TRENDS, CHALLENGES, AND PERSPECTIVES IN CITY LOGISTICS

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ABSTRACT. City Logistics aims to reduce the nuisances associated to freight transportation while supporting the sustainable development of urban areas. It proceeds generally through the coordination of shippers, carriers, and movements, and the consolidation of loads of different customers and carriers into the same environment-friendly vehicles. The paper presents an overview of City Logistics concepts, models, and planning issues. Based on the analysis of a large number of projects and proposals, it also identifies trends, challenges, and research avenues.

Keywords: City Logistics, advanced urban freight transportation, analysis and planning.

REZUMAT. Logistica urbană are scopul de a reduce neplăcerile datorate transportului de mărfuri precum şi de a veni în sprijinul dezvoltării durabile a zonelor urbane. Constă, în general, în coordonarea transportoarelor navale şi terestre, a deplasărilor, precum şi a transferării încărcăturilor diferiților clienți şi din diferite mijloace de transport către vehicule comune, care sa nu afecteze mediul. Lucrarea cuprinde o trecere în revistă a conceptelor, modelelor şi proble de planificare ale logisticii urbane. Sunt identificate, de asemenea, pe baza analizei unui număr mare de proiecte şi propuneri, tendințele, dificultățile şi direcțiile de cercetare.

Cuvinte cheie: logistică urbană, transport de mărfuri urban avansat, analiză şi planificare.

1. INTRODUCTION

The transportation of goods constitutes a major enabling factor for most economic and social activities taking place in urban areas. For the city inhabitants, it supplies stores and places of work and leisure, delivers mail and goods at home, provides the means to get rid of refuse, and so on. For firms established within city limits, it forms a vital link with suppliers and customers. Indeed, there are few activities going on in a city that do not require at least some commodities being moved.

Freight transportation is also a major disturbing factor to urban life, however. Freight vehicles compete for the street and parking space capacity and contribute significantly to congestion and environmental nuisances, such as emissions and noise.(OECD, 2003, Patier, 2002, Figliozzi, 2007). These nuisances impact the life of people living or working in cities, and the productivity of the firms located in urban zones and of the associated supply chains. They also contribute to the belief that "cities are not safe" that pushes numerous citizens to move out of the city limits. And the problem is not going to disappear any time soon.

The number of freight vehicles moving within city limits is growing and is expected to continue to grow at a steady rate due, in particular, to the current production and distribution practices based on low inventories and timely deliveries, and the explosive growth of business-to-customer electronic commerce that generates significant volumes of personal deliveries. Moreover, a world-wide urbanization trend is emptying the countryside and small towns and is making large cities even larger. Within the countries members of OECD, the urban population was 50% of the total population in 1950, was 77% in 2000, and should reach the 85% mark by 2020 (OECD, 2003). It is estimated that 2007 has seen for the first time in recorded history a larger world-wide urban population than the rural population.

The public, industry, and officials at all levels of government are increasingly challenged by these issues and acknowledge the need to analyze, understand, and control freight transportation within urban areas to reduce its impact on living conditions, e.g., congestion and pollution, and increase mobility, while not penalizing the city activities. In particuler, one aims to reduce the number of freight vehicles operating in the city, control their dimensions and characteristics, improve the efficiency of freight movements, and reduce the number of empty vehicle-km.

This has resulted in several *City Logistics* initiatives, proposals, and projects, which follow from the acknowledgement that, while necessary, traffic and parking regulations are no longer sufficient and "new" organizational strategies for urban freight transportation must be set up.

The fundamental idea underlying these strategies is that one must stop considering each shipment, firm, and vehicle individually; rather, one should consider them as components of an *integrated logistics system*, where shippers, carriers, and movements are *coordinated* and loads of different customers and carriers are *consolidated* into the same "green" vehicles. The term *City Logistics* encompasses these ideas and goals and explicitly refers to the *optimization* of such advanced urban freight transportation systems.

For operations research and transportation science, as for urban planning, management, and policy, City Logistics constitutes a challenge and an opportunity in terms of both methodological developments and actual social impact.

