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New Transit Technologies: An Objective Analysis is Overdue

Vukan R. Vuchic  
University of Pennsylvania, vuchic@seas.upenn.edu

Richard M. Stanger

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Abstract
New urban transit systems incorporating inefficient and obsolete technical features are being promoted, discussed and funded. Typically they involve automatic operation with rubber tyre guidance; rail systems which are clearly superior are concurrently ignored. Dr. Vukan R. Vuchic of the University of Pennsylvania and Richard M. Stanger of the Metropolitan Atlanta Rapid Transit Authority urge transit planners, operators and equipment manufacturers to exploit the great potential of rail technology rather than pursuing innovation for its own sake.

Disciplines
Engineering | Systems Engineering | Transportation Engineering
New systems challenge
New transit technologies: an objective analysis is overdue

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There is little doubt that the bus operating on streets with mixed traffic will remain the optimal mode on low volume routes. Similarly, for heavily travelled routes rail rapid transit remains without rational competition. However, there is a gap between low-investment low-capacity surface bus and high-investment high-capacity rapid transit.

Virtually all medium size cities and many lines in large cities require a mode which offers a considerably higher service quality (speed, reliability, comfort, capacity) than the bus can ever provide, but at substantially lower investment cost than full rapid transit.

The only cities which presently have such systems are those which have upgraded their street tramways into modern light rail transit (LRT) systems operating mostly on exclusive rights-of-way. Good examples are found in central Europe (Hannover, Köln, Goteborg, Rotterdam); others are under development (Boston and San Francisco in the US, Newcastle in Britain).

While LRT has—until very recently—been virtually ignored, a great number of new transit modes have not only received attention in professional literature, but have also attracted government funds for research and development in several countries. What potential in urban transport do these new systems really have, as compared to modern versions of conventional technologies such as LRT?

Proved systems neglected

All conventional transit modes have been neglected. On the other hand, numerous new modes incorporating various combinations of many unconventional concepts are often promoted vigorously by persons foreign to urban transport. In developing these systems, concepts of operation are often confused with technology; design ‘innovations’ are suggested to improve deficiencies of existing modes caused by inadequate financing and other factors totally unrelated to their technical features. Thus, personal rapid transit (PRT) promotion usually specifies that vehicles would be air-conditioned, while the possibility of accommodating the handicapped and elderly is quoted as a major advantage of bi-modal systems!

For a new transport concept or technology to be accepted, it must be

How important are the methods of support and guidance? Above left: The VAL test track near Lille combines rubber tyres and automation, but Frankfurt’s reserved-track tram (right) running into the metro may do the same job better and cheaper.

*The views of Mr. Stanger expressed in this article are not necessarily those of the Metropolitan Atlanta Rapid Transit Authority.
superior or at least equal to a conventional mode of the latest design. Since existing modes are quite sophisticated, innovative modes should combine some necessary new features along with conventional features which need no further improvement.

Most of the new modes proposed, however, are based on a different approach: they incorporate numerous unconventional features — including some improvements — together with features which represent an obvious regression from conventional modes. A particularly strong fashion at this time is to develop fixed guideway systems using rubber-tyred wheels for support and guidance. The extremely limited advantages of pneumatic tyres (ability to negotiate higher grades, less noise in curves) in comparison with their disadvantages (higher cost and complexity of guideway and vehicle, slow switching, higher energy consumption, loss of adhesion in bad weather) pass unnoticed because the new systems are presented without comparison with existing ones.

Many proposed systems are later modified through the introduction of some conventional features. For example, the Westinghouse Transit Expressway was initially proposed as a system operating entirely on-call with variable train composition. Now, fixed-schedule operation is becoming recognised as superior. Many small-cabin PRT systems were enlarged once they were designed for specific applications.

**VAL system**

The VAL system proposed for Lille, consisting of 132 m long two-axle automated vehicles on rubber tyres, is typical of these new systems. Since this system, described in RG January 1974, 1) is intended to provide service for which LRT would be ideally suited, it is logical to compare them. According to the developer’s prospectus 2), the basic objectives in the development of the VAL system were to provide:

1. Service with a commercial (overall average) speed of 40 km/h;
2. Transport capacity of 2000 to 15 000 persons/hour in each direction;
3. Fully automatic operation;
4. High quality of ride;
5. High frequency (1 min headways at the minimum).

