Chapter 2
City Logistics

City logistics service providers are expected to offer high quality, reasonably priced delivery services in the environment of congested urban areas. The role of city logistics service providers has become more and more important in recent years, since just-in-time concepts have found their way into complex supply chains. This is reflected by challenging restrictions for delivery in terms of tight delivery time windows. Furthermore, city logistics service providers are often the only physical and legal activity perceived by the customer, leading to increasing importance of reliability and service quality of delivery. Online retail, for example, makes consumers believe that goods are available at all times in almost no time at almost any costs, but delivery concepts are actually very demanding.

In this chapter, challenges for city logistics service providers are highlighted, especially with regard to increasing traffic volumes in urban areas and increasing complexity of supply chains (Sect. 2.1). Planning of reliable delivery tours asks for a more sophisticated planning approach, which can be derived from city logistics concepts. To this end, services of city logistics service providers are analyzed in relation with optimization of urban freight transportation systems (Sect. 2.2). City logistics concepts follow an integrated approach, aligning commercial activities with requirements of different stakeholders. Corresponding methodology is exemplified in Sect. 2.3, aiming at the modeling of the urban freight transportation system as a whole. Subsequently, the perspective is constricted to planning systems for city logistics service providers. Strategic, tactical and operational planning are distinguished, and functionality required for advanced planning systems in city logistics routing is defined (Sect. 2.4).

2.1 Challenges

The twenty-first century is going to become a century of urbanization, since growing cities facilitate more attractive opportunities for employment, education, cultural, and sport activities (Taniguchi et al. 2008). In 2008, for the first time,

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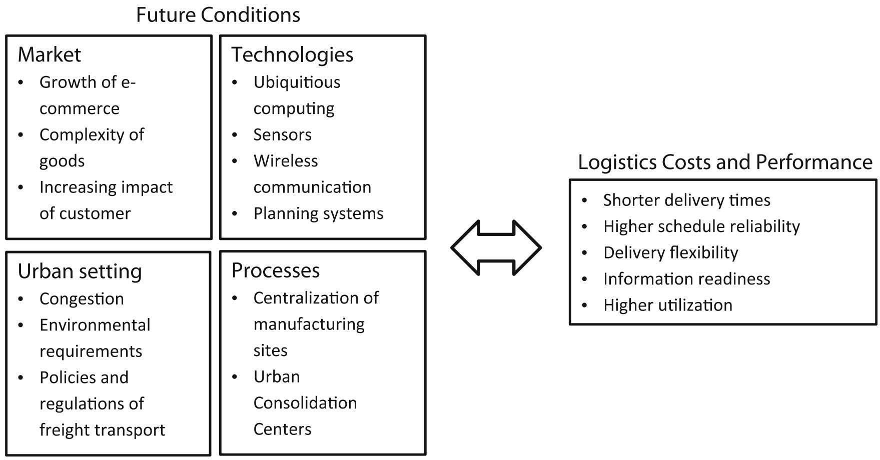

Fig. 2.1 Challenges for logistics service providers (adapted from Hülsmann and Windt 2007)

more people lived in cities than in rural areas worldwide (United Nations Population Fund 2007). An even further migration into cities up to the year 2025 is forecasted, when about 4.5 billion people are expected to live in urban areas, which corresponds to an increase of about 50% compared to the number of people living in cities in 2010 (Statistisches Bundesamt Deutschland 2010). Freight transportation is essential for the development of cities and the supply of their residents. Increasing cities depend on efficient and sustainable freight transportation systems to ensure their attractiveness, economic power, and quality of life.

Logistics service providers operate in the environment of emerging cities. They are exposed to a variety of challenges resulting from the future development of markets, increasing environmental requirements, new technologies, and evolution of complex supply chains. An overview on potential challenges is depicted in Fig. 2.1. Here, future conditions are faced by increasing importance of costs and logistics performance, resulting in, for example, shorter delivery times, higher schedule reliability, and flexibility. Customers expect that the quality of services will rise continuously.

In the following, selected challenges are discussed in more detail. Increasing congestion complicates planning procedures of city logistics service providers, since urban traffic infrastructure is limited, and evolution of supply chains requires the more reliable realization of delivery tours.