Currently, however, there are few models that address City Logistics issues. Concepts are proposed, studies are undertaken, and systems start to be deployed. Yet, the literature related to the design, evaluation, planning, management, and control of such systems is still scarce. The objective of this paper therefore is to present an overview of City Logistics concepts, issues, and trends, to explore models and methods required to evaluate City Logistics systems and plan their activities, and to identify research challenges and perspectives.

The paper is organized as follows. Section 2 describes the main City Logistics concepts and experiences. Associated planning issues are examined in Section 3. Trends and research challenges are discussed in Section 4. We wrap up in Section 5.

2. CITY LOGISTICS

"Logistics" is currently understood to target the analysis, planning, and management of integrated and coordinated physical, informational, and decisional flows within a potentially multi-partner value network. It is from this view that the term *City Logistics* has been coined to emphasize the need for a systemic view of the issues related to freight movements within urban areas. This section reviews the main business models and elements of City Logistics systems. Due to space limitations, we keep the references at a minimum. More detailed information may be found in, e.g., Benjelloun, Bigras, and Crainic (2008), Crainic (2008), Dablanc (2007), Russo and Comi (2004), and Taniguchi *et al.* (2001).

Historically, one finds a brief period of intense activity at the beginning of the 70's dedicated to urban freight transportation issues. This period yielded traffic regulation to avoid the presence of heavy vehicles in cities and limit the impact of freight transport on automobile movements. Very little activity took place from 1975 to the end of the 1980's.

The increased traffic-related problems and the associated public pressure have revived the interest from 1990 on and have resulted in traffic surveys and data collection activities, research projects, and experimental deployments, some of which continue to operate.

Data-collection activities confirmed that freight transportation within urban areas generates large numbers of movements of freight vehicles of various dimensions, that the average vehicle load is low, and that many vehicles are in fact empty. Moreover, traffic and parking regulations do not seem to be able to cope with the problem.

Better fleet management practices could partially address these issues through a more efficient utilization of vehicles with higher average load factors and fewer empty trips (e.g., the beer and soft drink delivery industry), but these would concern individual carriers or shipper-customer combinations only.

The construction of automated underground systems dedicated to freight transportation has been proposed as means to reduce the number of vehicles traveling in urban areas, but huge investment requirements make this concept unrealistic in most cases. As indicated in most of the City Logistics literature, significant gains can only be achieved through a streamlining of distribution activities resulting in less freight vehicles traveling within the city.

The *consolidation* of loads of different shippers and carriers within the same vehicles associated to some form of *coordination* of operations within the city are among the most important means to achieve this rationalization. The utilization of so-called green vehicles and the integration of public-transport infrastructures (e.g., light rail or barges on rivers or water canals) enhance these systems and may further reduce truck movements and related emissions. But consolidation and coordination are the fundamental concepts of City Logistics.

Consolidation activities take place at so-called City Distribution Centers (CDC; the term Urban Freight Consolidation Center is also used). Long-haul transportation vehicles of various modes dock at a CDC to unload their cargo. Loads are then sorted and consolidated into smaller vehicles that deliver them to their final destinations.

Of course, a "complete" City Logistics system would address the reverse movements, from origins within the city to destinations outside, as well as movement among origins and destinations within the city. Currently, however, most City Logistics contributions address in-bound distribution activities only, following the imbalance between entering and exiting flows that characterize most cities. To simplify the presentation, we adopt the same perspective.

The CDC concept as physical facility is close to those of intermodal logistic platforms and freight villages, which receive large trucks and smaller vehicles dedicated to local transportation, and offer storage, sorting, and consolidation (de-consolidation) facilities, as well as a number of related services, e.g., legal counsel, accounting, brokerage, and so on. Intermodal platforms may be stand-alone facilities situated close to the access or ring highways, or they may be part of air, rail or navigation terminals.

The city distribution center may then be viewed as an intermodal platform with enhanced functionality to provide coordinated and efficient freight movements within the urban zone. CDCs are an important step toward a better City Logistics organization and are instrumental in most proposals and projects.

