Passenger intermodal terminal stations: role and infrastructure

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Abstract

Public Transport (PT) is supposed to be probably the most up-to-date answer to the growing need for relieving traffic congestion, the associated environmental problems and the continuously increasing cost for transferring passengers. The expansion of urban centres cannot support a PT system that would serve the passenger directly from the origin to the destination point. The combination of various modes of transport between trip ends represents the new reality. The aim of this paper is to present general guidelines for securing safe and comfortable transfers between different transport modes.

Keywords: passenger transport, intermodal terminals, stations, transfer.

1 Introduction

It is well known that most of the developed countries worldwide are characterized by the continuous growth of the private car ownership index on one hand, and the increase of daily trips made by all transport modes on the other hand. This fact inevitably leads to heavily congested transport networks, which in turn leads to further downgrading of the quality of life and the environmental conditions, especially in urban areas. Up-to-date approaches applied in the field of transport engineering and planning have been trying to relieve the above mentioned situation by modifying the transport supply and demand respectively [1,2]. Since the growth of people's mobility represents, among other things, the level of the quality provided by the transport system, any solution to the problem should include the facilitation of the Public Transport (PT) system transfers in a

WIT Transactions on The Built Environment, Vol 101, © 2008 WIT Press
www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/UT080231

tactical, reliable, safe and comfort way. An integrated PT system which is supposed to be capable of meeting the above mentioned requirements as far the transfers are concerned must provide:

- Adequate coverage of the area
- Alternative PT modes, with respect to the size of the area and the travel demand
- High level of frequent services, depending on the type of the transfer (urban, interurban, regional)
- Opportunity for various combinations between different public transport modes in order to perform the transfer. Furthermore, the integrated approach should facilitate the simultaneous use of private and PT modes in the transfer process (i.e. Park and Ride installations).

The first three of the above mentioned characteristics which fall into the field of transport planning, are closely related to the topics of network development and routing/scheduling and play a key role at the determination of the level of services provided by a PT system. Taking into consideration the above preconditions, the paper is trying to highlight the role of the terminal stations in the transfer chain and to address the inter-modality issues of the PT transfers. Furthermore, the interrelation between these two subjects and the perceived level of the provided services by the individual users is also examined. Finally, within the framework of this paper a presentation of general guidelines for designing such terminals that promote intermodal transfers is also given.

2 Key elements of a public transport system

The efficient operation as well as the sustainability of a PT system is a combination of two parameters: the economic stability and its self-sufficiency. Inaccurate economic estimations can potentially lead to the lack of resources for the satisfaction of the passenger needs [3]. Nevertheless, PT means in general share a large portion of passenger transport. Very often though, their service infrastructure (in terms of stations–stops, vehicles/rolling stock and the conditions of movement along the terminals) is poor. So, be concerned primarily to increase the satisfaction of the passengers (that will also lead to the increase of demand for PT, the improvement of the level of service in terms of reliability, image, information and security) is an important step. More specifically, the following should be ensured [4,5]:

- Direct service between trip ends– without or at least with a limited number (one or two) of transfers – with journey times and travel costs, competitive to those with private means of transport.
- Frequent service, so that an acceptable waiting time in a satisfactory environment for the passengers, can be ensured.
- Reliable services that are based on an organized-coordinate program
- Clean and accessible vehicles and stations with a high level of provided services for all passengers (i.e. people with special needs, children, elderly)
- Waiting and boarding areas designed with high standards in passenger stations and stops with sufficient equipment for seating. In the case of urban areas, they

should also be located at acceptable walking distance, taking into account the land use density in the near area and the distance from the city centre.
- Coexistence of passenger stations together with parking infrastucture for passenger vehicles, where it is essential.
- Easy, comfortable and pleasant access to the PT stations.

Regarding the image of a PT system, the key points that should be taken into consideration are the following [4,5]:
- Ergonomic design of the system in total (vehicles, stops, stations, terminals), capable to give the sense of a modern and acceptable transportation mean, clean and without problems of damage and deteriorations.
- Low level of noise (and pollutants) not only inside the vehicle but also along the route areas, as well as in the waiting areas.
- Staff with positive attitude to serve the users of the system.

The information provided at stations or stops and within vehicles, is another key parameter, able to lead to a user-friendly transport system. The information should include elements such as:
- Route frequency, arrivals and departures, type of tickets and availability per type and route
- "Real time" information during the route, at the stops and at the terminals.

