Evaluation of the effectiveness of “innovative” and “unconventional” systems in urban areas

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1. Summary
The recent policies of the European Commission show that the sustainable mobility in urban areas is a question of prime importance. The growth of transport demand in recent years, combined with a modal distribution skewed towards polluting modes of transport, has led to consequences in terms of externalities production (congestion, environmental pollution, safety etc.), which have obvious effects on people’s quality of life.

In line with European Union directives, which promotes a policy of sustainable mobility\textsuperscript{1}, many cities have developed transport solutions based on reduction of private vehicles in cities, promoting forms of “alternative mobility” based on the use of bicycles and use of public transport or private transport shared (car-pooling and car-sharing).

In the promotion of public transport, in particular, the main aspects which are taken into account are performance's efficiency, energy efficiency, quality of service and reduction of differences compared to private vehicles (often defined by the term “discontinuity”): public transport is in fact generally characterized by limited accessibility in territory because available only in specific points (stations, bus stops, etc.), a time-limited service frequency and rigid and predetermined routes.

The reduction of these discontinuities is the principle underlying the new collective transport systems (innovative systems and unconventional systems): they are characterized by a high level of automation, and by technological features with high quality to achieve high level of energy efficiency and high performance even in terms of environmental sustainability.

This research provides an overview of the problem of mobility in urban areas (real city) and presents an analysis of cases where applications of unconventional and innovative systems have actually produced a positive outcome in terms of performance, energy efficiency and reduction of externalities, in order to determine which could be the design of mobility in a future city (ideal city).

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\textsuperscript{1} EU policy is described in “White Paper 2011: Roadmap to a Single European Transport Area - Towards a competitive and resource efficient transport system”.

The European Commission adopted 40 concrete initiatives for the next decade to build a competitive transport system that will cut the number of conventionally-fuelled cars in cities and at the same time, the proposals will dramatically reduce Europe’s dependence on imported oil and cut carbon emissions in transport by 60\% by 2050.
2. The “real” city
Mobility vs. sustainability

“Real” cities are places having a high level of accumulation and concentration of different types of activities and are complex spatial structures that are supported by transport systems. The most important transport problems are frequently related to urban areas and happen when transport systems, cannot satisfy the frequent requirements of urban mobility. Urban productivity is highly dependent on the efficiency of its transport system to move people and freight between different origins and destinations. Moreover, main transport terminals such as airports and railway stations are located inside urban areas, producing particular problems. There are different kind of problems: several are olden, like congestion, as others are recent like environmental impacts. Different categories of important urban transport problems are shown below:

- Traffic congestion
- Environmental impacts and energy consumption
- Public transport unsuitability
- Problems for bicycle and pedestrian mobility
- Accident and fatalities
- Land consumption
- Bad use of public space

Traffic congestion is one of the most common transport problems in urban centres. The spread of private cars is the main cause of the diffusion of this issue, because has increased the demand for new transport infrastructures. Nevertheless, the supply of infrastructures has often not been able to sustain the continuous increase of private mobility. Environmental impacts and energy consumption derived from the increase of private mobility, are the two most important issues considered by the policies for sustainability. Pollution and noise, produced by traffic has become a problem for the quality of life and the health of urban inhabitants. Moreover, energy consumption by urban transportation has significantly enlarged and consequently the dependency on petroleum, which, however, is a non-renewable resource.

Public transport unsuitability depends also of over or under used of many public transit systems. During peak hours, the large number of users creates discomfort. On the contrary, under-utilization of the system produces unsustainable costs. The increase of private vehicle traffic produce difficulties for bicycle and pedestrians mobility. These difficulties depends also of a low consideration for alternative mobility in the design of infrastructure.

Continuous growth of traffic in urban areas is linked with a increasing of accidents and fatalities. These accidents involves not only drivers but also vulnerable road users. As a consequence of traffic increases, people feel less safe to use the streets.

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2 Air pollutants released in one country may be transported in the atmosphere and harm human health and the environment elsewhere. Further information is available in the Air Pollution thematic assessment of EEA's recent 'The European environment — state and outlook 2010' report.

3 Data from Eurostat shows that in 2008, just under 34,500 people lost their lives in road accidents within the EU-27, even though continuing the steady decreas in the number of fatalities on Europe’s roads. Source: http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home.
The territorial impact of transportation, in terms of utilization, is considerable. An elevated percentage of urban land is usually dedicated to transport infrastructures. This land consumption highlights the importance of transportation in the economic and social well-being of cities.

