Operational requirements for new transit technology

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INTRODUCTION

Urban planning in North American cities over the last 5 to 10 years has been characterized by a strong interest in improving the quality of public transportation. This renewal of interest in public transit reflects changes in both community and governmental attitudes toward the increasing dependence on the private automobile that dominated urban planning in the postwar era. As a consequence, proposals have been produced in many North American cities for substantial investment in more extensive networks of high quality transit. In many cases, these proposals are intended to achieve land use objectives and influence the pattern of urban growth, rather than simply respond to a projected transportation problem.

Interest in public transit has been paralleled by increasing recognition of the financial difficulty of providing expanded transit service in lower density areas and in providing adequate service in high- and medium-density travel corridors. This is particularly true where new transit facilities are proposed in order to support land use objectives, but where demand levels fall below those that have traditionally been served by rapid transit.

The need for improved coverage of the urban area and for a high standard of transit service in medium-density corridors suggests a range of travel volumes that cannot be served adequately by surface bus or streetcar or economically by underground rapid transit. This has led to renewed interest in Light Rail Transit and busways and to the concept of Intermediate Capacity Transit Systems (ICTS), designed to provide a higher level of transit service than is possible with surface systems, but at costs that are substantially lower than conventional subways. Most new development work in the transit field in the last several years has been in this area of mediumcapacity transit systems. Perhaps the most difficult design requirement of these systems is the need for exclusive right-of-way in developed areas. Development of new systems in the medium-capacity range is severely constrained by the fact that they must be acceptable from visual, environmental, and social points-of-view, a fact which has not been given priority by developers of many new systems.

Application of medium-capacity transit in major metropolitan centres involves networks of high-quality service on "trunk" lines or on feeder routes to higher capacity, conventional subway lines. For smaller communities where demand levels do not justify subway construction, these services may serve as the backbone of the transit system. In addition, mediumcapacity transit can serve a special-purpose function such as ensuring high levels of accessibility to major activity centres such as airports or new regional sub-centres.

Another important application may be the use of parallel facilities or services to provide capacity comparable to that of a single subway line at similar total cost. For example, two parallel lines may provide better overall coverage and lower access times and distribution costs than a single, conventional rapid transit line. The lower costs of individual medium-capacity lines would be achieved through less stringent right-of-way and guideway requirements.

In summary, most new developments in medium-capacity transit have been in response to a perceived need for high-quality transit services in a capacity range that matches land use objectives, and at costs that are significantly lower than those of conventional rapid transit systems. These developments must be acceptable from a community point-of-view, and must offer economical operation over a range of demand that cannot be economically handled by conventional rapid transit, or adequately handled by existing surface systems. In Canada, the cities of Toronto, Ottawa, Hamilton, Calgary, Edmonton and Vancouver are now in the process of responding to or planning for requirements in this range.

Much of the recent interest in technological innovation in the urban transit field has centred on medium-capacity transit. However, there have been few successful applications of new systems and the thesis which this paper proposes is that transit technology to meet current development objectives in urban areas will be successful only if a clear statement of performance requirements is defined from the perspective of a transit operator and urban planner, rather than a system engineer or system designer.

PROBLEMS IN TECHNOLOGICAL INNOVATION

The current interest in improved public transit has generated considerable activity in the field of technological innovation. Most development work has been directly, or indirectly, sponsored by government agencies in Europe, the United States, and Canada. In spite of extensive development effort there has been very limited implementation of new types of transit systems. Unlike other fields requiring technological innovation, such as the military, space research, or process control, most transit research programs have concentrated on technical solutions, with little emphasis on careful definition of the operating problem. Consequently, many new concepts for transit improvement have emerged which have achieved little or no market acceptability among the municipal officials and transit operators who would ultimately implement and operate them.

There are several reasons for this. First, technological innovation in the transportation field has tended to occur only when there has been a profit incentive. As a result, in marine transportation we have seen the advent of containerization, and larger, more specialized ships, because it made economic sense to move in that direction; in the field of aviation, we have seen technological innovation because of the commercial viability and marketability of particular advances.

By contrast, technological innovation in railway passenger services and urban transit has been almost nonexistent because there is little or no profit incentive to be derived from services that are generally characterized by deficit operation and are extended or re-equipped rather infrequently.

