Modern Light Rail as a transport solution for large cities

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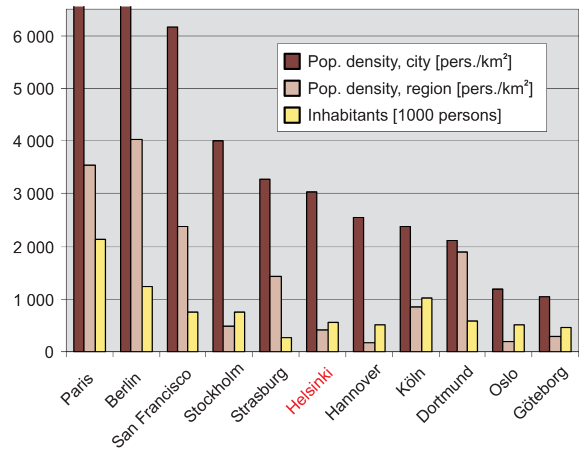
Introduction

Large cities are typically very tightly built in the city centres, which are surrounded with a large circle of suburban having much less buildings an population per area. This causes a problem for choosing a transport system. What is suitable in city centres – like underground metro systems – is too massive and expensive outside the city centre.

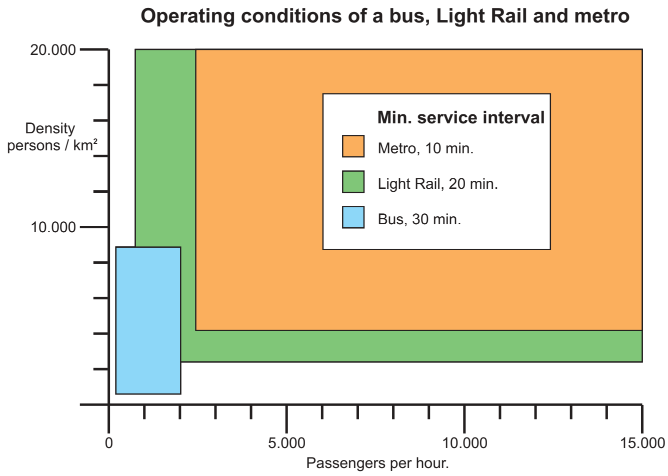


Population density in city centre and in urban area and total population in some cities.

This phenomenon was found in Europe and USA in 1960's, when private car traffic from suburban started to fill the cities. Very soon it was found, that the capacity of the street network is not enough for cars, trams and buses. Existing metro networks were able to manage the city transport where metros were already built, but were not suitable to extend outside the central city area.

As population density is the key factor for choosing a public transport system, the problem was, that the operation capacity of the traditional tramways (street cars) and buses does not overlap the metro's operation capacity. A bus systems capacity on one street is 2000 passengers per hour max, when a metro line is already uneconomical to operate at 2500 passengers per hour.

The solution was found in Germany, which did not destroy the tramway systems as had happened especially in USA and UK. Existing tramway systems were developed to fill higher standard than just a local bus like transport system on the streets. The benefits of a tram, metro and commuter trains was combined to one system. This kind of a tramway system was named as Light Rail in English.



Operating conditions of bus, Light Rail and metro system.

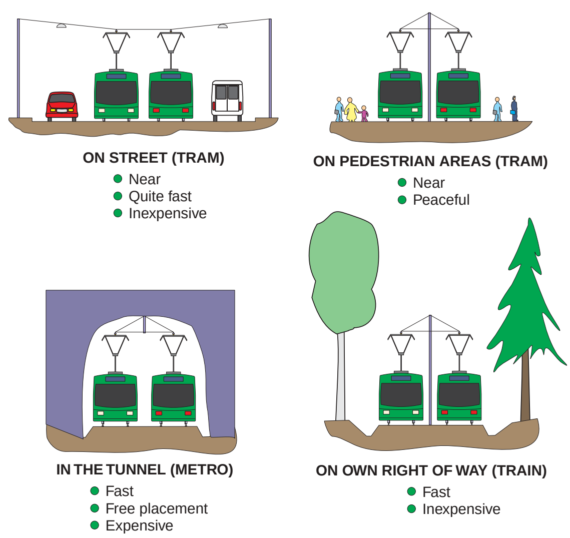
Light Rail principals

To rise both the capacity and the speed of a tramway train, high-speed lines were put underground where the street area was already used, and on the tramways own right of way outside the most dense city centre. This way the speed of the trains can be kept higher than the speed of the street traffic, and the street traffic does not cause delays for the public transport.

