

CHAPTER 3

3. DESIGN OF MULTIMODAL TRANSPORTATION

3.1. INTRODUCTION

Transport models are applied to support the planner in this process of planning and decision making. These models attempt to replicate the system of interest and the system's behavior. The presented model considers the transportation system with its interactions between the several supply systems and the demand system. The transport model consists of a demand model, a network model and a set of impact models. The demand model contains the travel demand data. It simulates activities and generates trip chains to estimate and forecast mode-specific origin-destination matrices for behaviorally homogeneous populating groups. Travel demand estimates are derived from structural land use data and service indicators determined by the impact model. Because the demand model describes the traveler's choice between various modes of transport it may be labeled multi-modal". The network model contains the relevant data of the supply systems describing their spatial and temporal structure. It consists of traffic zones, nodes and public transport stops, links and public transport lines (Mohd Y.I I., et. al, 2009).

The impact models take their input data from the demand model and the network model. It integrates different impact models to analyse and evaluate a transport system. A user model simulates the travel behavior of public transport passengers and car drivers (BOUMA A.,et.al, 1994). Based on routing and assignment models it calculates traffic volumes and service indicators, e.g, travel time, number of transfers of service frequency.

Routing and assignment procedures are called “inter-modal” if they combine different modes for one journey or a trip chain (Joel B., et. al, 2009). An operator model determines operational indicators of a public transport service, like vehicle kilometers, number of vehicles or operating cost. In combination with the demand data it allows to estimate to line revenues. An environmental impact model provides several methods to assess the impacts of motorized transport on the environment (Markus Friedrich, 1998).

3.2. DESIGN APPROACH OF MULTIMODAL TRANSPORTATION SYSTEM

Multimodal Transport System (MMTS) relates to single trip consisting of combination of modes i.e. vehicle modes (bus, metro, car, tram, etc.) or service modes (private/public) between which the traveler has to make a transfer (Fig.3.1a) (Fernandez.C.G, et. al, 2009).



Figure 3.1a Multimodal Transport Trip (Transfer Point is Denoted by the Bold T)

The various characteristics of MMTS are trips that involves more than one mode of transport. Use of different modes of transport at different opportunities, policy principle not to stick to one single mode, development of seamless web of integrated transport chains, linking road, rail and water ways, competition between transporters instead of between transport modes, transfer node and smooth interchange flow, seamless

travel an important characteristic of the system. The components of multi modal transport system comprises of rail facilities, bus facilities, water facilities, air facilities, passenger waiting area, commercial facilities, ticketing offices, parking facilities, vertical and horizontal passenger link. A design approach is required to integrate all these components for evolving of efficient transport system. It includes assessment of various parameters related to passenger movement, functional requirements of whole system, existing facilities and operation conditions, etc and their projection for future demand and supply (Jean, et. al, 2001).

3.2.1. Main characteristics

The aim of transport network design is to determine a network that has an optimal performance given a specific design objective. There is a set of decision variables that determine the characteristics of the network, while on the other hand there is an objective against which the performance of the network is evaluated. Furthermore, there might be a set of constraints that limit the set of possible solutions. The type of decision variables, and thus the characteristics of the design problem, depends on the method used to describe the network. The most common case found in literature is a description using nodes and links, while for public transport networks lines are also used as decision variables (Bousquet A, 2007).

It is obvious that the number of possible solutions increases more than exponentially with the size of the problem, which makes it a hard problem to solve. It has been shown that the network design problem in its simplest form is NP-complete,

that is, no algorithm exists that can solve the network design problem in acceptable computation time, except of course for small networks (Johnson et al, 1978). It is clear that if the decision variables may have more values than just being included in the network or not, for instance, accounting for the number of lanes that are available, then the combinatorial nature strongly increases. The decision variables then are limited to a few parameters such as network density, access density, network speed, and frequency, given a specific network type. The disadvantage is that due to the restriction to specific network types and the simplifying assumptions with respect to the demand pattern, the relationship with actual transport networks is limited. This drawback is perhaps the main reason that the discussion on transport network design in literature is dominated by the node- and link-based method to describe transport networks. Most of the design objectives are traveler oriented, with the exception of the design of an airline network. The design problem is split into sub-problems which is solved in a sequential order leading to stepwise procedure. An exception can be found in modules for airline networks (Aykin, 1995)

3.2.2. Design Problem Type

The topic of multimodal transport implies that different transport services should be considered in a similar systematic way, and thus that the approach should be suited for both service networks and physical networks. Since transport service networks are an essential part in multimodal transport the methodology should focus on the design and development of new networks.

