Advanced bus transit systems: "best practice" mobility solutions for emerging agglomerations

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Abstract

Current long-term socio-demographic trends in different world regions provide direct implications in terms of future requirements for efficient mass-transit systems in the existing and upcoming agglomerations around the world.

As most of the developing countries will lack the necessary financial and planning resources to establish rail-based systems (metro, light rail), the need for bus-based public transport technology will become inevitable, independent of any political desires and programs.

Currently, unorganized private minibuses ("paratransit") are taking a growing share of mobility in these cities, causing major environmental and traffic problems due to inefficient use of roadspace and outdated vehicle technology.

Advanced bus systems, such as "Bus Rapid Transit" (BRT) systems, which have proven successful and economically efficient in a number of Latin American and European conurbations, provide a potential solution for these agglomerations, based on readily-available vehicle technology and local capacities in conventional road building. The sustainability balance, the transportation performance, and the financial requirements of these systems are very positive, especially when coordinated with an integrated town-planning approach.

The paper describes obtainable advantages in mobility and sustainability of advanced bus transit systems, based on available and proven concepts and technologies.

Keywords: emerging agglomerations, mobility, Bus Rapid Transit, operating costs.

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1 Population, urbanization, and mobility

Transport and mobility definitely have to be considered as basic human needs, and with continuous global population growth it becomes more and more difficult to provide an adequate supply. In fact, a rapidly growing proportion of people, especially in poor suburban settlements in growing urban agglomerations, do not have access to even the most basic mobility services. Consequently, recent surveys show that for urban administrations worldwide future transport and mobility challenges are on top of their political agenda [1].

Urbanization is the main driving force in this context, and from a global historical perspective it has to be stated that just right now we are at a tipping point: from now on more people will live in urban agglomerations than in rural regions (Fig. 1).

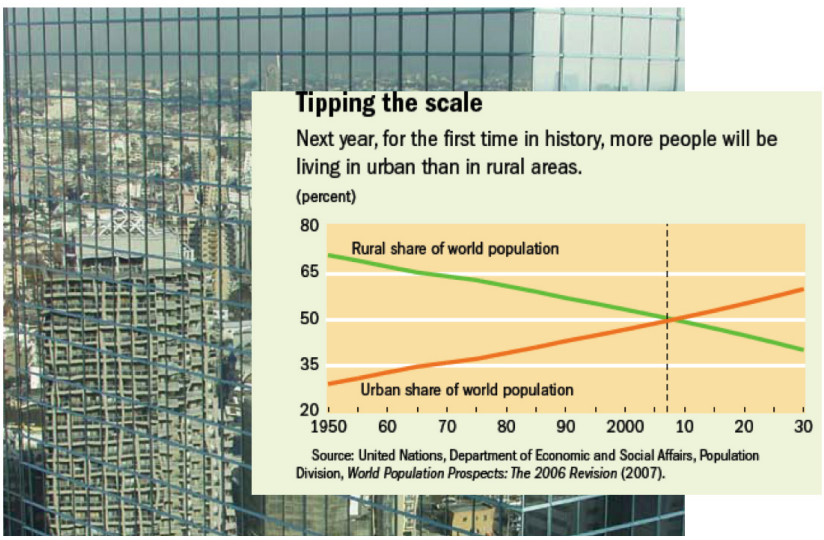

Figure 1: Urban vs. rural share of world population 1950–2030.

Another aspect has to be considered to avoid biased perception – quite often this global urbanization issue is focused on so-called "megacities". Whatever definition is chosen, above 5 Mio. Inhabitants, 12 or 15 Mio., the unintended impact of this focal view is an inadequate inconsideration of urban structures underneath this threshold. Even further, by absorbing common attention for these megacities, urgently needed efforts to cope with current and future transport and mobility challenges in the middle-sized agglomerations do not get sufficient support. From this point of view, there are more than enough reasons to elaborate a more detailed look into these kind of situations and to explore potential solution approaches – especially when looking into future prospects suggesting that some of these "middle-sized" agglomeration segments have or will be growing above proportion (Fig. 2).

