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FACTORS WHICH ACT AS BARRIERS TO THE ADOPTION OF URBAN RAIL TRANSIT INNOVATIONS

BY Martin L. Schwartz
Associate Professor of Marketing
Miami University
Oxford, Ohio

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Jeff

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16. Abstract

Exploratory research was performed to identify factors that acted as barriers to the adoption of urban rail transit technologies. Vehicle programs analyzed include ACT-1, ASDP, SOAC, the Flywheel ESU, the Morgantown People Mover, GT/E Commuter Rail Cars, and SLRV's.

Factors which appeared to impede the adoption of rail transit technologies were grouped into five barrier categories: 1) performance/reliability barriers; 2) transportation authority financial barriers; 3) the cost of capital investment barrier; 4) the mismatch between buyer needs and new products developed; and 5) inadequate demonstrations of innovations.

The extent to which UMTA has addressed these barriers is also discussed.

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1.0 INTRODUCTION

During the 1970's, eight urban mass transportation innovations encountered difficulties prior to and/or during their introductions into the marketplace. These innovations include Standard Light Rail Vehicles (SLRV), Flywheel Energy Storage Units (Flywheel ESU), Dual-Powered Gas Turbine/Electric (GT/E) Commuter Rail Cars, the Advanced Concept Train (ACT-1), the Advanced Systems Development Program (ASDP), the State-of-the-Art Car (SOAC), the Morgantown People Mover, and Transbus. This research study is being performed to identify the factors that acted as barriers to the adoption of the first six of these innovations. Barriers to the eighth innovation, Transbus, were identified by Chin (8) and by the House of Representatives' Subcommittee on Oversight and Review (46), and will, therefore, not be evaluated in this research report.

The results of this research study may allow UMTA to take steps, or to evaluate those already taken, to prevent similar barriers from occurring in existing or future programs. This study does not include the evaluation of potential alternative solutions which can be used in reducing the impediments identified.

2.0 RESEARCH PROCEDURE

2.1 Problem Identification, Sample Selection, and Data Collection

One research question was posed by this study:

What factors act as barriers to the adoption (continued-

sustained implementation) of new rail transit technologies into the marketplace?

Adoption of new rail technologies occurs when transportation authorities purchase products which have been developed and demonstrated by carbuilders and suppliers. Factors that act as barriers to adoption are the reasons that either the transportation authorities are reluctant to purchase the new technologies from the carbuilders/suppliers or the carbuilders/suppliers are reluctant to produce the new technologies for the transportation authorities.

To answer the research question, the following research procedure was used:

1. A literature search was performed to understand both the decision processes and the barriers to the adoption of innovation identified in other innovation research studies.
2. A sample of transit rail innovations was evaluated to identify factors that acted as barriers to their adoption.
3. Similar reasons identified in '2' above were combined into categories so that generalizations could be made.

The sample of rail transportation innovations selected for this study consisted of innovations that were developed using UMTA financial assistance. The sample includes:

Standard Light Rail Vehicles (SLRV)

Stored Energy Propulsion for Rapid Rail Cars (Flywheel ESU)

Dual-Powered Gas Turbine/Electric (GT/E) Commuter Rail Cars

The State-Of-The-Art Car (SOAC)

D.C. Chopper Control Propulsion System

Air Ride Trucks

Innovative Styling

The Advanced Concept Train (ACT-1)

Ring Damped Wheels

Monomotor Truck

Bolt on Wheels

Copper Disc Brakes

Energy Absorbing System

Plug Type Doors

Turbo Airconditioners

Modular Interiors

Flywheel

Advanced Subsystems Development Program (ASDP)

Delco A.C. Synchronous Propulsion System

Monomotor Truck

Improved Suspension System

Synchronous Brake Control and Detection System

The Morgantown People Mover

All of the above innovations are further described in Appendix C.

Barriers to the continued-sustained implementation of each of these transportation innovations were identified by: 1) reviewing UMTA files; 2) by discussing the possible barriers with UMTA personnel; and 3) holding personal interviews with five rail equipment manufacturers (5, 6, 9, 10, and 30) and one representative from the American Public

Transit Association (APTA) to determine if there was any correlation of viewpoints and perceptions.

To obtain data for this study, the researcher worked at UMTA headquarters in Washington, D.C. for a one year period. Working at UMTA headquarters gave the researcher frequent access to two valuable resources, UMTA personnel and UMTA files. UMTA files were used to gain knowledge of the history of some of the specific innovations chosen for study. The UMTA personnel were extremely helpful in identifying and explaining perceived problems that transportation authorities and the manufacturers have had in the development and implementation of the innovations selected for study.

Valuable data were also obtained from personal interviews with railcar builders, transit suppliers, and from an American Public Transit Association (APTA) Official. Transportation authorities were not interviewed. The decision not to interview transportation authorities was made after the secondary data search was complete. Based on the secondary data search, the factors which acted as barriers to the adoption of rail innovations were perceived to be obvious.

The innovations either performed differently from expectations, were unreliable, were too costly for transportation authorities to purchase or operate, or were withdrawn by producers prior to their introductions into the marketplace. These problems are discussed in more detail in the following sections of this report.

The information gathering approach in this study differed from those used by prior studies. Those studies used structured questionnaires to identify possible barrier factors, whereas this study used unstructured interviews to achieve its objectives. The unstructured interview approach is a more flexible approach for probing answers and does not precondition the respondent in any manner, thus avoiding self-attribution type effects. Unstructured interviews are normally used where the need to identify and to understand the nature of problems is critical. Structured questionnaires, on the other hand, are used where numbers and statistical analysis are important. Since this study attempts to identify the nature of the barriers to the introduction of transit innovation, the unstructured interview was used.

2.2 Literature Search

A literature search was performed which focused on the barriers to the adoption of new technology.

The literature search served two purposes: 1) it was used to establish the nature of the innovation decision process used within the rail transit industry and 2) it was used to identify a set of new technology barriers which would serve as an initial starting point for this investigation. (See Appendix A.) The innovation decision process used by the transit industry and the barriers to rail innovation adoption are discussed in the following sections of this report.

2.3 The Decision Process Model Used In This Research

Two major categories of organizational innovation decision processes were found in the literature. Behavioral and social scientists generally described the innovation decision processes from the perspective of the buyer organizations. Research and development engineers usually discussed the innovation decision processes from the perspective of the producing organizations. Both approaches were felt to be important and were taken into consideration by this report.

Studies which described buyer oriented decision processes include Zaltman *et al*. (50), Magill *et al.* (21), Arthur D. Little (3), Smith and Howard Associates and ATE Management and Services Company (32), and Gellman (12). Studies which describe producer oriented decision processes include: The Syracuse Research Corp. (34), the Transportation Systems Center (35), Innovative Systems Research (18), the Washington Consulting Group (49), and Gellman (12). Decision processes used in these studies can be found in Appendix A.

The decision process used in this study is a composite of the innovation decision processes described by research and development engineers and social scientists. Four separate decision processes are perceived by the author to occur during the development and adoption of transportation innovations. As shown in Figure 1, these are the R & D organization decision process, the potential buyer decision process, the producer decision process and the user decision process.

Figure 1

Decision Processes* Involved in a Typical Development Cycle

Developer Initiation Stage →	Development & Test Stage (Breadboard & Prototype →	Potential Buyer Initiation Stage →	Initial Implementation Stage (In service demonstration) →	Redefining Implementation Stage →	Producer Matching Stage →	Production Test Stage →	Continued-Sustained Implementation Stage
R & D Organization		Potential Buyer			Producer		User

*Note: Although these stages are shown to occur sequentially, they may also occur concurrently and/or be circumvented. For instance, a downtown people mover cannot be tried on a limited basis (in service demonstration) by a city. Infrastructure requirements are too expensive. The in service demonstration will, therefore, not be used by purchasers of downtown people movers.

The R & D organization decision process consists of two stages, a developer initiation stage and a development and test stage. The developer initiation stage is the process used by the developer in arriving at a decision to develop or not to develop an innovation. It consists of three substages: the problem identification or new product awareness substage, the matching substage, and a feasibility study substage. The development and test stage is the process of designing, fabricating and testing a prototype of the innovation.

The potential buyer decision process consists of three behavioral stages: the potential buyer initiation stage, the initial implementation stage, and the redefining implementation stage. The potential buyer initiation stage is the process used by the potential buyer in arriving at a decision to try or not to try the innovation. The initial implementation stage is the process of demonstrating and evaluating the innovation (50, p. 67). And the redefining implementation stage is the process of modifying the innovation to increase its compatibility with the needs and wants of the potential buyer (21, p. 29). One frequent tangible result of the redefining implementation stage is a specification which will form part of a request for a proposal or of an Invitation For Bid (IFB) distributed to potential producers. Proposals received from producers are evaluated against requirements identified in the redefining implementation stage.

The producer decision process consists of two stages, a producer matching stage and a production and test stage. The producer matching stage is the process used by the producer in arriving at a response to the

IFB. During this stage the producer will match 1) company resources and capabilities against the requirements specified in the IFB, and 2) company expected revenue and non-monetary benefits against the expected costs of producing the innovation and guaranteeing its performance. The production and test stage is the process used by producers in the manufacture, test, and delivery of innovations.

The user decision process consists of one stage, a continued-sustained implementation stage.* The continued-sustained implementation stage is the process of formally accepting and integrating the change into the user's organizational structure and processes (21). It is the adoption of the new technology.

A more detailed discussion of these decision processes is provided in Appendix B. The focus of this research paper is to identify reasons that developed rail transit technologies do not reach the final stage, the continued-sustained implementation stage, of the decision process.

The decisions that determine whether a new technology will be adopted occur in either the potential buyer redefining stage and/or in the producer matching stage. Potential buyers decide if they want to adopt the new technologies in the former stage. Producers decide if they want to supply the technologies to the market place in the latter stage. These decisions are influenced by information obtained from

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*Note: The user decision process was not expanded further to include additional stages, such as a post purchase evaluation stage and/or a discontinuance stage, since the additional stages are outside of the scope of this study.

both the R&D organization's development and test stage and the potential buyer's initial implementation stage.

3.0 FACTORS THAT ACT AS BARRIERS TO THE CONTINUED-SUSTAINED IMPLEMENTATION OF INNOVATIONS

3.1 General Discussion

It is advantageous to identify potential problems that may act as barriers to the adoption of innovations at the earliest possible stage of the innovation decision process shown in Figure 1. The earlier that potential problems can be identified the easier it is to either reduce the potential barriers via product design modifications or to terminate the innovation development efforts entirely.

As shown in Table 1, barriers that discouraged transportation authorities from adopting urban rail transit innovations were usually first identified during the development and test stage of the decision process.

It would have been advantageous, however, if these barriers could have been predicted sooner, for instance, during the feasibility study substage of the developer initiation stage shown in Figure 1.

Feasibility studies should be carefully structured to realistically identify market demand, future development problems, production costs and/or selling price. Without such data, one has difficulty determining either the feasibility or the practicality of the innovation as

Table 1

Barriers To Adoption and Stages in Which They Were Encountered

Innovation	Factors Which Acted as Barriers to Adoption of Specific Innovations	Stage of Decision Process at Which Barrier Was Encountered	Stage in Decision Process Attained by the Innovation
Stored Energy Propulsion for Rapid Rail Cars (Flywheel ESU) and ACT-1 Flywheel	High price and potential maintenance problems, noise, weight, and vibration problems. Inadequate demonstration	Initial Implementation	Redefining Implementation
Dual-Powered Gas Turbine/Electric (GT/E) Commuter Rail Cars	High operating cost and reliability problems	Initial Implementation	Initial Implementation
SOAC D.C. Chopper Control Propulsion Systems	Poor reliability of brushes, bearings, and chopper commutation circuitry. Perceived incompatibility with older transit system power distribution equipment	Development and Test	Continued-sustained Implementation
Air Ride Trucks	High maintenance costs	Development and Test	Continued-sustained Implementation
Innovative Styling	N/A	N/A	Continued-sustained Implementation
Ring Damped Wheels	Mechanical freezing problems encountered	Initial Implementation	Continued-sustained Implementation
Monomotor Truck for Heavy Rail Vehicles	No clearly demonstrated advantages over bimotor truck for heavy rail vehicles	Development and Test	Development and Test*
Bolt-on Wheels	Insufficiently demonstrated	Development and Test	Development and Test
Copper Disc Brakes	High price, cracking problems	Development and Test	Development and Test

*Note: Monomotor Trucks and Sliding Plug Type Doors have attained the Continued-sustained Implementation Stage on light rail vehicles.

