local governments, transport companies, logistics service providers, customers, residents, and companies [1]. Some of these challenges are necessary in order to find solutions to reduce the effects of traffic in urban areas and the restrictions applied in high traffic city areas due to environmental considerations, and the reduction of accessibility in very congested places. Although studies have been conducted related to the collection and delivery of retail packages and courier services, urban goods transportation also includes waste transportation in the broadest sense, equipment, and transport of materials for industry construction, and a wide range of other urban transportation [2]. Taniguchi [3]defines city logistics as the improving of process in transportation logistic activities by private companies, with the support of advanced information systems in urban areas. The author recommend staking into account the environment and traffic, the road safety, and saving energy in the context of a market economy through the implementation of some measures to reduce the negative effects by moving cargo vehicles in urban and metropolitan areas. That is the reason why the city logistics management has become a challenge due to its complexity and the dynamics of the multiple processes involved [4,5].

The increasing complexity of inter-organizational structures and a relative shortage of cutting- edge logistic infrastructure technologies for increasing the efficiency and effectiveness of existing logistic processes, combined with changes in marketing, and increased mobilities in cities, have important effects on the planning and control of logistic processes in a dynamic environment [6].One possible approach to deal with these challenges is the control and decentralization in logistics coordination of the participant parts with the ability to make independent decisions; in brief, autonomous cooperation logistic processes [7].

2. THEORETICAL FRAMEWORK

The systems theory, applied to city logistics, proposes that cities, like organizations, should be studied as a whole, since different parts of the system interact and, therefore, cannot be separated from each other. Despite studies carried out on urban logistic models [8,9,10,11,12],in many cases urban logistics is not as important in the planning of a city, as it is the transport of goods by road, due to costs optimization and efficiency in the supply chain [13].

It is important to highlight that in the last 20years, a general awareness regarding these factors has increased. Some initiatives have been carried out mainly in Western Europe and Japan [14,15,16, 17,18].

Projects and research in urban logistics in recent years

The growing demand of mobility of twenty-first century, challenges researchers from various fields to design and develop more efficient traffic and transportation systems, including control devices, techniques to optimize the existing network, and information systems. According to Bazzan [19], it is necessary to develop models that involve interdisciplinary approaches.

According to Taniguchi [1], the mobility problem can be fixed by establishing three objectives using a city logisctics system. This vision takes three principles into account: (a) mobility, (b) sustainability, and (c) feasibility. It also presents a number of characteristics associated with the problems of urban goods transportation. There are systems that have the potential to fully develop a vision of city logistics by incorporating urban goods transportation as an integral component of urban planning.

Browne [20] reviews the increase in public-private partnerships (PPPs) in urban distribution in recent years. He considers that ways in which PPPs have been applied to urban distribution, together with a detailed examination of the various strategies and policies, bring private capital to public investment in logistic and mobility of goods[21].

Muñuzuri [22] introduces the process followed to estimate an origin-destination matrix for the transport of goods in the city of Seville, Spain. This focuses mainly on the process of data acquisition, which is usually one of the main obstacles facing this type of analysis. The model, based on the maximization of entropy, and the solution algorithm, includes linear approximations. The results are shown by a comparison with the flow of vehicles observed in reality, which allows conclusions to be drawn for model validation.

Thompson [23] describes the development of a series of procedures designed to provide greater intelligence in programming urban bus routes (RBU), which allows for additional information to help making decisions when facing changes that take place in dynamic environments.

The concept of e-logistic distribution is applied to the city by Robusté and Galvá [24], who present a business to consumer (B2C) distribution model that evaluates the inclusion of time windows in delivery service over variables such as distances logistics, shipping, and stops.

There is growing recognition that transport models (such as gravity models, spatial price equilibrium, inputs and outputs) need to better represent the logistic and supply chains to estimate changes in the arising economy from the application of different urban planning policies [25]. In recent years, charge transportation models, through different perspectives, have been developed [26]. Some approaches to managing the supply chain and operations research have been also developed in order to improve the efficiency of business operations strategy for individual companies or group companies [27]. More recently, some models have been developed to incorporate behavioral performance supply chain management, and collaborative logistic network elements in the public sector [28,29,30,31,32,33,34,35,36].

3. AUTONOMOUS AGENTS AND COLLABORATIVE SYSTEMS

Autonomous cooperation is based on the concept of self-organization, which has its scientific roots in several academic fields such as physics, biology, and chemistry, and belongs to the research field of complexity science in the broadest sense [37]. The different concepts of self-organization, for example, synergistic, cybernetics, chaos theory and dissipative structures, have been points of origin for the concept of autonomous cooperation [38]. The aim of this interdisciplinary field of research is to explain and identify how a complex system creates ordered structures independently. Therefore, it can be added that autonomous cooperation has a narrower perspective than self-organization. It describes the processes of decentralized decision-making in hierarchical structures [39].

This methodology is associated toa computer system with the following characteristics [40]:

- Autonomy: agents operate without any direct intervention to control their actions and internal states;
- Reactivity: Agents perceive their environment and respond to changes in it ;
- Pro-activity: Agents represent a behavior and not just by their reaction to their targets;
- Social Ability: Agents interact with other agents and / or humans using explicit or implicit communication.

