The evolution of urban public transport

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Abstract

The development of urban transport and the particular role of public transport over the last century are reviewed. The study of this shows an evolutionary process in which the railway, bus and taxi prevailed and light rail and the trolleybus were almost forced into extinction in the UK. The present sorry state of urban transport and resultant congestion and pollution calls for a widespread reappraisal of the role and form of public transport.

The factors and driving forces which could influence the specification of urban public transport systems of the future are investigated, taking into account the environmental and economic pressures and constraints, technological development and the quest for sustainability.

1 The history

In the late 19th century in the town of São Bernardo Campo, Brazil, Giuseppi Setti came from Italy and founded a business transporting people and goods around the town by horse and carriage [1]. So successful was the business that in the 1920s, when motorised transport became available, the company acquired a fleet of ‘omnibuses’. The company is now a major bus operator in the São Paulo region.

Returning to the days of the horse and cart, it was soon discovered that, by putting the cart on rails, the horse could pull a far greater load for its effort, hence the evolution of the horse drawn, and eventually electric, tram which subsequently became the dominant form of public transport in almost every major town and city. Trams proved popular and reliable and fitted well into the street environment.

In the 1920s the tram was already established as the main form of public transport in most major towns and cities, including São Paulo, but was later to be
displaced by the bus. São Paulo introduced the trolleybus at a fairly early stage mainly for environmental reasons. These soon demonstrated improved performance relative to the bus and a trolley bus fleet still operates today.

2 The road to congestion

Development of the internal combustion engine has since had a dramatic effect on urban transport and, indeed, post war planning. The motor car was seen as the ultimate solution to transport problems. The economy was geared to mass production of vehicles and town planners were forced to accommodate the increased levels of traffic. It was possibly never envisaged that car ownership would rise to its present level, no longer restricted to a privileged minority. The effect of this varied from city to city. Most cities in Europe managed to retain their tramway network and to limit traffic accordingly, resisting the pressures of the motorcar lobby.

In the UK, with the exception of Blackpool, the motor car lobby prevailed, simultaneously with the development of the bus which was seen by public transport operators as far more manageable than the tramway network, arguing ‘flexibility’. Buses were also regarded by motorists as less of an obstruction. Since that time, however, public transport has evolved in a way described by Klau et al [2] who observed that public transport systems based on light rail were experiencing increasing patronage whereas those based on buses (with some exceptions) were experiencing decreasing patronage. The reasons for these trends need close examination. Factors favouring buses include:

- low initial cost
- low cost of introducing new routes
- ability to manoeuvre round obstructions
- lower obstruction to other traffic
- no requirement for electrification.

Figure 1: Systematic decline urban public transport.
Buses have formed the backbone of urban public transport for the past 50 years in many towns and cities but services are declining as private transport encroaches. In most towns and cities throughout the world, in the absence of draconian traffic management measures, congestion has prevailed along with associated pollution and environmental degradation and a decline in the quality of the bus services leading to the spiral of decline described in figure 1 [3].

Many cities, however, preserved and developed their tramway networks and, by doing so, have avoided this decline and preserved the environmental quality of their city centres.

Figure 2: Evolution of passenger transit vehicles.
3 20th Century development of urban public transport

During the last century, rail technology has been adapted to operate on city streets, with electrification providing the motive power. Thus urban public transport has evolved both from the metropolitan railway and from the bus. Lately there has been some fusion between these resulting in intermediate modes such as the trolleybus, guided bus and more lately, the tram bus, often referred to as ‘a bus disguised as a tram’. Figure 2 shows the evolutionary process. Street running options available today, in addition to the conventional bus are described below.

3.1 Tramtrain

This is a version of the light rail vehicle designed to operate on street or on conventional railway, sharing track with suburban metro trains. This practice is referred to as the ‘Karlsruhe model’ after the city in Germany which pioneered the idea. Karlsruhe has integrated the tramway and suburban rail system into a comprehensive network covering the whole region. Many other cities are following this example. Tramtrain systems are mainly electric but diesel and hybrid tramtrains are being developed for routes with unelectrified sections.

3.2 Diesel tram

This is a conventional tram adapted for operation on unelectrified routes. They use either on-board hybrid or diesel electric power.

3.3 Dual mode guided bus

This is a bus designed to have the same passenger appeal as a tram and is similar in appearance and interior design. It is normally articulated and can run in guided or unguided mode. It normally has electric transmission is powered externally or by on-board electrical generation. Lower cost versions are diesel powered but these offer a smaller advantage over conventional buses running on bus lanes, in terms of noise and ride quality.