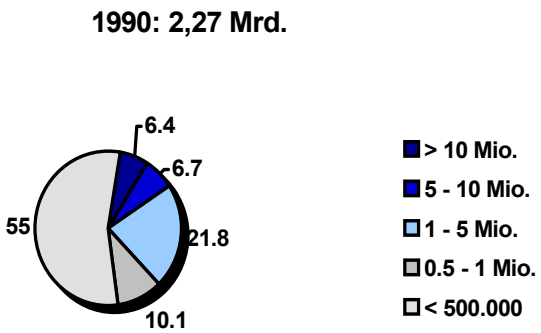

Figure 2: World urbanization by volume segments (source: Daimler Research).

One first remarkable step has been done by the World Bank: Their strategic project review led to the proposal, in future to concentrate rather on intra-urban transport issues than – as has been in the past – to support projects to enhance interurban or interregional transportation projects [3]. But also other actors on the international scene seem to be moving into the direction of focusing more on urban mobility topics in emerging regions [4]. Additionally, some programs are aiming at combining several sectors like energy, water, economy, housing, transport, and sustainability into a more integrated urban development approach [5].

Anyway, it can be expected that urban transport and mobility policies especially in emerging regions are determined to conquer a prominent place on the international agenda, and the related scientific scenery should be well prepared for that shift.

2 Urban mobility policies – framework and constraints

Although several attempts have been made to develop an actualized and comprehensive view about urban mobility patterns and conditions in different regions, one has to state that adequate database are lacking, either for being very selective or simply just too old [6]. But, what should be resumed, is that the conditions are so different making it impossible to draw any kind of general trend – be it in terms of daily trips, modal split, daily travel times, amount of income spent, public transport supply, etc. Besides the consequence to perform basic analyses in every single case, some structural approach like classification of mobility conditions in various emerging agglomeration types would be quite helpful.

Some practical impacts of such efforts are quite obviously: in urban agglomerations with poor transportation service, due to different sources and observations the situation might be somewhat alarming:

- Sometimes the majority of people have no access to the transport system at all;
- For commuters, transit costs might sum up to 25% of their income;

- In the same context, working days travel times could reach 6 hours;
- Mobility needs of the non-working population – students, elderly or handicapped persons, leisure and recreation, … – more than often are not considered;
- Environmental impacts and energy efficiency issues often show very critical assessments.

To sum up, need for action is given. But to make sure it is not only for the action's sake, systematic and unprejudiced analysis is a pre-requisite to develop adequate policy options. Moreover, we are strongly convinced that enhancements of people's mobility conditions (and, moreover, in a similar way applied for freight transport and logistics) form a key issue in dealing with regional development constraints, if this is part of some integrated development approach as mentioned above.

Another important parts of such approaches are:

- To mobilize financial resources and to choose the right policy with the best "output";
- To "match" the preferred policy with experienced know-how to operationalize different elements of the policy;
- To form organizational coalitions that can help to make good plans work.

In most cases, these tasks sound easier than they really are. On the other hand, some examples are known in which after implementation of public transport systems the mere success in form of unexpected additional demand formed somewhat new types of problems, which can be seen as indication that good solutions sometimes are not that difficult to realize [7].

3 Urban transport trend in the 1970s–1990s: paratransit

In an immediate response to insufficient or deteriorating urban traffic supply in countries with lax legal transport regulations, independent private entrepreneurs enter the market and offer their services to the general public. This has been observed in many countries throughout the world, and these services are well known under a variety of names like "Dolmus", "Colectivos", "Tuk-Tuk", "Matatu" or "Jeepney". In scientific terms, this service – offered by individual entrepreneurs that compete or co-operate in collective associations – is being called Paratransit.

Such forms of Public transport are (or: have been) dominant in many agglomerations in Central America, all African countries, Turkey, the Near and Middle East, Indonesia. With the economic transitions in Russia, even there some "Marshrutniks" appeared on the scene.

Frequently, the upcoming of Paratransit has ruined formerly existing but insufficient public bus services, as it did in the 1990s in Mexico City. Even if it is certainly an improvement compared to long walks on foot, it is still far away from being socially efficient, if the transport demand exceeds certain thresholds and the single minibus van vehicles crowd and jam themselves in densely built-up city zones or on bottleneck highways. Wild competition on the road and

scarce financial capabilities of the owners tend to be detrimental to road safety, and outdated vehicles consume far too much fuel and pollute the urban environment.

4 Metropolitan rail projects: successes and failures

Due to outstanding examples of efficient mass transit organisation with railways, metros, streetcars and Light-Rail systems, many proposals have been put forward to introduce such systems into the growing metropolises of the developing world also. As these systems require several years to plan and to construct, and as they require billions of Dollars for groundwork, track infrastructure, stations and vehicles, many proposals of the 1960s to 1990s have been dependent on international economic aid.