As a result, much of the so-called innovation has occured outside the traditional sources of equipment supply for the transit industry and much of it at government request or sponsorship. In most cases, the product simply has not responded to any real requirement of urban planners and transit operators and has not accounted for the realities of operating conditions, consumer proferences and community values. In fact, many unsuccessful development efforts have involved entire transit systems designed around a novel idea for suspension, propulsion, control or passenger service without sufficient consideration of the viability of these ideas in the transit market-place. Ideas or designs searching for an application are rarely an ideal match to any existing need. For example, during the "heady" atmosphere that characterized support for technological innovation during the 1960's, proposals for elevated "mono-rail" systems abounded; these proposals almost totally ignored one of the most fundamental concerns of transit operators – namely, the evacuation of passengers in case of emergency or break-down.

Second, many of the attempts to develop new urban transit technology have failed to understand the political and institutional constraints which impede technological innovation in the public arena.

At the general level, there may be considerable interest in development of new systems, but once proposals are made for specific applications, almost everyone is afraid to make the first mistake. Most elected officials and transit operators would rather be safe than daring. In the end, given a choice, they will almost always decide against major technological innovation in favour of more conventional, incremental solutions on grounds of system compatibility and "proven" reliability.

A third problem relates to the tendency amongst innovative "systems designers" to display more interest in sophisticated solutions (due to their presumption of high service standards) and less interest in some rather simple things that imply modest performance, but are relatively easy to achieve and could go a long way to improving the low quality of public transit service that now exists in suburban areas. In fact, because so much of the recent history of urban transportation is littered with the wreckage of ill-conceived transport technology, a back-lash against innovative, system solutions has led to renewed interest in technology that is basically "off-the-shelf". In many North American cities, for example, there is now considerable enthusiasm for new Light Rail Transit lines which emerged from disillusionment with air cushion vehicles, magnetic levitation, linear induction propulsion and highly automated, small-vehicle technology which characterized the personal rapid transit (PRT) era. Even in the case of interurban services and after years of assessing technology that included gravity vacuum tubes and tracked air cushion vehicles, it was finally concluded that it just might be "best" to run conventional railway equipment between Boston and New York at speeds slightly higher than the 40 miles per hour that is characteristic of the present service.

In short, many proposals for technological innovation in the urban transit field have never been implemented because some interesting or innovative engineering feature that formed the basis for the new system simply was not beneficial to transit operators and municipal planning agencies responsible for providing transit services. To succeed, therefore, the need for new systems or technological innovation in urban transit must first be defined in terms that are responsive to requirements or objectives of urban planners and transit operating agencies. This definition of need is referred to as an Operational Requirement.

THE SYSTEM CONCEPT

The Urban Transportation Development Corporation is now developing an ICTS system. Production of an Operational Requirement was one of the primary elements of the initial stages of system development, and that Operational Requirement is now a major determinant of system design.

The origins of the basic ICTS concept are illustrated in Figure 1. Transportation planning studies in several Canadian cities had identified a need for new transit facilities in a range of site and operating conditions which were not ideally suited to existing transit systems. These studies and their land use implications, together with the objectives of municipalities and local communities, suggested the need for intermediate levels of capacity that would support medium development densities but without creating pressures for rapid redevelopment to high densities. In many cases, these proposed transit corridors pass through already established communities that are sensitive to new transportation facilities and any disruption that they might generate. On the other hand, plans and objectives raised the need for high levels of service in terms of reliability, average speed and frequency, which could only be achieved with some form of separated right-of-way.

Separate right-of-way can be achieved through the use of underground facilities, or, where conditions permit, by at-grade or elevated facilities. Underground facilities, of course, introduce high capital costs; at-grade facilities have lower costs, but opportunities for separate at-grade alignment are extremely limited in already-established urban areas.

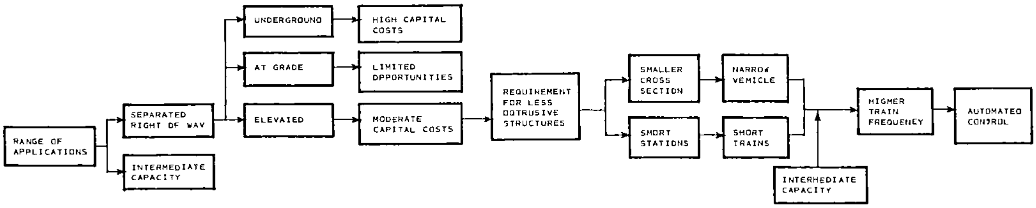

Figure 1 - Principal characteristics of ICTS

established urban areas. Elevated facilities have the advantage of lower capital costs but, for obvious reasons, may be considerably less acceptable from the community standpoint, particularly with regard to visual intrusion.