Traffic flows produce a bad use of public space influencing the life and relations of people and their possibility to use public space. People be inclined to walk and use bicycle less when traffic in urban areas is higher.

Many dimensions to the urban transport problem, as described above, are linked with the dominance of the automobile. The choice of automobile is linked to a variety of advantages such as comfort, speed, and convenience. The consequence of these benefits is that the number of cars in circulation is constantly increasing, and this phenomenon creates problems in particular in urban areas as a generator/attractor of movements.

3. The “ideal” city

“Real” cities all over Europe confirm similar problems in transport (congestion, road safety, security, pollution, climate change due to CO₂ emissions etc.) and these problems are increasing constantly. This situation shows a future scenario where people having to pay an higher price not only in economic and environmental terms, but also as health and quality of life. For this reason is important that urban transport policies present themselves as objective an “ideal” city where the problems related to transport could be reduced or even better removed.

To achieve this objective would be important to consider five main characteristics referred to an “ideal” urban mobility: free-flowing town, greener cities, smarter transport, wide accessibility, safe and secure travel.

Free-flowing town

Increasing traffic in urban areas leads to permanent congestion. This has negative economic, social and environmental impacts and degrades the built environment. The annual costs are estimated at almost 100 billion Euro or 1% of the European Union's GDP⁴.

In an “Ideal” city a fluid, correctly functioning transport system allows people a time-saving and a reduction of CO₂ emissions.

There is no only a single solution to reduce congestion. In an “Ideal” city, for instance, collective transport, walking, cycling, could be attractive and safe. Interchange between different modes of transport should be easy. Possible solutions range from improvement of connections between modes, application of innovative and transport solutions, good parking facilities in suburbs, carpooling and car-sharing.

Greener cities

The main environmental issues in towns and cities stem from the domination of oil as a transport fuel, which generates CO₂ and air pollutant emissions. Air and noise pollution are increasingly worrying. Urban mobility accounts for 40% of all CO₂ emissions of road transport and up to 70% of other pollutants from road transport ⁵. These have a negative impact on citizens’ health.

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“Ideal” city would develop new and clean technologies for energy efficiency and alternative fuels accompanied by traffic restrictions and green areas (pedestrian spaces, limited access zones, speed limits, etc).

Smarter transport
In “Real” cities there is a permanent increase of freight and passenger transport fluxes. At the same time, the construction of new infrastructure to cope with this increase in traffic is often hindered by limitations related to lack of space and environmental constraints.
In an “ideal” city Intelligent Transport Systems (ITS) and urban traffic management could be an added value for an efficient organization of urban mobility. A possible solution is given by implementations of systems for better traveller information and ITS applications in towns and cities.

Wide accessibility
People needs more intelligent and high quality mobility solutions, and require accessible collective transport.
The “ideal” city would be solve this problem through new solutions for high quality public transport, new intermodal terminals, and excellent links between suburban and urban transport networks.
The objective is to reach performance's efficiency, energy efficiency, quality of service and reduction of "discontinuity" compared to private vehicles: public transport is will have wide accessibility in territory because available in many access points, with a period service not limited, and more free routes.

Safe and secure travel
About two-thirds of road accidents and one-third of road fatalities takes place in urban areas with the most vulnerable road users being pedestrians and cyclists. In order to improve this situation, possible solutions in an “ideal” city this problem could be solved having strict enforcement of traffic rules concrete application of traffic rules.
If people perceive an high personal security are inducted to travel using alternative transport services, having as a consequence a reduction in use of private car.

4. “Innovative” and “unconventional” transport systems
What could be the way to reach the objective of an “ideal” transport (in an “ideal” city) in the real world?
One possible solution is given by development of new technology for a more sustainable use of the world’s resources. The technology currently being developed is in many cases aimed at facilitating a sustainable development using the latest applications in information and communication technology and in vehicle and fuel technology.
In the interest of sustainable mobility the "ideal" transport in an urban area should focus on public transport.
Despite cars have become fuel-efficient and the amount of emissions has dropped significantly, the use of private vehicles produce other consequences related to the probable congestion, as the cost of time loss.

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“Ideal” public transport takes into account performance's efficiency, energy efficiency, quality of service and reduction of differences compared to private vehicles (“discontinuity”): “ideal” public transport has a huge accessibility in territory, an unlimited service frequency and more free routes.