As far as the security is concerned, passengers should feel safe when they use the system; they need to feel safe when they travel, but also when they are waiting at the stops or terminals [4,5]. In a research that took place in Thessaloniki, Greece, the impacts derived from the implementation of different demand management measures, were examined. These measures consisted of improvement of PT services, construction of infrastructure for cyclists, pricing policy, maintainance of the road network, pedestrian streets, speed reduction etc. Research results include the following [5–10]:
- 21% gave priority to the measures that involved improvement of the PT sector and were considered to be the most important measures.
- 18% and 13.6% were assigned to the construction of a new road infrastructure and to the maintainance of the existing city roads respectively
- 11% and 9% were assigned to the reduction of parking lots in the city centre and to measures aiming to improve the environmental conditions respectively.
- 8% were assigned to the supply of infrastructure for cyclists and 3% to the measures for the Highway Code enforcement.

3 Urban, suburban and interurban Public Transport

3.1 Urban transport

In general, in urban areas, four types of transport users are obsreved: pedestrian, two-wheelers, private car users and PT users. The first two types are mainly referred to small distances (the second also for medium distances) or they are combined with one of the other two types for longer distances. However, private

cars and PT are the dominant modes [4]. The average capacity of the possible PT systems in urban areas are roughly the following:

i. Buses, with average capability 3000-5000 individuals/hour.
ii. Light Railway, with average capability 5000-15000 individuals/hour.
iii. Underground, with transfer ability that exceeds 25000 individuals/hour.
iv. New types of means of PT, that haven't been widely implemented and cannot be given further elements [11].

Analysing the role of an urban PT system, it is useful to examine the particular characteristics of the area served, as they determine the trip ends and the corresponding demand. The following areas constitute an urban environment [4]:

i. Areas of high density and land use mix (central regions, areas of high activity concentration, such as shopping centres or airports) – H
ii. Areas of medium density and land use mix (such as regions of mixed residence or industrial development zones) – M
iii. Areas of low density and land use mix (such as residential areas) – L

In the case of a connection of two regions which belong to the first category, there is a high concentration of potential passengers in both trip ends (starting and finishing point). The need for transfer can be satisfied primarily by a high transfer ability PT system, with good accesibility in both edges which means satisfactory level of service at the entrances and exits of the stations [4]. In the case of the tram/underground, flexible stations are required, with increased service ability, while in the case of bus transport, frequently stop points should be used. In the case where the one edge is in a high density area, and the other is in a middle density area, greater speculations are set for the area in which the transport system terminates (e.g. the latter area) and more specifically for the service to and from the corresponding station. It is possible to combine two different modes of PT (different type, e.g. underground - bus or same type, bus–mini bus) or PT and private means (e.g. underground–car, bus–bicycle e.t.c.) [4]. The latter area requires the construction and operation of a transfer station. In the case of connecting a high density region with a low density region (the transfer for work constitutes a representative example), high transfer ability transport modes will have to be combined with a low transfer ability transport mean which should be also capable of serving the passengers. The combinations in this case (and the corresponding requirements of terminal stations) consist of two different means of PT (different type, eg. underground-bus or same type, eg bus–small bus) or private means (eg. underground–car, bus–bicycle etc), with particular emphasis on Park and Ride) [4]. In the case of transfer where the trip ends are in regions of medium or low density, despite the fact that the car appears to prevail, the demand for PT still exists due to captive users. The main PT transfer station aims to serve the basic and auxiliary means of transport, even if the latter is a mini bus, or private means of transport [4].

3.2 Interurban transport

The length of interurban transfers exceeds 40 km. and is materialized with different modes of transport (land, coastal shipping and airborne for long distances) and/or (rarely) combination of all these, depending on the available

infrastructure and also on the special regional charactersistics. In Greece–at interurban level–road and railway coexist for the inland part, coastal shipping for the islands and air transport for almost the whole territory. However, the majority of passenger who travel short and medium length distances regarding interurban mobility use road (bus) and rail. Both means usually have terminal stations in (or near) central regions and are accordingly accessible by most users. A general principle for rail is that while it requires special infrastructure (without the flexibility of alternative), which is designated exclusively for its own service, no delays in schedule time arrivals or departures are observed compared to the road–bus, where delays, because of congested networks or because of the mix with the private vehicles, are a common situtation. In each case, the improvement of the provided PT services, with holding or even concurrent reduction of the cost of transfer, can increase the demand for PT.

3.3 Suburban transport

The suburban transfers are materialized in areas which are characterized by low density growth (regardless of residents' socio-economic characteristics). They are usually materialized (and served) near the railway conjuctions, while the density and the coverage of the regions by the road network, begins to be decreased and unsatisfied. This fact explicitly leads to higher car owneship. Despite that, PT modes should have a noticeable presence, as they are pertain to serve individuals without, in many cases, an alternative transport mode. In this case, "unconventional" forms of transport are often also operate, such as taxi for elderly, car pooling and sharing etc. [4].