3.2.2 Design Objectives

In contrast to some of the design methodologies found in the literature (Immerse et al., 1994), an explicit objective in which the opposing objectives of both the traveller and the investor or operator are balanced is preferred. In that way an identical objective can be used for physical networks and for transport service networks. Typical examples of such objectives found in the literature, that are suitable for both types of networks are minimizing total costs: that is minimizing the sum of the costs involved in travelling, that is the total door-to-door travel time monetized using the value of time, plus the investments, maintenance and operating costs and maximizing social welfare: that is maximizing the sum of consumer surplus and producer surplus. Consumer surplus consists of the benefits of all traveller who are able to travel at lower costs than they are willing to pay, while producer surplus is equivalent to profit (Jansson ,1996).

The objective of maximizing social welfare gives the most comprehensive description of the balance between the traveler's and the investor's objectives from an economic point of view (Berechman, 1993, Yang & Bell ,1997). It incorporates the sensitivity of the demand for the changes in the service level that is supplied. This relationship between supply and demand, however, makes it also more complicated than the objective of minimizing total cost in which a fixed level of demand is assumed. It can even be shown that combining a demand model with the objective of minimizing total costs might lead to the trivial solution of offering no services at all, resulting in no travel costs and no investment, maintenance, or operational costs. In the case of

urban public transport network design, it has been shown that both objectives yield similar outcomes for the resulting optimal designs (Van Nes, 2000). According to Berechman a long distance line-bound public transport profit maximization might also be a suitable design objective. This option is considered in the analysis of the organizational aspects of hierarchical line-bound public transport networks (Pawan Kumar S.Y., et. al, 2009).

The alternative approach of describing a network using a set of nodes, a set of links, and in the case of a public transport service network, a set of lines, obviously has the advantage that it can fit any topological situation found in reality. Furthermore, such a description allows a detailed description of travel behaviour. The crucial disadvantage, however, is that such an approach does not provide general insights that can be used in establishing guidelines for network design, unless a large number of cases are analysed (Van Nes R., 1988). The design variables in this study are thus the basic network variables for network density, access density, time accessibility, and speed. ① Road spacing is the distance between parallel roads in a linear, grid or triangular network. ② Line spacing is the distance between parallel lines in a linear, grid or triangular network. ③ Access spacing is the distance between access nodes for a road. ④ Stop spacing is the distance between access nodes for a public transport line. ⑤ Speed is the average speed in the network (Magnanti T L., et. al, 1984).

3.3 MULTIMODAL TRANSPORT NETWORK DESIGN

3.3.1 Introduction

Transportation systems with a number of modes can be seen from two different conceptual perspectives: ① Intermodal Transportation Network: a logistic system which is connected to two or more modes. Each mode has a service characteristic which generally enables goods (or passengers) to move to another existing mode in one trip from origin to destination. ② Multimodal Transportation Network: a set of transport modes which provide connection from origin to destination. Even if intermodal transportation can be applied, this is not compulsory. (Harun AI – Rasyid s.Lubis et.al, 2005). The network model describes the side of the transport system consisting of several supply systems. Each supply system is either of the mode-type “private transport” or “public transport” and uses one specific means of transport (car, heavy goods vehicle, bike, bus, train, light rail etc.). The combination of mode type and means defines the system’s characteristics which determine a set of rules for the operation of the vehicles. The actual speed of individual transport vehicles is influenced by the network’s capacity whereas public transport vehicles operate according to their timetable. Nodes of the network are connected through links, which describes the rail and road infrastructure, a link is defined by two nodes and characterized by the following input attributes such as a link-type for network categorization, the link’s length, the supply systems, which may use the link, the free-flow speed and capacity for private transport, the running time for public transport systems. Links which are permitted for a specific private transport system (e.g. car) are considered during private transport assignment. Links which are permitted for a specific public transport system (e.g. bus) are considered during the

construction of a public transport line. To model passenger transfers by foot between certain public transport stops a transfer walking link may be introduced to connect these stops. This link is part of special public transport system “walking transfer”. A public transport line has a particular line name and usually serves two directions. It may include one or several line variants (sub lines) which show different line-routes or running times between stops. Each sub line is described by the line’s name, the number of the sub line, a direction, a supply system, a line-route: sequence of nodes and stops with running time between stops, a timetable: list of departure times, operational data: name of operator and type of vehicle.(Markus Friedrich, 1998). Demand responsive transport systems are an alternative for the limited accessibility in space and time of traditional line-bound public transport services. Demand responsive transport might eliminate or reduce these limitations. The fact that these transport services are fully demand oriented makes them very suitable for tailor-made multimodal trips. The Traintaxi in the Netherlands, a share-a-cab service to and from railway stations, has already shown that such transport services have a clear potential in multimodal transportation, especially for the activity - based part of the trip (De Bruijn, 1998).

