tomorrow's transportation

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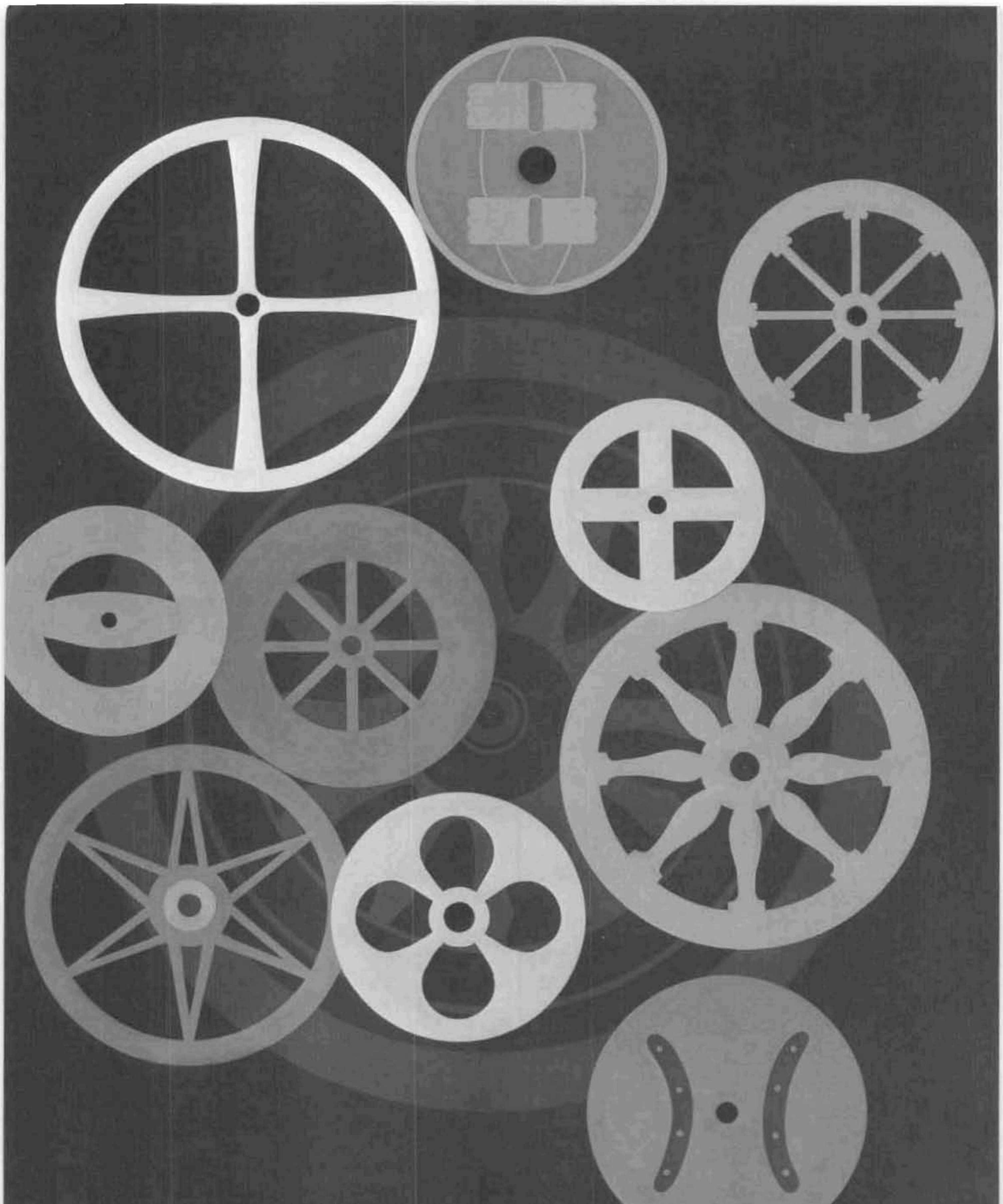
TOMORROW'S TRANSPORTATION

NEW SYSTEMS FOR THE URBAN FUTURE

"In the next 40 years, we must completely renew our cities. The alternative is disaster. Gaping needs must be met in health, in education, in job opportunities, in housing. And not a single one of these needs can be fully met until we rebuild our mass transportation systems."

LYNDON BAINES JOHNSON



TO THE CONGRESS OF THE UNITED STATES:

I am transmitting today a report on the study of new systems for urban transportation, entitled Tomorrow's Transportation: New Systems for the Urban Future.

Undertaken by the Secretary of the Department of Housing and Urban Development in accordance with the Urban Mass Transportation Amendments of 1966, the study has involved research and analytic efforts over a period of 18 months. It has explored areas of transportation research and development to ease the problems of Americans who live in or commute to work in cities.

The report identifies research and development which offers promising prospects for transportation improvements in our cities in the near future. It suggests a longer term program of research and development, concentrated in areas of greatest promise and benefit.

I commend the report for study by the Congress and the concerned Federal, State and local agencies. It provides a good foundation for decisions upon the program of research and development required to develop the needed new systems of transportation for our crowded metropolitan areas.

THE WHITE HOUSE,
May, 1968

U.S. DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT

Robert C. Weaver, *Secretary*

Robert C. Wood, *Under Secretary*

This report was prepared under the direction of

Charles M. Haar
Assistant Secretary for Metropolitan Development

Leon Monroe Cole, *Editor*
Harold W. Merritt, *Technical Editor*

foreword

THE FOLLOWING REPORT IS A SUMMARY of the recommendations for a comprehensive program for national leadership in research, development and demonstration in all aspects of urban transportation and of the basis upon which it was formulated. The study and its recommended action proposals were prepared in consultation with the Secretary of Transportation, under the leadership of Charles M. Haar, Assistant Secretary for Metropolitan Development of this Department. The insight and perception of the nature of urban problems shown by Assistant Secretary Haar and the staff which assisted him have resulted in the design of a program of research and development which could beneficially affect very aspect of urban life for many years. The recommended program involves not only new systems for meeting urban travel needs ranging from those of the pedestrian to those of the air traveler, but also improvements in existing service and facilities, new and improved system components, and new and improved methods of planning and operating urban transportation systems.

Throughout, our concern has been to relate technology and scientific innovation as closely as possible to the present and desired shape of our cities and the improved quality of life of urban residents. The role of the recommended program is stressed as only one of a number of tools needed to bring better cities into existence in the future through an orderly process of ameliorating the urban difficulties of the present. While urban transportation research, development and demonstration alone cannot solve our current urban problems or bring about our desired future cities, it is an indispensable instrument for our efforts to reach these goals.

This report should be viewed as a first major effort to formulate a comprehensive urban transportation research, development and demonstration program. The program, its focus and objectives, will evolve as it is carried out. This evolution must be consonant with research, development, demonstration and implementation programs in all aspects of urban service, facilities and development. It is our hope that we have been as successful in our effort as the Congress was farsighted in requesting that this effort be undertaken.

