URBAN PUBLIC TRANSPORT MODES

A public transport trip includes the following components:

- The walk components at the beginning and end of the trip.
- The in-vehicle component.
- The inter-vehicle or inter-modal transfers/interchanges to:
  - Support the operational concept of feeder, line-haul, distributor components to a public transport system.
  - Get closer to the origin and/or destination.
  - Achieve the objective of minimising costs that can be achieved through the economies of scale from using larger vehicles and the corollary of smaller vehicles to service low density (or smaller origins and destinations).
  - To maximise capacity in very dense areas; i.e. CBD where the activity and the value of land for public transport corridors is high.

There are three categories of right-of-way; i.e. fully controlled, longitudinally separated and mixed traffic.

When a public transport authority has to decide on which mode should be used to service a community, it could base this decision on criteria such as the ability of the mode to meet demand, cost, environmental impact, journey time, safety, comfort convenience, number of interchanges, flexibility, reliability, fare evasion, technical sophistication, implementation complexity and image.

Urban public transport modes can be divided into five groups; namely paratransit, bus, light rail transit (LRT), suburban rail and rapid rail transit (RRT).
1. INTRODUCTION

1.1 Overview

1.1.1 This chapter serves to provide an overview of the modes of transport that can be used to move people in an urban area. These modes include:

a) Para-transit; including the minibus-taxi.
b) Bus; mini-, midi-, standard and articulated.
c) Light rail transit.
d) Suburban rail.
e) Rapid rail transit or metro-rail.

1.1.2 Before discussing the modes individually, three aspects of public transport are discussed;

a) The operation of public transport in a system.
b) The concept of right-of-way.
c) The criteria for the selection of a passenger transport mode.

2. OPERATION OF A PUBLIC TRANSPORT SERVICE

2.1 The trip

2.1.1 Every public transport trip begins and ends with a pedestrian component (as do all private transport trips). In the case of the private transport trip, the pedestrian components are relatively short. In the case of the public transport trip, the route is fixed and the pedestrian component will depend on the location of the origin and destination relative to the public transport route and stops.

2.1.2 In the case of the private transport trip, the motorist usually can choose the route and how close he/she can get to the origin and destination. All points, with a very few exceptions, are accessible with one vehicle trip with short pedestrian components at both ends.

In the case of the public transport trip (Figure 1), the trip begins and ends with a pedestrian component to and from the public transport vehicle at a stop or station. If one public transport route does not have a stop within walking distance of the destination, the vehicular component of the public transport trip will need to include a transfer to another vehicle or mode.

Since many activities are located in the CBD (to which public transport traditionally has focussed), and along corridors; many public transport trips can be fulfilled without a transfer.

2.1.3 For a public transport system to be viable it requires that its vehicles carry sufficient passengers to cover costs less the subsidy that the authority is willing and able to pay. As such, many origin-destination pairs cannot be serviced directly since the vehicles fulfilling these routes would not run full; even in peak periods. In these cases the service would require a feeder system of smaller vehicles that feed larger vehicles that service the line-haul component and which is turn feed a set of distributor services provided by smaller vehicles.
2.1.4 Low volume vehicles are appropriate in low density situations because they can offer a more direct route between origin-destination pairs while at the same time operating relatively full. However, in high density environments they are no longer appropriate because they require more space to carry the same number of passengers as high volume modes. The highest density area is the CBD, where land is at a premium. It is in this environment that the higher volume modes become more appropriate. So in practice (see Figure 2), transport systems tend to operate on the basis of small vehicles collecting passengers from lower density areas and feeding them onto larger vehicles for the line haul to, or towards, their destination. If the route has a stop within walking distance of the destination then the passenger can complete the trip with a pedestrian component. If not the trip will require another vehicular trip, which could be considered as the distribution component.
2.1.5 The second reason for using higher volume vehicles is the fact that they can carry passengers at a lower cost, when they operate relatively full. Figure 3 shows the economies of scale emerging with increasing passenger volumes on larger vehicles.

FIGURE 3: EXAMPLE OF COST PER 20-KM TRIP VERSUS VOLUME OF PASSENGERS (after Durban, 1999)

2.2 Travel between stops and vehicle scheduling

2.2.1 Theoretical time-speed and time-distance profiles for a public transport trip are shown in Figure 4; which shows the acceleration, deceleration, passenger handling and "cruising" components.