4 Terminal stations and stop points of public transport systems

4.1 Basic definitions

Terminal stations pertain to be the infrastractures that are primarily destinated to be used as parking facilities of the fleet of a transport system or for the transfer between the different means of a transport system. Its objective is to create the appropriate conditions as well as to provide safe services for transition between two or more means of transport. In the case that they operate just for the embarking and the dissembarking of passengers and the vehicle remains at the station for a short period of time (for exit and entrance maneuvers, embarkation and disembarkation of the passengers etc) the infrastructure is characterized as stop point [2,12]. Depending on the transport system that they serve, the stations are divided in four categories: Bus Stations, Railway Stations, Airports, Ports. Depending on the trip length, bus and railway stations are divided in:

- Urban (terminal stations, stations for transitions and stop points)
- Interurban (terminal stations, stations for transitions and stop points)
- Mixed (stations for transitions and stop points aiming to serve urban and interurban means of transport).

The objective of the terminal station is straightforwardly connected with the meaning of the transition, not only between two different transport modes (e.g. underground and tram) but also between two vehicles of the same mode (e.g. different lines of the underground) [13]. In both cases, more or less depending on the number of the passengers that will be served, there is a need for transitional operation of the terminal station. An attractive reboarding should ensure the following:

- Reliable and satisfactory service by the involved transport means.
- Acceptable level of the infrastructure facilities for reboarding (the type and the provided services depends on the mode of means that are combined, the trip characteristics, and the average waiting time at the terminals and stops).
- Low cost (smaller or at least similar with the cost without transition).
- Sufficient accesibility of buses for all the users.
- Decrease of the total travel time (smaller or at least similar with the time without reboarding).
- The number of required transitions for the completion of a transfer should not exceed one for the 95% of total transfers and two for the 5% of the total transfers.
- The measurement and the determination of the number of the transitions should be specified with rational way through the use of questionnaire surveys aiming to analyze the trip patterns of the passengers and the respective trip ends.

In general, the transitions should be materialized under comfort and security conditions. Comfort presupposes the optimal operation of the station and the vehicles simultaneously. The system should take into consideration the estimated trip length and the special needs of the passengers (e.g. with or without handbags, people with dissabilities etc). The effort in safety should be focused on passengers' protection from the bad weather conditions (provision for roofed places), on the movement of the vehicles in terms of safety and also on the passengers' security (with the use of human or technological means).

4.2 Design rules for terminal stations

When a terminal station is designed, the objective should be the optimal usage of the available space as well as the service of the potential demand with a satisfactory way. In order to achieve that, the following should be specified:

- The determination of the various transport means that will be served.
- The time horizon that the terminal station is expected to operate at a satisfactory level, without the need for any extensions or reconstructions. Usually, for the transport infrastructure projects a period of 20 to 25 years is supposed to be a common time horizon for designing purposes.
- The expected level of activity, in terms of served passengers, the frequency of arrivals of/departures to/from the station respectively, and the average waiting time at the station. These elements can be determined through the use of existed researches and empirical data, but also with the use of forecasting models which are capable of estimating the potential demand for

travel. The input data for these models are parameters such as the desires, the needs and the particularities of the travellers as well as the available alternative means of transport. The implementation of theories such as the theory of passenger queues can assist the whole process and support the decision process regarding critical sizes and parameters.

- The diachronic, seasonal, monthly and daily fluctuations. The peak hours or days should not be taken into account since it oftens leads to overestimations and profusion of the available financial resourses. For this reason, the 30st highest peak hour or the 85^{th} hour in a centesimal scale is selected as the base period for designing (in equivalence to the definition of annual average daily traffic or the study speed for designing road infrastructure).

4.3 Essential facilities at reboarding stations

The number and the type of services usually intend to improve the level of comfort and relaxiation which is provided at the stations. The respective facilities could be waiting rooms, toilets, bulleting boards, free of charge telephones, litter bins etc. These facilities should be proportional to the estimated/expected demand of each station. Regarding the stations that intend to serve interurban transfers a special effort on passengers' comfort should be made since the waiting time is usually greater compared to the stations which serve urban transfers. For the latter stations, the attention should be paid on issues such as the fastest exit or entrance of the passengers from the stations, tickets purchase and invalidation etc. Each station has its particularities regarding design and operation issues, and so it is very difficult to follow standardization rules. However, some of the necessary infrastructure elements could be the following: docks–available spaces for parking or temporary stop of the vehicles, kiosks for purchasing tickets, waiting rooms or areas, toilets, available parking areas for private cars, bicycles, taxis etc., rooms or lockers for temporal safekeeping of baggage or priceless objects, equipment for passengers' information.