Table 1 (continued)

Innovation	Factors Which Acted as Barriers to Adoption of Specific Innovations	Stage of Decision Process at Which Barrier Was Encountered	Stage in Decision Process Attained by the Innovation
Improved Energy Absorbing System	Insufficient customer interest	Producer Matching	Development and Test
Sliding Plug Type Doors for Heavy Rail Vehicles	Reliability problems	Development and Test	Development and Test*
Turbo Air Conditioner	Reliability problems	Development and Test	Development and Test
Modular Interiors	Reduced square footage usable by riders	Development and Test	Development and Test
A.C. Propulsion System	Transit market too small to justify investment required, performance problems	Development and Test	Development and Test
Synchronous Brake	Not adequately demonstrated	Development and Test	Development and Test (currently in process)
Improved Suspension System (currently in development)	Not adequately demonstrated	Development and Test	Development and Test (currently in process)
Radial Steering Truck	Potential oscillation problem	Development and Test	Initial Implementation
People Movers	High price	Initial Implementation	Continued-sustained Implementation
AGRT's (currently in development)	High price, potential control problems	Development and Test	Development and Test

*Note: Monomotor Trucks and Sliding Plug Type Doors have attained the Continued-sustained Implementation Stage on light rail vehicles.

early as possible in the decision process.

This concern for early identification of potential adoption barriers is an important one which applies both to private and to federally funded projects; private endeavors for survival's sake, government, in order to minimize waste.

The data contained in Table 1 suggests that there are five general categories of barriers to consider: performance/ reliability barriers; transportation authority financial barriers; producer cost of capital investment barriers; the mismatch between buyer needs and new products developed; and inadequate demonstration barriers. These categories are discussed below and in Table 2.

3.2 Performance/Reliability Barriers

Table 2 indicates that an important barrier to the adoption of new transportation technology by transportation authorities has been the perceived failure of many products to achieve expected performance/ reliability characteristics during R&D testing and in service demonstrations.

This barrier has been caused, in part, by allowing insufficient resources and time for prototype and pre-production development, and by occasional mismatches between the technical capacity of the user and the ultra-complexity of the new system.

Although unsatisfactory product performance alone may be sufficient to

Table 2

Categorization Of Barriers To The Adoption of Transportation Innovations

Barrier	Products Which Were Either Not Adopted Or Were Not Produced For Revenue Service	Adopted Products
Performance/Reliability Problems	Copper disc brakes Turbo air conditioners ACT-1 flywheel Stored energy propulsion (Flywheel on R-32 car) Dual-powered gas turbine/electric cars Delco A.C. propulsion system	Ring damped wheels D.C. chopper propulsion system
High Price, Maintenance Cost, or Operating Cost	Copper disc brakes Stored energy propulsion (Flywheel on R-32 car) Dual-powered gas turbine/electric car	Air ride trucks People movers
Cost of Capital Investment	Delco A.C. propulsion system	
Mismatch Between Transportation Authorities Wants and Producers Products	Monomotor trucks for heavy rail Improved energy absorbing system Modular interiors	
Inadequate Demonstration of Innovations	Improved suspension system Stored energy propulsion (Flywheel on R-32 car) Monomotor truck Bolt-on wheels Synchronous brake	

prevent the diffusion of new products, (performance problems often have technical solutions) a substantial increase in capital and/or operating costs associated with implementing necessary technical solutions can effectively block widespread adoption.

The ACT-1 vehicles, Standard Light Rail Vehicles (SLRV's), the Flywheel Energy Storage Unit (ESU), and Delco propulsion system are examples of vehicles and other innovations whose performance problems acted as barriers to their adoption (see Appendix C for details).

One obvious way around a portion of this barrier is to devote greater emphasis on the early design, development, and test stages of prototype and pre-production models. But the implementation of this "solution" is not so clear or as easy as it appears. These stages are normally the first to be sacrificed in the name of expediency and other factors, which would suggest that an attitudinal change regarding innovations must take place first. Such changes are usually difficult and slow to accomplish.

The problem of perceived performance failures resulting from the technical mismatch between user and machine is equally vexing to resolve. When the aerospace firms entered the transit rail supplier industry during the early 1970's, they brought along a sophisticated technology. Consequently, specifications were prepared by consultants and operators to take advantage of this opportunity. The Standard Light Rail Vehicle and the Morgantown People Mover, were among the first to be developed to meet the new specifications. Sophisticated technological systems, however, also require sophisticated personnel to

debug and to maintain them. It took time to upgrade existing transit personnel or to hire new transit personnel for these activities. This factor combined with the increased performance complexity and reliability of the new systems resulted in early inefficiencies of operation and the perception that the new technologies could not perform up to their expectations.

Rejection of new products, even consumer products, often occurs because the products are not maintained or operated properly. Consumer product manufacturers have learned to either produce products which customers are capable of properly maintaining and operating, or to train customers to properly maintain and operate those new products. Innovative transit equipment manufacturers, if they are to be successful, must do the same.

3.3 Transportation Authority Financial Barriers

Transportation Authority financial barriers result from new products being more expensive than transportation authorities perceive that they can afford. High prices are caused by: 1) the small volume of products produced for the transit market; 2) excessive specification requirements; 3) warranty requirements; and 4) inflation.

The small volume of products produced for the transit market results from two factors: market fragmentation and the market's small size. Market fragmentation is caused by differences in the subsystems (motors, brakes, etc.) specified by various transportation authorities.

Various subsystems are specified due to differences in existing system characteristics, such as rail gauge, tunnel dimensions, electrical systems, platform lengths, and operational scenarios. The diversity of equipment specifications forces car builders to customize railcars for each transportation authority, resulting in significantly higher prices over what might be expected from utilizing mass production techniques. Boeing-Vertol discontinued its rail manufacturing business when the company management realized that the standard light rail vehicle specification would not be used by all transportation authorities (30).

The relatively small volume of products produced for the rail transit market also leads to high prices. Rolling stock builders and suppliers have relatively few units over which to allocate their overhead and capital investment costs. The potentially small size of total sales encourages the producers of innovations to adopt rapid cash recovery pricing strategies. A rapid cash recovery pricing strategy stipulates of a high price for equipment to recoup a supplier's investment in a new product as rapidly as possible. The strategy is most frequently used in risky market situations during product introduction, when the confidence in future demand is especially low.

For some particularly high risk innovations, federal involvement and assistance provides the only means for carrying through with a development, and allowing the cost of the resultant equipment to fall within the realm of the targeted users. A reduction in UMTA financial assistance for the demonstration of specific products could cause the

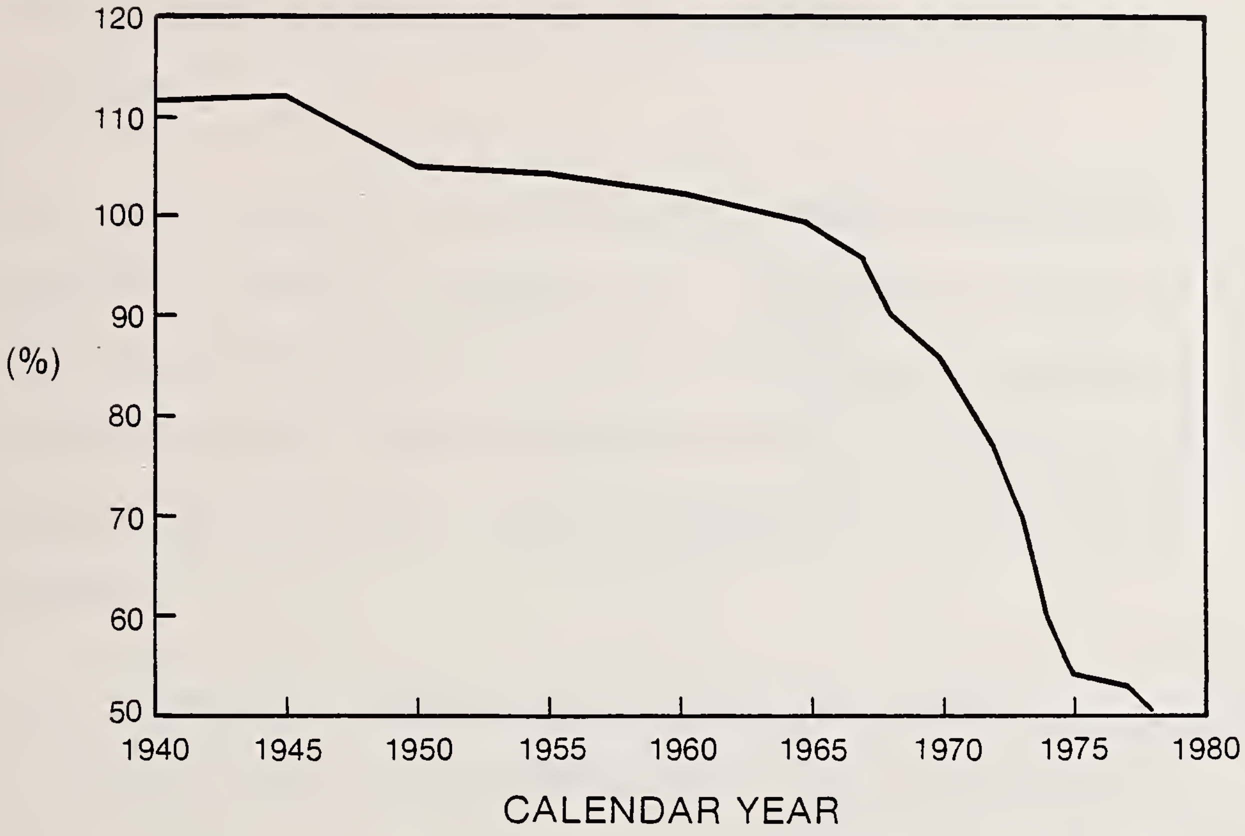
products to become too expensive for transportation authorities to obtain. This problem is currently evidenced in the recision of Federal government grants for the UMTA Downtown People Mover demonstration program. Cities which planned to install downtown people movers may not be able to afford them without the Federal assistance.

Excessive vehicle specification requirements can also add to the price of new products. The excesses generally arise because the exact relationships between specification requirements and actual operating conditions are sometimes difficult to ascertain, and because consultants (who usually write the vehicle specifications), may request unnecessary and expensive sophistication (24, 17).

Warranty provisions add to the price of new products by reallocating risk from the buyer to the producer of new transportation vehicles. Producers incorporate that expected risk into the prices which they charge transportation authorities for their products. As the availability of operating funds dwindles, it is anticipated that the emphasis on warranties by the authorities will increase. This shift in the risk factor will probably mean higher capital cost for innovation, resulting in an even greater barrier to innovation.

Cost push inflation tends to be harmful to both transportation authorities and to railcar builders. Transportation authorities have seen their operating costs increase faster than their fare box revenues (see Figure 2). Faced with this problem, transportation authorities have: 1) obtained additional funds from sources other than riders (for

Figure 2
TOTAL TRANSIT OPERATING REVENUES AS A PERCENT OF TOTAL OPERATING EXPENSES



Source: 24, pp. 3-3

instance, local, state and federal government agencies); 2) deferred purchasing of additional or replacement vehicles; 3) offered fixed price contracts without inflation escalation clauses; and 4) deferred maintenance.

Item 2, the reductions in new vehicle purchases by transportation authorities, results in increased unit costs due to the allocation of R&D and production overhead across fewer vehicles. In addition, producers have been faced with increased labor costs, utility costs, interest rate costs, etc., which have added to the price of new products.