In practice, the modern tramway, a Light Rail has four forms.

- 1) It works in the tunnels as a metro.
- 2) On the own right of ways it works like a train.
- 3) On the streets it works like a traditional tramway or a bus.
- 4) On the market squares and other pedestrian areas it works much like an old fashion slow streetcar or coaches.

Same four forms apply also for the cost of the public transport system. A Light Rail is expensive like a metro only when it is necessary to build like a metro, i.e. under ground. But also in this case, the construction is more flexible and there are many ways to save cost compared to traditional train like metro system. This kind of features are the possibility to build the line



immediately under a street, and no need for the deep and large underground stations with escalators and lifts and also the on-ground station building. Elsewhere the cost of the line is similar to the cost of building a two-lane street suitable for bus traffic.

Light Rail technical specification

Specification for a modern tramway system, a Light Rail:

- Overhead wire (catenary) current supply. (Metros usually have a third rail.)
- Train width max. 2,65 metres. Suitable for street traffic.
- Floor height app. 35 cm. from rail. Fast and easy access to train also from simple street stops.
- Trains capable for 20 metres curvature radius and gradients used on streets.
- Trains max. speed 80 to 100 km/h, acceleration and braking 1,3 m/s2.
- Units capable to be coupled as trains operated by one driver.
- Rail geometry designed for smooth running using balance curves.
- Wheel geometry suitable for phoenix-rail switches on streets.

System capacity:

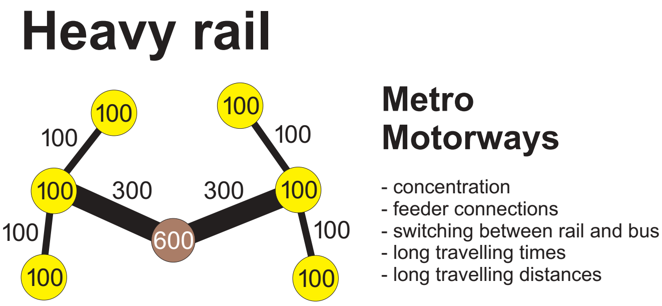
- Passengers per unit, usually 200 to 250 persons, of which seated 25 to 40 %.
- Number of units per train from 1 to 4, depending on the stop platform length.
- Train interval from 1,5 minutes upwards, depending on security system.
- On sections using automatic train control, train intervals may be less than 1,5 minutes.
- Minimum economical capacity usually 800 passengers per hour = one unit each 15 minutes.
- Maximum capacity per one dual line 30.000 passengers per hour with 4 unit trains. (Maximum capacity is limited with the length of the platform and in certain cases with the capacity of the exit ways from the platform area.)

Light and heavy rail networking

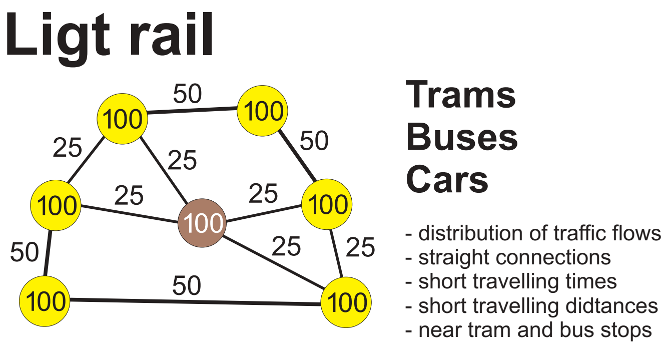
In heavy rail systems, large number of passenger capacity is concentrated into few services. This is based on the idea, that travelling cost per passenger decreases when the capacity of the system increases.

However, concentrated heavy rail network does not fit to the modern urban structure, which is not centre weighted. The travelling demand does not direct to the trips from suburbs to city centre, instead between locations all around the urban area. For the transport system this means, that there are plenty of demand for connections with relatively low capacity. Few heavy rail connections does not fit to this demand, but many light rail connections does.