It is interesting to note that both types of transport services lack a distinct network, since they use the road network. Rental services introduce a new limitation of the accessibility of the network, which is determined by the location of the rental services. In the case of demand responsive transport services the accessibility of the network is ideally comparable to that of private transport services. In practice, however, the need to make a reservation still leads to a substantial difference with private

transport services. Furthermore, the quality of the transport service itself will vary with actual demand patterns in space and time. The analysis of these demand oriented transport services will show that while they can improve the attractiveness of multimodal transport, they have no impacts on multimodal transport network design. Finally, the consequences of these findings for multimodal transport network design are discussed, resulting in a focus on the location of transfer nodes and the role and characteristics of more detailed network design models (Newell G.F., 1979).

3.3.2 Main Characteristics

The main part of the literature on transport network design focuses on single modes or transport services and on single-level networks. Typical examples are urban or national road networks, and urban or national public transport service networks (Van Nes R., 1999). A multimodal transport system, however, consists of several transport services and different network levels, which might also have different operators or authorities. A multimodal trip might consist of an access leg in which private car is used in an urban road network, and a main leg using an interregional train service on the national railroad network. The multimodal transport network problem thus adds at least two extra dimensions they are Network levels, Combinations of transport services (Fig.3.1b).

The third dimension of different operators or authorities is analyzed. The highest network level, level 3, is characterized by a coarse network, limited accessibility, and high speeds, and is especially suited for long distance trips. The lowest network level,

on the other hand, is fine-grained, has high accessibility and low speeds, making it suitable for short distance trips and for accessing the higher network levels.

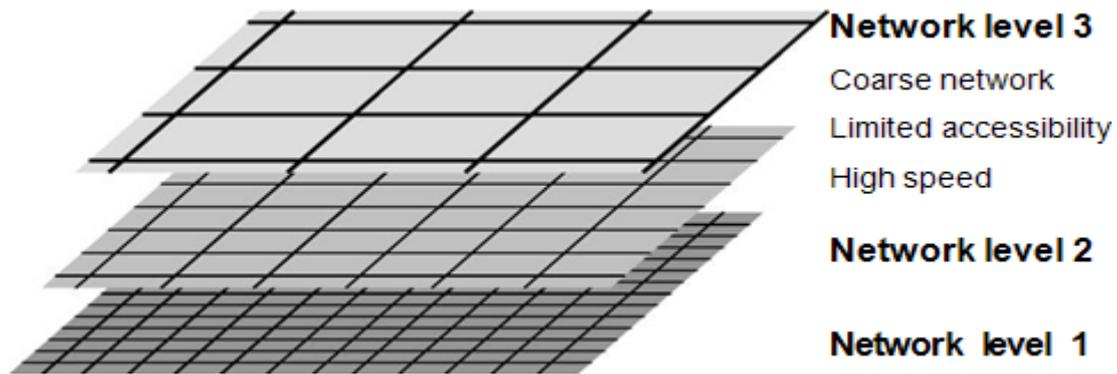


Figure 3.1b Illustration of multilevel network

Horizontally there are the transport services with a distinction between private and public modes. Examples of the private modes are private car (motorized vehicles), bicycle (human powered vehicles), and walking (no vehicles are used), while for the public modes a distinction is made between line-bound services and demand oriented services such as share-a-ride concepts.

On the vertical axis are the various network levels that might be distinguished, which are strongly related to the distance travelled. For each transport service the grey area shows the distance range for which it might be suited. For many transport services different network levels might be distinguished. The dashed lines and the vertical arrows illustrate the boundaries between network levels. Typical examples for car networks are motorways, regional roads, urban motorways, and streets. The

traditional transport network design problem usually deals with a single rectangle in this fig 3.2, for instance, an urban public transport service network.