In order to achieve the requirements of intermediate capacity, separated right-of-way, and lower capital costs, it is essential that a guideway structure be developed that has a low level of visual and environmental intrusion. In fact, this has become a major aspect of the ICTS development program.

Achieving less obtrusive elevated structures involves both reducing the apparent massiveness of the structure itself and, more importantly, reducing the size of stations. The minimum cross-sectional area of the structure is determined by suspension design, stability and the limited capacity of narrow vehicles, while the objective of reducing station length imposes a requirement for short train lengths. Achieving capacity requirements with this combination of narrow vehicles and short trains forces higher operating frequency than is traditional in the transit industry.

Thus, the characteristics of possible applications of new transit systems led to a system concept, responsive to capacity, level of service and cost targets, and characterized by high-frequency service involving short trains that operate on elevated guideways wherever feasible.

DEVELOPMENT OF THE OPERATIONAL REQUIREMENT

The process of developing an Operational Requirement involved three basic elements:

1. It was prepared with inputs from municipal planning and transit operating agencies so as to arrive at an accepted set of requirements for intermediate capacity transit systems. In other words, the ultimate users of the new system have been asked to define its performance requirements and ultimately to endorse the specifications of a particular technical solution.

2. The Operational Requirement was based on several applications studies involving typical corridors in a number of North American cities. These potential applications helped to define the geometric and performance requirements of the system, including grade-climbing ability, track curvature, capacity requirements, acceleration/deceleration rates and maximum speed.

3. Development of the Operational Requirement was an iterative process, involving continuous trade-off among operator and community requirements for economy, capacity, frequency of service and minimum impact on the community and environment.

At the outset, the program was proceeding along "traditional" lines, building on an operating concept and an assessment of available technologies and leading toward a preliminary system design. However, it was recognized at a early stage in the design process that non-engineering inputs were essential if the program was to be successful and, in fact, that the system concept might change substantially as a result of those inputs. The result has been an iterative process in the general form of Figure 2, but without the formality and structure implied by Figure 2. In fact, the development of operational requirements has involved continuous "give and take" between program management, design engineers, equipment manufacturers, transportation planners, planning agencies, transit operators, architects and cost analysts. The process has generally been one of constructive debate, sometimes of joint study and often of conflict between different points of view.

This process of debate, analysis and refinement extended to the point where there was substantial agreement on the Operational Requirement, as the basis for a "Model Specification" around which the system design would be developed. As the design has progressed, the Operational Requirement has been under continuous review as further information is produced on the projected cost, reliability and performance or the system.

Development of the Operational Requirement produced substantial changes in the initial system concept. At the start of the program in 1975, the system concept was presumed to have the following form:

– small vehicles carrying 10 to 20 passengers
– operating as single cars or in trains
– complex operating strategies, including skip-stop and express services with multi-platform stations
– extensive networking with direct transfer of vehicles or trains between lines through interchanges

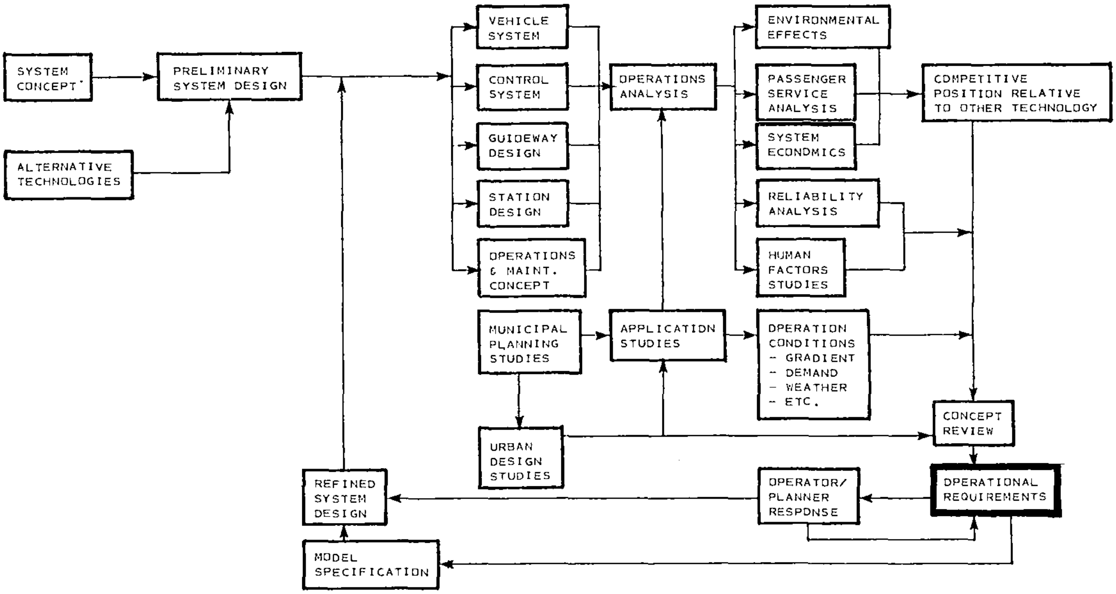

Figure 2-Operational requirements and the design process

– elevated guideway and stations over the full length of most applications
– direct service to low-density suburban areas
– demand-responsive service.