ROBERT C. WEAVER
Secretary of Housing and Urban Development

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summary

THE SECRETARY OF HOUSING AND URBAN DEVELOPMENT was directed in 1966 [by Section 6(b) of the Urban Mass Transportation Act of 1964, as amended] to

> . . . undertake a project to study and prepare a program of research, development, and demonstration of new systems of urban transportation that will carry people and goods within metropolitan areas speedily, safely, without polluting the air, and in a manner that will contribute to sound city planning.

This report summarizes the findings of the "new systems" study. The study reflects the concern of the Department of Housing and Urban Development for cities and their people, as well as for their transportation. For assistance in performing the study, the Department engaged 17 contractors from industry, scientific research centers, universities and the foundations over an 18-month period. Economists, engineers, scientists, technicians, urban planners, systems analysts, management consultants, and transportation experts were employed. The results of their efforts and a recommended research and development program are summarized here. A series of more detailed technical reports, containing the specific findings of the contractors, will be forthcoming.

In brief, the study found that progress in urban transportation technology, rudimentary today, could nevertheless be greatly enhanced and accelerated by vigorous leadership of the Federal Government—in cooperation with the private industries concerned—using a systematic, carefully designed, and reasonably funded research and development program as the major guiding stimulus.

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The capacity and the capabilities of American industry and private enterprise stand ready. The scientific and technical manpower needed for increased research and analysis in the field of urban transportation is available. But a stimulus is needed to progress, to prevent future neglect of *intraurban* transportation technology and systems, and to develop means by which this progress can contribute to the quality of urban life.

A part of this report examines the promise of existing technologies to improve present urban transportation systems. It identifies some exciting short-run improvements that could be undertaken. But beyond immediate improvements, this report projects a continuing research and development effort which could turn innovation into application, and accelerate transit technology in a careful and deliberate, rather than accidental, way.

The research and development program recommended as a result of the new systems study entails a total program funding of $980 million. This time-phased program could continue and accelerate the $25 million program contained in the President's fiscal year 1969 budget. It would involve these areas: Improved analysis, planning, and operating methods; immediate system improvements; components for future systems; and the development of entirely new systems for the future.

The recommendations maintain these major objectives for using the transportation system to enhance and improve the total city system: To achieve equality of access to urban educational, job, and cultural opportunities; to improve the quality of transit services; to relieve traffic congestion; to enhance efficiency in the use of equipment and facilities; to achieve more efficient urban land use; to provide cleaner, quieter, and more attractive public transportation; to provide more alternatives to urban residents in mode and style of urban living; and to permit orderly improvement of urgent transportation problems without preempting long-range solutions for the future.

Nearly 300 projects and proposals having immediate application possibilities were examined and evaluated. For example, to improve buses these possibilities were studied: Exclusive bus lanes; traffic flow control; passenger-activated traffic control; computer scheduling; better design of vehicles; and a dual mode bus that could operate on ordinary streets or high-speed rights-of-way. Similarly, recommendations were examined for improving intraurban rail systems, urban automobiles, and the options and opportunities for pedestrians.

Other proposals of more general application were considered to improve fare collection methods, security of passengers and operators, methods for communicating station and passenger information, and, of particular significance, management and operation of urban transit systems.

For the longer-term future, the new systems study found many promising technologies which should be further explored, such as: Automatic controls for vehicles and entire movement systems; new kinds of propulsion, energy and power transmission; new guideway and suspension components; innovations in tunneling; and the application of these potentials for movement of goods as well as people.

The more promising of these new systems are:

- *Dial-a-Bus:* A bus type of system activated on demand of the potential passengers, perhaps by telephone, after which a computer logs the calls, origins, destinations, location of vehicles and number of passengers, and then selects the vehicle and dispatches it.

- *Personal Rapid Transit:* Small vehicles, traveling over exclusive rights-of-way, automatically routed from origin to destination over a network guideway system, primarily to serve low- to medium-population density areas of a metropolis.

- *Dual Mode Vehicle Systems:* Small vehicles which can be individually driven and converted from street travel to travel on automatic guideway networks.

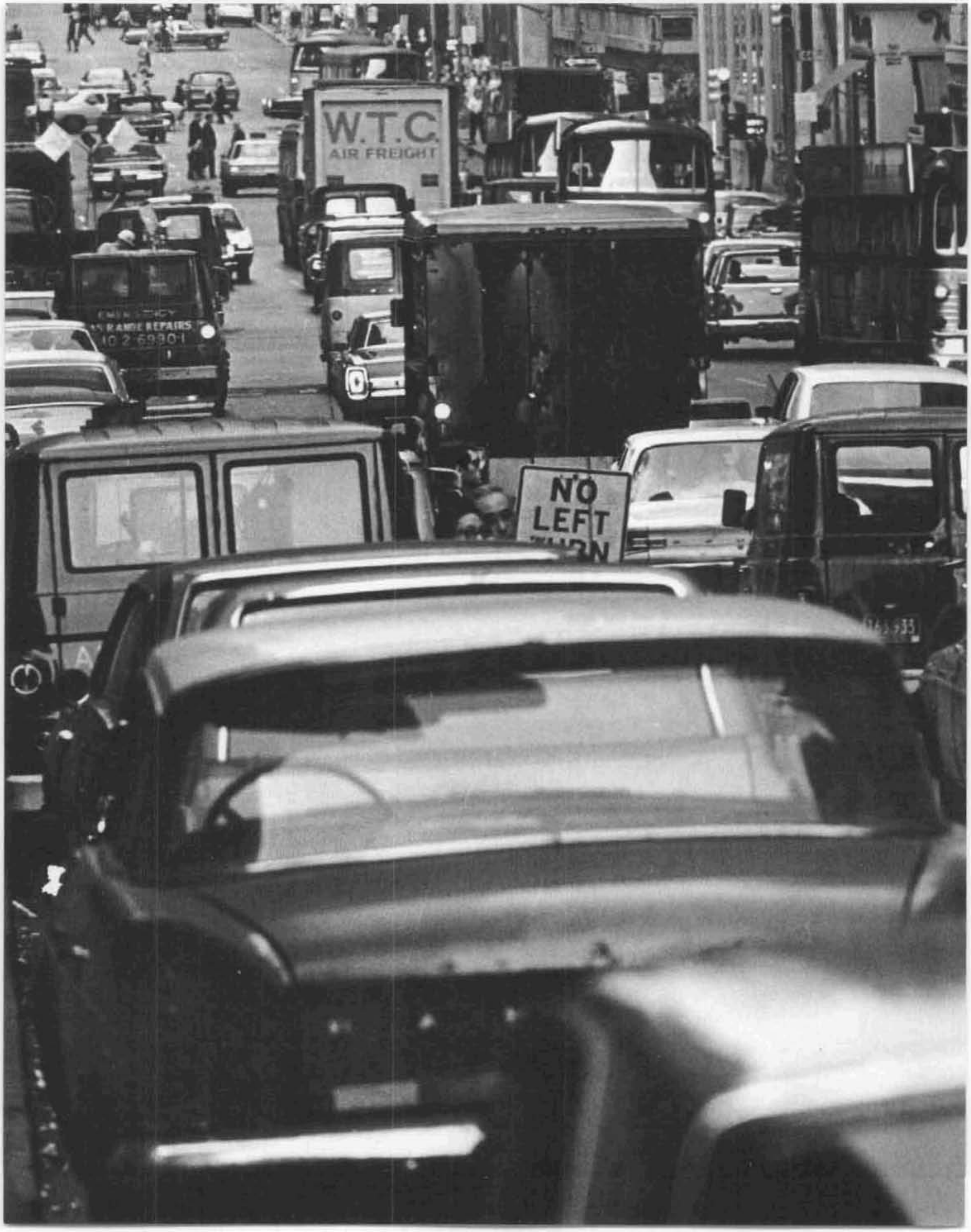
- *Automated Dual Mode Bus:* A large vehicle system which would combine the high-speed capacity of a rail system operating on its private right-of-way with the flexibility and adaptability of a city bus.