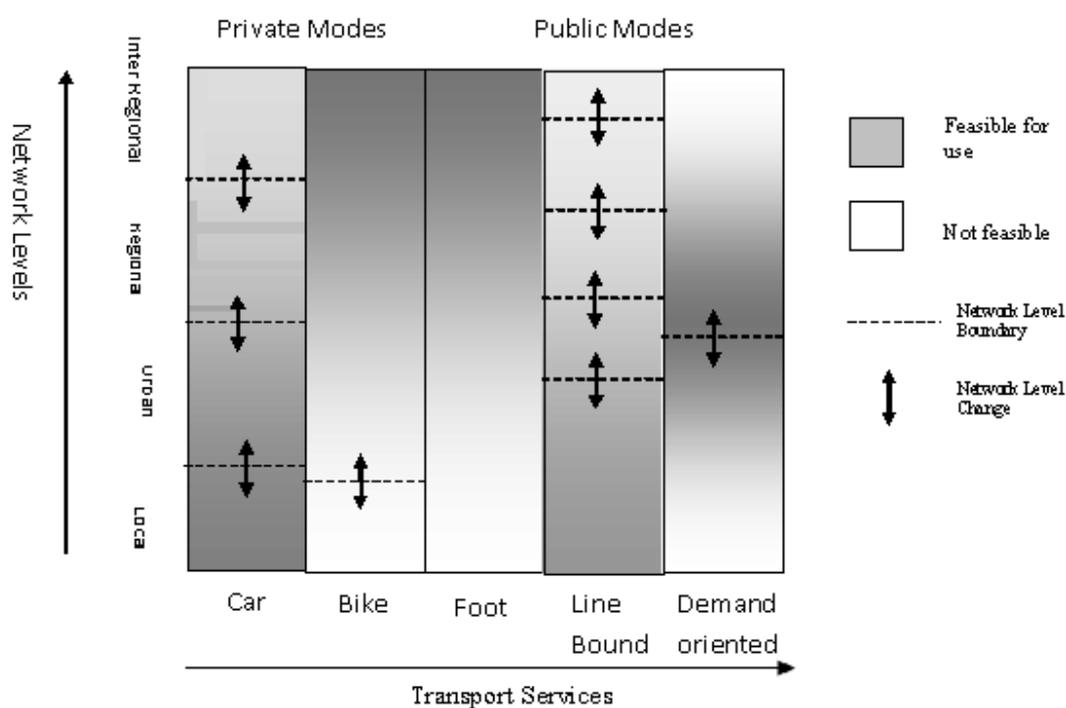


Figure 3.2 Multimodal transport system consisting of modes and network levels

Multilevel transport networks and multimodal transport networks are strongly related. A mode used to access another mode which is suited for the specific trip introduces a hierarchical relationship between these two modes and thus between the network levels that are used. The notion of hierarchy implies that a transport network, apart from having its own function, also provides access to higher level networks. Lower level networks support higher level networks. Consequently, multimodal transport implies multilevel transport networks. Multilevel networks on the other

hand, are not necessarily multimodal networks (fig.3.2). The road network, for instance, is clearly a hierarchical network having different network levels that are suited for specific trip lengths, while it is unimodal transport network because there is no need for the traveler to make a transfer: the same mode is used for all network levels (Yang H., et. al, 1998).

The notion of multilevel transport networks is also suitable for describing travel behaviour. Analyses by Bovy (1981, 1985) showed that the hierarchy in private transport networks enables a good description of route choice for cyclists and car drivers in cities.

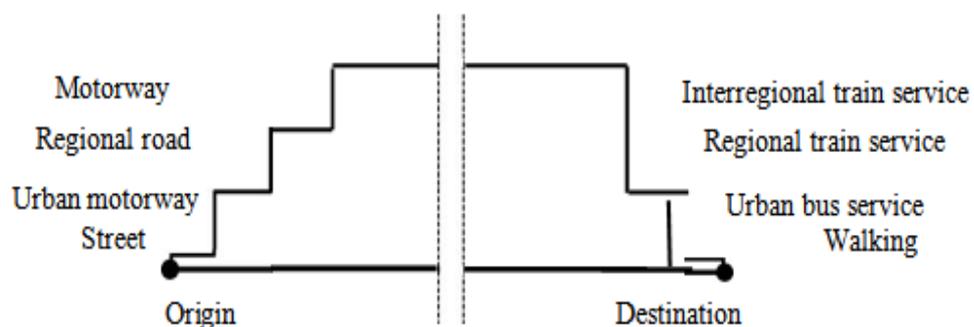


Figure 3.3 Example of pyramidal route choice for private car (left-hand side) and line bound public transport services (right-hand side)

The explicit use of the concept of hierarchical transport systems in route choice is called pyramidal route choice. Fig.3.3 gives an example of the network levels used for a long distance trip by private car and for line-bound public transport services. In a multimodal transport system, of course, private car might be used to access the interregional train service, yielding a similar representation!

The multilevel network concept introduces a second relationship between network levels. The lower-level network is used to access the higher-level network. The quality of the lower-level network thus determines the quality of the higher-level network. Furthermore, since there are travellers using both network levels, the quality of the higher-level network influences the patronage of the lower network. These additional relationships make the multilevel transport network design problem even more complicated than the single-level transport network design problem. The focus of the literature on single-level unimodal transport network does not mean that no attention is paid to other transport services. In project PI (Dutch Ministry of Public Works and Water management (1998)), for instance, both private and public modes are considered simultaneously, however, still as separate modes. In many studies in which the demand is assumed to be dependent on the quality of the services offered, mode-choice is used to describe this relationship, usually the choice between private car and public transport services. The various transport services are, again, analyzed as separate modes.