The use of concentrated heavy rail connections end up to situation, where the trips do take more time than necessary and passenger kilometres are generated and paid more than actually is required.



Heavy rail network with concentrated services between locations in urban area. Passenger kilometres are generated for 10.000 units. Number in a circle describes the travelling demand of each location and number by connection describes the number of passengers on the service.



Light rail services for the same situation as in the previous figure. Light rail offers direct connection between locations for the same demand as for heavy rail solution. Required capacity per service is much less. As there is no need for extra travelling, passenger kilometres are generated only in 3500 units instead of 10.000 units.

Economical background

By means of economy, a Light Rail system saves in building cost when compared to a traditional metro and connecting bus solution. Roughly it can be estimated, that only a quarter of the network is situated in the city centre, where underground lines may be necessary. At 75% of the network the savings in the building cost are 60 to 80% compared to build a kilometre of metro line.

The savings in building are based on several features in the line. For the first, for a Light Rail a level crossing with streets is possible saving to construct bridges. The track does not need heavy ground modifications, because same level of curvature and up- and downhill are allowed as for streets. Light Rail does not need expensive terminals as stops, instead simple tram stop on street level works. Bus and car connections are easy and inexpensive to arrange, as both operate on same street level with the tram, and buses can share the platform with the tram. On streets with low traffic volume Light Rail can share the street bed with road traffic like ordinary trams, so the only extra cost for Light Rail line is the track and catenary.

In operating cost, the basic advantage is the difference between bus and rail transport. The operating cost of a bus is roughly same as the operating cost of one rail unit. But rail units have remarkably higher capacity, which makes the cost per passenger kilometre in rail transport at least half of that in a bus.

In Light Rail operating cost compared to heavy rail systems the savings are based on the bigger share of rail transport than with the metro fed with diesel buses.

Another source of savings is the better correspondence between the travelling demand and offered capacity as what is the case with a metro system. The feeding bus lines also usually operate with higher capacity than what is required.

Metro stations also require cost for maintenance and security, which tram stops do not need at all.

Light Rail and investment flexibility

Light Rail based system requires more investments to create than a totally bus based system, if such a system is possible in the high density city area. This comes from the price of the rolling stock and from the fact, that buses do not need rails nor catenary. But the life cycle of a bus is app. 1/4 of the life cycle of a Light Rail unit, which means, that in long term the tram is cheaper.

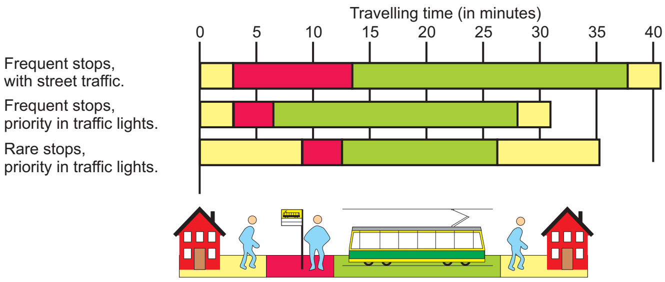
It is good to understand, that the cost of a bus “track” is not zero. Buses require their own space on the streets, very often own lanes and stop sidings. A bus is a heavy load for road bed, so streets planned for bus operation cost more than streets for just cars. The share of these from street construction and maintenance cost is the cost of bus track, even if it is taken from street building moment in the city’s economy, not from the budget of the transport authority.

Usually the investment resources are limited. The benefit of a Light Rail is that it can be built in several steps. Another benefit is, that the building of the system is not bound to other large investments that must be done at the same time, like business and shopping centres in which the station is a part. This kind of centres can be made with the Light Rail, but they are not the term to make the public transport system economically possible.

Competitivity as a transport system

One major benefit other than the economy, is the competitivity of a Light Rail as a transport system. This is a very important factor in Europe and USA, where people like to use their own cars.

When properly organised, travelling time from door to door is shorter with a Light Rail than with a metro system. The long stop distance of a metro increases the speed of a metro train, but requires more time for walking or in a feeder bus. In the best solutions, the travelling time with a Light Rail can be shorter than with a car in large cities, where parking is not possible as near as a Light Rail stop can be.