The reduction of these discontinuities is the principle underlying the new collective transport systems (innovative systems and unconventional systems): they are characterized by a high level of automation, and by technological features with high quality to achieve high level of energy efficiency and high performance even in terms of environmental sustainability.

An important aspect of technological development in the transport sector is that construction and operation of transportation systems is being transformed by computers, sensors, and communications technology, usually called information technology (IT)\(^8\).

The application of IT to transportation is called “Intelligent Transport Systems” (ITS). ITS have the ability to collect, organize, analyze, use, and share information about transportation systems. This new technological ability is essential for the efficiency of transportation systems.

ITS can be installed as part of the transportation infrastructure to: collect and distribute traveller information, control traffic signals and variable message signs and help manage the system. ITS also provides a wide array of in-vehicle technology to improve safety, productivity, and comfort of road travel.

ITS can be use inside infrastructure and vehicle of new transport systems to improve their performances and to reach the objective of reduce emissions, energy consumption, and discontinuities.

There are many examples of innovative and unconventional transport systems using ITS technologies that are characterize from a fixed guideways and full automation.

Several new systems generally classified as Automated guideway transit (AGT), have been developed and are in service, under test, or are conceptualized to solve specific transportation critic aspects.

Typical AGT consist in systems with variable capacity, fully automated, driverless, grade-separated, in which vehicles are automatically guided along a guideway.

Representative examples of this class of systems are Personal Rapid Transit (PRT) and Group Rapid Transit (GRT), People Mover, and Accelerating Moving Walkways.

Development and improvement of these systems could be the way to reach the concept of “ideal” transport.

**Personal Rapid Transit Systems (PRT)**

PRT is one of the most energy efficient urban transit system that has been designed.

PRT consists of small 2 or 4 passenger vehicles running on elevated guideways under computer control without human driver and with a speed of 40-60 km/h. The vehicles are electric and take power from electric contacts in the guideway.

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\(^8\) Information and communications technology (ICT) is often used as an extended synonym for information technology (IT) that underline the integration of telecommunication, intelligent management systems and audio-visual technologies. IT consists of all technical means used to handle information and aid communication. In other words, ICT consists of IT based on control and monitoring functions.
These vehicles are small because they are designed for a limited number of passengers, and consequently infrastructure (guideways and stations) require little space. Computers control the entire systems and for this reason is impossible to have congestions.

Stations are adjacent to the main lines, and travel is non-stop to the destination chosen by the passenger. Vehicles wait at stations for passengers to arrive and there are no schedules or fixed routes. Passengers decide their destination, and the system brings them there without intermediate stops. PRT guideways can be built underground or over the streets supported by posts on the sidewalk. Computers find the best path to each destination and decide the safe distance between vehicles. Guideways cross each other at different heights.

Comparing PRT to other systems is notable that:

- system use 4 time less energy than automobile;
- is 3-5 times faster than bases and 2-3 times faster than cars in rush hours;
- automation allows an high level of safe;
- one guideway lane has 4 times the passengers capacity of a street lane with traffic lights;
- 0,02% of land use compared to 30% for private vehicles;
- A factor of 100 less noise than cars, buses, and trains.

Group Rapid Transit Systems (GRT)

Group Rapid Transit (GRT) is a form of collective public transport using small automated electric “buses” (maximum capacity 24 passengers) to provide on demand service and shuttle services connecting different terminals placed in strategic points.

To use the system, passenger presses a button at the stop to call the vehicle and then another on the vehicle to select the destination. The automatic bus arrive and then go directly to the selected destination unless called by other users to pick up or set down along the way. This guarantees waiting times are shorter and vehicles are only used when there is a demand. Scheduled services are also possible to optimise capacity during periods of high demand.

GRT provide:

- a flexible alternative to bus schemes;
- highly efficient operation because operate when there is a demand;
- low operating costs compared to typical bus or tram;
- simple accessible services;
- low waiting times;
- automated, electric and quiet vehicle provide a pollution reduction.

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9 Source: http://www.personalrapidtransit.com/
10 Source: http://www.niches-transport.org/
Automated People Mover

An Automated People Mover (APM) is public transport system, which consists of vehicles that have automatic (driverless) guide system and use dedicated guideways. The term is applied to different systems, developed about at the same time. The term "people mover" is generic, and may use technologies such as monorail, automated guideway transit or maglev. Propulsion may involve conventional on-board electric motors, linear motors or cable traction.