In this more traditional unimodal context it is reasonable to assume that the relationship between network levels is transport service specific. The multimodal transport network design problem, however, introduces a dependency between different transport services. It is no longer necessary to assume that relationships for multilevel networks apply only for a specific transport service. On the contrary, other transport services might be essential to access higher-level transport networks. The quality of a network level of another transport service might thus be decisive for the characteristics of the higher-level network. A typical question then is what will happen with the

hierarchy of the transport service: will the characteristics of the network levels change or will they remain the same? What is, for instance, the impact on the hierarchy of line-bound public transport service networks if cycling replaces the role of walking? Will it change the characteristics of the lower-level network only, or will it influence all network levels of line-bound public transport services? Fig 3.4 schematically illustrates these possibilities. The left-hand side displays the network levels as shown Fig 3.2. The right-hand side shows two alternatives. In the first case only the characteristics of the lower-level network change, namely it is less suitable for short travel distances, while those for all other network levels remain identical. In the second case, however, the characteristics of all network levels change.

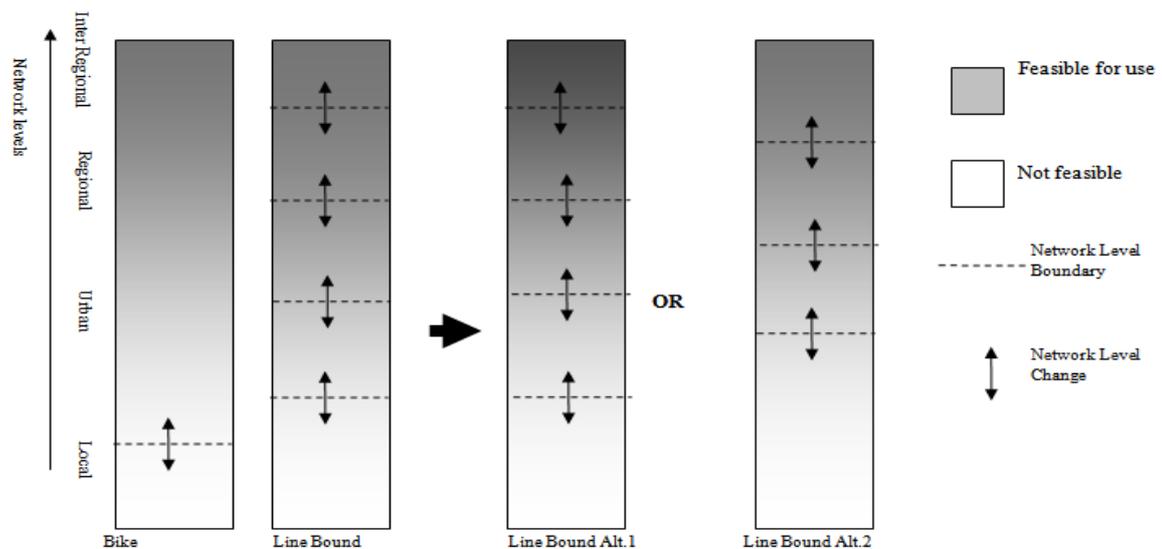


Figure 3.4 Two possibilities for the hierarchy of line-bound public transport service networks because of combining bicycle and public transport. Alternative 1. Only the lower-level network characteristics change Alternative 2. All network level characteristics change

A third characteristic of the multimodal transport network design problem deals with both transport service networks and physical transport networks. This is one of the reasons for choosing minimizing total costs and maximizing social welfare as design objectives. The combination of both network types, however, also adds to the complexity of the design problem. Service networks require physical networks. New links in the road network, for instance, enable new public transport services by bus, which in turn might even reduce the need for building those links. Combining transport services thus leads to additional combinatorial complexity. It is clear that the complexity of the multimodal transport network design problem is substantially larger than that of the traditional network design problem. How to deal with this complexity? The key issue in this discussion is the interdependency between network levels for different transport services. The key to dealing with this interdependency can be found in travel behavior. Multimodal transport will only be relevant if it is interesting for the traveller. Multimodal trips should be attractive with respect to travel time and travel costs. Furthermore, the concept of pyramidal route-choice requires that multimodal trips should have a logical pattern regarding the access leg, the main leg, and the egress leg. It might thus be stated that transfers between transport services are only plausible if they coincide with changes in network levels.