FIGURE 4: SPEED AND DISTANCE VERSUS TIME FOR PUBLIC TRANSPORT TRIPS
2.2.2 This information can be restructured to plot the distance-time diagram (Figure 5) for all the vehicles serving a route; i.e. a route schedule. The acceleration, cruising, deceleration and the passenger handling components can be seen; as can the repetition of this sequence for each stop. At the end of each route, time is required for administrative and operational activities to turn the vehicle around. In the case of a train for example, this driver has to shut down the train, walk to the other end and then prepare it to travel back. (9 minutes is allowed for this in the case of a 12-coach 9M train).

FIGURE 5: ROUTE SCHEDULING FOR PUBLIC TRANSPORT

The round trip time is the sum of times taken to accelerate and decelerate the vehicle and to handle the passengers at each stop, the “cruising” time between stops and the turn-around times at the ends of the routes. This time can be used to calculate the size of the vehicle fleet required to service the route using the following equation (This equation is a general equation which does not take into account the effect of lower demand values in the periods outside of the peak hour for round trip times longer than 1 hour):

\[ V = \frac{P}{C \cdot V/c \cdot R} \]

Where:
- \( V \) is the number of vehicle required in the fleet to be operational during peak periods; allowance might need to be made for the % of vehicles that might not be operational at any point in time
- \( P \) is the number of passengers/hr in the peak hour Consideration needs to be given to what is considered by the passengers to be acceptable conditions; i.e. density (in pass/m², or % seated)
- \( V/c \) is the operational ratio applied to ensure that delays to passengers due to the peaking nature of the demand are not excessive
- \( R \) is the round trip time in (hours)


The right-of-way is the strip of land along which the public transport vehicles travel. There are three right-of-way categories. These depend on the extent to which they are segregated from other traffic and can be described as follows:
- **Category A** represents the case where the right-of-way is fully controlled. Usually the crossings occur either above or below the right-of-way. The right-of-way could be at-grade, below ground (in cut or in tunnel) or above ground. This category could include some at-grade crossings; however they should be few in number and operated so that the service along the right-of-way always has priority; and is not delayed, affected or hindered by the crossing.
• Category B represents the case where the right-of-way is physically separated longitudinally, but at-grade crossings exist. In this case, the separation could be achieved with kerbs, barriers, physical space and grade, while the crossings would occur at-grade and permit pedestrians and other vehicles to cross the right-of-way.

• Category C represents the case where the public transport right-of-way is on-street in mixed traffic. In some cases, the public transport vehicles might have preferential treatment at the signalised crossings or along reserved lanes; although usually they would travel with the other traffic using the street.

4. CRITERIA FOR THE EVALUATION OF MODES

This section, discusses the criteria whereby a mode for an urban public transport service to be provided by a transport authority (rather than the choice of mode by a prospective passenger, which is the subject of the topic on mode choice in transportation planning) can be evaluated.

The following aspects can be taken into account in deciding which public transport mode is to be preferred:

a) The ability to cope with the passenger demand.
   The selected mode should be able to cope with the estimated volume of passengers expected to use the route. This also depends on the corridor width available for the route. If the mode cannot carry the passenger demand within the corridor space available, then either a more effective larger mode must be used, the corridor width widened or use made of two parallel routes. Table 1 provides a comparison of the capacities of one lane for each mode.

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<th>Mode</th>
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<th>Capacity</th>
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<th>Veh-cap</th>
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<td>10 500</td>
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<td>60</td>
<td>12 000</td>
<td>Rapid rail transit</td>
<td>30</td>
<td>80 000</td>
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</table>

b) Cost.
   The cost of moving passengers can be considered in a number of ways; namely:
   i) The total cost per passenger km; since this will reflect the financial costs of the service.
   ii) The capital cost; since this will be the amount of funds that will need to be sourced before the service can be introduced. The question arises whether the local economy or the government fiscus has the resources to fund the investment. One can compare the size of the capital cost with that of previous projects funded by the city, region or country. One can also convert the capital cost into ratios of capital cost/passenger; or capital cost/resident of the region.
   iii) Capital cost/operating cost ratio. Bus services have a ratio of the order of 16% whereas rail projects have a ratio of the order of 75%.
   iv) The sensitivity of the project to capital overruns and overestimates in passenger numbers.
   v) The percentage of cost recovery; since this will indicate the amount of subsidy the service will require from the government. The subsidy bill for transport is in
competition with other government expenditure responsibilities, such as housing, health, education, etc.