Timm [41] defines four levels of autonomy and investigates their execution possibilities using software agents. The first level is associated with strong regulation (not autonomy).In the second level is the operational autonomy (reactive systems). And the third level defines the tactic autonomy and final strategic autonomy (complex intelligent systems). It is established that a major feature of an autonomous agent is the ability to interact with its environment and with other agents. The pro-activity and interaction of agents in multi-agent systems generate emergent properties that are not explicitly modeled, so it is concluded that the whole system is more than the sum of its parts [42].

The above mentionned features can be directly related to the traffic and transport systems, especially the social capability, which is a key factor. An agent-based simulation model is a set of agents that encapsulate the behavior of different individuals. Thus the capabilities of the agents can be used to illustrate the advantages over a solution based on centralized optimization techniques [43].

4. IMPLEMENTATION OF COLLABORATIVE AUTONOMOUS SYSTEMS IN CITY LOGISTICS

To define how autonomous collaboration systems can improve logistics management strategies, some of the characteristics of autonomous collaborative systems such as autonomy, interaction and non-deterministic character must be considered.

A system is autonomous if it is guided, shaped and developed by itself. It is operationally closed, which means that its members' decisions, relationships, and interactions are not dependent on external controls [44]. As there is no fully closed operating system, this is explained from the concept of relative autonomy of a system or an individual in relation to certain criteria [44,45,46]. In theory, an organization must have an appropriate degree of autonomy to form and develop itself, and to maintain its identity. An appropriate degree of autonomy can preserve a logistics system from an information overload as it is able to find a balance between stability and flexibility.

The concept of interaction is based on complex and dynamic systems that develop from the different relationships of individual systems. Due to this process, the system develops new qualitative features [47]. These emerging structures could contribute to the ability of information management thank to the new structures and processes developed (e.g. new forms of decision-making by intelligent objects.)

5. LOGISTIC MODELING SYSTEMS THROUGH COOPERATION REGION

For some time, in the field of modeling, it has been recognized that micro-simulation approaches are appropriate to explicitly model the different aspects of choice behavior, to provide the explicit representation of travel, and to include specific performance limitations on an individual level (for example, [48,49,50,51]). Micro-simulation models of goods, with applications in urban areas [11,28,30,32,35], and in regional and national areas, have been developed [31,52] in the last ten years

Wisetjindawat [11] presents a micro-simulation model for Tokyo Metropolitan Area. The model consists of four main stages: (1) Commodity production (production and consumption), (2) Distribution, (3) Conversion of commodity flows into trucks' flow, and (4) Allocation of routes. The model generates the attributes of each company using Monte Carlo simulation. The four stages are developed through the following: generation of commodities, product distribution, transformation of material flows into the flow of trucks and routing [26].

Davidsson [53] presents a framework to describe and evaluate agent-based approaches to transport and traffic management, mainly focusing on freight transportation. In their study the authors discuss the suitability of agent-based approaches to the logistics domain, along with open questions about the systems in place. Ossowski [54] describes a design method for building support systems based on decision agents.

Collaborative driving is the subject of the article by Halle and Chaib-draa [55], in which communications are used independently to guide the collaboration of vehicles on an automated highway system. Subgroups of vehicles are modeled as software agents, driving with a hierarchical architecture based on three levels: orientation, management and traffic control.

Jedermann *et al*. [56] offer new approaches to managing supply chain based on autonomous logistics processes modeled by software agents. Their research shows the balance between the computational requirements of autonomous logistic processes and the capabilities of current embedded systems.

Recently, the Multi Agent Systems Group in the Technical system Forum (E4MAS) has produced valuable results on untapped concept of environment, especially in terms of roles, responsibilities, architecture, and practical applications, which sets many challenges in terms of modeling, methodology and engineering. Under this approach, Zargayouna [57] proposes a solution for multi-agent routing problem with time windows based on a focus on the environment.

Schönberger and Köpfer [58] use an independent approach to solve a logistical problem of transport, which requires repeated updating of an existing transportation program. The system load varies significantly and unpredictably over time.

Brintrup [59] scans the supply chain. Based on it, agents model and simulate a complex autonomous supply chain administered by computational agents, whichaim to minimize -delivery time and maximize revenue by evolutionary multi-objective optimization.

Table 1 shows some of the urban logistic models with a classification in this investigation.