Given this assumption a two step procedure is used to develop a design methodology for multimodal transport networks. The first step is to analyze the relationships that determine the network level boundaries for a transport service. In this analysis a distinction is made between private transport networks. The second step

focuses on the consequences of combining transport services for these relationships between network levels. In this way the multimodal transport network design problem is split up into two parts: unimodal multilevel networks and multimodal multilevel networks. Furthermore, the complexity following from detailed demand modeling, using mode- and route-choice in a multimodal transport network, is not considered in this thesis. The main goal is to determine basic relationships for transport network design, which are needed for the development of design guidelines. The proposed network levels for private transport and line-bound public transport networks are summarized in Table 3.1.

Table 3.1 Network levels for private transport and line-bound public transport

Network levels	Related spatial level	Network size	Road and line spacing	Network speed
<i>Urban</i>				
Street / Urban	Neighbourhood	City	1 / 0,6 – 0,8	20
Arterial / Express service	District	Agglomeration	3 / radial	35
Expressway / Agglomeration service	‘City’	Metropolis	10 / radial	55
<i>Interurban</i>				
Local	Village	Small region	3	35-40 / 30
Regional	Town	Region	10	60 - 70 / 50
Interregional	City	Province	30	100 - 120 / 85
National	Agglomeration	Country	100	- / 140
International	Metropolis	Part of continent	300	- / 235

The values for road spacing, line spacing, and network speed represent global averages and should not be interpreted as rigid standards. While these guidelines are not always different from existing guidelines, the type of support for these guidelines is quite different. The guidelines developed here follow from extensive analyses of the characteristics of transport networks. Some of the existing guidelines are based on current practice, which given the self-organizing properties of private transport networks might be in line with these new guidelines, such as the scale-factor for the path spacing in bicycle networks (Bach, 1999). The analysis of urban public transport networks, however, shows that guidelines on for instance stop spacing might be outdated due to changes in urban structures and related costs. Other guidelines, such as those advocated in Germany for interurban transport networks (e.g. FGSV, 1988), are based on the a priori distinction in spatial structures. The analyses focusing primarily on network characteristics, show that this distinction is indeed proper. As such, this thesis provides additional theoretical support for the German guidelines for private transport and public transport network design (VÖV (1981), FGSV (1988), Köhler (1989), Schönharting (1997), Bierschenk & Keppeler (2000)). This theoretical support, also identifies the need to make a clear distinction between network levels. While the German guidelines allow the possibility of having small differences in speed between network levels, these guidelines clearly recommend substantial differences in quality in order to exploit fully the benefits of hierarchical network structures.

The estimate of the future potential for multimodal transport showed that improvements in multimodal services might lead to a substantial increase of public

transport usage. If this growth were to be accommodated by train services alone, train trips between 10 and 30 kilometers would be tripled, while trips between 3 and 100 kilometers would be doubled. Improved multimodal transport thus implies a capacity problem for line bound public transport. It is more likely, however, that due to the limited rail infrastructure the existing train service network is not suited to accommodate the extra demand, and that additional transport services are necessary. Such transport services probably need dedicated infrastructure in order to meet the standards for the associated network levels, which makes them difficult to develop.

The concept of multimodal transport will not substantially change in public transport network design, since higher-level line-bound public transport networks are already a multimodal transport system. However, it strengthens the importance of the accessibility of access nodes for higher-level public transport networks, including parking facilities for private car and bicycles. The dependency between hierarchy in spatial structures and public transport networks, however, determines the location of these access nodes. The importance of accessibility and the location of these access nodes lead to an interesting design dilemma. From a multimodal transport point of view the accessibility by private car is important, while the higher densities related to hierarchy in spatial structures make it very expensive to provide adequate facilities for parking private cars in city centres. Furthermore, these higher densities set high standards for the environmental quality in city centres, which limit the possibilities to provide high quality access by private car.

Alternatively, the opposite approach of introducing new mostly peripheral access nodes to higher-level line-bound public transport networks which are primarily based on access by private car, lacks all the benefits provided by the concentration of activities found in urban city centres. Egeter et al., 1990 estimated that such a transfer node would generate 2,000 travellers per day at most, which is very small compared to an average access node of the regional public transport network. If all travellers needed for an economically sound operating transport system would arrive by private car, the size of the parking space would be enormous. On the other hand, an analysis of the potential of a transfer point in the national train service network in the Netherlands showed that given very high standards for the public transport system, the number of car drivers willing to transfer to public transport was still very limited (Mu-Consult , 1998). New access nodes based on car access alone do not seem to be a very fruitful solution. The accessibility of access nodes of higher-level public transport networks for bicycles is easier. Bicycles require less space for parking facilities and bicycles are an accepted environmentally benign transport mode in city centres. Although combining alternative modes and higher-level public transport does not influence the network hierarchy of line bound public transport networks, it increases the patronage of these networks. For the lower-level public transport network, however, the question remains whether combining alternative access modes may influence urban public network design. At first sight, it should. If, for instance, bicycles are used to access urban public transport, the access speed is four times higher than the speed for walking. If this access speed is used to determine the optimal network characteristics for the tram network analyzed. The impact on the network and its performance is substantial. Stop spacing