Most City Logistics projects address single-tier CDC-based systems, i.e., systems where delivery circuits are performed directly from a single CDC. Such approaches have not been successful for large cities, however, in particular when the large areas, usually identified as the city center, display high levels of population density as well as commercial, administrative, and cultural activities (Dablanc, 2007). Another characteristic of large cities that plays against single-tier systems is the rather lengthy distance a vehicle must travel from the CDC on the outskirts of the city until the city center where the delivery tour begins. Two-tier systems have been proposed for such cities, e.g., a three-tier (road – tram – road) system for Amsterdam (http://www.citycargo.nl/) and two-tier systems for Rome (Crainic, Ricciardi, Storchi, 2004, 2007, Gragnani, Valenti, Valentini, 2004).

To illustrate, consider the two-tier City Logistics concept, which builds on and expands the City Distribution Center idea. CDCs form the first level of the system and are located on the outskirts of the urban zone. The second tier of the system is constituted of satellite platforms, *satellites* for short, where the freight coming from the CDCs and, eventually, other external points may be transferred to and consolidated into vehicles adapted for utilization in dense city zones. In the more advanced systems, satellites do not perform any vehicle-waiting or warehousing activities, vehicle synchronization and transdock transhipment being the operational model (Gragnani, Valenti, Valentini, 2004 present a simpler proposal). Existing facilities, e.g., underground parking lots or municipal bus garages, could thus be used for satellite activities.

Two types of vehicles are involved in a two-tier City Logistics system, and both are supposed to be environmentally friendly. *Urban-trucks* move freight to satellites, possibly by using routes specially selected to facilitate access to satellites and reduce the impact on traffic and the environment. They may visit more than one satellite during a trip. Their routes and departures have to be optimized and coordinated with satellite and city-freighter access and availability. *City-freighters* are vehicles of relatively small capacity that can travel along any street in the city to perform the required distribution activities.

Notice that not all demand for transportation processed by a City Logistics system passes through a CDC. Freight may arrive on ships, trains, or light rail services and sorting and consolidation operations may be performed in CDC-like facilities located in the port, rail yard, or a rail station situated close to the center of the city. In this case, part of the workload normally undertaken by urban-trucks is performed by barges, ships, and rail or light-rail cars, which further decreases the impact of freight transportation on the city. Notice also that, some demand is generated at production facilities located close to the city and is already embarked in fully-loaded urban-trucks. Freight may also come from further away but also in fully-loaded vehicles that are allowed to enter the city, eventually at designated times, and may thus be assimilated to urban-trucks. To simplify the presentation, we refer to CDCs and all these facilities and sites as *external zones*.

From a physical point of view, the system operates according to the following sequence: Freight arrives at an external zone and is consolidated into urban-trucks; Each urban-truck receives a departure time and route and travels to one or several satellites; At a satellite, freight is transferred to city-freighters; Each city-freighter performs a route to serve the designated customers, and then travels to a satellite (or a depot) for its next cycle of operations.

From an information and decision point of view, it all starts with the demand for loads to be distributed within the urban zone. The freight consolidated at external zones yields the actual demand for the urban-truck movements and the satellite transfer activities. These, in turn, yield the input to the city-freighter circulation, which provides the last leg of the distribution chain and the timely availability of empty city-freighters at satellites. The objective is to have urban-trucks and city-freighters on the city streets and at satellites on a “need-to-be-there” basis, while providing timely delivery of loads to customers and economically and environmentally efficient operations. Single-tier systems follow similar but simpler processes.

3. PLANNING ISSUES

Similarly to any complex system, City Logistics transportation systems require planning at the strategic, tactic, and operational levels.

The strategic level is concerned with the design of the system and the evaluation of City Logistics proposals, the latter pointing to the study of the probable behaviour and performance of the proposed system or operating policies, or both, under a broad range of scenarios. Strategic planning also addresses the continuous analysis of the performance and behavior of deployed systems and the planning of their evolution, both as stand-alone systems and in relation to the general transportation system of the city and the larger region that encompasses it.

While very few formal models have been proposed specifically for City Logistics (Taniguchi and van der Heijden, 2000, Taniguchi *et al.,* 2001, Taniguchi and Thompson, 2002), these issues are generally part of transportation-system planning methodologies, which are well-known, particularly for passenger transportation within urban zones, but also for passenger and freight regional/national planning (e.g., Cascetta, 2001, Crainic and Florian, 2008, Florian, 2008).