- *Pallet or Ferry Systems:* An alternative to dual mode vehicle systems is the use of pallets to carry (or ferry) conventional automobiles, minibuses, or freight automatically on high-speed guideways.

- *Fast Intraurban Transit Links:* Automatically controlled vehicles capable of operating either independently or coupling into trains, serving metropolitan area travel needs between major urban nodes.

- *New Systems for Major Activity Centers:* Continuously moving belts; capsule transit systems, some on guideways, perhaps suspended above city streets.

The components and systems discussed in this report do not by any means exhaust the rich array of opportunities for innovation in urban transportation provided by the new systems study, as the forthcoming technical reports will indicate. The recommended research and development program, projected as it is into the future, is susceptible to modification as further knowledge is gained.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tomorrow's transportation

NEW SYSTEMS FOR THE URBAN FUTURE

U.S. DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT
Office of Metropolitan Development, Urban Transportation Administration
Washington, D.C. 1968

...The Secretary shall undertake a project to study and prepare a program of research, development, and demonstration of new systems of urban transportation that will carry people and goods within metropolitan areas speedily, safely, without polluting the air, and in a manner that will contribute to sound city planning. The program shall (1) concern itself with all aspects of new systems of urban transportation for metropolitan areas of various sizes, including technological, financial, economic, governmental, and social aspects; (2) take into account the most advanced available technologies and materials; and (3) provide national leadership to efforts of States, localities, private industry, universities, and foundations.

1966 Amendments to the URBAN MASS TRANSPORTATION ACT OF 1964, Section 6 (b).

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I urbanization and urban transportation

URBAN AMERICA will double in the next 40 years, growing as much in that time as all of American urban growth since the landing of the Pilgrims. In that short period, the needs of older cities must be met at the same time that more than 100 million additional persons will be living in the Nation's metropolitan areas. The question facing governments at every level, private industry, and the public, is not whether provisions can be made for this massive and complex growth. Houses will be built—as will schools, hospitals, libraries, airports, water and sewer systems, roads, shopping centers, and office buildings. Of this there can be no doubt. What is in doubt is the shape and substance of cities and their opportunities; i.e., the quality of urban life.

The form and quality of future cities is affected by many factors: Local administration, intergovernmental relations, municipal finance, private investment, water and sewer and other public facilities, and—basically—by urban transportation. The life of a city depends upon its transportation system. Inefficient transportation services increase the costs of local industry and commerce. They rob citizens of their time and comfort. They penalize especially the poor and the handicapped.

An 18-month study—the first truly comprehensive official look at urban transportation in the light of modern technological capabilities to deal with modern urban problems—was authorized by Section 6(b) of the Urban Mass Transportation Act of 1964, as amended in 1966. This report summarizes the findings of that "new systems" study—a systematic investigation of the possibilities for technological "breakthroughs" in urban transportation research comparable to those accomplished in the fields of medicine, atomic energy, and aerospace technology.

The study brought some of the finest research skills available—in government, industry, universities, research centers, and the foundations—together with experts possessing years of experience in dealing with urban transportation problems. Thus, traditional approaches were combined with new methods of research and systems analysis used successfully in the aerospace and defense industries. Working together, this unique team was able to explore urban transportation possibilities as never before, and to winnow fact from popular fiction. The improvements and new systems presented in this report also show the great potential benefits possible through combining technical advances with social service.

To help future urban transportation systems play a more active part in changing the city and the quality of urban life, eight general problems endemic to cities today were identified, against which total benefits anticipated from new transportation systems and subsystems could be measured as a guide to recommending an optimal research and development program. These eight problem areas are:

- *Equality of Access to Urban Opportunity:* Present urban transportation tends to immobilize and isolate nondrivers: The poor, secondary workers in one-car families, the young, the old, and the handicapped.

- *Quality of Service:* Public transit service too often is characterized by excessive walking distances to and from stations, poor connections and transfers, infrequent service, unreliability, slow speed and delays, crowding, noise, lack of comfort, and a lack of information for the rider's use. Moreover, passengers too often are exposed to dangers to personal safety while awaiting service. These deficiencies lead to a loss of patronage and a further decline in service for the remaining passengers.

- *Congestion:* Congestion results in daily loss of time to the traveler. Too often "solutions" are expensive in dollars and landtaking, destroying the urban environment in the process.

- *Efficient Use of Equipment and Facilities:* Increased efficiency and greater economy through better management and organizational techniques—including cost control, scheduling and routing, experimentation in marketing and new routes—is necessary to satisfy urban transportation requirements at minimum cost.

- *Efficient Use of Land:* Transportation functions and rights-of-way require extensive amounts of urban land, and compete with other important uses of the urban land resource. More rational urban land use made possible by new forms of transportation might help reduce travel demands, aid in substituting communications for urban transportation, and achieve greater total transportation services for the amounts of land required.

Urban travel is characterized by a large number of trips with many variations in trip lengths and highly diversified origins and destinations.

● *Urban Pollution:* Air, noise, and esthetic pollution from all current modes of urban transportation are far too high, degrading unnecessarily the quality of the urban environment.

● *Urban Development Options:* Transportation investments can be used creatively in the orderly development of urban areas. Present urban transportation is often not appropriate for the modern city: Service is generally inadequate or unavailable for low and medium density areas, for crosshaul trips and reverse commuting, and for circulation within activity centers and satellite cities. Urban transportation service should provide for choice in living styles and in locations as well as choice among modes of transportation. New town settlements, as well as other concentrations of urban growth, could be feasible options for land development patterns with improved intraurban transportation services.

● *Institutional Framework and Implementation:* An improved institutional framework—legal, financial, governmental and intergovernmental—is needed to eliminate rigidities and anachronisms which prevent the adoption of new technologies and methods. A framework which would assist metropolitan planning agencies and would enhance the effective cooperation of local governments in solving joint transportation problems is necessary.