There have been remarkable successes in applying metro rail systems for urban traffic, as can be seen in Buenos Aires (1940s) and Mexico City, but the number of systems that have either never left the drawing boards or have stalled after completing first rudimentary sections is much higher. Almost everywhere, the critical funding issue, unexpected difficulties in performing the necessary deep groundwork or technological difficulties in keeping a reliable, efficient operation alive, have severely cut back the original expansion plans.

From the 1970s on, a number of Light Rail Projects have succeeded in numerous cities of the developing world, an early adopter being the city of Tunis, which by now operates a 35km network with 4 lines into most suburbs. Such systems can save large parts of the groundwork cost by relying on surface tracks wherever possible. Compared to the European or North American Light Rail systems, longer trains may operate that reach transport capacities well above the conventional "tramway" shape that usually comes up in engineers minds.

5 The "Bus Rapid Transit" (BRT) approach

Curitiba in Brazil is being regarded as the "mother of all BRT systems". There, a long-term oriented policy of Jaime Lerner, the architect and city mayor who became later the provincial governor, has successfully proven that a stringent urban-development policy can channel the traffic flows into a number of designated traffic axes that would – under European conditions – have been equipped with metro or light-rail systems. Due to the financial restrictions and the rapid urban growth in the late 1960s, the city of Curitiba had to rely on existing, cheap traffic technology and installed extensive systems of separated bus lanes that were "designed for later conversion into Light Rail lines". The huge success of the bus services (in terms of rides-per-inhabitant) showed that an efficient bus operation could well serve the needs of the agglomeration for much longer than expected.

After several years of successful operation, other Brazilian cities adopted similar busways with accelerated operation speeds on single axes. The crucial breakthrough for "Bus Rapid Transit" as comprehensive public transport technology came around the year 1999-2000, when the city Mayor of Bogotá, Columbia, Enrique Penalosa, decided that constructing a metro system would be

much too slow and expensive. The specific situation in Bogota allowed reconstruction of the urban road network with extremely wide arterial roads that could bear double bus lanes per direction. The flexible overtaking of vehicles, which is absolutely impossible with rail-based technologies, now allows flows of up to 30.000 passengers per hour to be transported with up to 300 articulated buses per peak-hour.

This "TransMilenio" system, embedded into an ecologic overall urban planning scheme incorporating partial abolition of the once dominating "colectivo" bus services, major reconstruction of urban arterial streets, support of bicycle travel and a specific gasoline surcharge to help financing the infrastructure rehabilitation, today is being presented as a global archetype for full BRT.

The "TransMilenio" system features the following elements:

- Use of dedicated bus lanes on 100% of the arterial system length, much of it being double-lane in order to enable fluid overtaking of buses at the bus stops.
- Use of stations with same-height platforms for stepless vehicle access like in Metros and LightRail systems. This cuts the necessary stopping times at platforms down to almost a third of the time required with ordinary kerbside bus-stops and high-floor vehicles. In the "TransMilenio" system, specific driver training and use of electric platform doors ensures almost gap-less stopping of the vehicles at the platforms and metro-like boarding of the vehicles. (Other BRT systems apply different means of bridging the gap between vehicle and platforms like flipdown vehicle ramps, but the TransMilenio principle allows faster operation.)
- Fully closed ticketing system with pre-boarding inspections at every station. This enables all doors of the buses to be used for entry and exit and significantly reduces – or completely cuts – passenger queues.
- Use of specific large buses with adapted doors for the station platforms. The abolition of internal steps inside the vehicles significantly adds to the available interior space for standing passengers and enables children's prams or wheelchair passenger's easy access. The 18m articulated buses of TransMilenio incorporate significant gains in passenger-per-staff productivity. (Some bus manufacturers even offer 24m double-articulated buses with even larger capacity, but accepting certain technical and operational compromises.)
- Traffic priorization of BRT buses at certain traffic lights in order to speed up the operation and to avoid unnecessary stopping/accelerating energy waste.
- Controlled operation of the BRT trunk lines only on their own right-of-way corridors in order to avoid service irregularities from outside congestions into the BRT operations.
- Use of specific interchange terminals to integrate outside feeder bus lines into the BRT system. The "feeder buses" operate conventionally on ordinary roads, but are taking part in the integrated electronic

ticketing system of "TransMilenio" BRT. Passengers validating their chipcard tickets inside the "feeder bus" are granted free cross-platform access inside the interchange terminal into the mainline BRT buses.