Item 3, attempts by transportation authorities to neutralize inflation by offering fixed priced contracts without inflation escalation clauses, has had a negative impact on car builders. Boeing-Vertol, for example, left the carbuilding business partly because of inflationary costs incurred on their fixed price, Light Rail Vehicle contracts (30).

Pricing problems do not necessarily prevent the implementation and/or diffusion of new technologies, especially in situations where the cost or pricing problems have the potential of being solved. (See Table 2).

3.4 The Cost of Capital Investment Barrier

Rolling stock suppliers and builders are usually faced with a combination of small production runs and unstable demand. These adverse conditions are the reasons that suppliers and vehicle builders are not

interested in investing new capital in rolling stock innovations without first recovering their prior investments. Hence, suppliers have decided against producing some of the products which they have developed, despite the promising potential of those products.

Suppliers of transit components are sometimes unwilling to invest in capital equipment to produce new products for a transit market which is so small. GM ceased developing an A.C. propulsion system for rail transit vehicles after GM lost a military contract to develop a similar system for tanks (6). To produce the propulsion system for rail transit alone, would have required additional development, tooling and facilities investments. These investments were expensive relative to the expected revenue that the firm could have received by selling the system to transportation authorities.

3.5 Mismatches Between Buyer Needs and New Products Developed

Most transit technologies evaluated in this study originated from rolling stock builders suppliers, and/or from a foreign impetus, rather than from transportation authorities. One would expect, therefore, that some of the technologies that rolling stock builders and suppliers perceive are needed by transportation authorities, are not technologies that transportation authorities actually want.

Mismatches result from a lack of communication between transportation authorities and suppliers. Concept testing, one method for suppliers to obtain feedback from transportation authorities, has not been used

extensively to obtain potential user reactions to new rail transit concepts.

When feedback is not obtained, suppliers assume that they are developing equipment that transportation authorities need and will purchase. Mismatches occur when those assumptions are incorrect. Examples of mismatches include monomotor trucks for heavy rail vehicles, D.C. Choppers targeted toward New York City, modular interiors, and an improved energy absorbing system.

3.6 Inadequate Demonstrations of Innovations

New product demonstrations generally occur during either the development and test stage or the initial implementation stage of the organizational decision process shown in Figure 1. They may also occur when requested by transit operators. These demonstrations may be of relatively short duration in terms of revenue service time logged (10) and they frequently make use of prototypes which have not been production engineered. New products so demonstrated may not, on their own, encourage strong confidence on the part of either sellers or buyers in the new products' attributes or reliabilities.

Even products with promising potential may be perceived by transportation authorities as being too risky to purchase if they perceive the demonstrations to have been inadequate. On the other hand, there is an understandably strong reservation against committing funds for producing and testing a production engineered unit when the

market has not been established or is unstable. Examples of projects affected by this barrier include the ESU flywheel, bolt-on wheels, monomotor trucks for heavy rail (ACT-1 and ASDP programs), and improved suspension systems.

4.0 ACTIONS CURRENTLY BEING TAKEN BY UMTA TO REDUCE BARRIERS TO THE ADOPTION OF RAILCAR INNOVATIONS

Based on previous discussions, barriers to adoption appear to fall into two general categories: barriers that discourage rail transit suppliers from producing new products for the market place and barriers that discourage rail transit operators from purchasing new products that are offered to them. The cost of capital investment barrier falls into the first category. The remaining barriers (the inadequate demonstration of innovations; the unacceptable performance and/or reliability characteristics of the innovations; the high price, operating cost or maintenance cost of innovations; and the mismatch between product benefits sought by transit operators and those offered by transit suppliers) fall primarily into the second category.

Because UMTA's role, according to the UMT Act of 1964 as amended through 1978 (43), is to assist urban transportation authorities, UMTA emphasis is placed on reducing the barriers which appear to fall into the second general category. Although the success of UMTA's efforts to reduce the barriers cannot as yet be measured, the following discussion explains what UMTA actions are being conducted and how they relate to the barriers identified in this study.

4.1 <u>3(a)(1)(C)</u>:

The passage in 1978 of Section 3(a)(1)(C) of the UMT Act should assist in facilitating the trial of many new or improved products by transportation authorities, partially reducing "the inadequate demonstration of innovations" barrier mentioned above.

Under the Section 3(a)(1)(C) Program, UMTA provides both financial and technical assistance to transportation authorities who want to test new transit innovations. The program focuses primarily on systems and equipment that have been proven in demonstrations at one locality but which may need to be tested, and possibly modified, in other locales. Transportation authorities are thereby able to reduce their risk when a purchasing decision on the new product has been made. In effect, buyer and seller are given more time to understand the others' needs and wants.

4.2 <u>Railcar Standardization</u>:

UMTA has attempted to reduce both the "unanticipated performance and/or reliability characteristics" barrier and the "transit authorities financial" barrier in rail transit by encouraging the standardization of interfaces between railcar subsystems. Standardization of of interfaces between subsystems should help reduce these barriers by: 1) reducing the need to design completely new equipment for each order; 2) providing suppliers with sufficient hardware component experience to allow them to improve performance and reliability characteristics of

the components; and 3) reducing design/production set-up costs and increasing the number of suppliers from which transportation authorities can purchase replacement parts. As a result, costs are kept to a reasonable level and the performance of equipment is easier to anticipate.

4.3 Systems To Subsystems Policy Shift:

Another action taken by UMTA to alleviate the "unanticipated performance and/or reliability characteristics" barrier was to shift their attention from funding total vehicle programs (such as ACT-1, SOAC, and ASDP's), which embodied long-range complicated, and high risk combinational efforts, to concentrating upon funding for individual vehicle subsystems and incremental component improvements (such as ring damped wheels, and improved doors). The effect of this shift has been increased control over the subsystem development, enhanced adaptability of the subsystem to changing user needs, more focused technical attention, and a shorter turn-around time for results.

4.4 Transit Assistance Policy Shift

UMTA is currently addressing the "mismatch between product benefits sought by transportation authorities and innovations produced" barrier. To obtain a greater focus on what transit operators want, UMTA, during the mid-1970's, shifted its priorities from ones targeted toward assisting transit riders and potential riders (37, pp. 68-69; and 38, p. RD&D 3) to those targeted toward assisting transportation authorities (39, p. 68).

UMTA now perceives that it is more effective in the long term to fund the development of a technologies which have a high probability of acceptance by transportation authorities rather than to fund technologies which do not. Acceptance of new technology by transportation authorities has become, therefore, a critical measure of UMTA's success and an objective in its own right. To stay within his limited budget, the Secretary of Transportation, Drew Lewis, has placed emphasis "On the maintenance and improvement of existing, proven transit systems and on projects with near-term payoffs" (20, p. 3). Exceptions are being made only in those cases for which prior contractual commitments warranted the implementation of new rail systems and/ or downtown people movers.

4.5 Conferences/Seminars

Another step which has been taken by UMTA to reduce the mismatch barrier is the sponsoring of APTA liaison boards on all transit matters, an annual R & D conference and other regional meetings during which transportation authorities have opportunities to discuss their product and maintenance support needs with producers.

Urban transit suppliers have opportunities during these meetings: 1) determine what products the transit operators want to purchase; and 2) to test new product concepts and ideas on the user markets; 3) to determine the level of maintenance support and training that should be provided to transit authorities to ensure that the new products meet performance and reliability expectations.

5.0 CONCLUSIONS AND RECOMMENDATIONS

This research studied barriers which prevent products that have been developed from being adopted by transportation authorities.

The principal barriers were found, in this study to be caused by: 1) unacceptable performance and/or reliability characteristics of the innovations; 2) the transit authorities financial situation; 3) the cost of the producer's capital investment compared to the return on that investment; 4) the mismatch between product benefits sought by transportation authorities and benefits offered by innovations produced by rolling stock builders; and 5) the inadequate demonstration of some innovations did not build operator confidence in the performance/ reliability of the new technologies.

UMTA, as was described in the prior section, is already acting to reduce the barriers identified in this report. However, two questions ought to be answered.

Can UMTA's actions affect changes in those areas where they are most urgently needed, and, if not, what more needs to be done?

UMTA's current method of handling the mismatch between product benefits sought by transportation authorities and those offered by carbuilders is perceived by the researcher to be sufficient. Mismatches are caused by communications problems. The R&D and similar conferences sponsored

by UMTA address these problems directly.

UMTA's current method of addressing the weak financial situation of transit authorities may be only partially successful. The encouragement of standardization between subsystem interfaces resolves only a portion of the total cause of the high price and operating costs of transit vehicles.

The concept of standardization needs to be combined with an increased effort to improve the fare box revenue to operating cost ratios of transportation authorities and to reduce the cost of new rail rolling stock by encouraging suppliers to develop reliable, low price, and low life cycle cost alternatives to existing rolling stock.

UMTA's current method of handling the unacceptable performance and/or reliability characteristics of the innovations, primarily through standardization efforts and a shift to subsystem emphasis, may also be only partially successful. Standardization of components will result from standardization of subsystem interfaces. Although standardization will improve the quality of existing technologies it does not address the problems associated with radically new innovations.

The shift to a subsystem emphasis improves the quality and reliability of new technologies but will not alone, uncover potential problems early in the decision process.

Greater attention and adherence to front end planning and increased

development testing is a necessariy ingredient in combating performance and reliability problems. This objective requires that additional resources be invested in the developer initiation stage and in the development and test stage shown in Figure 1.

Currently, the developer initiation stage consists of a feasibility study which evaluates various innovation options for the purpose of selecting one for development and test.

Feasibility studies can be expanded to include more front end planning and additional design analysis of the selected option, so that design problems as well as price, costs, and market demand can be accurately ascertained prior to entering the development and test stage of the decision process. Once the development and test stage of the decision process has been entered, it becomes more difficult to terminate financial assistance.

UMTA's current method of handling demonstration inadequacies may also be only partially successful. Section 3(a)(1)(C) of the UMT Act reduces some, but not all, of the transportation authorities' technological risk of purchasing a new product. If the new technology does not operate up to expectations, the transportation authority is still obligated to pay twenty percent of the purchase price, the same percentage that it would have paid for a product with a long history.

What is needed is a demonstration concept which will allow interested transportation authorities to try new technologies on a limited basis

with some form of money back guarantee if the technologies do not meet specified performance/reliability requirements.

UMTA is currently doing little to reduce the cost of capital investment barrier encountered by suppliers. Reducing this barrier by assisting suppliers to increase their benefit-to-cost ratios represents a potential which UMTA has not considered and is not covered in the UMT Act (43). Maybe it should be.

This paper focused on identifying and understanding the barriers to the adoption of rail transit innovations. Although some of these barriers are being effectively addressed by UMTA, indications are that more might be done to reduce those barriers through further investigation. In particular, the relationship between the early stages of the decision process and the final decision to develop a new technology may merit additional study and analysis to provide assistance to UMTA planners. The reduction of barriers during these early stages of the decision process should lead to an increase in the number of transit improvements offered to transportation authorities by transit suppliers and carbuilders.

APPENDIX A

LITERATURE SEARCH

A literature search was performed to identify: 1) organizational innovation decision processes, and 2) barriers to the adoption of innovation used in other studies. Studies selected in the literature review were either transportation system oriented, government products oriented, or considered by this researcher to be pivotal to the field of communication theory.

Two categories of organizational innovation decision processes were found in the literature. Behavioral and social scientists describe the innovation decision processes from the perspective of the organizations that were making a purchase decision. On the other hand, research and development engineers describe the innovation decision processes from the perspective of the organizations that were producing the innovations. Both approaches are important if all barriers to the adoption and diffusion of innovation are to be identified and removed.

Studies that describe buyer decision processes include Zaltman *et al*. (21), Arthur D. Little (3), Smith and Howard Associates and ATE Management and Services Company (32), and Gellman (12). Studies that describe producer decision processes include the Syracuse Research Corp. (34), the Transportation Systems Center (35), Innovative Systems Research (18), the Washington Consulting Group (49), and Gellman (12). These studies are summarized in the following paragraphs.