Since the new systems study considered urban transportation to be not an independent function but a basic component of the entire urban complex, the changing urban context of transportation was examined. As cities grow in population and geographic size, their internal structure also changes, creating new and shifting patterns of urban travel demand. To keep pace with these changes, a service such as urban transportation must change also.

Major failings of the entire urban transportation system today are lack of both change and the capacity for change, resulting in a restricted choice of ways for people to get around the city and the metropolitan area. The common characterization of urban transportation modes as a blunt dichotomy between public rail transit and the private automobile is far too simple. Cities are the most pluralistic places in modern society; their citizens need a wide range of travel service, a mix of transportation services carefully designed to meet their varying travel needs.

The profiles of urban change, and some of the shortcomings of present urban transportation, are delineated in the following pages as an introduction to what must be done to develop new transportation components and systems for the future. While new "breakthroughs" in transportation systems and services are the ultimate aim, a sound research and development program must begin with present problems, available resources, and current behavior. Hence, a part of this report examines the promise of existing technologies to improve present transportation systems. Some exciting short-run improvements are

III what should be done

FINDINGS AND CONCLUSIONS

THE EXTENSIVE SERIES OF STUDIES conducted by the Department of Housing and Urban Development during the past months in consultation with the Department of Transportation, has yielded significant conclusions for the future of urban transportation, and for the future of cities and their people. In the briefest form they are:

1. Immediate and significant engineering improvements in automotive, bus, subway, and commuter train transportation are both possible and overdue, some of which require and merit Federal technical aid and financial stimulus.

2. Existing modes of urban transportation can be improved to serve urban goals and rider demands more effectively, through better use of regulation, pricing, education, management, and planning. Such improvements, in many cases, will require research, development and demonstration funds.

3. Even with engineering improvements and optimal management and utilization, present modes of urban transportation are inadequate to meet total future urban needs. The systems today—chiefly automotive, bus, and train—originated more than 50 years ago. They alone cannot provide the best solutions to foreseeable trip demands, changing urban patterns and rising standards for quality of the urban environment. A careful balance must be struck, in each metropolitan area and for the urban transportation industry as a whole, between immediate improvements and the fundamental development of new systems.

4. Incremental improvements in existing modes, as well as the development of new systems of urban transportation, will require better coordination of land use planning and transportation investments. Existing urban transportation planning too often does not identify the full range of transportation alternatives available, and fails to allow for efficient accommodation of improved systems in the future. Better planning methods will not only help to ameliorate urban transportation difficulties, but also will aid in achieving national goals for American cities.

The new systems study has produced a rich array of opportunities for improvements in urban transportation worthy of continued and intensified research and development. These opportunities can be grouped into two broad categories: Technological possibilities, or "hardware" components and systems worthy of further study and demonstration; and, improvements in the analysis of and planning for urban transportation and cities, along with improved operating and management procedures—a "software" category of the research and development program. A sound program must be based on work in both of these categories.

A STRATEGY FOR ACTION

THE MOST STRIKING OPPORTUNITIES for improvements in urban transportation are the technological innovations discussed later in this chapter. Attention fastens easily on a new vehicle or gadget. But such innovation is at the mercy of its institutional setting. Legal and financial impediments often hinder progress unnecessarily. Many of the greatest advances in urban transportation lie in areas such as analysis and planning, operations and management, intergovernmental relations, and financing, and in greater understanding of the whole complex social context of urban travel. Technology alone is not enough.

IMPROVED METHODS OF ANALYSIS, PLANNING AND OPERATIONS

The new systems study gave special attention to the potential value of "software" studies of two general types: First, studies of managerial, regulatory, pricing, educational, and operational innovation aimed at improving the efficiency and use of existing modes, vehicles and rights-of-way; second, studies preceding the actual building of prototype systems of components, including development and testing of models aimed at reducing the uncertainty inherent in advanced hardware projects.

An important focus of the first type of proposed software research studies is on the barriers that prevent the application of relevant technology to urban transportation. Although technical feasibility is a necessary condition for the successful application of technology to existing or future transportation systems, it is by no means sufficient. Many other conditions involving little or no technology must be satisfied lest they become institutional blocks preventing further innovation. Such impediments almost always arise whenever the status quo is perturbed, for example: when acquiring rights-of-way, leasing real property, neutralizing conflicting franchises.

Because private industry does not ordinarily manufacture, market, and realize a profit on institutional innovations, there is a serious knowledge gap in this area. As a result, there are many technically sound hardware concepts which have yet to be implemented in cities, although some have been used in special settings (such as a world's fair) where the institutional context is relatively uncomplicated. In sum, objectives of the proposed software program of research are to:

- identify impediments to the implementation of new technology and to propose methods by which these blocks might be overcome; and to
- identify appropriate nontechnological solutions which may be less costly than purely technical ones.

The importance of changes in the institutional setting may be illustrated by proposals to regulate peak-hour use of highways by requiring users during these hours to pay higher tolls or other charges, such as for parking. Charges would vary with the time of day and size of vehicles, and transit fares could vary with distance, replacing flat fares. While such proposals may involve difficult problems of equity or acceptability, the varied charges they contemplate, or staggered working hours alone, could have a more profound effect on the use of existing roadways, parking, and vehicle capacities than any immediately available new vehicle or equipment.

Research must be directed to improving the regulatory and administrative rules required of transportation companies. More flexibility in routes, schedules and fare structures, and labor practices and franchise costs based on performance incentives have substantial potential for improving urban transportation services.

Developing the training and professional opportunities for transit managers is another area of need, and one that the Department of Housing and Urban Development is already assisting. Closely related is the need to develop better marketing and information services.

Although other innovations may have a less direct impact, they may yield even greater benefits in the long run, for example: better methods of forecasting travel demands. New methods of computer simulation and analysis capable of handling the changes resulting from an expanding economy, including shifting locations of jobs and residences and rising levels of income and education, promise more accurate prediction of traffic, as well as prediction of the best locations for new construction.

The second category of software studies aims to reduce the uncertainty inherent in advanced hardware projects. Such studies could precede the actual building of prototype systems or components. Careful design and model building represent an inexpensive and highly efficient technique for moving forward against large uncertainties. A model is simply an analog of reality. The model can be purely physical, such as a hydrodynamic analog of traffic flow, or purely conceptual, such as a mathematical representation of the interaction between vehicles and guideways. Some models, of course, have both conceptual and physical components.

A major value of developing mathematical models of transportation systems as research tools is economic. By representing a yet to be developed transportation system mathematically, realistic bounds can be put on performance, land use impacts, and costs under a wide variety of conditions, and this can be done without having to build expensive prototypes or perform elaborate, time-consuming experiments. In recent years, the development and utility of these models has been enhanced by the use of high-speed computers. In most cases a thorough, mathematical evaluation of a proposed transportation system or subsystem can be performed for about 1 percent of the cost of developing an experimental prototype.