APM are usually in the form of trains consisting of one or more vehicles. Each train operates on a single route that can have intermediate stations. The system capacity ranges from 1000 to 30.000 p/h/d.

APM and PRT systems have many features which are similar. They are both systems featuring automatic vehicles running on segregated track, which may be at-grade, underground, or elevated and both have a series of dedicated stations.

However the nature of the transport service offered differs a lot.

Accelerating Moving Walkway

An Accelerating Moving Walkway\(^\text{11}\) (AMW) is a system that constantly moves passengers: system has an acceleration from a low speed at the entrance point to a higher speed at the mid-sector of the walkway, and then has a deceleration to a low speed again at the exit point. AMW has no waiting time, unless the capacity of the system is exceeded.

Actual moving walkways are providing transport along straight lines. However, there have been developments of spiral escalators and curved moving walkways. The high-speed sector of AMW has speed ranging between 1,3 and 3,3 m/s. The entry and exit speeds are the same and are between 0,5 and 0,83 m/s. Taking the common treadway width of 1 m a moving walkway can have a theoretical capacity between 9.000 and 15.000 p/h/d. The environmental impacts of AMW are relatively low. There is no local pollution because is powered electrically and the noise level is low, particularly in systems with a rubber- belt treadway. The characteristics of systems described above are compared in Table 1.

<table>
<thead>
<tr>
<th></th>
<th>Average Speed (km/h)</th>
<th>System Capacity (p/h/d)</th>
<th>Corridor width (m)</th>
<th>Headway (s)</th>
<th>Noise level (dB)</th>
<th>Energy use (MJ/pax km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRT</td>
<td>20-25</td>
<td>1.800-7.200</td>
<td>4-5</td>
<td>5-30</td>
<td>35-65</td>
<td>0.55</td>
</tr>
<tr>
<td>GRT</td>
<td>40</td>
<td>3.000-15.000</td>
<td>6</td>
<td>15</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>APM</td>
<td>15-50</td>
<td>1.000-30.000</td>
<td>4,4-6,5</td>
<td>60-180</td>
<td>54-72</td>
<td>1,62-12,78</td>
</tr>
<tr>
<td>AMW</td>
<td>4,75-12</td>
<td>9.000-15.000</td>
<td>2,5-4,7</td>
<td>0</td>
<td>54</td>
<td>0,11</td>
</tr>
</tbody>
</table>

Table 1. Main features of the transport systems described

\(^\text{11}\) Source: Sreejith P., Accelerating Moving walkway - An in depth analysis of pros and cons of Accelerating moving walkway, 2010
5. **Best practices in transport innovation for an ideal city**

**Masdar City PRT**

Masdar City\(^{12}\) will be one of the most sustainable cities in the world. Situated 17km from Abu Dhabi, the city will have 40,000 residents and hundreds of businesses and will use only renewable energy and sustainability technologies. In Masdar, a network of PRT will provide clean and quiet transportation to the city's residents, as well as commuters. In addition to the PRT system in Masdar City there will be a light rail, which will cross the city. Masdar City's PRT system will have no rush hour congestion. When the computer perceives that the network is approaching full capacity, will not allow cars to leave stations. Generally waiting time is no more than a three minutes at a station.

The PRT vehicles will travel at speeds of approximately 25 km/h, with the longest routes in the city being perhaps 2.5km. PRT cars will move along rights of way, approximately 6 meters under street level.

**GRT in Rotterdam: ParkShuttle**

ParkShuttle is an automated system of driverless electric buses connecting the Kralingse Zoom metro station and car park with the Rivium business park\(^ {13}\). The system became fully operational in early 2006. It uses 6 buses, each with seats for 12 and a maximum capacity (including standing passengers) for 24. The vehicles are electric and provide clean, green, efficient and sustainable public transport with low waiting times (1.5 to 3 minutes on average).

System infrastructure was built at ground-level to reduce costs. The infrastructure consists of a simple, 3 meter wide asphalt track. The distance between Kralingse Zoom metro station and Rivium business park is about 1.200 meters. The track is not fully separated. The only separation consists of a one meter high fence and a greenzone with bushes. Start up costs are more expensive than for a conventional bus scheme, but the operating costs are less.