Their main components are:

- *Supply modeling* to represent the transportation infrastructure, modes, carriers, services, and lines; vehicles and convoys; terminals and intermodal facilities; capacities and congestion; economic, service, and performance measures and criteria;
- *Demand modeling* to capture the product definitions, identify producers, shippers, and intermediaries, and represent production, consumption, and point-to-point distribution volumes, The determination of *mode choices* for particular products or origin-destination markets is also addressed here;
- *Assignment* of multicommodity flows (from the demand model) to the multimode network (the supply representation). This procedure simulates the behaviour of the transportation system and its output forms the basis for the strategic analyses and planning activities.

A number of methods and tools complement the methodology for the analysis, fusion, validation, and updating of information, as well as for studies based on assignment results, e.g., cost-benefit, environmental impact, tolls and tariffs, and energy consumption policies.

Figure 1 displays the classical combination of these models and methods into the so-called *four-step planning* method. Such an approach starts from the economic, demographic, social, and political current or forecast data in a given region. For City Logistics, this step should also address the organizational and managerial framework of the contemplated system, the involvement of stakeholders, including final customers and the local and central governments, and the planned business models. The initial step also determines the geographical division of the city into zones and identifies the product groups to be considered. All activity – production, consumption, shipping and reception of cargo – within a zone is aggregated and associated to a single point, the so-called centroid of the zone. This step thus reflects, and specifies for all the other steps of the planning procedure, the degree of aggregation of the data available for planning.

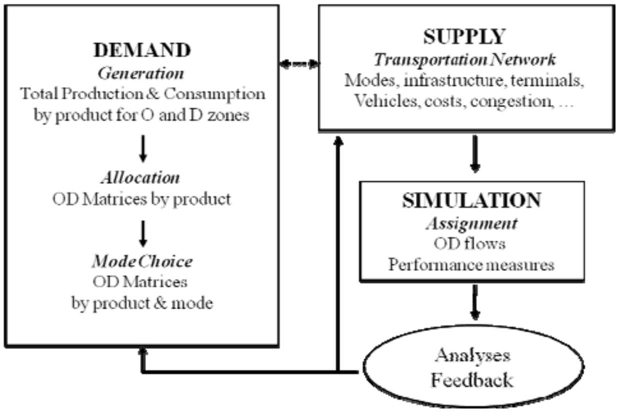

Fig. 1. Four-Step Transportation Planning.

The product-specific transportation demand is then generated in two steps: 1) total production and consumption volumes within each zone, and 2) the distribution of these quantities among the zone-to-zone pairs of the region. These steps are denoted *generation* and *allocation*, respectively. The modal-choice step of the demand-generation process specifies the set of modes – type of infrastructure and services – that may move the demand of each product and zone-to-zone pair.

The *assignment* step then determines the actual itineraries used to move the demand for each product, each zone-to-zone pair and each mode choice, thus performing the simulation of the global behaviour of the system given the particular scenario studied.

The last two steps require the definition of the transportation supply in the city, in particular the multimodal infrastructure and service network available to move the demand and its attributes in terms of costs, travel and terminal operation times, energy consumption or level of emissions, etc. The assignment step also requires the specification of criteria to select itineraries and to measure performance.

The actual planning process is rarely linear. Thus, for example, studies are performed on given sets of supply and demand data, both current and forecast, by varying the parameters (e.g., vehicle technology or system utilization policies) of the contemplated scenarios. On a more general scale, feedback mechanisms are used to modify the parameters of the demand generation steps for future scenarios given the simulated performance of the transportation system.

A few demand models have been proposed for evaluating the demand for freight movements within urban areas (see Gentile and Vigo, 2007 for a recent review). Most are descriptive models based on extensive surveys in large cities and economic principles. Thus, FRETURB (Patier, 2002) and WIVER (Ambrosini and Routhier, 2004), currently integrated into VISEVA (Friedrich, Haupt, and Nökel, 2003), are based on surveys within major French and German cities, respectively, while GOOD TRIP (Boerkamps and van Binsbergen, 1999) has been developed based on Dutch data and settings. A gravity-based methodology is presented in Gentile and Vigo (2007). The models integrate elements representing the city topology, traffic regulation, and some representation of the logistics chains and vehicle tours used to move products within major product classes. Significant work is still required in this area, however, to integrate City Logistics considerations to demand modelling.

