Understand and Calibrate Urban Freight Demand

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Abstract: Increases in population and economic growth in urban areas have led to a growing demand for goods and services by commercial and domestic users. This paper reviewed the analytical architecture of urban freight demand (UFD), and summarized two approaches to collecting and calibrating UFD, namely from macro and micro level. With time-access regulations and vehicle restrictions are increasingly used to improve social sustainability in urban areas, here points out that off-hour deliveries (OHD) or taking full advantage of daily road network capacity are alternative solutions if properly understand behavioral change of involved parties with the widely deployed ITS and GPS.

Keywords: urban freight demand, transportation demand management, congestion

1. INTRODUCTION

Urban authorities have traditionally considered freight only as a reaction to negative environmental impacts, often arising from complaints made by residents and other road users. [1] And when compared with the passenger vehicle fleet, trucks have significant impacts in road congestion, greenhouse gas and pollutant emissions and pavement wear. [2] As a result, coherent urban freight transport policies have not been developed to the same extent that they have for passenger transport.

Now urbanization is the world trend. Approximately 80% of European citizens live in an urban area, and urban populations are expected to grow in developed regions across the world over the coming decades (European Commission, 2007; United Nations, 2006). And China, the biggest developing country, is promoting urbanization. This is resulting in increased levels of demand for urban freight transport services. Many municipal authorities have begun to pay far greater attention on the efficiency and sustainability of freight transport due to its economic importance over the last decade. This has led to efforts to develop freight transport strategies and plans in some cities using a combination of the measures outlined by Stathopoulos et al. (2012), such as (i) market based measures, (ii) regulatory measures, (iii) land use planning measures, (iv) infrastructure measures, (v) information related measures, and (vi) management measures, as well as research projects, trials and operational schemes. [1]

Since urban freight systems are complex and cities vary in size and other characteristics, it's imperative to understand and calibrate urban freight demand (UFD). And site-specific data could be required for the development of assessment methodologies/models which could support the sustainable management of urban logistics. [2]

This paper outlined the analytical architecture of UFD, then introduced collect and calibrate UFD by macro and micro ways, finally discussed the alternatives of executing off-hour deliveries (OHD) or taking full advantage of daily road network capacity with the widely deployed Intelligent Transport System (ITS) and Global Positioning System (GPS).

2. UFD ANALYTICAL ARCHITECTURE

According to a recent report for the National Cooperative Freight Research Program, an institutional

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arrangement on freight transportation systems is defined as—a structural foundation that enables relevant parties to advance the general interests of freight mobility—infrastructure, operations, services, and regulations—or particular programs and projects to increase freight mobility (Cambridge Systematics, 2009).

To support the assessment of short-term policies/measures, a general methodology capable to simulate the urban freight transport should consist of a set of models as Figure 1. [2,3,4]