2.1.1 Evolution of Supply Chains

City logistics service providers undertake the local distribution of goods which have been consolidated in a shipping terminal. The corresponding logistics network consists of two transportation legs (cf. Fig. 2.2). On the first leg, freight

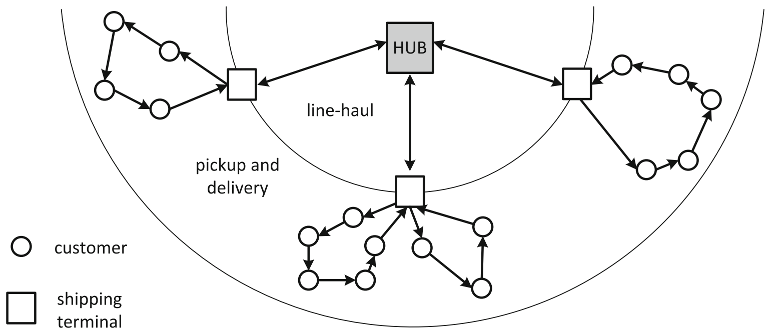

Fig. 2.2 Last-mile delivery in a hub-and-spoke network (adapted from Zäpfel and Wasner 2002)

is transported by large trucks to shipping terminals, where transshipment occurs. Line-haul transports refer to long distance transportation between the sending depots and the hub and between the hub and the receiving depots, respectively. On the second leg, city logistics service providers pick up the goods and deliver them to customers in terms of last-mile delivery. Last-mile delivery involves transportation over short distances with smaller trucks, and is carried out by the receiving depots in their regions. Corresponding hub-and-spoke networks may be operated by a single carrier or by a cooperation of several carriers. For more details on the design of a hub-and-spoke network, see Zäpfel and Wasner (2002).

Increasing importance of city logistics service providers arises from significant changes and developments in the ways in which freight operations are carried out nowadays. Following recent publications by Ruesch and Petz (2008); Crainic et al. (2009a, b), the following trends can be stated:

- Distribution concepts have changed considerably. There is a significant degree of centralization in manufacturing sites, stock keeping points, and retailing, leading to increasing demand for transportation.
- Current production and distribution practices are based on low inventories and timely deliveries. Changing stock keeping patterns and corresponding delivery patterns lead to more frequent, smaller deliveries undertaken by small freight vehicles.
- Supply chain structures have changed substantially, especially for larger companies. Many companies have restructured their supply chain by taking control over large parts and organizing deliveries to their branches themselves.
- Due to ongoing success of e-commerce businesses, distributors as well as retailers are eliminated from the supply chain. Thus, the importance of logistics service providers is increasing, since they undertake the physical distribution of goods, including issuing of a consignment certificate.

In sum, city logistics service providers are embedded in complex supply chains, requiring the fulfillment of demanding customer promises such as tight delivery time windows in the environment of congested urban areas. This emerges for commercial customers (e.g., for timely deliveries in just-in-time production) as well as for consumers (e.g., in online retail or e-commerce activities). The number of complex delivery operations increases parallel to the increasing utilization of road infrastructure, demanding for sophisticated support by planning systems.

2.1.2 Increasing (Freight) Traffic

Increasing traffic within limited city space leads to negative effects in terms of emissions and congestion. Here, city logistics service providers compete against other road users for the scarce traffic space, which cannot be extended unlimitedly. Nonetheless, congestion is usually not considered in city logistics routing. Defiance of varying infrastructure utilization may lead to lower service quality and higher costs of delivery.

Figure 2.3 exemplifies growing infrastructure utilization in Germany, especially within conurbations. Strength and color of roads denote an increase (orange) or decrease (blue) in traffic volumes up to the year 2020. Particularly in the area of conurbations, a huge increase of traffic volumes is expected. This is depicted by a mental orange “C”, reaching from Berlin in the eastern part via Hamburg in the north and the Ruhr district in the west to south Germany. For the area of Munich, a growth of 41% of vehicle miles traveled is expected comparing 2006 with 2020, for example. In the eastern part, which is characterized by rather low industrialization and decreasing population, traffic volumes are expected to decrease.

Corresponding to an increase of overall traffic volumes, the number of freight vehicles moving into and within cities is expected to grow at a steady rate (Crainic et al. 2009b). In European conurbations, more than 80% of today’s road freight trips are of distances below 80 km and can be defined as urban or urban regional transport (Ruesch and Petz 2008). Thus, the generation of efficient and customer-oriented delivery tours will become more and more challenging, forcing city logistics service providers to anticipate congestion in their logistics planning processes.