The use of mathematical models does not completely eliminate the need for developing prototypes and performing experiments. Major assumptions are required in such models concerning market acceptability, modal choice, changes in locational preferences, and so forth. Real urban experimentation is required to reduce the great amount of uncertainty surrounding these and other critical assumptions. Models do help reduce the cost of such experiments and demonstrations, however, by pointing up the most promising approach for implementing theoretically feasible systems and by eliminating from further consideration logically inconsistent ones.

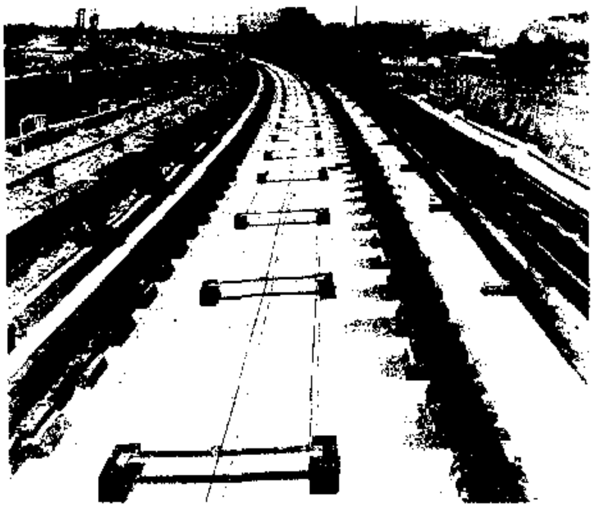
Other nontechnological innovations worthy of investigation are efforts to reduce the demand for transportation, either through substituting improved communications or improved planning of the location of related activity. Many of these concepts have been fairly well developed for some years. What is needed are methods for translating the ideas into action, in addition to research and development, such as more effective means for informing communities about feasible transportation alternatives and for helping them overcome the hostility or inertia that so often impede innovation.

URBAN TRANSPORTATION INFORMATION CENTER

A national urban transportation information center could help provide a focus for the kinds of activities mentioned above. Progress in the field of urban transportation has been seriously impeded by a scarcity of information. In many instances, promising new ideas are being tried and new techniques developed, almost in isolation. Consequently, a great deal of research effort is duplicated and the benefits of many useful innovations are limited to the locality in which they were developed.

A national information center established to seek out, analyze, preserve, and disseminate information about new developments and research in the field of urban transportation could perform a crucial service at a modest cost. Examples of the sort of work it might do include the compilation and analysis of statistical data, maintenance of a reference service, publication of bulletins, sponsorship of seminars around the country for transportation industry personnel, and coordination of urban transportation information with other Federal, State, and local agencies.

URBAN TRANSPORTATION TEST CENTER



The 4.4-mile Diablo Test Track, constructed as part of the San Francisco BART System, developed data on the relationship of ride quality and noise levels to track conditions and rail fasteners. Instrumentation provided for tests of trackside power collection equipment, train control systems, and automatic trouble-sensing equipment to perform safety checks of transit vehicles.

As part of the overall effort to more efficiently manage and promote scientific research and development in urban transportation, one other type of facility is required. An urban transportation test center could perform the analysis and investigation of new concepts, as well as of the social, economic and legal problems associated with their development and implementation. It would perform services which could assist in the solution of current operating problems as well as encourage research into future systems. The center could also assist in the establishment of performance criteria for new urban transportation systems, and could evaluate concepts, ideas and advanced systems prior to detailed development. Applications of emerging technologies—in terms of safety and reliability of new equipment—and prototype systems could be tested and proved for the benefit of both the transportation industry and the general public.

TECHNOLOGICAL POSSIBILITIES

Two questions are implicit in any decision that aims at immediate action:

- How can existing urban transportation systems be improved in the near future by applying present off-the-shelf technology?
- What kinds of entirely new urban transportation systems might be technologically feasible in the more distant future?

While the future systems described here are considered to be technologically feasible, only rough cost estimates are possible at this stage. Uncertainty inevitably characterizes proposed developments. Future systems depending on many new ideas to achieve major improvements in performance are much more uncertain as to cost and time of accomplishment than less ambitious projects. Reducing uncertainty is a key purpose of the research and development program that this report proposes.

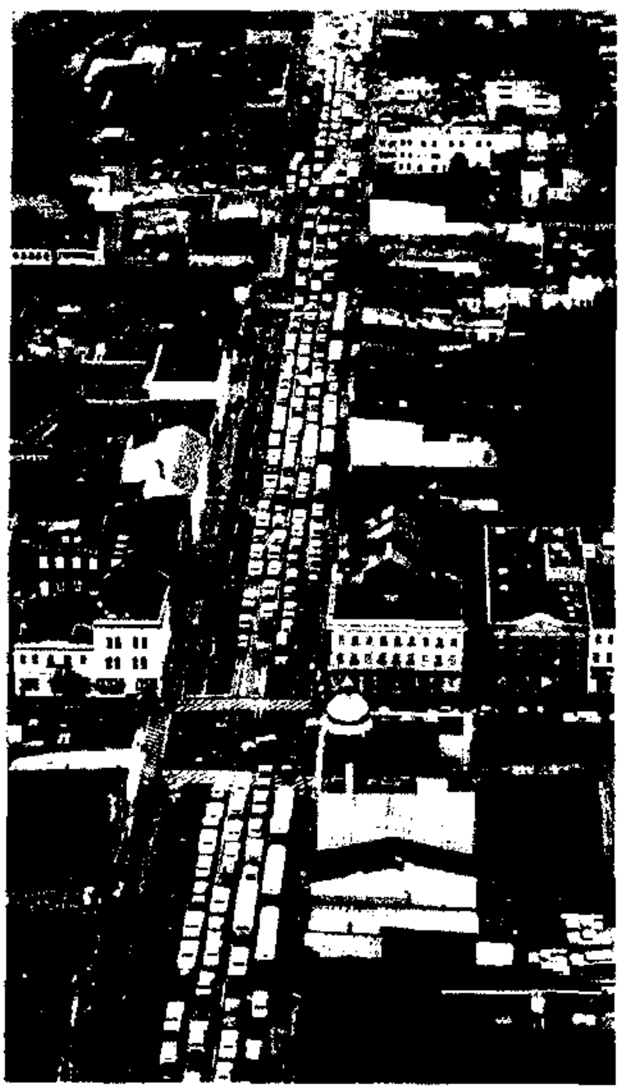
IMMEDIATE IMPROVEMENTS FOR PRESENT URBAN TRANSPORTATION SYSTEMS

NEARLY 300 SEPARATE PROJECTS OR PROPOSALS of an immediate, incremental nature were screened in the process of determining the best of the many alternative improvements which could, with relative ease, be made in the near future to present urban transportation systems and services in metropolitan areas. These are discussed in the following paragraphs.