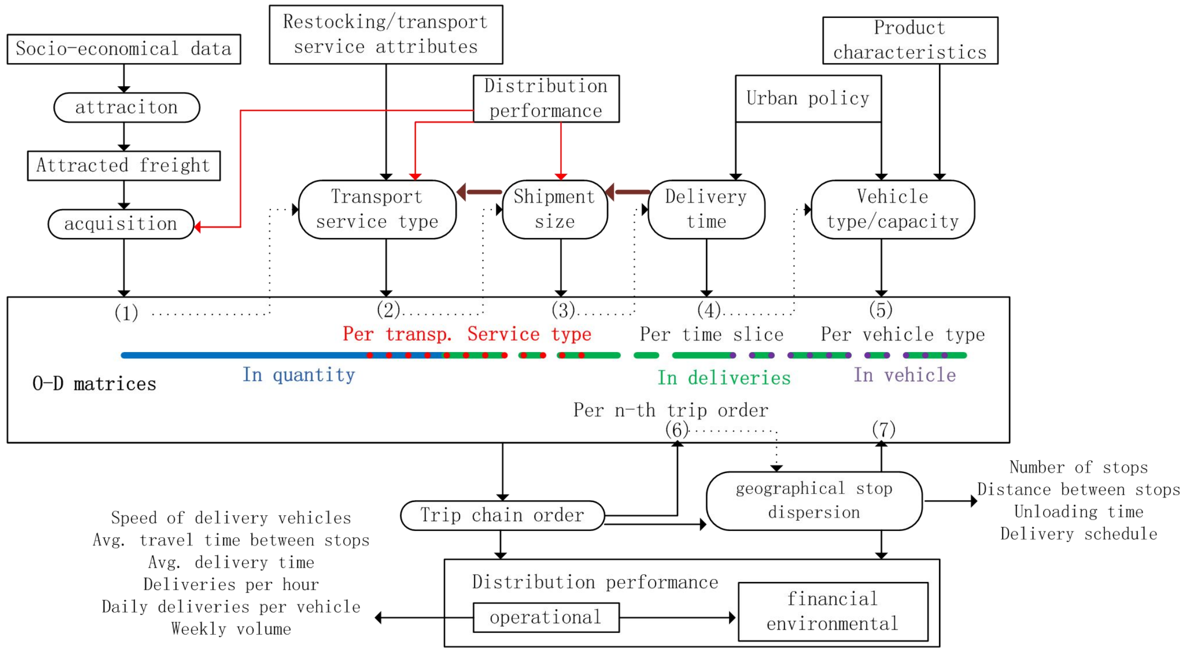

Figure 1. System models of architecture for simulating urban goods movements

They usually refer to the multi-stage modelling approach and can be classified in terms of reference units like truck/vehicle, commodity/quantity, delivery and mixed. [5]

- Socio-economical data, e.g. business and employment, housing and population/households, number of retailers and wholesales;
- Forecast the freight quantities requested by end-consumers through the simulation of shopping mobility;
- Transportation demand is derived from the interactions among economic sectors geographically dispersed. Freight demand is the result of complex interactions among numerous agents, including producers, shippers, freight forwarders, carriers, receivers and regulatory agencies etc.. The most important agents are (i) shipper refers to the economic agent(s) associated with the production and the shipping of goods; (ii) carrier represents the companies (e.g., transportation companies, Third Party Logistics providers) that are physically in charge of transporting the goods; (iii) receivers represents the consignees of the cargoes. [6]
- Supply models: represent the transportation infrastructures with their operational characteristics and how to modify supply in order to optimize given objectives while satisfying given constraints;
- Assignment models: assign the multi-commodity flows to the multimode network.

3. COLLECT AND CALIBRATE UFD

In medium and large cities, the delivery of goods represents a significant contribution to the problems of congestion, lack of parking, pollution and energy consumption. The characteristics of this type of transport are also quite different from passenger mobility, even though they are often assimilated, due to the lack of specific tools for estimation and analysis, and also of indicators to evaluate improvements in the systems of urban goods distribution. [3] Modelling the complexity of UFD requires large amounts of data related to supply chain management, delivery practices, tour configuration, time windows, etc., but when all this detailed data is not available local authorities still need models that represent this type of transport and its contribution to congestion and environmental impacts. [7] So here reviewed avenues for calibrating UFD from macro and micro.

3.1 UFD in quantity with spatial and economic patterns

3.1.1 Statistics and surveys in typical

In order to identify spatial patterns characterizing the urban freight distribution, details socio-economic characteristics and commercial structure of the each city and the surveys areas. In particular, a description considers population data, extension of the study area, number of shops and number of warehouses. Also, where the warehouses/restocking centers are located with respect to the shops to be restocked through the retailer and warehouse employees respect to population. [2] For instance, using information gathered from some 30 UK surveys undertaken over the last 15 years, Cherrett and Allen et al. [1] provide planners with an understanding of road-based urban retail freight transport activity. The findings suggest that the average High Street business could expect up to 10 core goods and 7.6 service visits per week, in non-peak trading periods with 25% additional activity during the build up to Christmas. Vans were in charge of 42% of delivery activity with a mean dwell time of 10 min.

The transfer of a previously estimated model to a new application context can reduce or eliminate the need for a large data collection and model development effort in the application context. Therefore, Ibeas and Moura et al. [2] compared the freight transport demand in Rome and Santander in order to highlight which similarities and differences depend on some factors and demonstrates that there are many different patterns of urban distribution that need to be taken into account.

3.1.2 Large traffic generators and the last mile

Large traffic generators that cluster multiple businesses should be paid special attention to because these facilities tend to generate significant amount of truck traffic and handle incoming and outgoing deliveries with a central delivery station. [8]

After the goods arriving at the urban fringe, the last mile turns into a big issue to meet the customer requirement, especially with time-access regulations and vehicle restrictions. Muñuzuri and Cortés et al.(2010) [7] gave a demand model for B2B and home deliveries during the morning peak hour that uses very limited data to estimate the number of delivery vehicles entering and leaving each zone of the city. Actually each zone of the urban area usually has quite altered traffic temporal characteristics and demand intensity and needs special treatment. And widely deployed ITS and GPS make this possible.