In the following, city logistics concepts are introduced, focusing on the interaction of urban traffic and transportation systems. This is an important perspective for the improvement of common planning systems.

2.2 Solution Concepts

The need for efficient and environmentally acceptable urban transportation schemes is conjoined by the idea of city logistics. City logistics concepts facilitate integrated solutions for the fundamental dilemma of urban freight transportation: on the one hand, urban freight transportation is fundamental to serve industrial and

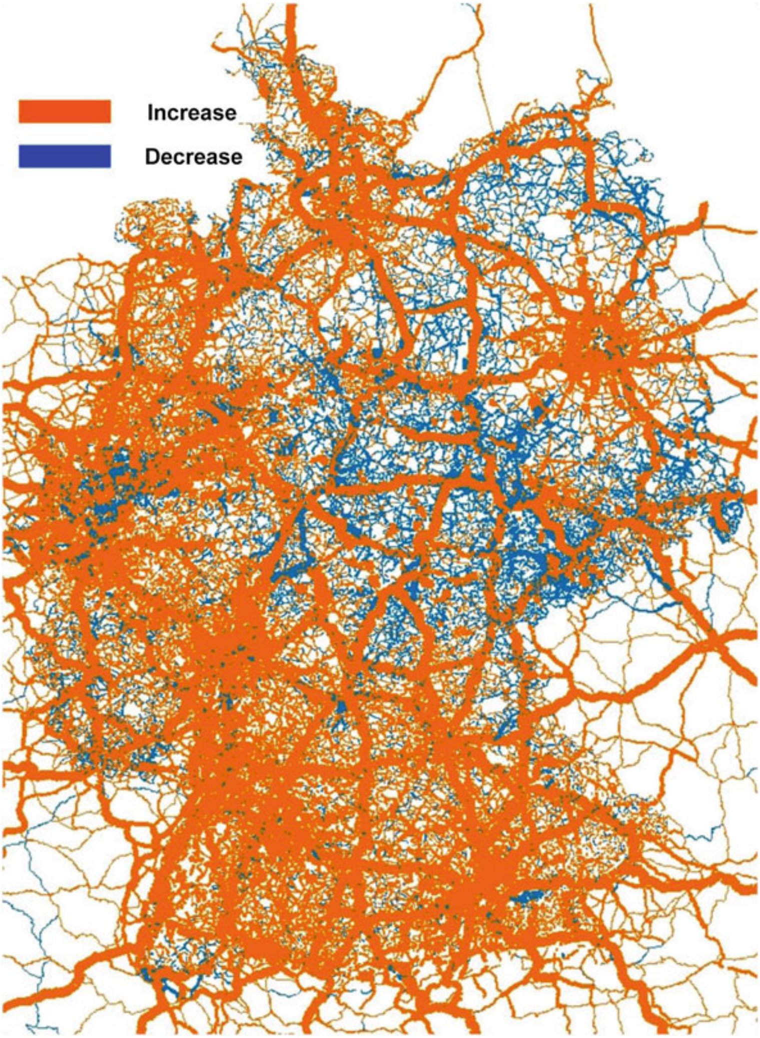

Fig. 2.3 Forecasted traffic volumes in Germany by 2020 (Pape 2006), with kind permission of acatech—Deutsche Akademie der Technikwissenschaften e.V. © 2006 Fraunhofer IRB Verlag, Stuttgart

trade activities in urban areas, ensuring their competitiveness; on the other hand, negative impacts of freight transportation should be limited.

Taniguchi et al. (1999) define city logistics as "the process for totally optimizing the logistics and transport activities by private companies in urban areas while considering the traffic environment, the traffic congestion and energy consumption within the framework of a market economy." Crainic (2008) focuses on the optimization and the utilization of transportation resources that contribute to the realization of profits as well as to environmental nuisances. He hence defines city logistics as the aim of "reducing and controlling the number, dimensions, and characteristics of freight vehicles operating within city limits, improving the efficiency of freight movements, and reducing the number of empty vehicle kilometers."

City logistics concepts aim at the optimization of urban transportation systems as a whole. They explicitly consider the congestion of traffic network infrastructure, which is neglected by planning systems for routing so far. In the following, core parts of city logistics concepts are introduced and applied to routing for city logistics service providers. First, the alignment of different stakeholders' goals in urban transportation systems is presented. Then, integrated planning and realization of urban freight transportation by Urban Consolidation Centers (UCC) is discussed. Both aspects are at the heart of many city logistics concepts. They embed the planning activities of city logistics service providers into urban transportation systems as a whole.