Total travelling time is not only the time in the coach. It includes also the walking time, so increasing the speed of a train with longer stop distance decreases the total travelling time.

To travel in a rail transport unit is much more comfortable than in a street bus or even in a car at rush hour. Light Rail is also competitive to a metro system, as Light Rail offers much more straight connections and less changes than a metro with feeder buses. To get a metro from a suburb requires often a bus travel for the first and for the last when returning. This makes the metro trip as comfortable as the bus trip, when the Light Rail trip is a rail trip from the beginning to the end.

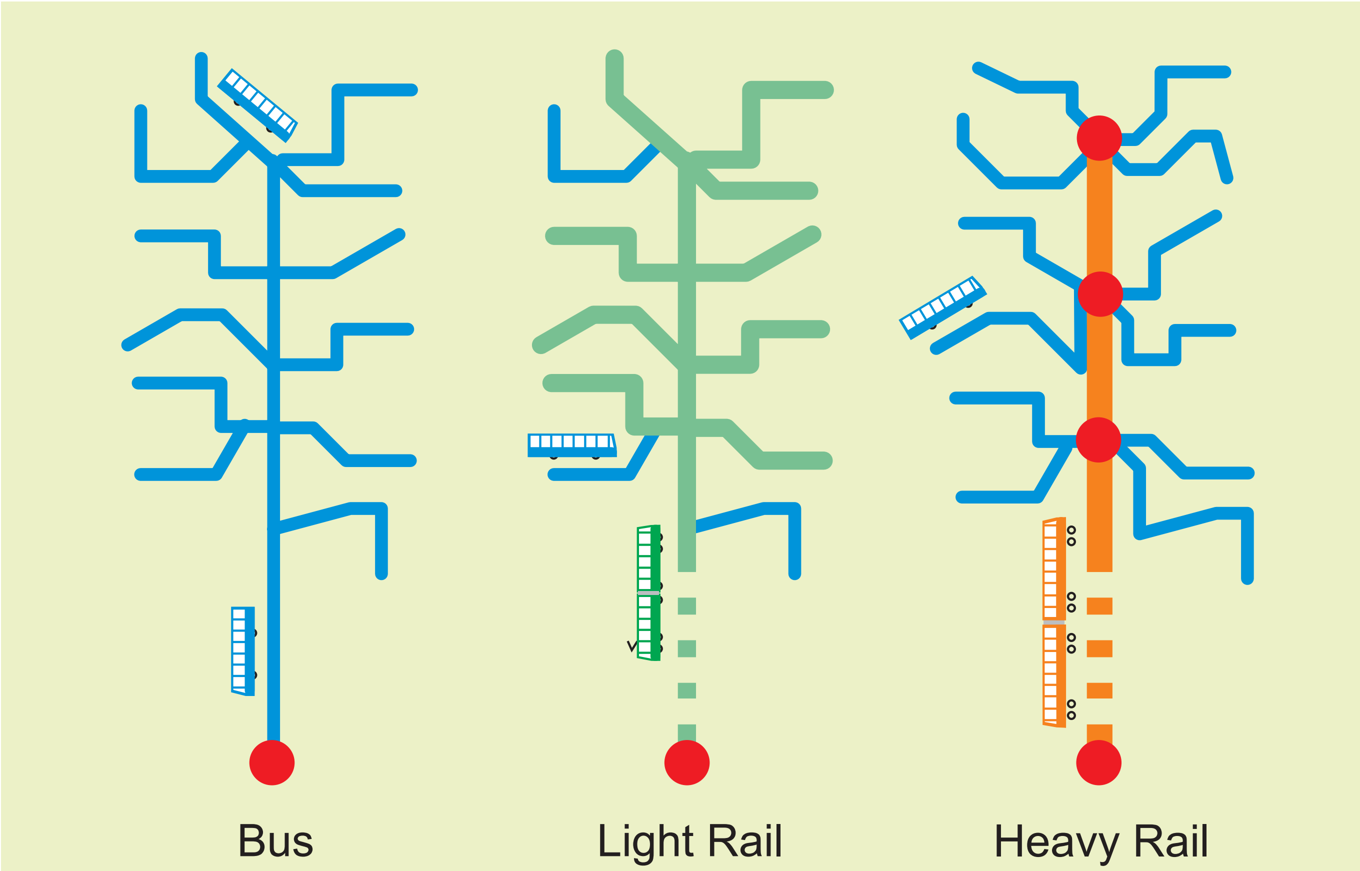
Comparison study of Light Rail, metro and bus systems