In Bogotá and subsequent applications in agglomerations like Mexico City, León (MX), Pereira (CO), Guayaquil (EQ) and Medellín (CO), the "Bus Rapid Transit" approach showed striking success – both in terms of reduced traffic congestion, improved ecological balances and social access into the city centres for less-privileged shares of the population.

However, some applications of BRT systems showed less success or even initial failure. A number of reasons might contribute to such disappointing results, which leads to a shortlist of political factors that should always be observed when improving agglomeration traffic and infrastructure:

- Continuous political dedication and massive championing by local administration leaders is necessary to keep tight schedules in system realisation. Changing political attitudes can completely stall construction of useful systems
- Early integration of existing Public-Transport operators into the scheme, avoiding conflicts of diverging interests between the parties involved. Private "colectivo" operators can be urged to establish consortia for operating parts of the physical transport performance of the system.
- Strict separation of passenger ticketing revenues from operator's income, which should be paid on a vehicle-mileage base. This prevents arguments about "profitable" or "deficitary" bus courses and ensures smooth system operation at all times-of-day.
- Strong focus on public-information and awareness campaigns helps to accompany the envisaged changes and prevent public disturbances.

6 Frequent prejudices against BRT systems and observed facts

During discussions over the last years, quite often experts, practitioners, and planners were surprisingly unaware of basic features and performance criteria of BRT systems. In most cases it was a result of prejudices rather than lack of information. Here some typical mental reserves and their rectifications:

- "BRT systems do not attract car users"

Despite Curitíba has second highest car ownership rates of Brazil, the gasoline consumption per capita is lower than in any other comparable city.

In Bogotá, traffic analysis showed, that about 15% of TransMilenio passengers previously travelled by car. Generally, travel speed, ride comfort, system reliability and the cost relation are crucial for attracting passengers. A well-equipped BRT system can easily compete with private cars, if these criteria – including security aspects – are met.

- "BRT systems are slower than Light Rail/Metro"

Commercial speed strongly depends on station design and traffic light priority. Express services on BRT can easily overtake regular services at stations and be

much faster. Observed commercial speeds in Bogotá – with passing lanes – are 21–32 km/h, which is equal to metro systems (Example Sao Paulo: 29 km/h). In Quito – without passing lanes – 15–20 km/h are similar or above LRT systems (Example Tunis: 13–21 km/h).

- "BRT has lower passenger capacities"

BRT throughput can be much higher than Light Rail, if off-line station designs are constructed. Regularly achieved maximum volumes are over 20.000 pax/hr*direction in Sao Paulo, Belo Horizonte and Bogotá – while LRT capacities are at 13.000 (Alexandria) or 9.000 (Tunis).

- "BRT systems contribute to local air pollution"

Diesel engines create more on-road pollution than electric systems. The sustainability balance of BRT will depend on the quality of fuel available in the country. Diesel engines with EURO-3 / -4 standards are available everywhere in the world. This generates rapid improvement in phasing out the small minibuses that did not even comply with EURO-1 levels.

7 Investment costs and realization schedules of BRT systems

For the local administration, the most striking advantage of using BRT technology to resolve the agglomeration traffic issue is certainly the high share of local technology in roadwork construction and bus bodybuilding, compared to high investment volumes into foreign technology that is necessary for rail-based urban transport solutions. Also, the employment effect of BRT systems with high numbers of bus drivers will be favourable for the local economy. Apart from these economic impacts, the operational flexibility of bus systems in case of short-term traffic incidents or the ability to restructure the services in case of changing spatial structures and traffic demand is striking compared to metros or light Rail systems.

Some available investment cost examples for BRT infrastructure suggest average financial requirements between 1.5 and 5.5 million US$ per km, depending on the busway width and the desired aesthetic / technical qualities [8]. Typical examples of LightRail systems usually consume the threefold amount of money, and full metros are again much more expensive.