The supply and assignment aspects are even less developed. The former requires decisions on the number, location, and characteristics of facilities, CDC, satellites, etc. The models should also select the City Logistics network, e.g., the access corridors and the street networks open to each vehicle type and the determination of the vehicle fleets composition and size. We are aware of only two contributions, Taniguchi *et al.* (1999) and Crainic, Ricciardi, and Storchi (2004), targeting these important and challenging issues.

The assignment step requires simulating the behaviour of the system under various scenarios relative to the system organization and the social, economic, and regulatory environment. Dynamic traffic simulation, where passenger and other freight vehicles may be considered as well, appears as the methodology of choice for such evaluations.

City Logistics simulators require methods to represent how vehicles and flows would circulate through the city and how the proposed infrastructures services would be used under the conditions of a given scenario. These are the same tactical and, eventually, dynamic routing models and methods that are also required to plan and control operations for an actual system. We are aware of only one contribution where a traffic micro-simulator is coupled to a City Logistics dynamic routing model (Barceló, Grzybowska, and Pardo, 2007). This methodology has been used to evaluate City Logistics projects for small European cities, but appears difficult to scale for larger urban areas. Mezo-traffic simulators coupled to tactical planning models offer more promising perspectives for larger urban zones, but no such contribution has been made yet.

City Logistics systems rely on consolidation. Tactical planning for consolidation-based transportation systems aims to build a plan to provide for efficient operations and resource utilization, while satisfying the demand for transportation within the quality criteria (e.g., delivery time) publicized or agreed upon with the respective customers (Crainic, 2000, Crainic and Kim, 2007). The same issues must be addressed in a City Logistics context, but for a shorter planning horizon due to the day-to-day demand variability.

Tactical planning models for City Logistics concern the departure times, routes, and loads of vehicles, the routing of demand and, when appropriate, the utilization of the satellites and the distribution of work among those.

Tactical planning models assist the deployment of resources and the planning of operations and guide the real-time operations of the system. They are also important components of models and procedures to evaluate City Logistics systems, from initial proposals to deployment scenarios and operation policies. According to the best knowledge of the authors, Crainic, Ricciardi, and Storchi (2007) is the only contribution targeting these issues.

On the operational side, issues related to the work schedules of vehicles, drivers, and terminal personnel must be addressed, as well as the control and dynamic adjustment of vehicle and terminal operations within an ITS environment. We are not aware of any specific contribution to the first topic, and only a few papers deal with the second, focusing generally on the operations of a single fleet within a limited part of the city (Taniguchi, Yamada, and Tamaishi, 2001, Thompson, 2004). Again, much work is required before City Logistics enjoys the same level of methodological richness as the other, more traditional, transportation systems.

4. TRENDS, CHALLENGES AND PERSPECTIVES

A review of projects, proposals, and actual systems (Benjelloun, Bigras, and Crainic, 2008, review some seventy City Logistics projects) reveal a number of additional trends and challenges.

Different business models and strategies have been tested over the years, particularly in Europe and Japan.

The “City Logistik” concept, developed in Germany and also applied by a number of Swiss cities, corresponds to “spontaneous” groupings of carriers cooperating for consolidation and distribution activities with very light government involvement. There are no privileges granted to participating enterprises (in terms of access or parking regulations, for example) and projects, being a private initiatives, are supposed to become profitable over a short period.

The policy introduced by the Dutch ministry of transportation and public works is based on strict licensing practices that impose restrictions on vehicle loads and the total number of vehicles entering the city on any given day (as well as promote the use of electric vehicles). This policy has resulted in carriers initiating collaboration activities to consolidate shipments and reduce the number of trips. Local and central governments play important roles in these projects (e.g., traffic regulations were modified to permit longer delivery hours), which may explain the success and continuation of these projects within the Netherlands.

A third major approach was first introduced in Monaco, making urban freight delivery a public service. Large trucks are banned from the city and deliver to a CDC, a single carrier taking charge of the final distribution with special vehicles. The later move from a public carrier to a private one did not modify the system structure and general operating policy.