There are few real world examples where it is possible to compare different public transport systems. In many cities there are now experience of switching from one system to another, like from bus to Light Rail or from tram to Light Rail. Many middle European cities are good examples, like Dortmund, Duesseldorf, Köln and Strasbourg. One interesting example is Berlin, where the shared city grow with metro in west and with tram in east. After joining the city, the eastern tram system is modernised and it is growing when the metro network remains mostly as it was.

This study is based on a 20 kilometres transport corridor, and the public transport of that corridor is compared between a bus, a Light Rail and a metro and feeder bus system. The idea is, that the system has one end in the city centre and on the other end the system divers in suburb area. The rails – both metro and Light Rail – are put into a tunnel in the city centre, but on outer area on ground. The buses operate on streets all the way.

Each system has equal capacity, app. 10.000 passengers per peak hour, to the city centre. So they all offer same service that is possible to manage with a metro and feeder bus system, but not taken into account the advantages of a Light Rail network to direct connections without travelling via the city centre.

The study proves, that the bus system is weighted to operating cost and the rail based systems are far less expensive to operate. The metro replaces a large part of the bus network and saves bus operating cost, but metros capacity and connecting services to buses require large investments. Light Rail replaces the major part of the bus network saving most of the



Structure of each network in the study. Each network has a main station in the city centre (red circle). A metro and feeder bus system requires also 3 more stations for connecting the feeder bus lines. A Light Rail network has only 3 feeder bus lines for the areas considered not dense enough for economical building of rail.

bus operating cost. Still the investment is 20% less than metro network.

Starting investment

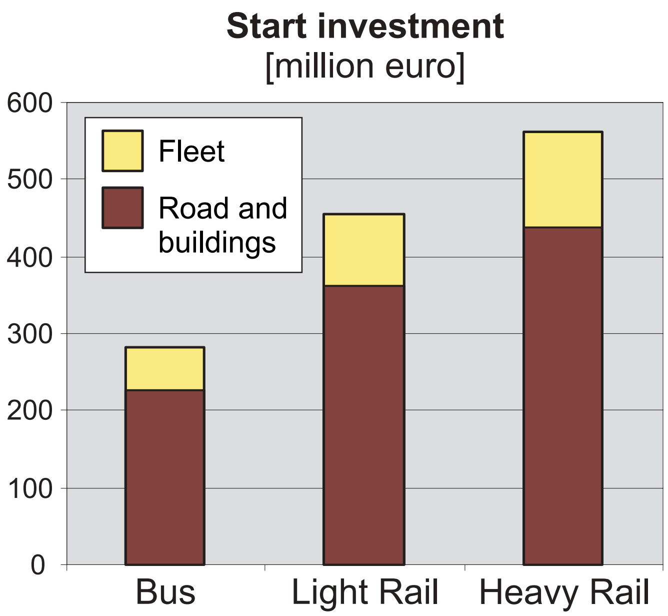
To set up each system requires the investment for the infrastructure and a set of rolling stock. As the rail rolling stock last for 40 years but the buses for only 10 years, that gives a benefit for the bus system.

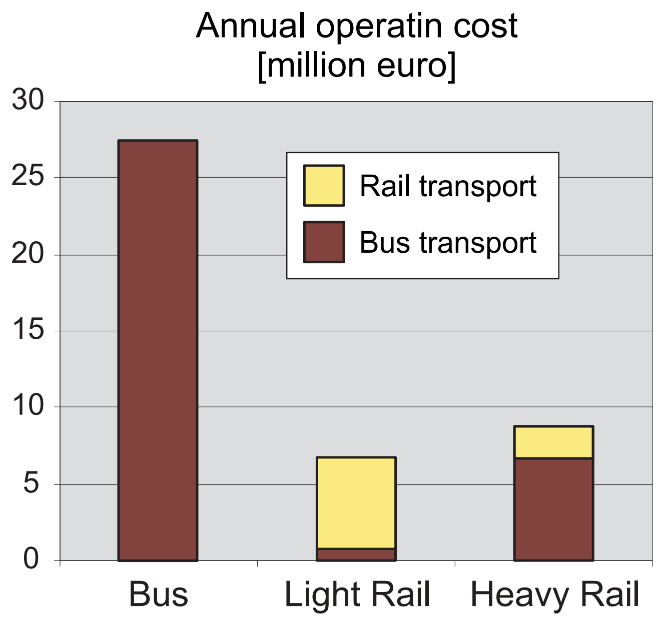
Anyhow, in many cases the rolling stock is leased. In that case, the leasing fee is based on the estimated age of the units, which makes the leasing of the railway rolling stock cheaper than leasing the set of buses required.