c) **Environmental** aspects such as the generation of **noise** and **air pollution**, and the project’s **visual intrusion**; as well as the **consumption of energy**.

d) **Savings in journey times.** “The magnitude of these savings will depend on the number of passengers and the value placed on the time saved by each passenger. Most passengers on transit are commuters making non-business trips. Some authorities consider that no value should be placed on time saved in making non-business trips; while others suggest that it is equivalent to 25 - 35 % of the income earning rate”. (Armstrong-Wright, 1986, 35)

e) The expected **relative safety** of each mode; usually expressed as the expected number of fatalities, injuries or collisions. These parameters would need to be defined on a per passenger or per passenger-km basis.

f) Less quantifiable aspects include the following:

i) **Comfort** of the passenger.

ii) The **convenience** of accessing the mode.

iii) The number of mode/vehicle **interchanges** required.

iv) **Flexibility** of changing route should the estimated number of passengers not materialise. On the other hand, rail modes, which are fixed, can be considered to give confidence in predicting in which direction the city will develop, since they cannot be easily moved.

v) The **reliability** of the mode in operation.

vi) Problems with **fare evasion** and revenue leakage.

vii) The **sophistication** of the operation and system maintenance; and the availability of adequately trained personnel to perform these functions.

viii) The complexity of **implementation**.

ix) **Image**.

5. PARA-TRANSIT

5.1.1 Para-transit, is the term applied to small passenger transport which operates **informally** on a fare paying basis. They have become very popular because they fill the gap where growing demand has not been satisfied by organised public transport services. Organised public transport services have declined over the past few years due to reduced subsidy budgets and a lack of expansion into newly settled areas.

This mode takes many different forms. In South Africa, the minibus-taxi is the best example. In other countries they are also converted scooters, shared taxis, and LDVs.

The service can be a personalised door-to-door service, a service that is partially along routes used by more formal services, and a regular service along well defined routes.

Para-transit operators are free to choose the vehicle, the route, vehicle schedule and their hours of operation.

In some cities para-transit may be regulated. In South Africa, the fares are decided upon by the taxi association operating the route, with **input** from the local residents, usually through their civic association.
Para-transit operations have built-in flexibility, in that operators can change their services to respond to passenger needs. Because of the relatively small size of their vehicles, they can offer more frequent service, where there is insufficient demand to use scheduled larger vehicles. They can also penetrate closer to the home; thereby providing a more accessible service.

In South Africa, the government policy is aimed at formalising the minibus-taxi industry. This has already started through the registration of minibus-taxi associations and taxis operating along routes. There are proposals to form minibus-taxi operators into co-operatives so that they can bid for contracts to service public transport routes.

Para-transit services are operated by individual private owners or small entrepreneurs in a highly competitive environment. They have to run at a profit. As such they do not use government finances. In most countries, para-transit is considered to be dangerous; due to poor driving and maintenance. This image needs to be verified against accident statistics, rather than being accepted on the basis of perceptions.

5.1.2 Vehicle capacities range from a few passengers to 20. The capacity of a minibus-taxi corridor could be as high as 15000 passengers/hr (i.e. 1000 minibus-taxis/hr carrying 15 passengers each).

5.1.3 According to Armstrong-Wright (1986), their journey speed ranges between 12 and 20 km/h and they cost between 2 and 4 US¢/pass.km. South African costs are of the order of R120 000/vehicle, 22c/pass km. (Durban, 1999).

6. BUS TRANSPORT

6.1 Motorised buses

6.1.1 Bus services are the most prevalent mode in developing countries. This could be due to the fact that the level of technology is compatible with local experience and facilities.

Bus services operate on a schedule along specified routes; unlike the minibus-taxi services in South Africa at present. Fares are fixed for the trip. Zonal, staged and flat fares (i.e. one fare regardless of distance within the zone) are used.