Table 1. Established Urban Logistics Models

AUTHOR (S)	YEAR	RESEARCH TOPICS	CHARACTERISTIC
Tavasszy, L. A. et al.	1998	City Logistics	Collaborative logistics networks in the public sector
Boerkamps, J. et al.	2000	City Logistics	Micro Simulation of goods, with applications in urban areas
Robusté, F et al.	2002	City Logistics	System of urban public transport
Robusté, F. and Gálvan, D.	2002	City Logistics	E-logistics applied to the urban distribution has a B2C distribution model
Allen, J.	2003	City Logistics	Sustainable urban distribution
Crespo, J.M.	2004	City Logistics	Systemic concept of city logistics
Nemoto, T	2004	City Logistics	Public-Private Partnerships in urban distribution
Segalou, E. et al.	2004	City Logistics	Urban movement of goods with environmental approaches

AUTHOR (S)	YEAR	RESEARCH TOPICS	CHARACTERISTIC
Taniguchi, E. et al.	2004	City Logistics	Route planning with time windows and traffic simulation to evaluate the effects of electronic commerce
Thompson, R.	2004	City Logistics	Programming urban bus routes
Vleugel, J.	2004	City Logistics	Urban route choice distribution
Bazzan, A., and Klüg, F.	2005	Autonomic logistics	Interdisciplinary approaches and smart systems
Bovenkerk, M	2005	City Logistics	Collaborative logistics networks in the public sector.
Davidsson, P. et al.	2005	Freight Transportation	Develop agent-based approaches to transport and traffic management
Fischer, M. J et al.	2005	City Logistics	Freight modeling using collaborative logistics networks
Halle, S., Chaib-draa, B.	2005	Collaborative Driving	Collaboration of vehicles on automated highway system
Muñuzuri, J. et al.	2005	City Logistics	Intercity freight
Ossowski, S. et al.	2005	Simulations of urban areas	Based support systems decision agents
Yin, Y. et al.	2005	Supply Chain	Collaborative logistics networks in the public sector
Browne, M. et al	2006	City Logistics	Public-Private Partnerships in urban distribution
Liedtke, G.	2006	City Logistics	Micro-simulation of goods (in urban areas)
Ben-Akiva, M	2007	City Logistics	Micro -simulation of shipping size selection of the transport chain
Hensher, D.A., Figliozzi, M.A.,	2007	Supply Chain	Urban distribution systems
Hunt, J.D., Stefan, K.J.	2007	Supply Chain	Collaborative logistics networks in the public sector
Ming, Z. et al.	2007	City Logistics	Micro-simulation of goods (in regional and national areas)
Wisetjindawat, W. et al.	2007	City Logistics	Micro-simulation of goods (in urban areas)
Jedermann, R. et al.	2008	Supply Chain	Autonomous logistic processes with software agents
Wang, Q. y Holguín-Veras, J.	2008	City Logistics	Micro-simulation of goods (in urban areas)
Zargayouna, M. et al.	2008	City Logistics	Multi-agent solution for the routing problem with time windows
Brintrup, A.	2010	Supply Chain	Modeling complex supply chain independently, managed by computational agents
Roorda, M. et al.	2010	Supply Chain	Model based on logistics service agents
Robu, V. et al	2011	Transport Logistics	Multi-agent system for allocation of charges

6. COLLABORATIVE AUTONOMOUS SYSTEMS IN LOGISTICS MANAGEMENT

Creative and innovative systems are required to ensure that the movement of goods in cities increases the accessibility and welfare of their residents. They are also required to not jeopardize the chances of future generations to enjoy a similar or better quality of life [60]. However, in the XXI century, there is a good accessibility to be able to use the profits generated by the Information and Communication Technology (ICT) and Intelligent Transport Systems (ITS) that make it possible to achieve a balance between efficiency and respect for the environment.

The rapid and continued development of modern ICT, such as telematics, mobile data transfer, etc., opens new possibilities for the emergence and development of intelligent logistic systems, which can meet the requirements in autonomous logistic processes. However, to maintain a dynamic logistic system controlled, technological development should not only provide short-term changes to the standard of logistics operations, but also take into account that the introduction of autonomy has a significant impact on operational management and strategic logistics services.

The dynamic and structural complexity of logistics networks makes it difficult to provide all the information needed for planning and central-controlling of logistics entities making the self-control presented as a promising approach. This autonomy can be applied in the logistics processes of adaptation, including capacity building for decentralized coordination of autonomous entities, given that autonomy is an interaction between the entities that have the capacity and ability to decide autonomously in non-deterministic systems [61].

Autonomy enables and requires new strategies and decentralized control systems for logistics. In this context, aspects such as flexibility, adaptability and reactivity to dynamically changing external influences can be treated independently, while maintaining the objectives is of central concern. The integration of strategic and tactical planning combining operations' strategy (capacity, supply chain networks, processes and technology, management and organization) allows the system to act independently, to compensate for a temporary malfunction, or an unlimited entity, or a relationship between two or more entities. Consequently, independent performance of the entities involved allows a shifting of responsibility in making decisions from a central decision system (whether technical or human) to a single logistics entity. This should be considered in developing a concept of objects self-management in the logistics and complexity of the whole system.

7. CONCLUSIONS

In this paper, different aspects of the complexity and dynamics in modern logistics systems, and the possibilities that arise in introducing the concept of collaborative autonomy were related. It is reported that the autonomous processes can be useful in the management of growing and complex dynamic logistics systems, which would not only benefit the company in the route planning in high congestion, but also allow a more efficient logistics management, which would benefit the cities in regard to pollution and traffic factors.

The city logistics programming is a relatively new concept aimed at increasing the efficiency of urban systems of transportation of goods, and reducing traffic congestion and environmental impacts. However, it requires new models of assessment and planning techniques to conduct thorough investigations before those logistics systems can be used effectively in large cities.

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