3.4 Ultra light rail vehicle

This is a derivative of the tram or streetcar but is designed to operate without overhead power supply and has on-board hybrid electric power. It is specifically designed for high energy efficiency and is thus a strong candidate for future use of a hydrogen fuel cell as prime mover.

4 Future development

The driving force behind the future development of light rail systems is the need to reduce cost. The driving forces behind future bus development are the need to reduce their environmental impact and to provide a quality of service equal to
that of light rail. This presents a major challenge to vehicle developers and is leading to an element of cross fertilisation of technologies between the two modes, resulting in a restyling of buses to provide LRV appearance and quality and the development of low emission autonomous power for both buses and light rail vehicles to avoid the need for costly electrification and, in the case of rail, track insulation.

The factors likely to shape new urban public transport systems in the future are:

a) technological development
b) the choice between segregation and street running
c) the opportunity for traffic management.

The objectives are likely to be the need to

- improve air quality
- improve passenger and pedestrian safety
- reduce CO₂ emission
- encourage a shift from private to public transport
- improve the accessibility and environment of city centres.

5 Technological development

The light rail vehicle has, through its development, become the preferred mode of urban travel where it is available. Trams carry a higher proportion of car drivers than do buses. This is because of the high quality of ride and service which LRT offers. However, the introduction of new LRT schemes is being inhibited by the high cost. Whilst LRT has possibly reached a plateau in its development, the bus is benefiting from developments in propulsion technologies, whilst assuming tram like qualities.

Hybrid propulsion systems are undergoing rapid development at present with high efficiency and low or zero emissions as the main objectives. Flywheels or ultracapacitors could replace batteries in the future because of their higher storage efficiency, cycle life and ability to recover brake energy.

6 Automated systems

Advances in control technology have resulted in the development and implementation of automated systems such as the VAL system in Lille and Paris. Here a two-car vehicle operates along a segregated guideway on rubber tyres, without a driver. For safety reasons stations and route must be designed to prevent any access to the track. This considerably adds to the cost as the stations and track need to be underground or elevated to avoid severance. This makes access more of a problem. However, the result is a reliable service unhindered
by externalities. This could be a preferred solution where new urban centres are being planned but cost is a major consideration.

A variant of the automated metro is Personal Rapid Transit which provides the equivalent of a taxi service between selected locations, affording equivalent privacy for its passengers. Passengers can select their destination as required. This is an attractive concept particularly in the design of new urban centres, analogous to automatic lifts operating horizontally rather than vertically. Such systems are being developed for airport terminals.

7 Capacity

A current problem encountered by proponents of light rail is that, in order to justify the cost, patronage forecasts are often optimistic, leading to specification of high capacity vehicles (in excess of 200 passengers). The financial risk of overestimating patronage is now often built into the initial cost, so increasing it further.

Ultra light rail provides the option of smaller vehicles at lower cost, operating under the economics of former tramways or minibus services. Capacity can be tailored to meet the actual patronage, so avoiding the above mentioned risk. The route capacity can be increased if necessary by increasing the service frequency, which, in turn, increases its attractiveness. Ultra Light Rail is therefore flexible in capacity.

8 Meeting targets

Government’s targets for reducing toxic pollution, carbon emissions and traffic congestion in urban areas can only be met by introducing an improved system of public transport to replace the diesel bus. Such a system needs to have the following characteristics:

- Zero or near zero carbon dioxide and toxic emissions
- Popularity with the public, to encourage modal shift from cars
- Ability to operate in pedestrianised areas without worrying pedestrians
- Low noise levels
- Affordability

8.1 Zero emissions

Standard production fuel cells are now sufficiently well developed to provide a feasible source of the power required for a tram. Weight, size and energy density are not such crucial issues for a tram as they are in designing a car. Because of its high energy efficiency and hybrid configuration, the ULR tram can benefit from fuel cell technology long before it is commercially or technically practical for cars or buses. Trams thus provide the best opportunity for the introduction of the hydrogen fuel cell into transport. The existing CUTE fuel cell buses (three of
which are currently running satisfactorily in London on the 25 route) have already shown that fuel cells are a practical alternative technically, but not yet commercially [4].