Urban transportation presents a paradox of technological obsolescence in the midst of an abundance of relevant new techniques. A review of available technology showed that a solid foundation of technical expertise and knowledge already exists, much of it developed in other fields of application, including the defense and aerospace industries. No national apparatus now exists in the field of public transportation for systematically culling from innovative American technology the devices, perhaps already on the shelf or merely on paper, that could be applied to urban transportation. Nor are there arrangements for developing and improving them in a manner to make the systematic testing and evaluation of their applicability possible. This inadequacy obliges officials responsible for planning and initiating urban transportation systems to select from among a very few alternatives, most of them already obsolete or obsolescent, not because American technology is at fault, but because incentives for urban transportation innovation—the synthesizing and application of science and technology—have been weak or nonexistent.

The following paragraphs describe salient and currently feasible improvements for bus, rail transit, and commuter rail service, as well as for urban automobiles and pedestrian movement.

Traffic control systems responsive to the movement of people could reduce delays like this for bus passengers and increase the capacity of the street network.



URBAN BUS SYSTEMS IMPROVEMENTS

Bus systems are now and will continue for some time to be the most heavily patronized form of public urban transportation. Buses now carry annually approximately 70 percent of all urban public transportation passengers. Most cities in the United States are entirely dependent on them for public mass transportation. While some of the larger cities are likely to build rail transit systems, they too are finding that buses are an indispensable concomitant to rail systems. In New York City, for example, about one-third of the residents who work in the central business district begin the day by taking a bus. A similar pattern is projected for San Francisco's new Bay Area Rapid Transit (BART).

Buses represent a promising subject for new technology because they can go anywhere on present rights-of-way. This ubiquity is significant. Because buses can go wherever streets go, they have the potential for door-to-door service and that may be essential if public transit is to attract patronage in the future. It also means that bus systems can involve relatively low initial investments because they avoid the tremendous cost burden of building and maintaining their own rights-of-way or guideways.

[illegible] lanes improve the flow of buses through [illegible] Plaza of the Lincoln Tunnel.

RIGHT-OF-WAY IMPROVEMENTS

Bus transport, while relatively low-cost, is also low in quality and will remain so as long as buses get caught in traffic jams and consume large amounts of time boarding or discharging passengers. The new systems study examined two possible solutions:

- Put buses into reserved lanes that are physically separate from the rest of the traffic or perhaps on exclusive "bus only" streets; or
- Decongest the flow of all vehicular traffic on the streets and highways used by buses and give buses some kind of priority in the traffic stream.

Exclusive Bus Lanes: The first approach may be implemented by building new urban highways with separate transit lanes or streets, for exclusive bus use. Technologically, such solutions are entirely feasible, although they have been infrequently attempted. Additional new highway lanes in urban areas inflict ever-increasing problems of disruption and dislocation, whether or not the additional pavement is used exclusively for buses. The second alternative is often impossible because of the difficulty of fitting special and exclusive lanes into most of the existing urban street and highway patterns.

The more promising of these alternatives, especially for the near term, is to provide technologies for decongesting urban arteries for all— public transit users as well as the private automobile in order to improve bus operating conditions. Two somewhat different technologies for decongesting the traffic stream have been examined by the study. The first is flow control on limited access highways or freeways; the second is traffic control on city streets.

Traffic Flow Control: The flow control on freeways involves metering vehicles onto a freeway at a rate which will hold traffic concentration below the point of congestion. At such a point, even minor perturbations in the traffic stream cause slowdowns that may finally result in stoppages that greatly diminish the freeway's capacity. Metering vehicles onto the highways keeps the stream moving by preventing traffic "clots." Under the flow control idea, buses would not be "metered on" as would other vehicles, but would enter the freeway "at will," perhaps on their own bypass lanes as is done now in New York City at the Lincoln Tunnel. Once on the freeway, the buses would travel as fast as the rest of the free-flowing traffic streams, and the total traffic flow through a corridor would be improved.

People-Activated Traffic Control: Because most buses travel over city streets rather than freeways, a related technology, street traffic control, is of particular importance. It needs to be applied, however, more directly to the problem of moving *people*, not just vehicles. At present, most traffic control systems are programed simply to move vehicles with no regard to differences in vehicle size or number of passengers carried. All vehicles are thus treated equally which means that their

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passengers are treated unequally. For example, traffic lights are set to favor three people in two cars over 50 people in one bus. This, of course, fails to maximize the flow of people through the street network.

To increase the people-moving capacity of the network, the new systems study examined traffic control systems which can be designed to count and move people rather than vehicles. Technically, there are several ways to sense the approach of buses in the traffic stream. One system that is already on the market uses a rapidly pulsing optical beam to transmit a signal from the bus to an electronic phase selector which controls the traffic light.

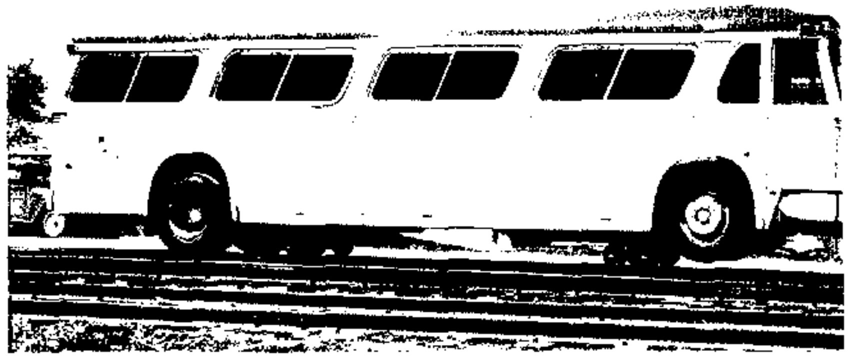
Though simple, this people-moving approach can improve bus speeds considerably. In a recent experiment sponsored by HUD, traffic lights on a street in Los Angeles were manually changed to favor buses. The data indicate that bus passenger delays were reduced by as much as 75 percent. However, the basic costs of automation are still high, with considerable work remaining to be done to improve information gathering and control devices. In addition, carefully supervised experimentation is needed to determine actual effectiveness.

COMPUTER-ASSISTED BUS SCHEDULING

The preparation of daily driver assignments (run-cutting) and the scheduling of available buses to routes is presently a manual process. The complexity of the factors involved—multiplicity of choices, limitations of time and driver selection preferences and restrictions—assure that such manual processing cannot provide the most efficient and economic operations. On the basis of projects sponsored by HUD at West Virginia University, the potential has been established for automating ridership counting and the computerizing of run-cutting and scheduling. A mathematical model for optimizing the assignments of operators and equipment has been developed. Coupled with reliable, yet less costly, ridership data, computerizing the entire process can aid in providing flexible and optimum levels of service to meet fluctuating demands. While this process shows promise for near-term application, future extensions of the concept could make hourly adjustments possible by communicating data on passengers and bus location to a central dispatcher for more demand-responsive bus service.