6.1.2 The vehicle capacities for buses range as follows:
   a) Minibus-taxi 15
   b) Midi-bus 40
   c) Standard bus 100
   d) Double-decker 120
   e) Articulated 180 to 270

Conventional route capacity is of the order of 15000 passengers/hr/lane in one direction. Although corridors in South America are carrying as much as 30 000 passengers/hr. Journey speeds of buses range between 10 and 12 km/hr in mixed traffic, and up to 25 km/hr in low density areas.
6.1.3 The cost of bus services range between 0.6 and 2.5 US¢/pass. km (Armstrong-Wright (1986). South Africa costs are of the order of R650 000 per 80-seater vehicle and a total cost of 17c/pass. km (Durban, 1999)

6.2 Electrically driven buses

6.2.1 Electrically driven buses are also used, although these have been found to be more expensive than conventional buses. Trolley buses can achieve the same capacities as conventional buses and are environmentally better. The higher costs are due to the need to install transmission lines. These transmission lines make them less flexible, in that they are limited to the routes served by these lines. This would inhibit route changes when passenger numbers decline or projected numbers do not materialise.

7. LIGHT RAIL TRANSIT (LRT)

7.1.1 The term light rail refers to a wide range of electrically powered rail systems. The distinguishing features are:

a) Passengers usually board from the street surface or a low platform
b) Vehicles operate either as single vehicles or short trains (3 coaches)
c) They generally operate on B or C rights-of-way.

Armstrong-Wright (1986) proposes three main categories of light rail transit:

a) **Tramways;** which consist of simple trams or street-cars; operating on fixed rails in single units in mixed traffic and using the city streets
b) **Light rail transit;** which consists of newer vehicles, usually operating in small trains (some are articulated), on street or in partially segregated rights-of-way
c) **LRT metro;** which consists of light rail vehicles operating on a totally segregated facility. This would have the same characteristics as Rapid Rail Transit (RRT) (Section 9), and are sometimes referred to as Pre-Metro.

7.2 Tramways

7.2.1 Tramways operate in mixed traffic along city streets. They are therefore slow and have limited capacity. They do however provide a relatively cheap form of public transport. They have no flexibility; being limited by the track and the transmission lines. Power failures would affect the route and even sub-areas of the city.

7.2.2 Vehicles range in capacity from 100 to 200 passengers. They can be articulated and double-decker. Operating in mixed traffic they can carry between 6000 and 12000 passengers/hr on one lane. Journey speeds are of the order of 12 km/h. Exclusive rights-of-way can increase this capacity and speed.

7.2.3 Capital costs amount to approximately US$ 4million/km of track with transmission lines. A 100-passenger vehicle costs approximately US$ 300 000. Operating costs amount to between 2 and 8 US¢/pass.km and total costs amount to between 3 and 10 US¢/pass.km (Armstrong-Wright, 1986). No South African costs are available.
7.3 **Light Rapid Transit (LRT)**

7.3.1 LRT systems operate on tracks along streets and may be segregated for parts or all of the route. They may even have grade separated crossings; otherwise they would have priority at the signals at crossings. Passengers board from the road surface or low platforms. Because it is a rail operation, it would be very expensive to change the route should passenger travel patterns change.

7.3.2 Vehicles are usually linked to form a train of 2 or 3 coaches (although trains of 5 to 6 coaches are mentioned in the literature), resulting in a train capacity of between 700 and 900 passengers. Using the shorter trains and partially segregated rights-of-way, lane capacities of 20 000 passengers/hour can be attained. Average journey speeds are about 15 km/h. With segregated rights-of-way, capacities of 36 000 passengers/hr can be achieved and journey speeds can reach 25 km/h.

7.3.3 Light rail transit infrastructure on the ground costs between US$6 and 10 million/km. A light rail transit coach, with a capacity of about 240 passengers costs about US$ 800 000. Operating costs range between 8 and 10 US¢/pass.km and total costs range between 10 and 15 US¢/pass.km. No South African services exist, but costs are estimated at R12 000 000 for a 3-car train with total costs at 27c/pass.km.

8. **SUBURBAN RAIL**

8.1.1 Suburban rail operates on the same tracks as inter-city passenger and freight trains. Many of these tracks are old and require upgrading to become efficient in carrying urban passengers. Upgrading will include improvement of the signalling system, rehabilitation of the track and ballast, and refurbishment (if not replacement) of the coaches.