3.2 UFD characteristics in vehicles on tour

Daily life in urban centers has resulted in increasing and more demanding freight requirements. Manufacturers, retailers and other urban agents have thus tended towards more frequent and smaller deliveries, resulting in a growing use of light freight vehicles (<3.5 ton).

Routing constraints limit the number and characteristics of the feasible set of tours that carriers can use to meet customer demand. Figliozzi has a series work to understand the impact of congestion on urban tour characteristics, carriers' costs, and distance/time traveled. Figliozzi (2006) models tour constraints using Daganzo's (1991) approximations to route problems and analyzes how constraints and customer service time affect trip generation using a tour classification based on supply chain characteristics and route constraints.

Figliozzi (2007) [9] modeled and analyzed the generation of vehicle kilometers traveled (VKT) by tour type; discussed the relative influence of the number of stops per tour, tour duration, and time window constraints on VKT ; Multi-stop tours generate more VKT than direct deliveries even for equal payloads. In the tour model, the percentage of empty trips has no correlation with the efficiency of the tours regarding VKT generation; the average trip length and the trip length distributions shape are strongly dependent on the tour type, distance from the depot/distribution center to the service area, density of stops, and number of stops per tour. The work defined capacity constrained tours, frequency of service constrained tours, tour duration constrained tours, and time window constrained tours. And the last two types are the most affected by congestion. Figliozzi (2010) [10] categorized tours into three classes based on their tour efficiency and variable costs structure. Travel time/distance between customers and depot is found to be a decisive factor that exacerbates the adverse impacts of congestion. Travel time variability is a significant factor only when travel time between depot and customers is considerable in relation to the maximum tour duration. For each client, it is possible to define a dimensionless coefficient that provides an indication of the relative impact of congestion on routing constraints. Congestion also affects carriers' cost structure, as congestion worsens the relative weight of wages and overtime escalates and the comparative weight of distance related costs decrease.

4. TIME-ACCESS REGULATIONS AND VEHICLE RESTRICTIONS

Time-access regulations and vehicle restrictions are increasingly employed to improve social sustainability in urban areas. These regulations considerably influence the distribution process of retail chain organizations as well as the ecological burden. Quak and de Koster [4] studied the impact of governmental time windows, vehicle restrictions, and different retailers' logistical concepts on the financial and environmental performance of retailers. They use data provided by the retailers to calculate the impacts of different scenarios based on a fractional factorial design in which urban policies and the retailers' logistical concepts are varied, utilizing vehicle routing software. They show that the cost impact of time windows is the largest for retailers who combine various deliveries in one vehicle round-trip. The cost increase due to vehicle restrictions is the largest for retailers whose round-trip lengths are limited by vehicle capacity. Vehicle restrictions and time windows together do not increase a retailer's cost more than individually. Variations in delivery volume and store dispersion hardly influence the impact of urban policy and the retailer's logistical concept decisions.

After the goods getting into the borough area, usually illustrated as a Vehicle Routing Problem (VRP). Qureshi and Taniguchi et al. [11] presented a micro-simulation-based evaluation of an exact solution approach for the soft time windows variant of the VRP that also considers penalties on the late arrival. The rigorous solution way of the Dynamic Vehicle Routing and scheduling Problem with Soft Time Windows (D-VRPSTW) is based on the column generation (Dantzig-Wolfe decomposition) scheme. Evaluations shows that the D-VRPSTW helps in avoiding additional cost as well as the lateness for the freight carriers, caused due to an unexpected change in travel times along the roads. And lately TRANSPORTATION SCIENCE had a special issue on advances in VRP [12].

And there are a few technical solutions for the management of stop and access areas for goods transport vehicles in order to allow the on-time delivery as well as to mitigate the traffic induced issues towards citizens. In particular, Dezi and Dondi et al. [13] paid attention on various issues concerning the areas where goods are loaded and unloaded, proposing a method that allows their size, their number and their location to be optimised.

5. OHD OR MAKE FULL USE OF DAILY ROAD NETWORK CAPACITY

Urban congestion is one of the pervasive issues impacting large metropolitan areas. It is also a problem that has defied easy solutions and that is likely to get worse as forecasts indicate that demand will continue to grow, leading to increases in the duration of the peak periods. In this context, transportation demand management could play a key role in reducing congestion by inducing a behavior change on the part of the users, because there are numerous agents with inconsistent interest involved in this intricate system.