Buyer Decision Processes

Zaltman *et al*. (50) described the innovation decision process as consisting of two stages, an initiation stage and an implementation stage. The initiation stage consisted of three substages: 1) knowledge awareness, 2) formation of attitudes toward the innovation, and 3) decision. The implementation stage was described as consisting of two substages, the initial implementation substage and the continued-sustained implementation substage.

Zaltman *et al*. (50) identified product, organizational, and individual attributes which act as barriers to the adoption of innovation. Product attributes which act as barriers are listed on Table A-1, intra-organizational barriers are listed on Table A-2, and individual barriers are listed on Table A-3. In all three tables, the stage of the decision process in which the barrier is suggested to occur is also indicated.

Magill *et al*. (21) used the same two stages -- the initiation stage and the implementation stage -- described by Zaltman *et al*. (5). The substages were, however, described differently. Magill *et al*. (21) described the initiation stage as consisting of an agenda-setting substage and a matching substage. They described the implementation stage as consisting of a redefining substage (which may also occur during the initiation stage), a structuring substage and an interconnecting substage.

TABLE A-1

Probable Interaction of Attributes
with Innovation Process Substances

Attributes of Innovations	Decision Stages: Knowledge	Attitude Formation	Decision	Initial Implementation	Sustained Implementation
Cost		X	X		
Returns to investment		X			
Efficiency		X			
Risk and uncertainty		X			
Communicability	X				
Compatibility		X			
Complexity		X			
Scientific status			X		
Perceived relative advantage			X		
Point of origin	X				
Terminality				X	
Status quo ante		X			
Commitment			X		
Interpersonal relationships				X	
Public versus private				X	
Gatekeeper	X				
Susceptibility to successive modification					X
Gateway capability					X
Gateway innovation					X

Source: Zaltman *et al*. (1973), pp. 164.

TABLE A-2

Resistance and Stages of Organization Innovation Decision Making

Decision-Making Stage	Nature of Resistance
Knowledge awareness	Need for stability Coding scheme barrier Impact on existing social relationships Personal threat Local pride Felt need
Attitude formation and decision	Division of labor Hierarchical and status differences Physical separation of relevant parties
Initial implementation	Forces altering the innovation Feigned acceptance and utilization Conflict Passivity Perceived manipulation Felt mistrust of subordinates by superiors
Continued occurrence sustained implementation	Continued conflict Occurrence of unintended dysfunctional effects Disillusionment because of false expectations

Source: Zaltman *et al*. (1973), pp. 166.

TABLE A-3

Resistance of Stages of Individual Innovation Decision Making

Decision-Making Stage	Nature of Resistance
Perception	Selective processes
Motivation	Primacy Habit
Attitude	Illusion of importance
Legitimation	Dependence
Trial	Self-distrust
Evaluation	Insecurity Regression Anxiety
Adoption-rejection resolution	Homeostasis

Source: Zaltman *et al.*, pp. 167.

Magill et al. (21) used the "process" approach described by Mohr (1978) to identify the key activities and functions that led to the eventual implementation of new transportation methods. Although not specified, barriers were implied to be any occurrences which would potentially disrupt or negatively impact those key activities and functions.

Arthur D. Little (3) described the innovation decision process as a convergence of six elements, knowledge generated through R & D, user need, an advocate or champion, availability of resources, favorable risk factors, and favorable timing. An aggregated simple compensatory model was used by Arthur D. Little to evaluate the convergence of the above factors for nuclear power, coal, motor vehicle safety, urban mass transportation, soy protein, and biological pesticides as shown in Table A-4.

Arthur D. Little, Inc. (2) described the barriers to innovation as those identified to be important by a cross section of industrial firms located within the United States. A listing of the significant barriers identified and the extent of the priority that each was given in indicated on Table A-5.

Smith and Howard Associates and ATE Management and Services Company (32) describe the five stages of diffusion for transit to be awareness, trial, evaluation, rejection/adoption, and resolution. The most significant problem in transit is perceived by them to occur during the awareness stage. This particular model is more similar to individual decision process models than it is to organizational decision process

TABLE A-4

Convergence of Critical Factors for Innovation

	Nuclear Power	Coal	Motor Vehicle Safety	Urban Mass Transportation	Soy Protein	Biological Pesticides
Knowledge	4	2	4	3	2	3
User Need: End Users	4	2	1	1	1	0
User Need: Manufacturers and Suppliers	3	1	5	1	1	0
Advocate/Champion	5	0	4	3	0	1
Resource Availability	4	3	5	2	3	3
Favorable Risk Factors	4	0	4	0	0	0
Timing	4	1	4	2	1	1
Total (out of 35)	28	9	27	12	8	8

Total Score

No Convergence: 0-8
Low Convergence: 9-17
Medium Convergence: 18-26
High Convergence: 26-35

Source: Arthur D. Little (1976), pp. 10

TABLE A-5

Priorities for Public Policies to Overcome Barriers to Innovation*

Barrier Factors	Public Policy Option	Priority H=High M=Medium L=Low
1. Market Related		
• Industry lacks information on: customer needs, market characteristics and trends, competition (incl. foreign)	• Establish a pilot cooperative clearinghouse for market information (oriented initially to one or two selected industries) and scale up as utility of pilot program is demonstrated	H
• Market Fragmentation (particularly in state/local government purchases): insufficient economies of scale, high marketing costs, customer inability to evaluate innovative offerings	• Experiment with aggregation of markets (local/state/Federal), using appropriate performance criteria for desired goods and services	M
• Market Creation: Needed in areas of "Public Needs" (e.g., transportation, education, health care), where public funds determine size, characteristics, and timing of market demand	• Formulate performance criteria (technical, economic, social, institutional), considering both public needs and industry's delivery capabilities, in order to clarify market demand and characteristics	H
2. Corporate Financial Considerations		
• New, independent, small, innovative companies are disadvantaged by five-year limitation of IRS "Loss Carry Forward" provisions	• Extend "Carry Forward" period for losses of qualifying, small, technology-based companies	H
• High start-up costs of high technology innovation, particularly in capital-intensive industries)( )( )( )(	((• Explore feasibility of fiscal incentives for innovation (bearing in mind need to be "industry-sector specific") that satisfy the following criteria:	M

*The Barrier Factors cited are those perceived by industry as important. The Public Policy Options recommended were suggested by industry, government, finance, and labor. The Priorities suggested reflect the judgment of these four groups.

Source: Arthur D. Little, Inc. (1973), pp. 23-25

Barrier Factors	Public Policy Option	Priority H=High M=Medium L=Low
	(Target on main barriers of start-up costs (Reimburse costs and risks incurred rather than subsidize future costs (Maintain fair competition	
3. Corporate Organizational and Behavioral Perspectives		
• Threat to individual positions in corporate hierarchy • High individual risk of being blamed for failure	• Sponsor research to illuminate "internal" corporate barriers, related to "People Problems" in innovation, and dissemination results widely	M
• High degree of management difficulty and differing style of "Corporate New Venture" group	• Explore feasibility of providing special fiscal, regulatory, legislative incentives to stimulate trend toward formation of corporate new venture groups	H
4. Government Policies - Patents		
• Quality of patent protection) • Exclusive licensing of government-held patents)	(• Accelerate submission of administration-sponsored bill on patent reform to Congress and speed passage of bill	H
• Patent-licensing limitations) • Off-shore infringements)	(• Consider additional incentives for independent inventor/small business to lessen costs of pursuing patent applications	M
• Over-classification (security) of government-held technology) • Trivial and invalid patents) • Government "reach-Back" in contract R&D)		
5. Government Policies - Antitrust		
• Uncertainties in private sector about current and prospective rulings on multicorporate R&D and multicorporate prototype test facilities. (Both needed in specific industry sectors to achieve economies of scale)	• Assess rigorously the actual effects on private sector's innovation potential of current and proposed antitrust provisions, and formulate policies consonant with keeping U.S. industry competitive at home and abroad	H

Barrier Factors	Public Policy Option	Priority H=High M=Medium L=Low
• Uncertainties in public sector about industry needs for economies of scale • Competition with foreign firms and governments not bound by U.S.-type anti-trust law	• Create private sector advisory board to help develop criteria for above assessment, and to advise on opportunities and consequences of potential policy changes	M
6. Government Policies - Regulatory		
• Uncertainties in private sector about Federal regulatory policies and future rulings	• Upgrade professional staffing of regulatory agencies to improve ability for standard-setting	M
• Uncertainties about state/local government practices	• Establish "Forums" to interchange industry/government views on regulatory effects on innovation	H
• Inconsistencies and confusion between Federal and state/local practices	• Rationalize Federal and state/local regulatory practices and standards	M
• Unrealistic standards, test requirements, and timetables, e.g., for environmental, safety, and consumer-related regulation	• Expand pre-regulation and pre-legislation research to determine impact of proposed measures on industry's innovative risk-taking ability	M
• Unfair competition from foreign suppliers not subject to same burden of environmental safety standards	• Account for full "Social Costs" (incurred abroad) by customs duties	L
• Lack of precise data on effects of regulation and independent regulatory agencies' scope and practices on innovativeness of traditionally regulated industries, i.e., transportation and utilities	• Undertake research to assess effects of regulatory scope and practices on innovation, e.g., by comparing performance of industry under differing systems of Federal and state regulatory practices	H
7. Venture Development and Finance		
• Shortage of seed capital leading to shortage of soundly structured innovative ventures	• Federal financing of additional seed capital through quasi-public agency or under contract with qualified organization	H

Barrier Factors	Public Policy Option	Priority H=High M=Medium L=Low
	• Fiscal incentives to venture capital and other investors, and large corporations, to stimulate seed-capital investments	H
7. Venture Development and Finance (continued)		
• Venture capital hesitation due to high uncertainty and risk of innovation, and long lead period of non-liquidity	• Fiscal incentives to balance inherent high-risk situations	M
	• Ad-hoc support for venture formation in defined areas of public interest	
• Trends in capital gain versus income tax rates, desire for lower-risk investment	• Ad-hoc support for venture formation in defined areas of public interest	H
• Reluctance in major corporations to commit to a "Corporate New Venture" program	• Formation of National Venture Department Program to pull together mix of public policies to encourage innovative venture formation	L
8. Labor Perspectives		
• Loss of income • Skill obsolescence • Changed conditions of work	• Provide information of adverse labor effects on innovation to private and public-sector decision-makers	M
	• Financial assistance to displaced workers	L
	• Retaining and reemployment assistance	L
	• Sponsor research and experiments to improve working conditions	L

models. It appears to be a combination of Rogers (28) and of Zaltman/s (5) individual decision processes.

Smith and Howard Associates and ATE Management and Services Company (32) describes institutions, funding, risks and lack of incentives, and external factors barriers to the diffusion of innovation. Institutional barriers include problems related to: the development of concepts, policies, and regulations; the role of governments, labor, and transit management; and information dissemination among members of the transit community. External factors include problems related to: attitudes among members of the transit community; the characteristics of the environment; and the characteristics of innovations.

The impact of these barriers on various classes of innovations is shown in Table A-6. Characteristics of innovations which accelerate or inhibit diffusion are listed in Table A-7. Information needed by adopters is listed in Table A-8.

Producer Decision Processes

The Syracuse Research Corporation (34) described the innovation decision process to be search, development, market introduction, commercialization and appraisal (which feeds back to search).

The Syracuse Research Corporation (34, pp. 28-36) identified the barriers to new technology to be Market Barriers, Local User Barriers, and Company Barriers. Marketing Barriers are further divided into Market Fragmentation, Lack of Information on Market Characteristics,

TABLE A-6

Effects of Barriers on Classes of Innovation

Classes of Innovation \ Barriers	Concepts	Governments	Goals and Objectives	Labor	Management & Organization	Information	Funding	Risks	Incentives	Attitudes	Characteristics of the Environment	Characteristics of the Innovation
Revenue & Financing		o	o			o			o	o	o	
Service Variations		•	o	•		o	o	•	•	o	o	
Institutional Changes		•	•	•	o	•		o	•	o		
Labor-Management Relations		o		•	o	•		o	•		o	
Marketing, Education and Information Dissemination	•	•	•		o	•	•	•	•	•		
Vehicles, Equipment and Facilities	•		o	•		•	o		o	o	o	•
Management and Planning Tools	o	•	o		o	o	o	o	o	o	o	o

o = Strong Effect • = Prohibitive Effect

Source: Smith and Howard Associates and ATE Management and Services Co. (1979)(26), pp. II-2.