Preparation of the Operational Requirement forced consideration of this concept in respect of all of the factors listed in Table 1. In the process, engineering, economic and planning studies, together with input from planning agencies and transit operators, produced the following concept, representing a substantial departure from the initial concept:
– vehicles with a capacity of 50 to 70 passengers, and a minimum of 2 cars per train
– a system "optimized" for line-haul operation, but capable of extension to accommodate complex strategies
– concentration on single lines with branching capability
– elevated structures wherever possible with extensive design effort to produce acceptable structures, but with the overall system designed for efficient, economic operation at-grade, elevated or underground
– service confined to medium-density corridors of 5,000 to 20,000 pphpd
– scheduled service.

These examples illustrate the most fundamental changes in the Operational Requirement and system design that have occurred at this point in the development program. In addition, there have been many changes in areas such as train control, station operation, grade climbing capability, passenger evacuation, fleet management and maintenance concepts. Rather surprisingly, engineering analysis has initiated very few of these changes; and this appears to be a key factor. Transit development programs that have failed in the past have tended to be approached as an engineering problem, in isolation from other disciplines or other points of view. The Operational Requirement and the involvement of several disciplines and outside interests in its development is designed to avoid this pitfall.

Table 1-Principal elements of the operational requirement

1. *Level of Service*
   - Service strategies
   - Headway
   - Speed/Acceleration/Deceleration
   - Hours of Operation
   - Comfort Criteria
   - Interior noise, vibration and air conditioning
2. *System Performance*
   - Line capacity
   - Station capacity
   - Directionality
   - Grade capability
   - Turning radii
   - Switching performance
   - Exterior noise, vibration and appearance
   - Performance in adverse weather
   - Reliability
   - Safety and security
     - structural integrity
     - fire protection
     - passenger evacuation
     - operations control
   - Passenger/system interface
   - Passenger information
3. *Guideway Design*
4. *Station Design and Operation*
5. *Operation*
   - Maintenance operations and maintainability
   - Operation procedures

The experience and objectives of transit operators and municipal planning agencies was a major factor in changes in ICTS concept that occurred as the Operational Requirement was developed. However, systems analysis that concentrated on the application of the system, and the costs, public acceptance, service quality and performance of the system, was the major influence on the Operational Requirement. For example, the shift in vehicle size is an outcome of transportation planning studies that included, as one consideration, the capital cost of the proposed ICTS system. Initially these studies were based on small-vehicle systems in the entire range of applications that had been proposed by municipal planning agencies, extending from closely-spaced lines in suburban areas to heavily-travelled radial or cross-town routes. By comparison with other modes – private and public – and considering cost, service and community effects, it became evident that the fixed-guideway concept was feasible only on the more heavily-travelled applications and, in fact, that its performance in these applications would be improved by increasing vehicle size. The process was repeated with alternative vehicle size, finally arriving at a vehicle size that is a good match to potential applications. It is worth noting that, at the outset of this process, some of the participants were convinced that the very small vehicle was the obvious route to take, that a small vehicle was central to the ICTS concept, and that any upward shift in vehicle size would lead to a system design that violated basic objectives of high service standard, low cost and high public acceptance. Others felt, equally strongly, that without larger vehicles the concept was not viable and would not be applied at competitive or acceptable costs. The Operational Requirements and the design process adopted for the ICTS program forced analysis and conclusion on this issue. In other circumstances, the debate over vehicle size might never have emerged or, in a design process that was closed to non-engineering input, the design might have proceeded without regard to a view that a different vehicle size might strengthen the concept.

A similar process has been applied to all of the principal system characteristics and, in fact, will extend throughout the entire design process. It is a process that relies on constructive conflict between disciplines or interests within the design agency and between the design group and "client" or public interests.

In the case of the ICTS program, the Operational Requirement has provided a focus for several different perspectives that might otherwise have been overlooked, and produced a system concept that is responsive to conditions, concerns and requirements in developing urban areas.