2.2.1 Perspective of Different Stakeholders

City logistics concepts aim at the integration of different perspectives of particular stakeholders. According to Taniguchi et al. (2008), the most important stakeholders are as follows:

- *Shippers* send goods to other companies or persons and receive goods from them. They tend to maximize their levels of service in terms of costs and reliability of transport.
- *City logistics service providers* deliver goods to customers. They aim at the minimization of their costs by more efficient pickup and delivery tours, and they are expected to provide a high level of service at low costs. To achieve a high level of service, freight vehicles are loaded inefficiently. They often have to wait near the location of customers when they arrive earlier than the designated time.
- *Residents* are the people who live, work, and shop in the city. They suffer from nuisances resulting from urban freight movements near their residential and retail areas. However, residents also benefit from efficient and reliable delivery.
- *City administrators* attempt to enhance the economic development of the city. They are interested in the reduction of congestion and environmental nuisances as well as in increasing safety of road traffic. To this end, they consider urban transportation systems as a whole to resolve conflicts between the other stakeholders.

Activities of city logistics service providers depend on the interaction of stakeholders presented above. On the one hand, city administrators affect planning procedures by setting complex restrictions for the realization of delivery tours, for example, certain time slots that permit or prohibit the entrance of freight vehicles in pedestrian areas. On the other hand, city administrators collect mass data from the operation of traffic information systems, which are a valuable

Fig. 2.4 Transshipment in UCCs (Allen et al. 2007), with kind permission of ptv AG, Karlsruhe, Germany

source for the more efficient and reliable planning of pickup and delivery tours (cf. Chap. 5). Residents and shippers correspond to customers of city logistics service providers. They expect an economic and reliable delivery service. The interaction of residents and city logistics providers is exemplified by online retail applications (cf. Chap. 3).

2.2.2 Urban Consolidation Centers

A major problem tackled by city logistics initiatives is the inefficient utilization of freight vehicles in urban areas, which contributes significantly to congestion and environmental nuisances such as emissions and noise. A more efficient utilization of freight vehicles can be achieved by consolidation of freight in “city distribution centers” or “urban consolidation centers” (Allen et al. 2007; Crainic et al. 2009b). Increasing efficiency, though, is accompanied by increasing complexity of the corresponding supply chain.

A UCC is a logistics facility that is situated relatively close to the area that it serves, for example, a city center, an entire town, or a specific site (Browne et al. 2005). It canalizes shipments of different companies in terms of an integrated logistics system. UCCs offer storage, sorting, consolidation, and deconsolidation facilities as well as a number of related services such as accounting, legal counsel, and brokerage. An exemplary UCC is depicted in Fig. 2.4, showing large trucks and city freighters as well as corresponding transshipment processes in the UCC of Padova, Italy. Consolidation of deliveries may lead to a decrease of kilometers driven, for example, of approximately 30% for the UCC of Stockholm, Sweden (Neveling 2007). However, increasing efficiency due to transshipment may be counteracted by increasing efforts for more complex cooperation and planning procedures. Transshipment demands for integration of different companies' information systems as well as for the more reliable realization of pickup and delivery tours, considering tight pickup, and delivery time windows.

Crainic et al. (2009b) extend the idea of UCCs by a number of "satellite platforms" that are relatively close to the city center. Freight arrives at an "external zone," where it is consolidated into urban trucks. Each urban truck delivers to one or several satellite platforms. Here, freight is transshipped into environment-friendly vehicles adapted to pickup and delivery in crowded inner city areas. Satellite platforms offer no storage facilities, requiring complex real-time coordination, control, and scheduling of urban trucks and city freighters. In the city of Amsterdam, such a system is in operation ("City Cargo," www.citycargo.nl): freight is consolidated at warehouses on the outskirts of the city and transshipped to specially configured trams. Trams move them to satellite platforms inside the city, where they are picked up by smaller electric freight vehicles.