TABLE A-7

Characteristics of Innovation

- costs (capital and operating)
- payoffs -- magnitude, form, visibility
- payoffs -- long and short term
- "jazziness" (i.e., attention-getting qualities)
- visibility (i.e., how many people will see it)
- perceived advantage over the status quo
- compatibility with existing values and norms
- complexity
- divisibility (i.e., ability to be applied on a limited or incremental basis)
- communicability (i.e., how easy it is to describe to another person)
- risks
- relationship to transit performance (in terms of efficiency, effectiveness and financial performance)
- impacts on community, particularly non-users
- performance impacts
- reliability (i.e., day to day performance)
- track record (i.e., failure or success over the long run)

Source: Smith and Howard Associates and ATE Management Services Co. (1970), pp. II-76 (26)

TABLE A-8

Transit Officials Information Needs

- Cost. These include not only the economic costs of implementation, but staffing requirements and estimated levels of involvement for other non-transit agency officials and staffers.

- Payoffs. These must describe the benefits in qualitative as well as economic terms. It is important that payoffs be defined in terms related to implementation. For example, the payoffs of an employer subsidy program may be that it paid the salary of the person who implemented it, as well as generating additional ridership. These payoffs must also be both meaningful and understandable to the key members of the decision-making process - especially those at the beginning and the end of that process.

- Barriers and Problems Encountered. Potential innovators must know what barriers exist to the implementation of new techniques and approaches, what methods may be used to overcome them, and where problems are likely to appear in the approval and implementation processes. Of particular importance is information about project failures -- information which is seldom diffused.

- Environmental Considerations. Those characteristics of a city's financial, political or institutional environment affecting implementation, and how, are critical informational elements. Such items include which agencies have control over which variables (e.g., streets), and to what degree. Also of importance are the number of participants in the approval process, their powers and their roles. Such differences allow for overwhelming successes in one city and failures in others.

- Implementation Process. Innovators need to know what is involved in the implementation of a new idea in order to help determine whether the risks are worth the effort. Such considerations include what members of the approval process were involved, what their responses were, what "selling" had been done by the innovator, and how long the implementation took.

- Contact Points. Those responsible for the development and implementation of an innovation must be identified so that interested officials elsewhere can ask the often difficult questions about the innovations (e.g., costs, payoffs, and other details) which may help to determine the innovation's applicability to different environments.

A serious problem with the need for such information is that not only are there no formal mechanisns to share it, but no incentives for individuals to do so on their own.

Source: Smith and Howard Associates and ATE Management and Services Co. (1979), pp. II-41 (26).

Cost of Entry, and Federal Regulatory Policies. Local User Barriers are further divided into Local User Operating Budget, Local Agency Capital Budget, User Training/Lack of Trainer Personnel, Product Education, and Shortsightedness of Local Users. Company Barriers are further divided into two subcategories, Limited Funds for R & D and R & D capabilities. The stages of the decision process in which the barriers occur are shown in Figure A-1.

TSC (35) described the adoption process as exploratory development, advanced development, preproduction engineering, manufacturing, construction and installation, and initial operation.

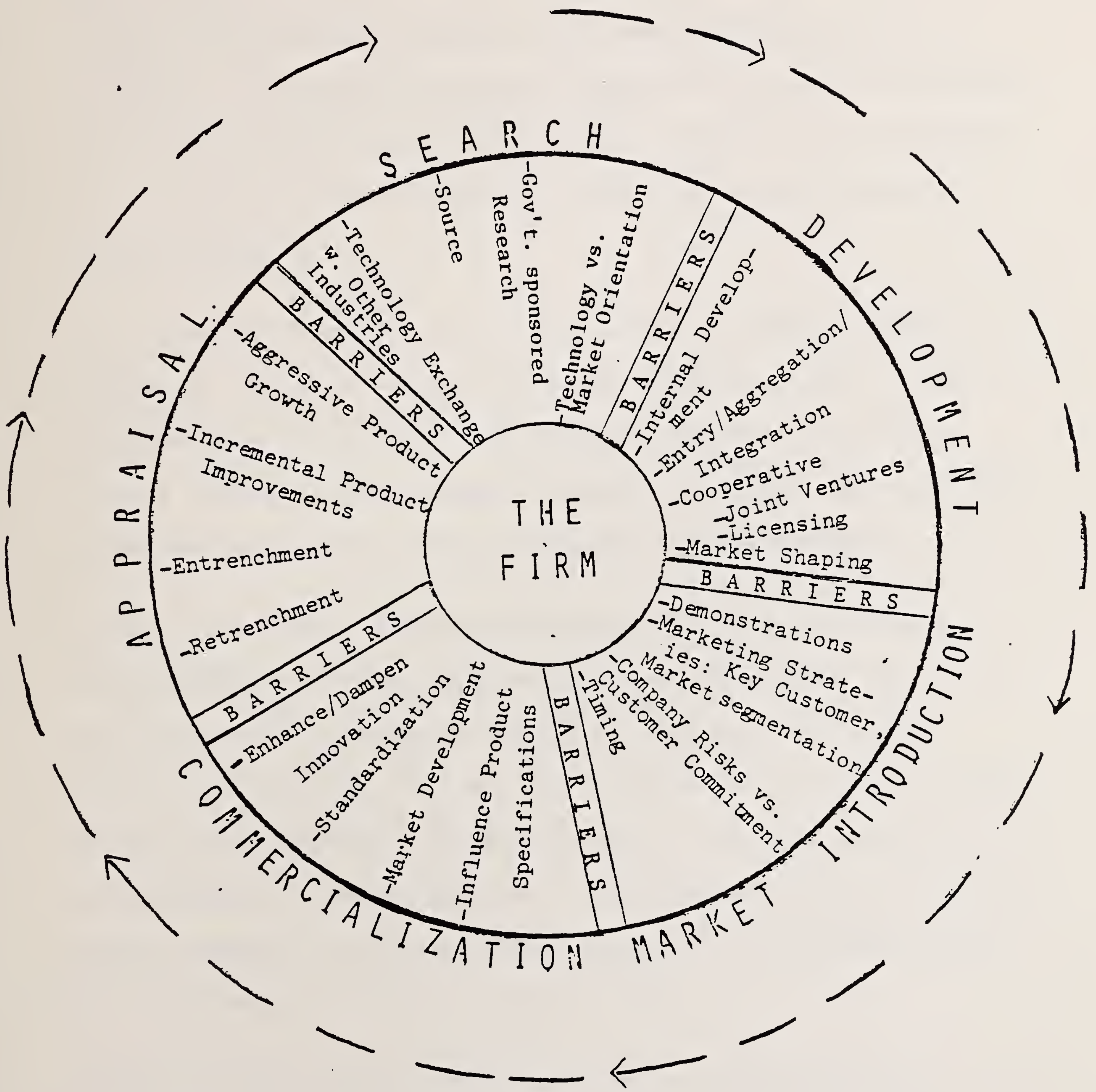
TSC (35) identified the barriers to new technology deployment to be Poor Product Reliability, Cost Overruns, Cost Escalation, Uncertain Technological Eligibility for Capital Assistance, and Poor Financial Conditions of Suppliers. TSC perceived that barriers were created as a direct or indirect result of curtailing critical steps in the innovation decision process. Reasons given by TSC for foreshortening the deployment process are: Insufficient Time, Insufficient Funding, Inappropriate Contracting Mechanisms, Unintentional Counter Incentives, and Insufficient Technical Capability.

Innovative Systems Research (18) described the stages of the adoption process as research definition, applied research, development, and utilization.

Innovative Systems Research (18) classifies technology introduction barriers and incentives as: Economic/Financial, Information Transfer,

FIGURE A-1

Major Phases in
Urban Industry Innovation



Source: The Syracuse Research Corporation (1978), pp. 36.

Legal, Market, Need, Policy, Organizational, Regulatory, and Technical. Each of these categories were in turn further divided into more specific incentives and barriers to the commercial utilization of innovation. The specific incentives identified are shown on Table A-9. The specific barriers identified are shown on Table A-10. The stages in the innovation decision process in which the barriers occur are shown in Figure A-2.

The Washington Consulting Group (49) described a typical decision process as need identification, ascertain market potential, develop specifications and estimate costs, design subsystems and products, develop prototype, test, production engineering, marketing, manufacture subsystems and product, delivery and test, and revenue service.

Gellman (12) listed the disincentives and incentives to innovation which influence individual (Tables A-11 and A-12), firms (Tables A-13 and A-14), public enterprises (Tables A-15 and A-16), industries (Tables A-17 and A-18), and the nation (Tables A-19 and A-20). Public policies that influence transport innovations were also described. These policies include competition, the purchasing function, financing, public enterprise, antitrust, market aggregation, and identification and amelioration of social or external costs.

Results of the literature search were used in constructing the innovation decision process which was used in this study. The process is shown in Figure 1 and discussed in Appendix B.

TABLE A-9

Specific Incentives

Economic/Financial

- arrangement of project funding increases through contract or grant amendment
- permitting intraproject transfers of R&D funds
- arrangement of advanced payments to contractors

Legal

- development of contract specific patent arrangements
- use of letter contracts
- contract modifications of a legal nature

Organizational

- interagency agreements and transfers of funds
- establishment of industry/government advisory panels
- transfer of contract administration to more suitable subagency office

Technical

- government certification of equipment
- rent free provision of government equipment and/or facilities
- allowance of time extensions for purpose of overcoming technical difficulties

Information Transfer

- presentation of project generated papers at an industry conference
- "loan" of a specialist to a contractor
- requirement that the inventor of the Federally supported technology be consulted in its development
- funding of trips to foster the exchange of project related information

Policy

- arrangement of grant continuations
- allowing a project to proceed prior to budget approval
- issuance of sole source contracts

Market

- securing project approval from a potential producer of a technology
- securing approval of project developed products from the consuming agency

The single Regulatory incentive observed was the suspension of government regulations which prohibited the testing of several products. No incentives of the Need type were observed in those R&D projects included in the study.