**People Mover in Venice**

This project\(^ {14}\) was created to meet a specific need of residents and visitors, within a context of rethinking Venice's main access points. System links three poorly-connected areas: “Piazzale Roma” (bus and ferries terminal), “Tronchetto” (the main parking area of Venice) and the “Marittima” station (harbour area). The need was connect them, because these locations are strategic access points. The adopted solution was the fully-automatic, driverless APM system that connects Piazzale Roma and Tronchetto with an intermediate stop in the Marittima station.

The length is 822 m and is a monorail built at an average height of 7 metres, along which shuttle-trains run at a top speed of 28 km/h. Each train can carry up to 200 passengers, thus giving a maximum 3.000 pax/h capacity. The trains use rubber tyres to guarantee minimal noise. The infrastructure is completed by three stations with steel and transparent glass architectural solution.

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\(^{13}\) Source: [http://www.2getthere.eu/](http://www.2getthere.eu/)

\(^{14}\) Source: [www.apmvenezia.com/](http://www.apmvenezia.com/)
Moving Walkways in Hong Kong: Central-Mid-Levels escalator

The Central–Mid-levels escalators\(^1\) in Hong Kong is the longest outdoor covered escalator system in the world. The entire system covers more than 800 metres in distance and elevates over 135 metres from bottom to top. It was constructed in 1993 to provide a better commute by linking Central and Western District on Hong Kong Island.

It links Des Voeux Road in Central with Conduit Road in the Mid-levels, passing through narrow streets. The daily traffic exceeds 55,000 people, although originally estimate 27,000.

It consists of twenty escalators and three moving side-walks. The total travel time is twenty minutes. Considering the particular geographical situation, the same distance corresponding to several kilometres of roads if travelling by car.

Apart from serving as a method of transporting, it is also a tourist attraction and has restaurants, bars, and shops along the path with a point for entrance/exit on each road it passes.

6. Conclusions

Pollution and congestion are between the most challenging issues of the economy of our days. A long series of policies and recommendations at various administrative levels were developed to reduce their impact.

It is well-known that the current automobile-based transportation contributes actively to both these causes and that a encouraging modal split towards transit may help to lessen the external costs induced from urban mobility.

This paper has dealt with the main features of “ideal” public transport and has described the features and the implementation of some real less impacting transportation systems.

Among the proposed systems APM have the highest hourly capacity and speed. Their visual impact on the area is certainly significant if built over the streets supported by posts, but is lower if designed underground. Also the noise impact and energy consumption are lower than those of a private vehicle.

In an “ideal” city, a transport system with these characteristics would be suitable for commuting between suburbs and central areas: interchange park areas located far from the center (thus with lesser impact on the territory compared to central areas) would swap between private electric vehicles and APM systems, allowing users to reach the city center in a very short time (considering system automation and the potential headway), hereby radically reducing congestion impacts.

An “ideal” transit service in the city centers can be provided by GRT and PRT systems.

The operating principle of these two systems is very similar: they reduce significantly time and space “discontinuities” typical of the most common public transport systems (bus, metro, tram). Noise and visual impacts are lower than the APM systems. Impacts are significant if built over the streets supported by posts, but are lower if designed underground.

The increased safety for vulnerable users is a consequence of the movement in its own fix guideway.

Congestion reduction resulting from the use of such systems are two key elements that produce positive effects on pedestrian and bicycle mobility and a better use of public space.

The choice between a PRT or GRT for the management of mobility in urban areas is linked to the results of feasibility and demand analyses.

\(^1\) Source: “Hong Kong’s Central-Mid Levels Escalator - The Longest in the World”, Rory Boland.
AMW systems are particularly suitable planning an “ideal” transport system for travel within the historic city centers. The historical centers of the cities of ancient formation are essential elements in the reasoning about the “ideal” city: they represent an heritage to preserve and are usually great points of attraction where many activities are located. Because of their shape and constraints, the management of public transport within them is often complex.

AMW systems were likely to be ideal for the management of travel in the city centers: they have an high capacity, a very low noise impact and a low energy consumption (the lowest among the systems analyzed in this study). The visual impact is minimal because the system can be realized on the ground level. Infrastructure, system and access points have compact size and are therefore well adapted to complex urban structures.

These systems optimize the use of public space and produce a positive effect on pedestrian and bicycle mobility. These rows show that such systems may provide a solution to the problem tackled above and that their implementation may be promising within transportation planning.

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