8.1.2 Trains are composed of motor and trailer coaches in combination. In South Africa, trains are usually composed of 10, 12 and 14 coaches. A 12-coach 5M metro train has a full load capacity of 2750 passengers. The rail capacity per lane is therefore approximately 55 000 passengers /hr at headways of 3 minutes. More sophisticated signalling equipment and priority on the tracks can increase the capacity to RRT capacities. With modern equipment journey speeds of between 45 and 55 km/h can be achieved with station spacing of between 2 and 3 km.

8.1.3 Track costs range between US$6 and 10 million/km. (Cost of an extension in Durban is estimated at R16 million /km). The cost of the vehicles amounts to US$1 million/coach. Operating costs range between 5 and 10 US¢/pass.km and total costs range between 8 and 15 US¢/pass.km. (SA costs are estimated at R85 million for a 12-coach M9 train with a minimum costs of 10c/passenger km; Durban, 1999).

9. **RAIL RAPID TRANSIT**

9.1.1 This system operates on an exclusive right-of-way and at high speeds. Exclusive rights-of-way are usually located in tunnels, in cuttings or elevated.

Rail rapid transit systems require sophisticated signalling and control devices to achieve high speeds and frequencies. This level of technical sophistication is not usually available in developing countries;
and would require training by overseas experts. Stations have high platforms so that passengers can walk directly onto and off the trains.

Once the rights-of-way have been established, it would be very difficult and costly to change these; except possibly during the extension of the network.

Because implementing these systems is very costly, attempts are made to increase passenger numbers as much as possible. To achieve this, existing bus operations are re-routed to become feeders to the RRT. This can affect the viability of bus operations and the passenger travel patterns and convenience.

RRT provides a high level of reliability; since it is not affected by the weather (especially if it is underground) nor is it affected by congestion at ground level.

9.1.2 RRT can operate at 2 minute headways and can reach top speeds of 100 km/hr; thereby carrying as many as 80 000 passengers/hr, at journey speeds of between 30 and 35 km/h.

9.1.3 The cost of RRT is high; of the order of US$40 to US$120 million per km of track depending if it is in tunnel or not. Vehicles cost the same as suburban rail vehicles. Operating costs range between 10 and 15 US¢/pass.km and total costs range between 15 and 25 US¢/pass.km. There are no examples of RRT in South Africa.

10. REFERENCES


11. QUESTIONS

1. Discuss the concept of category of right-of-way; refer to which modes operate in which category [6]
2a Discuss why high volume vehicles are appropriate in high density areas and not in low density areas. [2]
2b Discuss why low volume vehicles are appropriate in low density areas and not in high density areas. [2]
3. Describe what is meant by feeder, line-haul, distributor and inter-modal transfer. Give reasons why they are components of the public transport trip. [4]
4. Compare the urban public transport modes in terms of:
   a) Costs; operating, infrastructure and vehicle
   b) Capacity
   c) Journey speed
   d) Environmental impact [20]
5. Use the following information to advise a public transport authority on which mode it should select on the basis of cost to service each community described below (Indicate what additional information was required/assumed):

a) Calculate the fleet size and capital cost.
b) Calculate the annualised cost of the fleet.
c) Calculate the capital and annualised costs of the way, the terminal and stops.
d) Calculate the annual operational cost of the service assuming that the peak hour, second peak hour and third peak hour amount to 20%, 15% and 10% of daily one-direction trips (Calculate the off-peak hourly volume assuming a 17-hour daily operation)
e) Add the operational and annualised capital costs to calculate the total annual cost.

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Annualised cost = (capital expenditure – residual value) * \(\frac{i}{100} * (1+i/100)^n/(1+i/100)^n-1)\)
Where \(i\) is the interest rate and \(n\) is the life of the facility. [50]

6. Draw a diagram to show the time distance profiles for a bus service over the peak 3-hour period that has:

- A peak direction travel time of 39 minutes, a return trip time of 29 minutes and a turnaround time at each end of 1 minute.
- The passenger demand volumes during each of the peak 3 hours in the peak direction are 1000, 1500 and 500 passengers respectively. (Assume that the busses depart the end of the route at regular intervals in each of the 3 hours)
- Buses have a passenger capacity of 50 passengers

From determine the number of vehicles required to service the passenger demand. [20]