TABLE A-10

Specific Barriers

Economic/Financial

- budget overruns
- budget revision difficulties
- inflation induced problems
- subcontractor difficulties of a financial nature

Legal

- need to rebid contracts due to inherent illegalities
- inability of contracts to cope with detailed contracting procedures
- disputes in regard to patent arrangements

Organizational

- delays in subcontract approval
- contractor personnel turnover
- union difficulties which interfere with work schedule
- disputes between prime contractors and subcontractors

Technical

- weather problems which interfere with testing
- inadequate plans and specifications
- supply problems

Information Transfer

- poorly written contractor reports
- reports which have inadequate or incomplete cost specifications

Policy

- reluctance of contractors to proceed without assurances in regard to proprietary rights
- difficulties in obtaining testing permits

Regulatory

- conflicts with existing government regulations
- changes in existing regulations

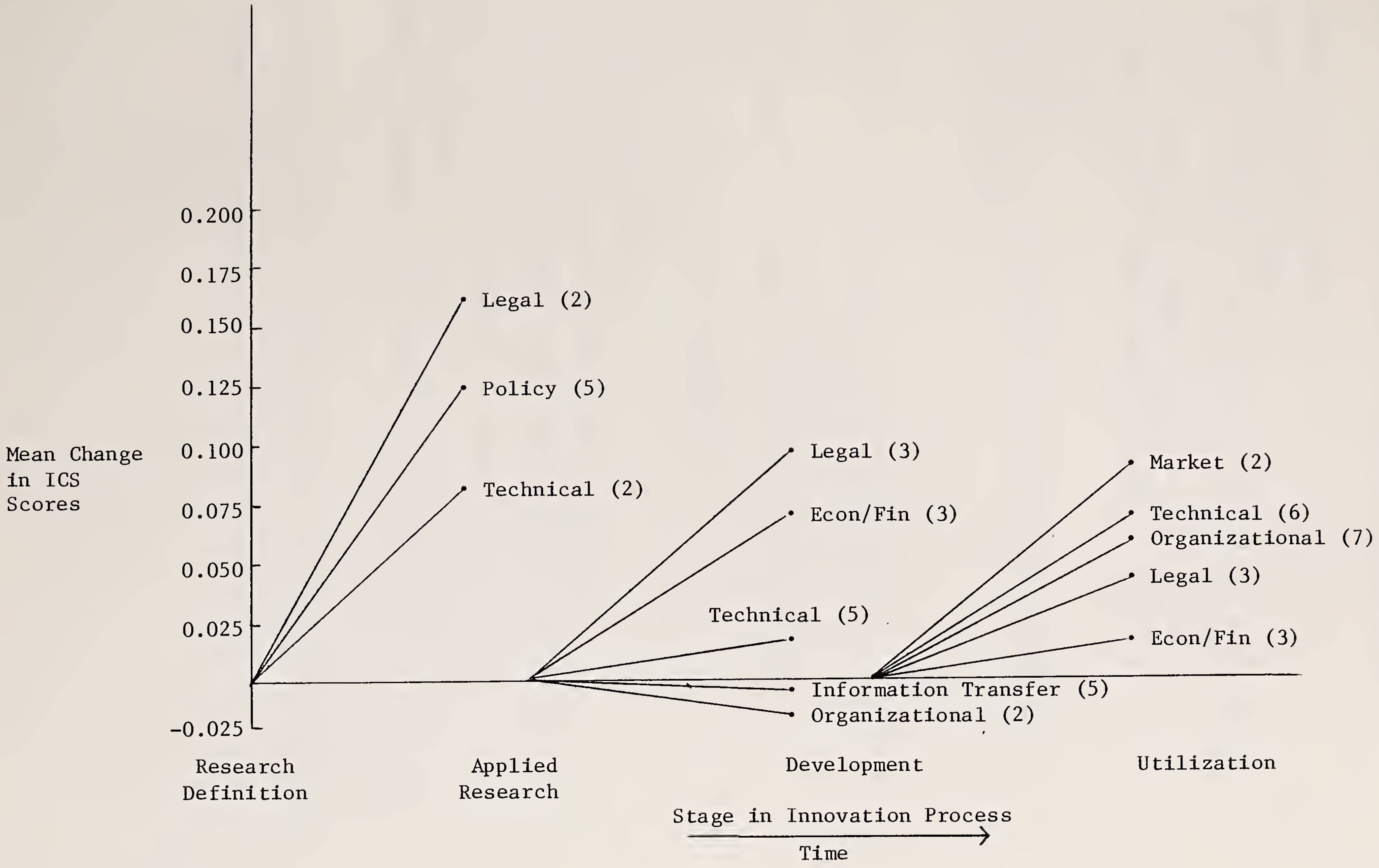
Need

- reduction in project priority
- conflicts of opinion with regard to the ability of the newer technology to replace existing technologies

The single Market barrier observed was the presence of a poorly defined and disaggregated market for the R&D.

FIGURE A-2

Effect of Incentives on Project Development
(By type of incentive and innovation stage)



Source: ISR (1979), pp. 24

TABLE A-11

Incentives to Innovation That Influence the Individual

1. Increased current income
2. Increased future income
3. Nonsalary "perks" of value (e.g., stock options, professional travel)
4. Job promotion or heightened probability of promotion
5. Increased prestige and/or responsibility
6. Job offers
7. Shop rights
8. Opportunity to participate in the application of one's own ideas or invention

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TABLE A-12

Disincentives to Innovation That Influence the Individual

1. Lack of rewards, even if "successful"
2. Increased visibility
3. Increased responsibility
4. Extra effort required to perfect the "innovation"
5. Likelihood of job change (e.g., new responsibilities and/or geographical shift)
6. Frustration (e.g., inability to advance a "good idea")
7. Risk of failure
8. Employer attitude toward failure of an innovation process

Source: Gellman (1979), pp. 107.

TABLE A-13

Incentives to Innovation That Influence the Firm

1. Increased current earnings
2. Increased future earnings
3. Achievement of revenue growth objectives
4. Achievement of profit objectives (e.g., reduce costs, stimulate demand)
5. Achievement of corporate diversification objectives
6. Increased market share
7. Increased multiple on stock
8. Capital conservation (e.g., promote non-capital-intensive production methods)
9. Reduced dependence on labor
10. Availability of IR&D funds
11. Meet regulatory requirements
12. Presence of regulation that heightens the probability and/or profitability of successful innovation
13. Improve recruitment results
14. Enhanced image

Source: Gellman (1979), pp. 108.

TABLE A-14

Disincentives to Innovation That Influence the Firm

1. Insufficient competitive spur
2. Risk of capital loss
3. Capital shortage
4. Short-term earnings penalty
5. Insufficient period of "monopoly profits," even if successful
6. Sufficiently high returns and growth rates without assuming the risk of innovation
7. Durability of capital equipment on hand
8. Inelastic demand for current product(s) or service(s)
9. Rate-of-return regulation employing a deferred rate-base calculation
10. Technological integration (e.g., "lumpiness" of investment need to fit into technologically complex system)
11. Regulation -- economic or other
12. Antitrust implication of innovation
13. Industrial standardization (externally or internally imposed)
14. Lack of corporate/divisional growth objectives
15. Risk or fear of "failure"
16. Inappropriate reward structure to promote innovation

Source: Gellman (1979), pp. 109.

TABLE A-15

Incentives to Innovation That Influence the Public Enterprise

1. Increased revenues
2. Expanded responsibilities (e.g., functionally, geographically)
3. Increased return on invested capital
4. Improved ratings of debt instruments
5. Amelioration of complaints (from customers, citizens)
6. Meet regulatory requirements
7. Accommodate "customer" innovation
8. Accommodate political pressures (e.g., demand for increased labor intensity in operations)
9. Enhance "owner's" image generally, in the community served and beyond

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TABLE A-16

Disincentives to Innovation That Influence the Public Enterprise

1. Lack of competitive spur
2. Capital constraints
3. Durability of capital equipment on hand
4. Inelastic demand function
5. Absence of life cycle costing
6. Absence of explicit growth objectives
7. Absence of conventional profit-and-loss statement and balance sheet
8. Increased operating costs
9. Lower productivity, labor and/or capital
10. Innovation not required by regulation
11. "Customer" resistance to change
12. Labor content "requirements"
13. Inappropriate reward structure to promote innovation
14. Threat to "low-profile" existence

Source: Gellman (1979), pp. 110.

TABLE A-17

Incentives to Innovation That Influence an Industry

1. Increased current earnings
2. Increased future earnings
3. Improve financeability
4. Increase share of GNP
5. Thwart foreign competition
6. Promote favorable government action
7. Increased tolerance of industry-wide cooperation
8. Increased visibility (favorable); improved image
9. Improved recruiting results
10. Meet regulatory mandate

TABLE A-18

Disincentives to Innovation That Influence an Industry

1. Lack of sufficient competitive spur (high concentration ratio?)
2. Capital constraints
3. Durability of capital equipment
4. Technological integration
5. Standardization (externally or internally imposed)
6. Inelastic demand for industry output
7. Regulation -- economic or other; regulatory process
8. Rate of return regulation and deferred rate base calculation
9. Fear of hurting weak competitor (especially in highly concentrated industry)

Source: Gellman (1979), pp. 112.

TABLE A-19

Incentives to Innovation That Influence the Nation

1. Increased GNP (real)
2. Enhanced productivity -- any and all factors
3. Increased employment
4. Improved distribution of income
5. Increased development of new enterprises
6. Improved U.S. balance of payments: cut imports/expand exports
7. Improved "quality of life"
8. Increased decentralization of industry
9. Enhanced international prestige
10. Strengthened military posture

TABLE A-20

Disincentives to Innovation That Influence the Nation

1. Regulation -- economic, safety, environmental; regulatory process
2. Chronic inflation
3. Tax level and structure
4. Egalitarian philosophy (e.g., redistribution of income objectives)
5. Decreased employment (e.g., from automation)
6. Natural resource constraints
7. Import barriers
8. Export barriers
9. Golden Fleece-type awards

Source: Gellman (1979), pp. 113.

APPENDIX B

THE ORGANIZATIONAL INNOVATION DECISION PROCESS USED IN THIS STUDY

The organization innovation decision process shown in Figure 1 is a composite of the innovation development decision processes described by research and development engineers and the innovation adoption decision processes described by social scientists. Four separate decision processes are thought by the author to occur during the development and adoption of a transportation product: the R & D organization decision process, the potential buyer decision process, the producer decision process, and the buyer decision process.

The R & D organization decision process consists of two behavioral stages, a developer initiation stage and a development and test stage. The developer initiation stage is the process used by the developer in arriving at a decision to develop or not to develop an innovation. The development and test stage is the process of designing, fabricating and testing a prototype of the innovation.

The developer initiation stage consists of three substages: the problem identification or new product awareness substage, the matching substage, and a feasibility study substage. The problem identificaion or new product awareness substage of the developer initiation stage may be initiated either by the customer (the transportation authority), by the R & D organization (a supplier), or by the government. Problem identification results from an analysis of existing product attributes or operating characteristics to determine where improvements might be

made to better meet customer needs. Data analyses indicate most innovations were initiated by the rolling stock builders and suppliers.

The matching substage examines the fit between a problem and an innovation which may solve the problem. This definition is similar to the one used by Magill et al. (21, p. 29). The differences lie in the type of innovation studied. Magill et al. analyzed transportation methods developed and used by transportation operators. This paper analyzes transportation equipment developed by transportation suppliers or car builders, and utilized by transportation operators.

Also matched is the fit between the proposed innovation and the resources, capabilities, and objectives of the potential developer.

The feasibility study substage describes and evaluates various conceptual designs of an innovation to determine the benefits and the practicality of developing each. Cost-benefit tradeoffs are usually performed during this stage of the decision process.

The potential buyer decision process consists of three behavioral stages: the potential buyer initiation stage, the initial implementation stage, and the redefining implementation stage. The potential buyer initiation stage is the process used by the potential buyer in arriving at a decision to try or not to try the innovation; the initial implementation stage is the process of demonstrating and evaluating the innovation (50, p. 67); and the redefining implementation stage is the process of modifying the innovation to increase its compatibility with the needs and wants of the potential

buyer (21, p. 29). One tangible result of the redefining implementation stage is a specification which forms part of an invitation for bid (IFB) distributed to potential producers. Proposals received from producers are evaluated against requirements identified in the redefining implementation stage.

The potential buyer initiation stage consists of knowledge-awareness, formation of attitudes toward the innovation, and decision substages defined by Zaltman et al. (50). (The agenda setting and matching substages described by Magill et al. (21) are thought to be inappropriate for innovations that are externally produced.) The knowledge-awareness substage consists of potential buyer perceptions that a new product alternative is available, which might offer benefits over existing products.

The formation of attitudes toward the innovation substage is similar to Rogers and Shoemakers (29) persuasion stage during which buyers become favorably or unfavorably disposed toward the innovation. The capability within the organization for utilizing the innovation, prior success or failures with other innovations, and the innovativeness of the organization partially determine attitudes toward the innovation.

The decision substage consists of the potential buyer deciding whether to try or not to try the innovation (29).

The producer decision process consists of two behavioral stages, a producer matching stage and a production and test stage. The producer matching stage is the process used by the producer in arriving at a

response to the IFB. During this stage the producer will match: 1) his resources and capabilities against the requirements specified in the IFB, and 2) his expected revenue and non-monetary benefits against his expected costs of producing and guaranteeing the performance of the innovation.

The production and test stage is the process used by producers in the manufacture, test, and delivery of innovations.

The user decision process consists of one stage, a continued-sustained implementation stage. The continued-sustained implementation stage is the process of formally integrating the change into the user's organizational structure and processes (21).