Additionally, the stations located in urban or interurban places could provide the following facilities: restaurants, post offices, banking facilities, kiosk for renting cars, tourist information, shopping areas. A modern station should provide: sufficient ligh, close circuit television systems in order to increase the safety and security in the docks and at the waiting rooms, rolling staircases and hallways, lifts, depending on the special design characteristics of each station, support equipment for the safety and the security of people with disabilities (e.g., sound messages), security staff. Regarding the accesibility to the station, special attention should be paid to the potential users of the transport system. They can approach the station by walking or by another means of transport such as taxi, private car, moped, bicycle etc. Additionally, the conditions should be fullfilled in order to be used also by the people with special needs. Therefore, apart from the conventional meaning of the entrance and exit from the station, particular ramps should be provided combined with specific depressions for the stop and disembarkation/ embarkation from/to private means and taxis. The position of station exits and entrances depends on various parameters such as pedestrian flows, traffic flows, traffic management constraints etc. Their design should take

into account the user's conveniency and comfort, the avoidance of mixture with the road traffic and the distance from the junctions (which affects pedestrian safety). Traffic can be served in both directions if the available space is sufficient. The level of service for the pedestrian's movement is presented in Table 1 and for the queueing conditions in Table 2. Anothet criterion for the determination of the level of service of the passengers movement, is the capability or the comfort of movement. The respective criterion for queueing is the average distance between the pedestrians [2].

Table 1: Level of service for pedestrians at sidewalks.

Level	Pedestrians' Surface (m^2/pedestrian)	Unitary Pedestrian Flow (pedestrian/ min/meter)	Comment
A	>12,1	<6,6	Self movement, no likelihoods for collisions
B	>3,7 and <12,1	<23	Self choice for speed and movements, no likelihoods for collisions, the presence of other pedestrians is noticeable
C	>2,2 and <3,7	<33	Normal speed of walking, capability for overtaking, small collisions between pedestrians
D	>1,4 and <2,2	<49	The speed and the movement doesn't depends primarily on passenger choice, The capability for overtake is restrained. The likelihood for collisions is increased
E	>0,56 and <1,4	<82	The free flow speed is decreased, the walking is adapted according to the conditions, frequently stops and breaks of the walk, pedestrian flows close to the saturation flow
F	<0,56	Varies	Very limited speed, the collision is inevitable, queues are observed

Source: [2]

Table 2: Level of service for passengers' waiting areas.

Level	Average occupied surface (m^2/pedestrian)	Average distance between pedestrians (m)	Comments
A	>1,21	>1,22	Self choice of the seat and movement at the area
B	0,93 – 1,21	1,07 – 1,22	Self choice of the seat and possibly constraints at passengers' movement, acceptable quality without annoyances
C	0,65 – 1,93	0,91 – 1,07	Free choice of the seat, there are constraints at passengers' movements, acceptable levels of density

Source: [2]

The level of service "E" (average occupied surface 0,18-0,28) is observed only in cases like elevators or at PT vehicles during peak periods. Likewise, level of service equal to D is observed in cases were pedestrians wait near the road to cross the street at intersections or at docks during (re)embarkations. Regarding the necessary installations inside the stations, and more specific at the waiting

rooms and at the docks, the provision of seats for all the categories of potential users should be anticipated as well as adequate areas for people with disabilities. The seat height should be divided into two categories. The first should be 40cm high, so as to facilitate the needs of children and the elderly. The second should be a 60cm high for the rest of the users. It is also necessary to provide a ramp in the basic entrances and exits to/from the station with the appropriate dimensions. Acceptable infrastructure is one which accommodates a wheel chair of 70*125 cm (ISO 7193). Thus a space of at least 100*150 cm is required. Finally, surveys carried out at terminal stations, in Thessaloniki, for short trips [14], as well as at stations for long distance trips [15], highlighted the fact that passengers have a especial concern on issues related with the comfort and the quality of the waiting areas. Additionaly, in urban level, special emphasis is given on safety issues related to the location of the stops near the streets.

5 Conclusions

PT plays an important role in (captive and non-captive) people's everyday life, and holds a major percentage of the transport share at urban, suburban and interurban level. The continuously increasing demand for trips, combined with the technological evolutions in the sector of the vehicle fleets and the supportive systems as well as at the sector of traffic management, could lead to the estimation that the demand for transfer through the PT means will be increased. The "station" constitutes the conjunctive chain in the complementarity and the combination of the means of transport. The promotion of combined passenger transport depends primarily on the station that interferes and operates as a connection point of different means of transport. Conclusively, the following issues should be addressed:

- The subsystems of the PT and the corresponding infrastructures must operate supplementary.
- Each transport means should serve the demand that is capable of satisfying (in terms of comfort, safety and security).
- The transitional stations should obtain the essential conditions of comfort and security for the connection of different means of transport.
- The particularities of all potential users of system, without social exclusions, should be taken into consideration.

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