is nearly twice as large, line spacing more than twice as large, while the optimal frequency becomes 12 vehicles per hour. The weighted travel time is about 40% lower, as is the operational cost. Social welfare is 26% higher. This approach, is clearly too simplistic. Travellers may choose between using a bicycle to access public transport and walking to the stop. Given the resulting values for stop and line spacing, the maximum access distance becomes about 850 meters, which makes it likely that many travellers will prefer to walk. Therefore, a more detailed analysis is needed to assess the impact of alternative access modes.

An option would be to follow the suggestion by Jung (1996) who used the average access time for all access modes to determine the optimal network characteristics. In his study, however, Jung used scenarios with respect to the modal split for the access modes, and did not consider a more detailed description of travel behaviour such as access mode choice. Furthermore, Jung focused on minimizing travel time only, and did not use the preferred objective of maximizing social welfare. The following section presents an analytical model that explicitly accounts for access mode choice, using the objective of maximizing social welfare. This approach is an improvement of the method used by Van Nes (2001).

3.4 APPLICATIONS OF MULTIMODAL TRANSPORTATION

Design approach for Multimodal Transportation System (MMTS) can be classified as follows: Design for Integration and Design of Interchange. Design for integration at MMTS terminal integrates bus, feeder services, bicycle, rickshaw, etc with

rapid transit system. The design provides an access pattern for multiple modes while assuring integration, safety and ease of use for all persons. The effect of design interchange or the degree of integration can be assessed in terms of the utility of interchange. The utility of interchange has three main components: Requirement to interchange which has a penalty associated with its dependent on the amount of time spent. Time spent transferring between modes, and Time spent waiting for a connection. Design of multi modal transport system involves planning techniques; design & construction of sound, economical and aesthetic buildings; engineering expertise etc.

There are various factors associated with high quality of interchange such as ① High quality waiting environment ② High provision of timetable information (outstand, easily to get). ③ Reliable telephone information services. ④ High levels of personal security. ⑤ Easily get ticketing and pricing systems. ⑥ High signage within the interchange and for the bus or train services. ⑦ Staff available to ask for helps. ⑧ Easily getting to the first vehicle and then finding the next service during the interchange activity.

Focusing on multimodal transport might lead to several improvements in the transportation system. Five important possible improvements are: ① Transfers become less uncomfortable due to better design of transfer nodes and better synchronization of public transport services ② Accessibility of public transport services for private modes might be improved, especially in rural areas having low densities; ③ Availability of transport modes at the destination end might be improved by

for instance rental services, especially for areas having a low quality of public transport services. ④ Information might be more easily available, before and during the trip, thus making it easier to plan and complete multimodal trips; ⑤ Financial aspects of multimodal trip making might be simplified, either by electronic payment facilities or by transport service integrators. ⑥ Improvements in the transport services themselves are not included in this selection, because these improvements are independent of a focus on multimodal transport.

When discussing the potential of multimodal mobility it is essential to make a distinction between niche markets and the transport market in general. A typical niche market is long-distance travel. In this market many travel agencies exist who arrange tailor-made trips either for recreation or for business purposes. An example is the earlier mentioned concept of the Odessey-Card of Transvision in the Netherlands, mainly for business trips. Upon request, Transvision arranges the whole trip using services such as rent-a-car, with or without a chauffeur, train, taxi and Traintaxi, including all financial aspects. Typical characteristics of these niche markets are that they are fully demand driven, and that they focus on additional services given the existing transport system. The fact that these niche markets are demand driven implies continual prospects for change in suppliers and in services. The market for the Odessey-Card, for instance, proved to be too small to make it profitable for the operator, and the service ceased in 2000. The transport market in general, on the other hand, is characterized by a large number of trips having diverse characteristics, a strong relationship with infrastructure and spatial development, and a substantial involvement of the authorities. The transport market in general thus

determines transport network design. There is, of course, still a strong relationship between supply and demand; however, a typical characteristic of this relationship is that it is strongly determined by basic activities such as work, education and shopping. Furthermore, given the common nature of these trips and the resulting trip frequencies, the focus is more on fundamental characteristics of travelling, that is travel time and costs, than on all related service aspects. Finally, in assessing the potential of multimodal mobility the results of the analysis of current multimodal mobility should be taken into account, especially the critical factors of trip length, destination area, and trip purpose.