Running cost

Running cost here includes the driver's salary and the kilometre based cost of the rolling stock, which is the energy and service. Administrative expenses are calculated separately.

The operating cost is calculated for a working day. The result is expanded to year level using factors to cover the weekend cost.

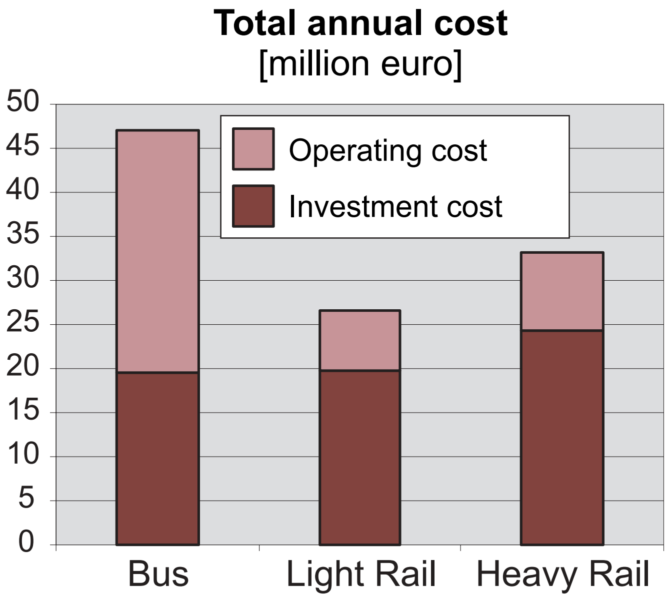


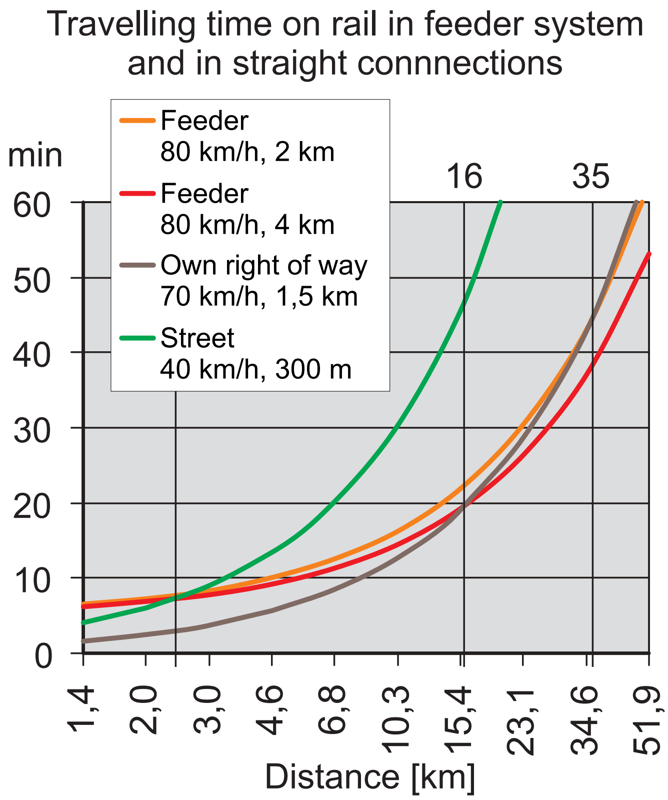


Total annual cost

Total annual cost is calculated as a sum of operating cost and the liquidation of the investment. The liquidation is calculated here based on 3 % annual interest and 40 years period.