A detailed breakdown for the initial 38 km stage of "TransMilenio" infrastructure elements (1999/2000) shows the following figures. Here, the double-width bus lanes show their significant influence on the total BRT cost:

The realisation speed of BRT projects is strongly dependent on political circumstances and necessary legal and planning procedures, before any first groundwork can start. As BRT technology is usually less complex than electric rail systems, one to two years of planning can be regarded usual, and the physical work may be completed within six to twelve months, if no difficult construction of elevated or underground sections are necessary.

8 Typical operating-cost issues of BRT systems

The dominating factors in BRT operation costs – as with all bus operations in the world – are:

- Vehicle depreciation cost, depending on purchase price, local interest rate and economic vehicle lifetime
- Diesel or alternative fuel costs for vehicle operation, depending on local import or production cost, tax levels and political surcharges. Frequently, costs for engine lubricants and bus tyres are included here.
- Driver's wages and cost for supervision staff, depending on local price levels, average assumptions for duty roaster efficiency and sickness / holiday shares.
- Maintenance cost for vehicles. This will mainly consist of staff wages and spare parts, but can be contracted out to third companies.
- Cost for operation and maintenance of ticketing systems, fare revenue collection and correct distribution towards the several sub-contracting enterprises within the BRT system.
- Additional costs arise for maintenance of infrastructure, electrical power consumption of stations and terminals, for general insurances, and for the support of general planning / marketing departments that are essential for the system's success.

The level of cost per passenger strongly depends on the average vehicle load (Passengers per vehicle and day), which depends on the hourly traffic shares in peak- and off-peak time, the passenger travel distances, the operational system speed, and the total operating-hours per day (per week, per year).

An example calculation shows the general relation of the cost elements for a Latin American case, where high numbers passengers per bus, low average staff salaries and very low fuel prices allow an almost 100% cost-covering service, even with quite dominant vehicle depreciation cost. A model calculation with European levels for staff wages, fuel prices and vehicle depreciation shows a completely different picture, where staff salaries dominate the total cost.

The necessary amount of public subsidies for BRT varies strongly according to the local circumstances. In the very favourable Bogotá example with balanced traffic flows throughout most of the day – and with very cheap diesel prices – no government subsidy is required at all for daily system operation and maintenance – it was only necessary to tax a small gasoline surcharge for private cars to collect the necessary funds for roadside investments into bus lanes and stations.

Component	Total Cost [US$ million]	Cost per km [US$ million]	Share [%]
Trunk line bus lane	94,7	2,52	47%
Stations	29,2	0,78	15%
Terminals	14,9	0,40	8%
Pedestrian overpasses	16,1	0,43	8%
Bus depots	15,2	0,41	8%
Control Centre	4,3	0,11	2%
Others	25,7	0,69	13%
Total		**198,8**	**5,30**

Figure 3: BRT cost structure – TransMilenio.

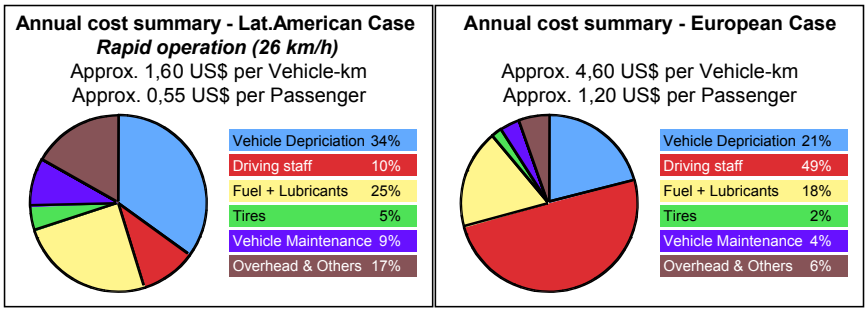

Figure 4: Cost comparison (source: own calculations, based on Mercedes-Benz data).

9 Conclusions

In this paper, current and future challenges of urban mobility especially in agglomerations in emerging regions have been described. The observations are suggesting that for the majority of public urban transport situation advanced bus systems, such as "Bus Rapid Transit" (BRT) are the most feasible approach. In terms of productivity and investment/operating costs, BRT-systems clearly are offering the potential to outperform other public transport concepts. Anyway, successful implementation requires strong and constant political will as well as experienced planning and design capacities – which quite often are considerably scarce resources.

But, being aware of the challenges and the potential future benefits, plus developing sensitivity for new and seemingly unconventional concepts, may open some mindsets to really go ahead and be prepared to apply approaches promising essential contributions to the challenges mentioned above.

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