5.1 OHD initiative in New York City metropolitan area

Holguín-Veras and Wang et al. (2006) [14] assessed the impacts of the Port Authority of New York and New Jersey's time of day pricing initiative on the behavior of commercial carriers, and found out that carriers respond to time of day pricing by implementing multi-dimensional responses involving productivity increases, cost transfers, and change in facility usage.

Based on empirical evidence [14], Holguín-Veras(2008) [8] discussed the economic conditions needed to move urban freight delivery traffic to the off-hours, and found the most potent stimulus is provided by freight road pricing in combination with financial incentives to receivers in competitive markets.

Holguín-Veras and Ozbay et al.(2011) [15] designed a system of incentives to the receivers of deliveries, combined with remote sensing monitoring based on GPS enabled smart phones, to induce a shift of deliveries to the off-hours (7PM-6AM). The concept was pilot tested in Manhattan by 33 companies for a period of a month. And the participants reported being very satisfied with the experience of the in-depth interviews conducted after the test. The analyses indicated that the economic benefits of a full implementation of an OHD program are in the range of $147-193 million per year corresponding to travel time and environmental pollution savings for the regular hour traffic, and productivity increases in the freight industry.

Silas and Holguín-Veras et al.(2012) [16] developed mathematical formulations to gain insight into the best way to distribute financial incentives to receivers of urban deliveries to maximize participation in OHD, which considers exogenous and endogenous of incentive budgets.

5.2 Make full use of daily road network capacity

The most significant negative social impact of OHD is the noise produced by unloading operations during the night (Yannis et al., 2006). And usually commercial trucking firms already attempt to avoid peak periods for travel; they are highly concerned with meeting customer demands, while not violating district curfews and union-agreed working hours.

Now with widely deployed ITS and GPS, it's straightforward to gather dynamic traffic information, which allows the integration of dynamic traffic assignment data and diverse traffic operation patterns during different day periods. Thereby improving delivery performance. [17] Built on a case study of two different-sized Spanish cities using data from GPS, a vehicle observation survey and complementary driver's interviews, Comendador and López-Lambas et al. [18] proposed a categorization of urban freight distribution. X. Wang proposed Urban Freight Service Capacity Dynamic Coordination System (UFSC-DCS) effectively supported the transportation agencies dynamically regulate permits of freight trucks access municipal areas to take full advantage of the road network capacity as well as meet the urban freight demand. [19] Therefore, UFSC-DCS as a prototype decision support system was proposed, which integrated a simulation model with optimization objectives and balanced the interests of various participants and tentatively provided regulators with candidate solutions under different spatial-temporal traffic resources constraints. [20]

5.3 Calibrate the joint response by behavioral models

However it is fundamental to have methods and models to allow an ex-ante assessment of policies and measures that can be implemented by local administrators in order to make urban freight mobility more sustainable.

There is the absence of empirical studies that provide evidence on observed behavioral influences; and of a general behavioral theory that could explain the complex interactions underlying freight decision making. Transportation policy must target the diverse agents in order to induce a meaningful behavioral change. [8] The effectiveness of any policy aimed at changing trucks' time of travel will be determined by the joint response of carriers and receivers.

Holguín-Veras et al.(2007, 2008) discussed behavioral models estimated with stated preference data collected from receivers and carriers [21,22]. To create the behavioral micro-simulation model which determines the shift in deliveries to the off-hour in various industry segments for various incentive levels. [23] Holguín-Veras(2011) [24] developed a set of analytical formulations as Table 1 to study the behavior of the urban delivery industry in response to cordon time-of-day pricing, time–distance pricing, and comprehensive financial policies targeting carriers and receivers.

Table 1. Analytical formulations and theoretical and numerical analyses

operation type	pricing schemes	types of carriers operations	scenarios in terms of profitability of the carrier operation
a single carrier that is delivering goods to a set of receivers during the regular hours from a location outside of the tolled area	cordon time of day	single-tour	perfectly complementary
a mixed operation with both regular hour and OHD	time–distance pricing	multi-tour	the expected value
			the worst case

This analytical formulation contributes to a general idea of evaluating the proposal of making full use of daily road network capacity, which needs further investigation.

6. CONCLUSIONS

This paper presented UFD analytical architecture built on multi-stage modelling approach urban goods movements. At the upper level, should collect and calibrate UFD at first. This includes statistics and surveys in typical for UFD in quantity with spatial and economic patterns and captures its characteristics in vehicles on tour. In the supply level, time-access regulations and vehicle restrictions have a significant impact on urban tours under congestion. Thus, the assignment level should provide with changes, such as OHD or daily road network capacity properly allocated with the widely deployed ITS and GPS, if properly understand behavioral change of the involved parties.

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