The continued-sustained implementation stage consists of two substages, a structuring substage and an interconnecting substage. During the structuring substage, "Organizational structures directly relevant to the innovation are altered to accept the innovation" (21, p. 21). During the interconnecting substage, "The relationship between the innovation and the rest of the organization is clarified, so that the innovation eventually loses its separate identity and becomes an ongoing element in the organization's activities" (21, p. 29).

APPENDIX C

DESCRIPTION OF INNOVATIONS STUDIED AND BARRIERS TO THEIR IMPLEMENTATION

Stored Energy Propulsion for Rapid Railcars (Flywheel)

A flywheel energy storage unit was built by Garrett Corporation for trial by the New York City Metropolitan Transportation Authority (MTA). The purpose of the flywheel was to reduce power consumption, maintenance costs, and the amount of heat released in subway tunnels during the braking cycle. The energy storage system worked as follows: During the braking process, energy normally dissipated as heat through the resistor grids spun the flywheels through a motor/generator. During acceleration, the spinning flywheels produced electricity through the motor/generator to assist in driving the traction motors. The result was a reduction in peak power demand from the third rail during acceleration and less wasted heat during braking. A DC chopper system, used at BART and on UMTA's State-of-the-Art Car, was the heart of the solid state control system.

One of the most significant benefits of the project was to be improved safety. In the event of a power failure, a train will ordinarily stop and the passengers have to walk along the tracks to the nearest station. Using the stored energy principle, the train was to have been able to travel to the station even after electrical power has been interrupted. Thus, passengers would have been spared this potential hazard.

Two conventional New York City Transit Authority R-32 cars were retrofitted with the energy storage system. The cars underwent performance and others tests at the Pueblo (Colorado) Transportation Test Center in 1974 and on the New York City rapid transit system in 1976. A second generation energy storage system was incorporated into the ACT-1 vehicles which were also tested at Pueblo.

Barriers To The Introduction Of Flywheels For Railcars

Results of the prototype testing in New York uncovered unanticipated bearing and seal problems requiring complicated and expensive maintenance. A combination of the maintenance problems and potentially high capital cost, persuaded MTA that the flywheel was too risky to purchase without a demonstration of production units. MTA requested that UMTA subsidize a demonstration of twenty cars. UMTA was unable to do so because of lack of funds. MTA was not sufficiently interested in the demonstration to continue exploring other options for obtaining additional flywheel in service tests.

Dual-Powered Gas Turbine/Electric (GT/E) Commuter Railcars

Gas Turbine/Electric (GT/E) commuter rail cars were developed by both G.E. Company and Garrett Corporation for the purpose of providing a vehicle which could operate on either electric power or on diesel fuel. The vehicles were developed in response to operational constraints on the Long Island Rail Road. The railroad is only partially electrified, necessitating that two entirely different propulsion systems be used on cars traversing its tracks. One potential solution to this problem was

the development of a railcar that could be driven either electrically or by diesel fuel. Both the G.E. and the Garrett vehicles were operated in revenue service during 1976-1977 on the Long Island Rail Road system.

Barriers to the Introduction of the GT/E Railcars

The rapid increase in diesel fuel prices resulted in the rejection of GT/E rail cars by MTA. Diesel fuel prices affected by OPEC pricing decisions increased to the extent that extending third rail electrification became a lower cost solution than were the use of GT/E rail cars. In addition, reliability problems were created by the vehicle complexity necessitated by different wayside configurations encountered along the MTA track (26).

The State-Of-The-Art Car (SOAC)

UMTA used the services of Boeing-Vertol as a systems manager contractor to develop two State-of-the-Art Cars. The two cars were built by the St. Louis Car Division of General Steel Industries. The purpose of the SOAC was to create a climate to advance state-of-the-art rapid transit equipment that had relatively low technological risk. The SOAC featured a D.C. chopper control propulsion system (which had been used only at BART) by Garrett AiResearch, new air ride trucks, and innovative styling by Sundberg-Ferrar incorporated into an R-44 shell. The two SOAC's were demonstrated in revenue service in New York, Boston, Cleveland, Chicago, Philadelphia, and on PATCO's Lindenwold

High Speed Line in the Philadelphia region during 1976. (The original target market consisted of the old domestic transit systems located East of the Mississippi.)

Although no transit system purchased a complete SOAC per se, the three major innovations demonstrated in SOAC are currently being utilized by various transit systems. Regenerative, D.C. chopper control propulsion systems are currently in revenue service in Atlanta (MARTA), San Francisco, and Toronto even though chopper motor-bearings, commutation circuitry, and brush problems were observed on SOAC.

The air ride trucks were used first at BART. They performed well during SOAC demonstration and are currently in revenue service at WMATA, MARTA, as well as BART. Because of increased maintenance costs, they were not purchased by New York.

The innovative styling of the SOAC was similar, although not exactly the same, to the styling currently found on trains utilized by MARTA and WMATA.

Incentives To The Introduction Of the SOAC

The SOAC subsystems diffused because they were low risk, state-of-the-art products which offered benefits to transit properties at a reasonable price. The ACT-1 which will be discussed in the next paragraph was quite a different story.

The Advance Concept Train (ACT-1)

ACT-1 cars were built under the systems management of Boeing Vertol with the Garrett Corporation acting as prime contractor. Features of the ACT-1 were to include a new lightweight, easily maintained monomotor truck using automotive concepts such as improved sliding, biparting, plug type doors; turbo airconditioning; split axles; bolt-on, ring-damped wheels; copper disc brakes; an advanced flywheel energy-storage propulsion system (eliminating major highpower electronics); all major auxiliaries driven from the flywheel (eliminating many electric motors); an aluminum frame with composite panel car-body for easy manufacture; an energy-absorbing system for low-speed impact control; modular interiors for demand-tailored applications; and a reduced lifecycle cost of ownership and operation.

ACT-1 cars did not progress past tests performed at the Transportation Test Center, Pueblo, Colorado. Unlike the SOAC, the majority of the innovative subsystems incorporated into ACT-1 were not placed in revenue service by transportation authorities.

Not all subsystems failed. Ring-damped wheels provided wheel noise reduction benefits to transit systems at acceptable prices. They have been placed in revenue service at SEPTA and CTA, and are being tried in New York. This diffusion is occurring despite ring mechanical freezing problems found at SEPTA.

A lightweight aluminum frame similar to the one used on ACT-1 has been purchased by MARTA and was used on Rohr cars purchased by BART and by

WMATA. The lightweight aluminum frame, however, had been used prior to ACT-1 on rail cars. ACT-1 is an example of a vehicle that failed due to lack of knowledge on the part of UMTA and car builders of: 1) the benefits/disadvantages that previously untried total vehicles would offer; 2) a lack of concern for product price; and 3) a lack of knowledge of transit operator needs.

Barriers And Incentives To The Introduction Of The ACT-1 Monomotor Truck

Advantages that suppliers perceived the monomotor truck to offer over the bimotor truck were: improved wheel/track adhesion; reduced wheel and track wear; reduced truck weight; reduced axle loading; increased simplicity; reduced price; reduced maintenance, and reduced wayside vibration.

These advantages were not well demonstrated on the ACT-1 cars which were never placed in revenue service.

Transportation authorities were reluctant to purchase monomotor trucks due to both the lack of their demonstrated advantages and certain disadvantages which were thought to exist. The monomotor truck wheel diameter is more critical than is the bimotor truck wheel diameter. To maintain similar wheel diameters, either the wheels have to be trued when wheels are replaced, or they will become trued via wheel slippage during operating cycles. The first case increases maintenance costs. The second negates the monomotor truck adhesion and track wear advantages.

Although the monomotor truck eliminates one motor, it does not reduce system complexity. For instance, two gear boxes, which continue to be required, combined with the development costs associated with a new product, negate the expected price benefits. In addition, removal and replacement of the monomotor is more expensive than is bimotor removal and replacement, increasing maintenance costs.

When interviewed, Garrett Corporation management (5) indicated that the advantages obtained from the monomotor may be site specific. The monomotor truck may be more cost advantageous for light rail vehicles where they are currently being used than for heavy rail ones where they have not been adequately demonstrated.

Barriers To The Introduction Of Bolt On Wheels

Bolt-on wheels were designed to simplify wheel removal and installation by bolting wheels on the axle instead of using a press fit. Wheels which are press fit on axles have to be removed and replaced by machine after the carbody has been separated from the truck. Bolt-on wheels can be removed and replaced by hand without the carbody being removed from the truck.

Bolt-on wheels were not sufficiently demonstrated to transit properties to justify their purchase. Older properties perceived no great advantages would be obtained from the simplified operation. They already owned equipment to remove and replace the existing press fit wheels. In addition, risk was associated with bolting wheels on axles.

Bolts can shear or bend, and nuts can come loose, creating safety and maintenance problems.

Barriers To The Introduction Of The Copper Disc Brakes

Copper disc brakes were expected to provide a longer brake life. Instead they overheated and cracked during test. Although these technical problems were conceivably correctable, the selling price was unacceptable.

Barriers to the Introduction of the Improved Energy Absorbing System

To obtain an improved energy absorbing system for low-speed impact control, pistons were added to the existing anticlimber systems. The purpose of the pistons was to absorb impact shock. Because low speed shock protection was not a major concern of operators of heavy rail vehicles, the idea died with the ACT-1 at Pueblo.

Barriers to the Introduction of Sliding Plug Type Doors and the Turbo Air Conditioner

Because both the improved sliding, biparting, plug type doors and the turbo air conditioner proved to be unreliable on heavy rail vehicles, they never entered revenue service on heavy rail vehicles. They did, however, enter revenue service on the MBTA and San Francisco Light Rail Vehicles.

Barriers to the Introduction of Modular Interiors in ACT-1

Modular interiors for demand tailored operations were aesthetically pleasing, but reduced the usable square footage in the interior of the ACT-1 car. Because the square footage per passenger in a crowded train is more important to transit systems than aesthetics, the idea was abandoned.

Barriers to the Introduction of the Flywheel on ACT-1

The flywheel installed on ACT-1 was an improved version of the one installed on the R-32 car in New York City. It was designed to assist in braking operations and to store energy for acceleration, thus reducing brake wear and energy usage. The flywheel was not placed in revenue service in new transit systems because it offered only a slight advantage over the regenerative chopper in energy conservation, but was noisier, heavier, produced increased vibration, and was more expensive than the regenerative chopper. It was not adopted by the older systems, (for instance in New York were it offered greater energy conservation advantages over the cam propulsion system) due to the increased noise, weight, vibration, price, and risk of encountering reliability and maintenance problems associated with new products.

Advanced Subsystems Development Program (ASDP)

The ASDP was developed concurrently with the Advanced Concept Train. The purpose of the ASDP was to develop subsystems which: 1) were responsive to the needs and desires of the transit industry; 2) had

near term applicability; and 3) offered minimum risk. The subsystems were to be incorporated into a SOAC vehicle and tested at the Transportation Test Center in Pueblo, Colorado.

Included in the ASDP were an A.C. synchronous propulsion system, a monomotor truck and a synchronous brake control and detection system. The synchronous brake control and detection system was designed to sense wheel spins and slides virtually as they occurred and to apply the proper force to correct these conditions more rapidly than did the present systems. The result was to be more effective braking and more consistent stopping distances. In addition, a split-disc configuration was to provide improved maintainability.

The monomotor truck featured a lightweight steel design with an improved suspension system. The improved suspension system was to provide a ride quality equal to the ACT-1 vehicle. The truck was developed by the Budd Company.

The AC propulsion system was to be developed by the Delco Division of General Motors Corporation. It featured liquid-cooled brushless motors and solid state control.

Although the ASDP subsystems were never tested in combination on a SOAC vehicle, spinoffs were obtained from the technology developed. For instance, the suspension system which utilized a non-linear spring is currently being installed on new trucks. The side bearers, which transmit vehicle loads, allow trucks to be steered more easily and prolong the life of sliding components. The rubber suspension system

and the computer program designed to analyze wayside noise is being used in the development of new systems. The Westinghouse air brake system was a spinoff from the monomotor truck. Finally, the roll bar from the ASDP vehicle will be used on AMTRAK cars.