While the first four are logical requirements for cities with populations between 200 000 and 1 500 000, the last objective is certainly debatable. High frequency of service may be needed when vehicles leaving a station go to different lines or stop at different stations, but when all vehicles serve a single line, as proposed for VAL, operating two-vehicle trains at 1 min intervals would not be a sound policy.

Optimal frequency of service is determined by the trade-off between passenger waiting time and the cost of system construction and operation. As Fig. 1 shows, passenger waiting time (which can be considered as a form of user cost) decreases with frequency, but at a decreasing rate. Thus, by reducing intervals from 2 to 1 min, the average waiting time is decreased by only 30 sec which is quite insignificant.

On the other hand, operational experience in transit shows that with increasing frequencies both complexity of control and operational difficulties increase exponentially. This is particularly the case when frequencies approach 30 to 40 trains/hour; stability of service is reduced, delays propagate rapidly, speed and quality of service suffer. The cost of automatic control not only increases sharply, but it is questionable whether such technology exists today. Experience with rapid transit, as well as with Airtrans at Dallas-Fort Worth airport and the Morgantown system, indicates that control of a system like VAL is not presently feasible.

**System design**

It is reported 3) that VAL was developed through a systematic parametric analysis of functional requirements and component characteristics; in other words, from scratch. Also typical, no indication is given that existing modes were studied, or used at least for a comparison of costs, performance and service quality. Consequently, the VAL system incorporates some advanced concepts as well as features greatly

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**Table I. Technical characteristics of VAL and LRT options. Data for VAL are from references 1, 2 and 3, and for LRT from reference 5 and specifications for new ACEC and Boeing LRT vehicles**

<table>
<thead>
<tr>
<th>Item</th>
<th>VAL</th>
<th>LRT 4-axle</th>
<th>LRT 6-axle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (m)</td>
<td>13-20</td>
<td>14-2</td>
<td>21-2</td>
</tr>
<tr>
<td>Width (m)</td>
<td>2-05</td>
<td>2-2</td>
<td>2-2</td>
</tr>
<tr>
<td>Doors, number</td>
<td>four</td>
<td>two-three</td>
<td>four</td>
</tr>
<tr>
<td>width (m)</td>
<td>31</td>
<td>1-3</td>
<td>1-3</td>
</tr>
<tr>
<td>Number of seats</td>
<td>53</td>
<td>110</td>
<td>158</td>
</tr>
<tr>
<td>Total capacity</td>
<td>2</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Number of axles</td>
<td>8</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>Number of wheels</td>
<td>11-0</td>
<td>15-2</td>
<td>28-5</td>
</tr>
<tr>
<td>Net weight (tonnes)</td>
<td>0-208</td>
<td>0-138</td>
<td>0-180</td>
</tr>
<tr>
<td>Net weight/passenger (tonnes)</td>
<td>22-5</td>
<td>22-5</td>
<td>38-6</td>
</tr>
<tr>
<td>Gross weight (tonnes)</td>
<td>15-5</td>
<td>15-5</td>
<td>7-4</td>
</tr>
<tr>
<td>Axle load (tonnes)</td>
<td>7-75</td>
<td>7-75</td>
<td>7-75</td>
</tr>
<tr>
<td>Speed (km/h)</td>
<td>1-3</td>
<td>1-3</td>
<td>1-3</td>
</tr>
<tr>
<td>Acceleration (m/s²)</td>
<td>1-5</td>
<td>1-5</td>
<td>1-5</td>
</tr>
<tr>
<td>Viaduct width (m)</td>
<td>6</td>
<td>6-7</td>
<td>6-7-5</td>
</tr>
<tr>
<td>Minimum radius (m)</td>
<td>40</td>
<td>50*</td>
<td>40-13*</td>
</tr>
<tr>
<td>Maximum gradient (per cent)</td>
<td>10</td>
<td>10*</td>
<td>9*</td>
</tr>
</tbody>
</table>

* Possible on existing routes but not recommended for new lines

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**TOTAL COST (SYSTEM PLUS USER)**

**BELLOW:** Fig. 1. As the service frequency increases beyond about 30 trains/h, system costs rise faster than user costs fall because very small savings in travel time do not justify the much higher level of investment in automation and signalling.

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vent loss of adhesion in inclement weather. Experience in Morgantown has shown this to be a very expensive proposition.