UCCs are at the heart of many city logistics concepts and initiatives (Janssen and Oldenburger 1991; Ruske 1994; van Duin 1997; Köhler 1997; Köhler 2000; Thompson and Taniguchi 2001; Browne et al. 2005; Taniguchi et al. 2008). Although UCCs are expected to increase the efficiency of urban freight transportation, resulting complexity prevents success of realization in practice. The introduction of a UCC as additional point in the supply chain expects strict compliance of logistics service providers to pickup and delivery time windows, since storage space of UCCs is limited or—in the case of satellite platforms—even not available, and physical properties of goods might require immediate handling. Furthermore, the outsourcing of last-mile delivery to third-party logistics providers may induce suspicion of suppliers, since they lose their direct interface to customers. This is crucial especially for online retail applications, where last-mile delivery is often the only physical and legal activity being perceived by the consumer (see Chap. 3). Though, city logistics initiatives still promote the usage of UCCs, often supported by funding of local city authorities.

2.2.3 City Logistics Initiatives

Urban policies for freight transportation are investigated by a number of public initiatives. The *OECD Working Group on Urban Freight Logistics* focuses on solutions to minimize pollution, noise, and congestion caused by freight transportation, establishing best practices through a review of innovative approaches in OECD cities (OECD 2003). The projects *BESTUFS I and II* summarize best practices of urban freight solutions from a European perspective (www.bestufs.net, Allen et al. 2007). *Trendsetter* describes 54 projects aiming at the improvement of mobility, quality of life, quality of air, reduction of noise, and congestion; five European cities participate in the implementation of innovative city logistics concepts (www.trendsetter-europe.org). The *CIVITAS Initiative* promotes city logistics schemes in terms of sustainable, clean, and efficient urban transportation measures. From 2008 to 2012, 25 European cities take part in five pilot schemes (www.civitas-initiative.org).

The *Institute for City Logistics* (www.citylogistics.org) canalizes research activities on all aspects arising from and around urban freight transportation. Since its foundation in Kyoto, Japan, in 1999, a number of international conferences on city logistics have been organized, resulting in textbooks providing state-of-the-art city logistics concepts and implementations. For a recent overview it is referred to Taniguchi and Thompson (2006); Taniguchi et al. (2008).

City logistics concepts aim at the improvement of urban freight transportation by integrated analysis of transportation infrastructure, transportation resources, and political and economic environment. They induce increasing cooperation between the different stakeholders, resulting in a demand for more reliable delivery services. Especially for UCC operation, advanced planning systems are required which integrate information about customer orders and information about the expected state of urban traffic networks.

2.3 Modeling

City logistics environments may be assessed by comprehensive models describing urban infrastructure, transportation resources, and the impact and behavior of the different stakeholders. In this section, a systems approach on city logistics is presented. The focus is especially on the role of input data for city logistics models. The systems approach is applied to planning procedures of city logistics service providers, enforcing the provision and integration of time-dependent travel times.

Taniguchi et al. (2008) present an overview on the elements of city logistics systems and their relationships. In Fig. 2.5, solid arrows denote the well-known approach of modeling and solution of analytical problems that can be described by models. This comprises the definition of the problem accompanied by objectives and criteria, followed by determination, evaluation, selection, and implementation of a solution. Since city logistics concepts aim at the overall optimization of urban transportation systems, detailed information about transportation resources, constraints, and alternatives are considered for problem solution. Dashed arrows denote the corresponding data collection loop, which enforces the collection and consideration of empirical data in the improvement of urban transportation systems. While this approach is fundamental to the analysis of city logistics problems, it is not acknowledged by planning systems for routing in city logistics, for example, it is not properly exploited by the majority of planning systems up to now.

According to Taniguchi et al. (2008), possible instantiations of the particular components may be as follows:

- Typical city logistics *problems* regard traffic congestion, fleet planning, and fleet management as well as environmental nuisances of urban traffic.
- Corresponding *objectives* are the reduction of operational costs, the increase of efficiency and the reduction of environmental nuisances.