Barriers To The Introduction Of The ASDP Innovations

The ASDP is an example of the danger of combining more than one innovative subsystem in one vehicle. Due to technical difficulties, possible combined with a small potential market and large capital investment requirements, General Motors (Delco) did not install the AC propulsion system on a SOAC truck as planned. The monomotor truck with its improved suspension systems and the sunchronous brakes were designed to work on a SOAC truck having an AC propulsion system. Termination of the AC propulsion system program resulted in a modified SOAC which did not run, and hence, could not be tested. One of the subsystems, the synchronous brake, was eventually implemented. A synchronous brake is currently being used by MARTA. The improved suspension system was recently tested in Pueblo by the Budd Company and may be introduced in the near future.

Radial Steering Trucks

Radial steering trucks are being developed for the purpose of reducing wheel squeal noise and rail wear. PATCO is currently evaluating a prototype built by Budd.

Barriers To The Introduction Of Radial Steering Trucks

The primary barrier to adoption of radial steering trucks may be a technical one. Mathematical models indicate that truck oscillation (kinematic instability) may occur under certain conditions. This problem, if it should occur, may have deleterious effects on transit property perceptions of equipment safety. The Budd Company has, however, sufficient confidence in the future of steering trucks that it has invested its own funds in developing, as part of its product line, steerable trucks for mild curves.

The Morgantown People Mover

The only people mover subsidized by UMTA was installed in Morgantown, West Virginia. It was developed primarily by three manufacturers; Boeing which designed the cars and managed the program; Trumbull which installed the people mover guideway structure; and Bendix, which designed the control system. The Morgantown People Mover consists of a concrete guideway, multi-channel off-line stations, a car which can carry 21 passangers (8 seated), and a synchronous control system which operates vehicles at 15 second headways.

The effort has been viewed critically as a result of both final costs being higher than those originally estimated by Alden Starr Car and the safety and performance problems which existed during the Morgantown People Mover's initial demonstration.

The safety and performance problems stemmed from the political decision to demonstrate the people mover prior to the 1972 election. The

demonstration should have occurred after research and development were complete. The cost escalation was caused by the unrealistic initial cost estimate.

The final system cost approximately 33 million dollars per double-lane-mile to develop and install, a relatively low cost by today's standards. The Morgantown People Mover currently costs forty-five cents per passenger mile to operate with a twenty-five percent load factor (six passengers), a low operating cost compared to other modes.

Barriers To The Diffusion Of The Morgantown People Mover

The Morgantown People Mover did not diffuse to other transit systems for several reasons. First, it is more complicated than is required for most downtown people movers; second, Boeing was unwilling to modify its existing design to bid it as a downtown people mover. The company management believed the market to be too small to warrant the expensive proposal activities requested by most cities interested in DPM's.

Downtown People Movers (DPM's) and Advanced Group Rapid Transit (AGRT)

Downtown People Movers are an example of a innovative idea which, after being implemented in Morgantown, West Virginia, will be prevented by government policy from diffusing to many other transportation systems. Touted as a means of rejuvenating urban central business districts, DPMs consist of a guideway, automated vehicles to reduce operating costs, stations, a maintenance and storage facility, and a control system capable of providing short (one to two minutes) headways between

vehicles. People Movers are offered by Westinghouse, Urban Transportation Development Corporation (UTDC), Matra/Otis, the Vought Corporation, and others.

Interest in DPMs was expressed by a number of cities including Miami, Los Angeles, Detroit, St. Paul, Jacksonville, and Indianapolis, and Norfolk. Construction contracts were about to be let in Los Angeles, Miami, and Detroit when the Reagan Economic Recovery Program specified that new starts, including DPM, could no longer be funded within current budgetary constraints.

However, because of Congressional appropriations for the Miami and Detroit Downtown People Movers, those systems may proceed into implementation, but not in the framework of a demonstration program. Technical and pricing problems of AGRT systems are severe. AGRT's are being developed by two suppliers, the Boeing Company and the Otis Elevator Company. Boeing's design is an outgrowth of the Morgantown People Mover. It uses a rubber-tired vehicle which moves along a U-shaped guideway. The Boeing AGRT holds 12 passengers and has a three-second headway capability.

The Otis Elevator AGRT design uses a linear induction motor for propulsion, and on air cushion suspension. It also moves along a U-shaped guideway, holds 12 passengers, and has a three-second headway capability.

Barriers To Further Diffusion Of Downtown People Movers And AGRT Systems

Barriers to the further diffusion of Downtown People Movers may be the lack of government assistance. People movers and AGRT systems are expensive and offer high technical risk. Guideways, if constructed, may create potentially major urban impacts. Because most transportation authorities are in a very unhealthy financial condition, UMTA funding priority is devoted to meeting the immediate capital needs of those transportation authorities. The Reagan administration's mandate that government spending must be reduced to hold inflation in check has resulted in the reduction of funding for futuristic programs such as AGRT and downtown circulators, and DPM's.

BIBLIOGRAPHY

1. American Public Transit Assoc., Transit Fact Book - '77-'78-'79-'80-'81: 1981.

2. Arthur D. Little, Inc. and Industrial Research Institute, Inc., Barriers to Innovation in Industry: Opportunities for Public Policy Changes, September 1973.

3. Arthur D. Little, Inc., Federal Funding of Civilian Research and Development, February 1976.

4. Bowerman-Davies, John (Mack Truck), Personal interview on June 16, 1981.

5. Bowler, William (Garrett Corporation), Personal Interview on July 16, 1981.

6. Bullard, Walter, Ronald Eber, and Eric Lutz (Detroit Diesel Allison), Personal Interview on June 5, 1981.

7. Chakrabarti, Alok W. and Albert H. Rubenstein, "Interorganizational Transfer of Technology: A Study of Adoption of NASA Innovations," IEEE Transaction on Engineering Management, Vol. EM-23, No. 1, February, 1976, pp. 10-34.

8. Chin, David (The Onyx Corporation), Review of Possible Effects of Some Selected Federal Actions on New Transit Product Introduction, July 1979.

9. DeClaire, G., G.J. Plannery, Mel. Montie, and D.W. Humphrey (Rockwell International), Personal Interview on June 3, 1981.

10. Dickhart III, William (Budd Company), Personal Interview on June 22, 1981.

11. Feller, Irwin (Penn State University), "Three Coigns on Diffusion Research," Knowledge: Creation, Diffusion, Utilization, Vol. 1, No. 2, Sage Publications, December 1979, pp. 293-312.

12. Gellman, Aaron Jo, "Incentives to Innovation in the Transportation Sector," Proceedings: Innovation in Transportation, National Academy of Sciences, 1980, pp. 104.

13. Goeddel, D.L. and G. Ploetz, Analysis of Life Cycle Costs and Market Applications of Flywheel Energy - Storage Transit Vehicles, UMTA-MA-06-0044-78-2, April 1979.

14. Heaton, George R., Jr. (MIT), Government Involvement in the Innovation Process, A Contractors Report to the Office of Technology Assessment, Report 3-85-81.

15. Highway Research Board, Design and Performance Criteria for Improved Nonrail Urban Mass Transit Vehicles and Related Urban Transportation Systems, prepared for the U.S. Department of Housing and Urban Development, Washington, D.C.: National Academy of Engineering, 1968 (NTIS no. PB 178 804).

16. Horwitz, Paul (MIT), Direct Government Funding of Research and Development: Intended and Unintended Effects on Industrial Innovation, January 15, 1979, Report 3-88-81.

17. Howard, Denny (Gillig), Personal Interview on July 17, 1981.

18. Innovative Systems Research, An Analysis of the National Science Foundation's Experiment on Federal Actions to Accelerate Utilization of Civilian Oriented R & D, 1979.

19. Landon, Robert (Grumman Flxible), Personal Interview on June 8, 1981.

20. Lewis, Drew (Secretary of Transportation), Statement Before the Subcommittee on Housing and Urban Affairs (Senate) Concerning Proposed Mass Transit Legislation, May 15, 1981.

21. Magill, Kathleen P., Thomas E. Shanks, and Everett Rogers (Stanford University), The Innovation Process of Three Mass Transportation Innovations: Vanpooling, Auto-Restricted Zones, and Priority Highway Lanes for High-Occupancy Vehicles, June 1980 (Report no. UMTA-CA-06-0115-80-1).

22. Manning, Don (Don Manning Consultants), Telephone Interview on July 7, 1981.

23. National Research Council (National Academy of Sciences), NRC Transbus Study, 1979.

24. Pastor, George (Past Associate Administrator for Technology Development and Deployment. Presently with UTDC), Telephone Interview on July 8, 1981.

25. Payne, George and Ronald Ward (Abex), Personal Interview on June 3, 1981.

26. Raskin, Donald, Charles Stark and L.T. Klauder and Associates, Dual-Powered Gas Turbine/Electric Commuter Rail Cars: Test, Evaluation and Economics, September 5, 1980 (UMTA-NY-06-0005-80-1).

27. Roessner, J. David (Georgia Institute of Technology), "Technology Diffusion Research and National Policy Issues," Knowledge: Creation, Diffusion, Innovation, Vol. 2, No. 2, Sage Publications, December 1980, pp. 179-201.

28. Rogers, Everett M., Diffusion of Innovations, The Free Press, N.Y., 1962.

29. Rogers, Everett M., Communications of Innovations, The Free Press, N.Y., 1971.

30. Schagrin, Edward and Peter Venuti (Boeing Vertol Co.), Personal Interview on June 19, 1981.

31. Schlemmer, Carl J., "A Manufacturer's View of the Transit Market," Transit Journal, APTA, Summer 1980, p. 5.

32. Smith and Howard Associates, Inc. and ATE Management and Services Company, Inc., Barriers to the Diffusion of Innovation in the Transit Industry, June 1979 (DOT-I-80-5).

33. Stokel, Ed. (GMC), Personal Interview on June 2, 1981.

34. Syracuse Research Corporation, The Role of Industry in Urban Technology Transfer: A Comparative Profile, November 1979 (NSF-PRA-77-23746).

35. Transportation Systems Center (DOT), An Assessment of the Deployment Process for Urban Transportation Products, January 1976 (PPA-UM-634 Sponsor: URD).

36. Transportation Systems Center (DOT), UMTA Data Book, August 1980.

37. UMTA (DOT), Fiscal Year 1972 Budget Estimates, for Submission to Congress.

38. UMTA (DOT), Fiscal Year 1973 Budget Estimates, for Submission to Congress.

39. UMTA (DOT), Fiscal Year 1981 Budget Estimates, for Submission to Congress.

40. UMTA (DOT), Innovation in Public Transportation, 1976 through 1980.

41. UMTA (DOT), Proceeding of the Second R & D Priorities Conference, November 30 - December 1, 1976 (3-DC-157-77-1).

42. UMTA (DOT), Baseline Advanced Design Transit Coach Specifications, November 1978.

43. U.S. Congress, Urban Mass Transportation Act of 1964, as Amended Through December 1978, and Related Laws.

44. U.S. Department of Transportation, Procurement Study: An Evaluation of the Procurement Process Used to Purchase Rolling Stock and Technical Equipment for Mass Transit, March 1980.

45. U.S. Government, The Budget of the United States Government-Fiscal Year 1981.

46. U.S. House of Representatives' Subcommittee on Oversight and Review, Report on the Urban Mass Transportation Administration's Technology Development and Equipment Procurement Programs "Do We Know What We're Trying To Do?" March 1980 (96-34).

47. U.S. House of Representatives, Hearing Before the Subcommittee on Transportation, Aviation and Communications, April 1, 2, 1980 (No. 115).

48. Von Hippel, Eric, "Successful Industrial Products From Customer Ideas," Journal of Marketing, January 1978, pp. 39-49.

49. The Washington Consulting Group, Final Report: Program and Communications Plan, Prepared for the Office of Safety and Product Qualification (UMTA), January 15, 1981.

50. Zaltman, Gerald, Robert Duncan and Jonny Holbek, Innovations and Organizations, John Wiley and Sons, N.Y., 1973.