The license-based systems have not gained much acceptance outside the Netherlands. The private City Logistik projects have yielded mixed results, as most did not continue once the initial funds secured through EU programs were over (only 15 out of some 200 planned or carried out projects were still in existence by the end of 2002). Indeed, consolidation in CDCs results in extra costs and delays, which are rather difficult to account for in the context of a combination of hands-off policy practices by authorities and short-term profitability requirements. As for the "public utility" system in Monaco, it performed and continues to do so as planned. Yet, for some time, it was the only one of its kind.

The field is continuously evolving, however, and the new generation of projects are to be found over a broader geographical range and combine elements from the three previous approaches. As mentioned, most initial City Logistics projects were undertaken in Western Europe and Japan, involved only one CDC facility, a limited number of shippers and carriers, and little, if any, advanced information and decision technologies, e.g., Intelligent Transportation Systems (ITS). Interest is steadily growing, however, and studies are being reported in Australia, Asia, Eastern Europe, and North America.

The distribution center is still at the core of most systems, but a broader range of options is being investigated. The notion of "corridor" is thus emerging in North America as opposed to the more traditional "city center" approach proper to European systems. The shift in focus follows the differences in the spatial organization and land use among countries and continents. A coherent study of the linkages between these characteristics and success factors for City Logistics systems constitutes a fascinating but challenging research topic.

One notices a higher rate of "success" (defined as systems still in existence after a certain number of years) for small to medium size cities where, in general, a single zone is under City Logistics conditions. Such homogeneity facilitates the deployment and operations of enhanced Monaco-type systems. Traditionally, large cities have fared less well, but things are starting to change.

More complex systems are emerging for large cities, encompassing a number of not necessarily integrated sub-systems. Most of these display a multi-tier structure and have access to some of the city infrastructure (e.g., the light rail system or municipal parkings), even when they result from private initiatives (e.g., the Amsterdam CityCargo truck-tram-electric truck system). In fact, the involvement of public institutions, municipal authorities principally, and the private-public partnerships are significantly stronger than previously, and the number of private initiatives that become part of City Logistics systems is also on the rise.

From the year 2000 on, the need for advanced information and decision technologies is also increasingly acknowledged. One direction in this respect focuses on linking, and eventually integrating, a given urban zone's City Logistics and Intelligent Transportation systems. A second, and complementary perspective, focuses on the models and methods required to analyze, plan, and manage optimally City Logistics systems. In all cases, we are still at the very beginning or R&D efforts with few actual implementations. They challenge research, however, in several disciplines. The challenges and opportunities are particularly interesting for Operations Research and Transportation Science, most of the models and methods required by City Logistics having to be developed, tested, and integrated into management software and instruments.

5. CONCLUSIONS

City Logistics ideas appear to hold one of the keys to achieving a balance between the benefits of moving freight in, out of, and within the city and the environmental, social, and economical nuisance and cost associated to these activities, particularly in congested urban zones. The core concept is the coordinated delivery of freight of many different shipper-carrier-consignee commercial relations, through consolidation facilities. City Logistics explicitly refers to the optimization of such advanced urban freight transportation systems. City Logistics concepts are also convergent with the sustainable development principles and the environmental concerns (e.g., attempting to reach the Kyoto targets for emission reductions or, at least, to conform to the spirit of the accord) that are increasingly characterizing the development of transportation systems and urban areas.

We presented an overview of City Logistics concepts, trends, and challenges, focusing in particular on research needs and opportunities related to the models and methods required to evaluate City Logistics systems and plan and manage their activities. A review of practice and literature reveals, show that 1) after an initial period of "experimentation", a number of concepts seem to emerge in terms of business models and system organization; 2) from 2000 on, many new initiatives and innovations are been introduced that open new perspectives and challenge research; 3) the "optimization" and utilization of advanced information technologies (e.g., ITS) components of City Logistics are not very developed yet; 4) not all countries and regions are at the same level of analysis and action, but the City Logistics ideas are spreading.

The field is young and evolving rapidly. The paper is thus also an invitation to join in the efforts to address these issues and challenges, develop these models and methods, and help in making our transportation systems more efficient and our cities more pleasant to live.

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