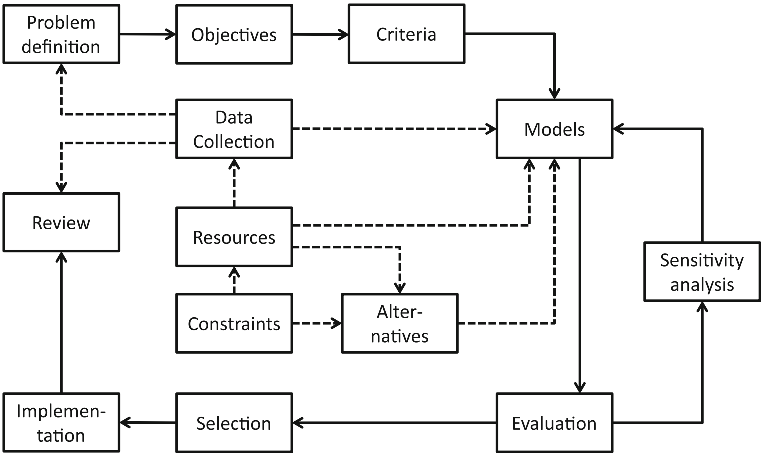

Fig. 2.5 Modeling and analysis of city logistics problems (adapted from Taniguchi et al. 2008)

- *Criteria* may be the number of used freight vehicles, load factors, average speed, or vehicle kilometers traveled.
- *Resources* concern transportation and communication infrastructure, for example, roads, terminals, mobile communications, and freight vehicles.
- *Alternatives* are the options having the potential to solve the problem, for example, route guidance, modern planning systems, or electronic tolling. Financial, legal, social, or political issues limit the range of alternatives that can be considered.
- *Data collection* is required to establish a rational basis for analysis, for example, based on operational data or sensor data such as FCD.
- *Models* provide a simplified representation of the urban freight transportation system. They allow the effects of various changes in the system to be estimated without actually changing the system.
- *Evaluation* involves the methodical comparison of alternatives based on economic, social, financial, energy consumption, and environmental reasons.
- *Sensitivity analysis* investigates the variability of predicted effects of the alternatives with respect to the assumptions made within a model.
- *Selection*, *implementation*, and *review* concern the selection of the best alternative, the implementation of new operating and organizational procedures as well as the investigation if the initial problem has been solved and if the objectives have been attained.

To extend a common planning system for routing in city logistics, the systems approach is applied as follows:

- Efficient and customer-oriented delivery of goods is crucial for the development of viable freight services (*problem definition*). The *objective* is to reduce

operational costs and to improve service quality by taking into account congestion of urban road infrastructure. Reliability of pickup and delivery tours, overall travel times and overall distances, as well as the number of used vehicles define *criteria* for the evaluation of a planning system for routing in city logistics.
- A core point of investigation is the provision and analysis of *information models and optimization models*. Optimization models are formed according to the given criteria of transportation resource optimization. Data collection supplies comprehensive input data for optimization models in terms of information models, which are derived from telematics-based *data collection* by FCD, for example. Information models embed information about typical states of transportation *resources*, for example, the city road network. For routing, this information is represented by extended digital roadmaps, which may lead to more efficient tour *alternatives* due to consideration of time-dependent infrastructure utilization.
- *Evaluation, selection,* and *implementation* of models is done by enhanced planning systems, which consider several variants of planning data sets and optimization procedures. Computational experiments allow for the comparison of efforts for model building and resulting quality of delivery tours with regard to defined criteria.

The presented systems approach aims at the improvement of urban freight transportation by consideration of the different stakeholders' objectives. It provides a big picture of an urban freight transportation system and its numerous components and relationships. In the following, the focus is on the perspective of city logistics service providers and the optimization of pickup and delivery tours within the city logistics framework. Therefore, the integrated collection and provision of detailed traffic data as suggested by the systems approach is examined, which is not properly exploited by common planning systems up to now. The conception of a city logistics planning framework will explicitly focus on the reasonable interaction of data collection and problem solution.

2.4 Planning Systems

In this section, different levels of planning tasks for city logistics service providers are distinguished. Then, a common planning system is extended by advanced routing functionality.

2.4.1 Levels of Planning

Planning systems for logistics service providers may support different levels of planning activities. According to Roy 2001, strategic, tactical, operational, and real-time levels can be distinguished. Individual levels differ by the impact they have on future activities:

- Decisions within the *strategic level* concern a large part of the organization. They have a major financial impact and typically comprise the design of the transportation system, for example, the size and mix of freight vehicles and equipment or the type and mix of transportation services. Corresponding decision problems are poorly structured, complex, and of high risk and uncertainty. They constrain the activities and decisions made at subsequent levels.
- *Tactical planning* deals with short or medium-term activities. Tactical decisions concern the efficient and effective use of transportation infrastructure and the alignment of operations according to strategic objectives. Here, logistics service providers deal with the acquisition and replacement of their equipment, long-term driver to vehicle assignments, and cost and performance analysis. Decisions made at the tactical level limit the activities of operational and real-time management level.
- Decisions of *operational management* concern short term, day-to-day operations. Operational planning is characterized by a short planning horizon and decision problems of detailed problem structure. Here, logistics service providers plan current and next day activities. They should anticipate future developments such as congestion or expected transportation requests. Routing for city logistics service providers is an operational task: a known set of transportation requests is assigned to a given set of transportation resources. Automated planning systems support the corresponding tasks.
- Within *real-time level*, execution of operational decisions is controlled, for example, real-time decisions react on discrepancies between planned and actual state of the transportation system. Activities at the real-time level depend on the decisions made at the higher levels. They are sensitive to the quality and the reliability of operational planning. Deficient anticipation of real-time conditions in operational planning may lead to costly replanning within real-time level.

Since the focus of this work is on routing in city logistics, an advanced planning system for the support of operational planning of city logistics providers is developed. The corresponding architecture is presented in the following.

2.4.2 Architecture of a Planning System

Operational planning of logistics service providers aims at the optimal assignment of transportation requests to transportation resources. Partyka and Hall (2010) give an overview on recent planning systems and their functionality. *Transportation requests* correspond to customer orders, which comprise information about physical properties (e.g., length and weight of a package), geographical properties (e.g., location of pickup and delivery) and logical properties (e.g., customer time windows). *Transportation resources* denote physical properties of the fleet

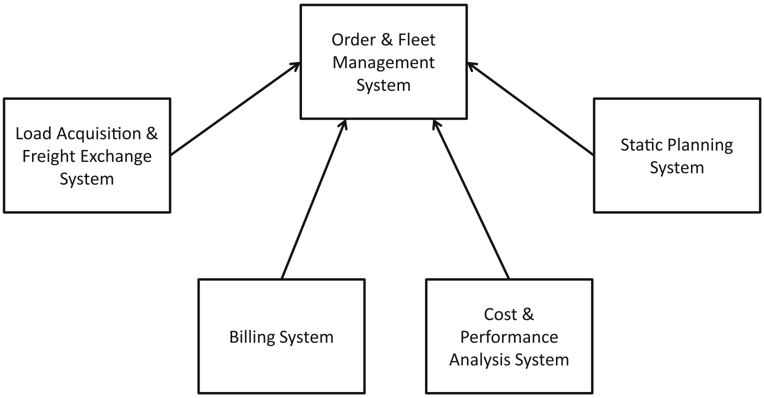

Fig. 2.6 A common planning system for operation of commercial vehicles (Goel 2008)

(e.g., maximum capacity of a freight vehicle), the location of a vehicle (e.g., to which depot it is assigned), and logical properties (e.g., the maximum of drivers' working hours). Goel (2008) presents a comprehensive elaboration of these properties for commercial vehicle operations.

As a result of operational planning, customer orders are assigned to freight vehicles by determination of the most efficient visiting order of customers and routes of vehicles. Corresponding pickup and delivery tours are characterized by a large number of stops within a relatively small geographical area. For instance, warehouse delivery tours in urban areas have a length of about 105 km per day and vehicle in the US (Chatterjee and Cohen 2004).

A common planning system supporting operational planning of a logistics service provider is depicted in Fig. 2.6. The *Order and Fleet Management System* is the central component containing all information about transportation requests and transportation resources. Shippers may enter new transportation requests via an interface to the *Load Acquisition and Freight Exchange System*. The *Billing System* prepares the invoice after order completion. The *Cost and Performance Analysis System* evaluates and aggregates operational data for the support of tactical and strategic decisions. The *Static Planning System* optimally assigns transportation requests to transportation resources by routing functionality, supporting operational planning as described above.

Goel (2008) proposes to extend such a common planning system by a sophisticated real-time telematics component, which automatically adjusts scheduled delivery tours to actual traffic conditions to reduce the planning gap between operational planning and realization. For city logistics routing, this approach is not sufficient, since pressure on city logistics service providers has increased over the past years and time-varying utilization of infrastructure has an enormous impact on the efficient and reliable usage of transportation resources. Expected traffic states should be anticipated as early as in the operational planning phase in order to reduce the planning gap between the operational level and the real-time level. Thus, the focus of this work is on the elaboration of the Static Planning System component by processing and integration of time-dependent travel times.

A recent application example enforcing the planning of more reliable delivery tours is presented in the next chapter.