The only emission from a fuel cell tram is water. The hydrogen fuel can either be a by-product of existing industrial activity, or produced from biomass or by electrolysis of water, using electricity from renewable sources. Hydrogen provides the ideal means of storing energy from renewable sources, making the energy available for transport use as required. Hydrogen storage and use as fuel allows a greater proportion of energy production from renewables. Ultra light rail transport offers the best prospect for the introduction of hydrogen fuel for transport in view if its energy efficiency and fleet operation and thus offers the best opportunity to meet urban air quality and CO2 emission reduction targets.

8.2 Popularity

Market studies all over the world have established that the public greatly prefer trams to buses and that consequently trams, unlike buses, achieve a high degree of success in attracting travellers out of their cars into public transport. This is confirmed by the greater modal shift achieved by new tram systems. A further important confirmation of this popularity is provided by the fact that tram tracks can raise adjacent property values far more than a bus route.

8.3 Pedestrianisation

City centres need to be made accessible, attractive and free from pollution if the notorious doughnut effect, characterised by empty derelict centres and sprawling suburbs, is to be avoided. Pedestrianising central areas allows shoppers to roam unmolested by cars and buses. This creates a stronger sense of community, especially in smaller towns, which huge out-of-town shopping estates, surrounded by acres of car parks, cannot hope to achieve. Towns like Zurich and many others have proved that shoppers do not mind the predictable path of even large conventional trams in pedestrianised streets, where a bus would be unacceptable.

8.4 Noise

Internal combustion engines cause intrusively high levels of noise in towns. Fuel cells and electric motors are virtually soundless. The electrical energy storage system of the tram allows for smooth, fast, noiseless acceleration. Well laid tracks and modern wheel drive systems can reduce noise further.

8.5 Affordability

High cost is the principal factor limiting the introduction of trams. Ultra Light Rail Transport (ULRT) has been developed with the specific aim reducing costs without compromising on quality of service, by adopting the features set out below.
8.6 Design

ULR vehicles are designed like buses that are adapted to run on rails in the road. Conventional trams are designed like railway trains, only slightly adapted to run on roads. ULR trams are thus lighter than conventional trams, with important consequences for the design and cost of the infrastructure and the drive train of the vehicles.

8.6.1 Infrastructure
On-board power supply in ULR trams eliminates the need for overhead wires and thus avoids the need to insulate the rails. The low weight of the ULR tram requires only light rail, which can be easily moved and replaced by temporary track if sub-surface work on services needs to be done. This makes it unnecessary to build a deep substructure or move the services under the road, two of the main causes of the high cost of conventional light rail transport.

8.6.2 Energy efficiency
The low rolling resistance of steel wheels on steel rails reduces the energy needed for a tram to one third that of a bus. The energy requirement is further reduced by the hybrid drive train, which enables the primary energy source (prime mover) to run steadily at optimum efficiency and allows brake energy recovery. The consequent reduction in the power specification of the prime mover brings big savings both on the cost of the hybrid fuel cell or diesel electric drive train and also on the cost of fuel. Fuel will become an increasingly significant cost factor with hydrogen and also with fossil fuels as prices increase.

8.6.3 Durability
The normal life of a tram is 30+ years compared with 8-13 years for a bus. This reduces the amortisation cost dramatically.

8.6.4 Patronage
The popularity of trams leads to higher patronage levels and increased revenue.

8.6.5 Permanence
Tram tracks laid in the road demonstrate a commitment by the local authority to long-term operation of a reliable, comfortable and attractive public transport service. The importance of this commitment is reflected in the uplift in land values for properties adjacent to newly installed tram routes. New tram systems can be funded by capturing this uplift in value for the public benefit.

9 Conclusion

Figure 3 shows a comparison of the characteristics of urban passenger transit systems (apart from metro). Technological development is providing the opportunity for urban designers and planners to reinvent town and city centres to meet people's needs without destroying the immediate or global environment.
Transport system designers can thus play a full part in the move towards the zero carbon economy and minimum ecological footprint by adopting energy efficient vehicles running on hydrogen produced from renewable sources. Public transport systems can be designed to improve air quality, accessibility, social inclusion and also to cut carbon emissions. Such development will shape our towns and cities for the future, enabling them to develop sustainably and provide a healthy environment for all its citizens.

![Comparison of the characteristics of urban passenger transit systems.](image)

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* at point of use.  ** using renewable energy sources

Figure 3: Comparison of the characteristics of urban passenger transit systems.

References