The investment here includes the price of the rolling stock for 40 years. The total investment for both the bus and Light Rail is near equal, therefore the annual liquidation is also equal.





A Heavy Rail feeder system competes with straight bus or Light Rail connections. It is competitive only in city centres, but not in the connections between city centre and suburbs. A bus on a motorway or a Light Rail on it's own right of way is faster below 35 km distances.

Total annual cost gives a figure of the price of the public transport system. Public investments can be financed also tax based, when there is possible not to count any interest for the investment. In that case the annual investment cost may be considered as the share of tax income to be used for public transport building.

Conclusion

This comparison is calculated as a theoretical sample urban sector, in which the public transport can be organised either with a metro line and connective bus service or with Light Rail network, that covers the most of the suburbs. The length of the sector is 20 km, which in case of metro is the length of a metro line.

The study shows, that most of the cost in the bus system is based on the operating cost. This is because the cost per passenger kilometre is high with buses.

Replacing part of the bus transport with rail transport in metro system saves operating cost, but plenty of bus operating still remain. The major drawback with the feeder bus system is, that the travelling time increases highly because of the switching between bus and train. The travelling distance in the metro train should be 30 to 35 km, until the switching delay is covered with the higher speed of the train compared to buses on a motorway or Light Rail in its own right of way.

The best savings in operating cost can be achieved with a Light Rail system, that replaces the most of the bus transport with rail transport. Light Rail is also cheaper by means of investment, as it does not require expensive bus interchange stations as the metro system needs. To build the rail is also cheaper with Light Rail than with metro, because thanks to the overhead power supply, the line can cross the streets in level crossings and bridges and two level stations are not required.

The calculation does not take into account the possibility to build circular lines, which is possible with bus and Light Rail systems, but not with a heavy rail metro system. If this had been made, the operating cost of the Light Rail systems had been even more competitive than the metro system, as the total amount of passenger kilometres had been less than with the systems compared here.

The calculation does not include any estimate of the income, but the cost may be shared by population to have an idea of ticket cost. But as the cost of each system is different, a pay back calculation for the Light Rail compared to a bus systems can be made. It shows, that a Light Rail covers it's investment as savings in operating cost in app. 7 years.

The networks cover areas in the city centre with a population density of app. 6000 persons/km^2 or more and in suburbs with an average density of 2000 persons/km^2 in built areas. With these figures, the total population that the system serves is 170.000 to 200.000 inhabitants. The capacity in the study equals for app. 40 % public transport share in urban travelling. This share depends on local circumstances and varies strongly around the world.

Unit cost used in the study

The unit cost are valid in Finland and based on the cost level in Finland in year 2002. As the labour cost varies around the world, calculation should be made with the local unit cost.

One Euro equals to one USD in the end 2002.

Typical investment costs

Rolling stock

- Light Rail rolling stock unit for 250 persons: 1,8 M euros
- Metro train unit for 400 persons: 2,7 M euros
- Diesel bus for 65 persons: 0,25 M euros
- Share of rolling stock units to be as spare (in service and repair) over the required capacity: 10 %

Rail structure

- Street base suitable to carry tram rail: 1,2 M euros / km
- Track and catenary on street, two ways: 1,5 M euros / km
- Track right of way in plain ground, two ways: 5 M euros / km
- Tunnel Track, two ways: 7,5 M euros / km
- Track bridge for two tracks: 9,3 M euros each

Stops and stations

- Tram or bus stop with shelter: 120.000 euros pair
- Combined tram and bus stop with large shelter: 0,7 M euros each
- Simple tunnel station with one on-ground building: 20 M euros each
- Metro type station on-ground with bus terminal: 25 M euros each

Operating cost

Operating cost is calculated from 2 components. Then there are included service, maintenance, salaries and energy of the system.

- Cost per hour: 24 euros per driver per day
- Cost per kilometre in rail unit: 0,3 euros per km
- Cost per kilometre in a bus: 0,4 euros per km

Administrative cost of the system: 4 M euros per year

The required number of rolling stock units is based on the peak hour of the day. Systems are running 16 hours per day and peak hours are 6 hours per day. Operating cost is calculated based on working day. For a year there are used factors to expand the working day cost for the whole year with weekends.