The advantages of Multimodal Transportation are as follows : Multimodal Transport, which is planned and coordinated as a single operation, minimizes the loss of time and the risk of loss, pilferage and damage to cargo at trans-shipment points. The multimodal transport operator maintains his own communication links and coordinates interchange and onward carriage smoothly at trans-shipment points: The Faster transit of goods made possible under multimodal transport reduces the disadvantages of distance from markets and the tying-up of capital. In an era of Globalization the distance between origin or source materials and consumer is increasing thanks to the development of multimodal transport. The Burden of issuing multiple documentation and other formalities connected with each segmented of the transport chain is reduced to a minimum. The savings in costs resulting from these advantages are usually reflected in the through freight rates charged by the multimodal transport operator and also in the cost of cargo insurance. The consignor has to deal with only the multimodal transport operator in all matters relating to the transportation of his goods, including the settlement

of claims for loss of goods, or damage to them, or delays in delivery at destination. The inherent advantages of multimodal transport system will help to reduce the cost of exports and improve their competitive position in the international market.

An extensive analysis of hierarchy in urban networks shows that unless a hierarchy in demand densities is assumed, a single-level network is optimal from a social welfare perspective. The addition of a faster higher-level network has two effects resulting in a net negative impact on social welfare. The operational costs are increased leading to a potentially lower profit. Part of this increase is compensated for by a lower quality for the lower-level network. The resulting network consists of a lower-level network having lower frequencies, and a higher-level network, which does not have high frequencies either, and which has limited space accessibility. For travellers having an origin close to the stops of the higher-level network, the introduction of the higher-level network leads to shorter travel times, but for all other travellers travel times are increased. The net result is a reduction in social welfare. Only when the number of travellers who benefit from the higher-level network is increased substantially, does a hierarchical network structure lead to an increase in social welfare. The analysis showed that this higher demand should be twice or preferably three times as high as the uniformly distributed demand level assumed in the analysis.

For train services, which are usually related to higher-level interurban networks, it has been found that walking and cycling are dominant access and egress mode. This suggests that spatial structures influence the hierarchy in public transport networks.

Furthermore, the analysis of interurban public transport service networks shows no evidence of relationships explaining hierarchy as a natural characteristic of public transport networks themselves. These findings lead to the conclusion that for hierarchical interurban networks the main explanation can again be found in the hierarchical organisation of settlements. As such the findings in this chapter support the ideas in Germany on network design (Köhler (1989), Bierschenk and Keppeler (2000)).

Given the outcomes of a variety of analyses, the main conclusion is that multimodal transport does not require significant restructuring of transport networks. The explanation for this conclusion is that properly structured transport networks, that is private transport and multilevel line-bound public transport networks, on themselves are already well suited for serving multimodal travel demand. The emphasis in this conclusion is on the word properly. Clear rules have been established that determine hierarchy in both private transport and line-bound public transport networks, and thus also in multimodal transport networks. Ignoring these basic rules leads to poorer performance of all networks involved.

The conclusion that an efficient multimodal transport system requires properly designed transport networks, reduces the multimodal network design problem to the allocation of transfer nodes. Given the strong relationship between hierarchy in spatial structures and in public transport networks, this leads to clear criteria for the location of intermodal transfer nodes: ① Within city centres, offering access to higher-level public transport networks, ② Within local centres, offering access to cities by public

transport services and ③ At the edge of cities near motorways, offering access to city centres by urban public transport services, or even offering access to the motorway network using urban public transport or bicycles.

The attractiveness of multimodal travel thus depends more on the quality of the transport services offered than on newly designed transport networks. The quality of the transfer nodes, the transport services themselves, the availability of information and all kinds of financial aspects are decisive. Stimulating multimodal mobility does not require a new grand design for the transport system, but benefits more from doing little things properly. Multimodal transport is essential for the accessibility of city centres and for the profitability of higher-level public transport services. Actors who are responsible for these two issues, should take the lead in the development of multimodal transport services and facilities.

The massive growth in containerization which introduced the modern concept of Multimodal Transport has shifted the cargo delivery system from "port-to-port" to "door-to-door". Moreover, several industrial and agricultural companies have changed their production methods to be able to use containers for export and capture the advantages of MT. A good example is the Japanese square melons (Sufian AA, 2005).



Figure 3.5 Japanese Square Melones Being Prepared for Transport to the USA (Sufian AA, 2005)

3.5. SUMMARY

Multimodal transportation is designed using network model representing various modes of transport represented as links between the nodes. It is obvious that the number of possible solutions increases exponentially with the size of the problem, which makes it a hard problem to solve. The basic relationships for transport network design, which are needed for the development of design guidelines, are discussed in detail in this chapter.