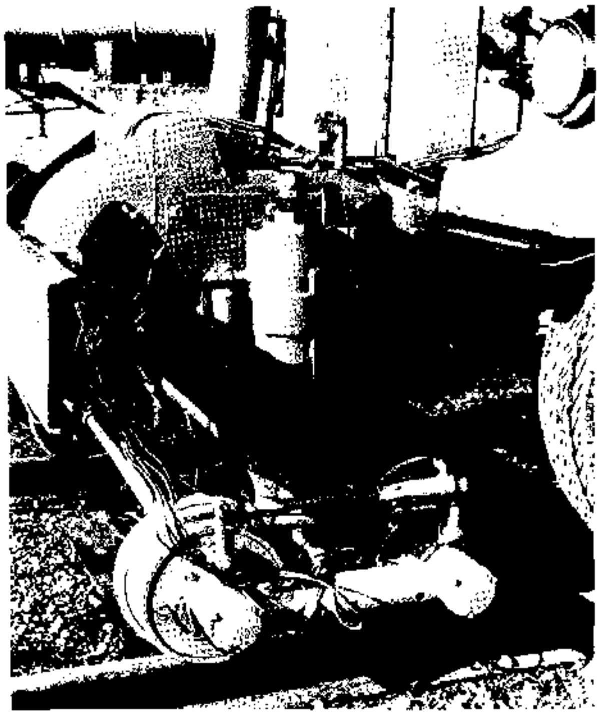
IMPROVED BUS DESIGN

The Standard City Bus: While today's standard 50-passenger bus represents a considerable improvement in comfort over its predecessors, it falls far short of satisfying modern expectations of service quality. It should not fume, or roar, and—among other improvements—it should have smoother acceleration, better ingress and egress, and most important, either much easier steps to climb or none at all. Private industry can now meet such requirements, if they are stated in specific terms. To assist such specification, the Department of Housing and Urban Development is financing the development of new de-

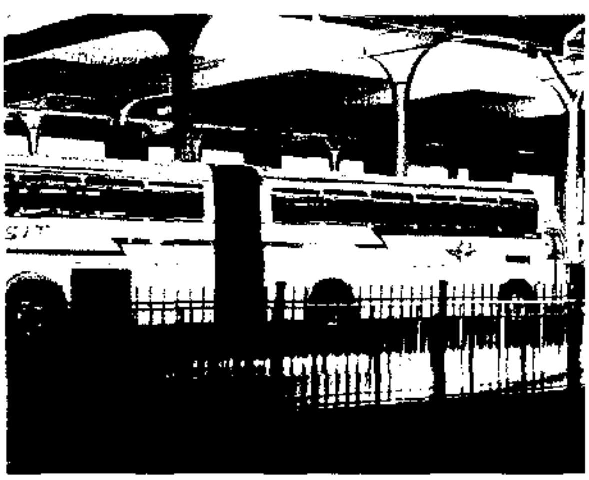


[illegible] dual mode bus being developed to operate on [illegible] and rail tracks.

Details of a rail conversion unit under evaluation for dual mode operation.



An articulated bus offers the potential for greatly increased passenger capacity and comfort without proportional increases in maintenance and operating costs.



sign criteria for improved buses by the National Academy of Sciences and the National Academy of Engineering.

Dual Mode Bus: A dual mode bus combines the high-speed, congestion-free characteristics of a rail vehicle operating on its exclusive right-of-way, with the flexibility and adaptability of an ordinary bus. This flexibility would make it possible to combine collection and line-haul service in areas where travel demand is too low to justify an extensive rail network. (With automation, the dual mode bus could be driverless over the line haul rail portion of the trip. Such an advanced dual mode bus is described in a subsequent section of this report.)

Two dual mode buses have already been tested in experimental service. In both cases, ordinary city buses were fitted with flanged steel wheels which could be lowered into position when the vehicles were to ride on rails. The steel wheels guide and help support the buses; traction is provided by the buses' rubber-tired rear wheels. While the dual-mode concept appears promising, additional work is required to insure a smooth ride during all weather conditions, especially in snow and ice.

Articulated Bus: The articulated bus can carry up to 75 people as compared with 50 or 55 in a conventional bus. Larger buses would substantially lower per passenger costs by improving labor productivity; two-thirds of present costs represent wages and fringe benefits for the bus driver. Extra-long buses are not widely used now because they are too big for local operation on city streets. They are, however, promising for express operation on freeways.

Double Deck Bus: The double deck bus has always been a standard vehicle in some countries; it has had limited use in the United States, most notably on the Fifth Avenue Line in New York City. The greater capacity within standard vehicle lengths makes the double deck bus desirable for some urban applications. New wheel arrangements involving powered differentials would make it possible to pivot-steer a large double-decker. If better methods of loading and collecting fares can be developed, this type of bus would be an attractive candidate for improved bus design.

URBAN BUS PROPULSION

Urban buses, because of greater freedom from the weight restrictions and the variable operating conditions of the personal vehicle, offer especially good opportunities for immediate use of propulsion subsystems alternative to the standard gasoline or diesel engine. Steam engines, gas turbines, and hybrid engines are propulsion components requiring the least new development and would be the easiest innovations to adapt to present bus transportation systems. More advanced propulsion subsystems are discussed below under future technology.

Improved Steam Propulsion: An especially good candidate for immediate use in urban transportation is steam propulsion. Both closed and open cycle reciprocating steam engines, as well as hybrid engines, are being considered because of their low contamination levels and quiet operation. These engines operate smoothly, produce high torques at low speed, can tolerate a variety of fuels and exhibit superior cold weather starting performance. Steam generators now available practically eliminate the delayed starting problem which plagued earlier steam vehicles, and are entirely safe. At present, however, they are both bulky and costly. Since no major technical obstacles are foreseen in manufacturing suitable engines, costs no doubt would decline as production increased.

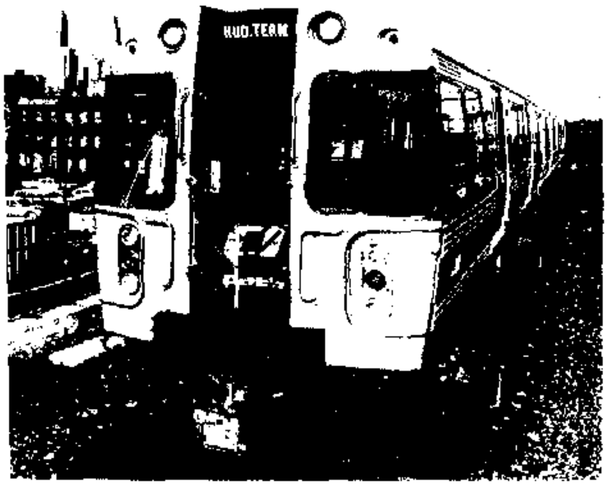
Gas Turbines: These also exhibit less pollution than internal combustion engines. Gas turbines have been tested recently on automobiles, trains, and trucks. Their greatest problems are high manufacturing cost because of precision engineering requirements, mechanical power transmission, the waste heat in their exhaust, and the sluggishness of their throttle response in small vehicles.