It is obvious that, since very short intervals are not really needed for the operation which VAL provides, the only advantage of rubber tyres remains the ability to climb 10 per cent grades with greater facility than LRT vehicles. The significance of this feature is negligible compared with the lower cost, and the greater reliability, simplicity and riding comfort of modern rail technology.

**System comparison**

It is interesting to make a systematic comparison of VAL with a modern LRT system which would be adopted to meet the same objective, and have the same basic service features as VAL. For this purpose one could use either a four- or six-axle articulated vehicle, and either of these could operate singly or as a multi-vehicle train. It is entirely possible without any technical breakthrough to build LRT vehicles with a maximum seating arrangement, any desired number of doors, and to negotiate tighter curves (due to the use of two-axle bogies) than VAL.

The basic features of VAL taken from references 1, 2 and 3, and two possible choices of LRT vehicle types from reference 4 are given in Table I.

Different transit systems can be compared correctly only if all of their aspects affecting passengers, operator and the community-at-large are considered. The methodology for this is explained and definitions of items are given in reference 5. Each of the items is briefly discussed below and the VAL and LRT systems are evaluated with respect to it:

**Availability:** since both modes would serve the same line and stop at all stations, their availability would be the same.

**Reliability of service:** measured by schedule adherence and immunity to breakdowns, inclement weather, etc. Exclusive right-of-way would guarantee high reliability of both modes, but, due to its simplicity, much longer operational experience and ability to operate well under all weather conditions, LRT would be significantly superior.

**Frequency of service:** could always be the same for the two modes, ensuring that VAL might offer higher frequency at very high passenger volumes. But this would not be desirable, and probably not physically possible. Furthermore, frequency maxima are determined in large part by the limits of control technology, which would affect both systems similarly.

**Operating speed:** as Table I shows, LRT can provide higher acceleration, maximum speed and deceleration values than VAL, so that the better adhesion of VAL does not represent an advantage. In addition, boarding and alighting would be faster for LRT because of much greater space for passenger circulation in vehicles.

**Comfort:** various options in vehicle design permit provision of the same number of seats by different train compositions of both systems. Physical comfort of sitting in transverse seats or standing in bogie-supported rail vehicles would be substantially superior to sitting in longitudinal seats in two-axle VAL vehicles.

**Safety and security:** comparable, assuming mechanical design of VAL is satisfactory.

**Operating cost:** although no cost data could be found for VAL, the great complexity of its guideway and vehicles would involve higher operating and investment costs than would LRT. This advantage of LRT would only be slightly reduced when extensive use of steeper gradients for VAL could make its alignment cheaper. Mechanical feasibility of 40 m minimum radius curves claimed for VAL is, however, questionable due to its extremely long wheelbase (10-7 m). Due to the much higher rolling resistance of rubber tyres and greater weight per passenger on VAL, its power consumption and energy costs would be substantially higher. Also, maintenance of the more complicated vehicles, switches and guideway would make VAL operating costs higher than those for LRT.

**Capacity:** due to their better design and utilisation of vehicle length, LRT vehicles have a substantially greater capacity per metre of vehicle length. Thus, one 21-m articulated LRT vehicle has the same capacity as a 39-m long three-car VAL train! For any given conditions LRT can supply approximately twice the capacity of VAL.

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**References**

2. MATRA, 'VAL: Métro à Véhicules Automatique Légers', a technical prospectus.
4. Also, presented to the OECD, Sector Group on Urban Environment, April 21, 1973.

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Side effects: These include aesthetics, air pollution and noise. The use of third rail by LRT instead of overhead catenary could eliminate this obtrusion. The depth of the VAL's guidance channel increases slightly the profile of its structure above that of LRT. Neither vehicle produces any air pollution nor any appreciable noise, but VAL may be slightly quieter. Thus, differences are minor and both systems are considered equal in this respect.

This comparison of individual characteristics clearly shows the inferiority of the VAL system to LRT. VAL's minor advantages in better negotiation of grades, less noise in curves and a few others are negligible in comparison with the LRT advantages in lower cost, higher reliability, capacity, comfort and so on. Even the narrower body of VAL, implied as an advantage, is actually a major disadvantage, since it drastically reduces vehicle capacity and increases relative weight without reducing guideway width.

Since most of the differences between the two systems are inherent in their technologies and operational concepts, most conclusions of this analysis would be valid for any application of the two systems. Consequently, it is not likely that VAL would be superior to LRT for any type of application.

Although other medium capacity automated rapid transit systems—so-called people movers—differ from VAL in various technical and operational concepts, it can be shown by a similar analysis that they, too, are generally inferior to the LRT concept. Most of the advantages claimed for new systems, such as higher proportion of seating, air-conditioning, full automation, and so on are totally independent of the guideway technology. They could actually be achieved more effectively by LRT, which already has a vastly superior guidance mechanism.

**Misdirected effort**

A logical question is how is it possible that there is such a strong misdirection of industry, academic and government resources to highly questionable concepts, while a viable, proved concept of rail technology is so badly neglected? How can 'fashion' without rational support be stronger than professional expertise, facts and experience?

There are several causes of this confusion, which is causing serious delay to the provision of much needed transit improvements in cities. One is that the opponents of transit modernisation have focused their efforts on discrediting the most efficient modes for medium and heavy volume lines—those using rail technology. Irrational claims that 'rail is obsolete' have been accepted by those who are unaware of modern achievements in rail technology.

Another reason is that many industries without experience in transit systems have been active in designing new concepts, while transit operators and rail vehicle manufacturers have been rather passive, showing little interest in major innovations. For example, there is an extreme skepticism among operators toward full automation of rail systems. London and Hamburg are notable exceptions. In addition, transport professionals have seldom come out with scientific evaluations of modes which would greatly help in determining the proper direction for further modernisation and innovation in transit.

While there are strong arguments to support the claim that no unconventional fixed guideway system has so far been developed which is superior to rail technology overall, the pressure exerted by new systems, however illogical, is valuable in one sense: the new systems have emphasised the need and potential for several important innovations. They could in several ways breathe new ideas into existing public transport which for too long was slow to react to a changing world. These innovations, if combined with the best forms of guidance, propulsion, vehicle body design and type of operation, would bring significant advances in transit performance. Specifically, it appears highly appropriate that research and development be undertaken into the following aspects of rail systems:

- **Full automation for LRT:** this would only be applicable on fully segregated routes;
- **Smaller rail vehicles** for higher frequency service on medium-volume routes when full automation does become operational;
- **Reducing the cost of construction and operation**;
- **Reducing vehicle weight** with consequent lower energy consumption, lower noise and so on.

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**Novelles technologies relatives aux transports: une analyse objective s'impose!—De nouveaux systèmes de transport où l'on remarque côté à côté certains concepts d'avant-garde et des caractéristiques techniques non seulement périphériques mais aussi inefficaces sont actuellement élaborés, discutés et financés. D'une manière typique, ils font appel au fonctionnement automatisé avec guidage automatisé des pneus, à la conception de véhicules étroits et à la disposition longitudinale des sièges; alors que des systèmes de chemins de fer qui présentent un caractère nettement supérieur et qui font preuve d'excellentes performances se trouvent totalement négligés. Dr. Vukan R. Vuchic de l'Université de Pennsylvanie et Richard M. Stanger de Metropolitan Atlanta Rapid Transit Authority demandent instamment aux planificateurs, compagnies d'exploitation des réseaux de transport, et fabricants d'équipement d'exploiter l'énorme potentiel sur le plan perfectionnement que présente la technologie des chemins de fer dans le domaine urbain plutôt que d'innover pour innover.

**Nuevoas tecnologías de transporte: se ha necesitado largamente un análisis objetivo—Al presente se promueven, discuten y financian nuevos sistemas de transporte que incorporan algunos conceptos avanzados juntamente con características técnicas anticuadas. Típico de esto es la inclusión de un funcionamiento automático con control de neumático automático, vehículos estrechos y asientos longitudinales; los sistemas de ferrocarril que son claramente superiores y que han prestado un funcionamiento excelente son en la actualidad ignorados. El Dr. Vukan R. Vuchic, de la Universidad de Pensilvania, y Richard M. Stanger, del Metropolitan Atlanta Rapid Transit Authority, han urgido a planificadores de transporte, a empresarios y fabricantes de equipo a la explotación del inmenso potencial para un desarrollo mayor de la tecnología del ferrocarril en el campo urbano, más que a la búsqueda de innovaciones nada más que por la innovación misma.**