Turboelectric Powerplants: Using a hybrid combination of gas turbine, alternator, induction motor drive and lead-acid storage battery, turboelectric powerplants show imminent promise for bus propulsion. More efficient use of the turbine should further reduce pollutants, electric power drive could eliminate problems with mechanical transmissions and the battery would improve acceleration characteristics while affording essentially emission-free operation for short periods in tunnels or congested central city areas.

Other new types of propulsion systems for urban buses and automobiles are under active investigation. The most promising of these are discussed in a subsequent section dealing with longer term improvements.

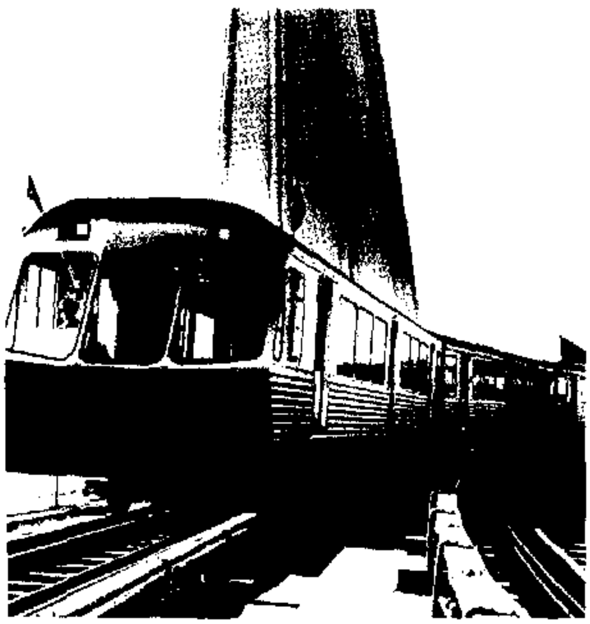
IMPROVEMENTS IN EXCLUSIVE GUIDEWAY SYSTEMS

"Guideways" are the components of transportation systems which guide and support moving vehicles. A street is a guideway in the simplest sense; one which may be shared by several kinds of vehicles. A railroad track is a guideway which is restricted to flanged wheel vehicles and thus is termed "exclusive." As described below, however, newer systems of exclusive



New air conditioned rail rapid transit cars, combined with improved operating practices and modernized power, communications and track switching equipment, can enhance service throughout an entire commuter system.

The automatic, fail-safe operation of the Montreal Expo Express carried an estimated 35 million visitors to Expo 67.



guideways different from the conventional steel rail are being developed and show promise for use in urban transportation.

CONVENTIONAL RAIL SYSTEMS

Six large American cities with high transit usage now have rail systems—either commuter railroads, rapid transit (subways), or streetcars. The present value of the investment in these systems is quite large, totaling more than $3.4 billion. After a period of contraction, the number of miles in use of rail rapid transit has stabilized and has even increased in recent years. Peak-period usage, ranging from 18,000 to more than 60,000 passengers per hour, has always been the most important contribution of this type of service.

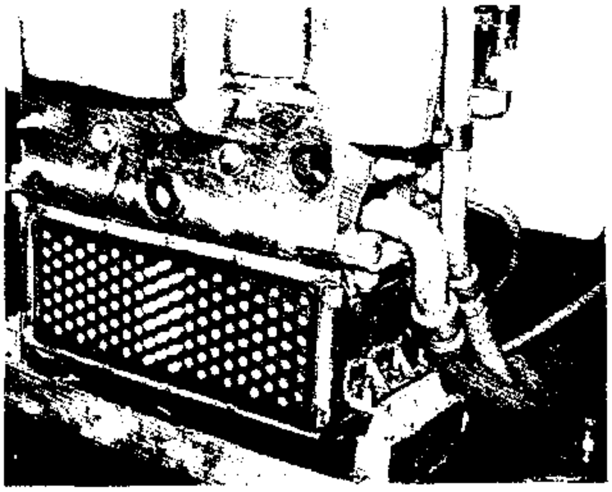
For the most part, however, these systems were developed more than 40 years ago and have had limited upgrading of rolling stock and plant since that time. Many of the properties are using outdated equipment and operational policies as a result of their inability to charge the fares and obtain the necessary usage to maintain and upgrade service.

Improvements to existing systems usually imply an increase in the speed of travel. The new systems study, however, found no pressing requirements for markedly improving the speed capabilities of conventional intraurban rail vehicles in the near future. In most cases, the closer station spacings of existing urban rail systems would cancel most of the advantages gained by increasing speeds. The potential advantages of reliable braking, fail-safe signaling and control systems which could reduce headways and improve the flexibility of service were studied, and the need to improve operating efficiencies and service amenities of conventional rail systems was found to be essential.

Automatic Operations: Most existing rapid rail transit and commuter trains can be fully automated with far greater ease than individual street vehicles, and without extensive rebuilding of the system. The cost of making these installations, particularly in older properties, must be carefully measured in terms of possible reduced operating costs and increased revenues resulting from closer or more flexible headways. The Pittsburgh Transit Expressway project and the Expo Express in Montreal show what is possible even with current equipment. Controls in these systems, unlike conventional trains, are along the guideway and in central computers. These provide an inventory of all vehicles at once and are prototypes of the control system required in advanced systems using fixed guideways.

The efficiency of rail systems can be considerably improved by less than full automation, however. For example, automatic train identification and monitoring with route allocation can avoid additional construction costs by improving the utilization of existing track, parallel tracks, and tunnel capacity. Computerized scheduling can tailor service to actual needs by optimizing car and crew assignments and thereby reducing operating costs.

Rail Transit Components: Improvements to certain critical rail transit vehicle components can lead to important increases



Automatic rail car couplers could increase operating efficiency and reliability through push-button interlocking of signal and control lines.

in operating efficiencies. Automatic couplers, for example, would permit cars to be coupled or detached by pushing a button in the operator's cab. This could, in itself, substantially decrease the manpower costs of making up trains. In combination with the computerized scheduling described above, automatic coupling would lead to a closer match between train sizes and passenger loads, thus reducing unnecessary car miles and maintenance costs.

The time currently required to couple and uncouple cars can be reduced to seconds. Since a key factor in many rail transit and commuter services is train turnaround or reassembly time, the reduction in time consumed for these operations from minutes to seconds is of vital importance. Saving as little as 2 or 3 minutes on some tightly scheduled commuter runs could mean placing an entire train of equipment back into a peak time slot where it could produce additional transportation services.

Braking and Suspension: Existing transit braking systems are complex, slow acting, and depend heavily on the wheel-rail adhesion which can be developed- a limiting and often variable quantity. A thorough exploration of current technology to include the evaluation of hydraulic, dynamic, magnetic, and advanced air brakes and improved control and actuation systems appears warranted. Promising methods of maximizing wheel-rail adhesion during braking suggested by the study should be further evaluated.

Conventional Suspension: The truck, or frame containing the springs, axles, and wheels upon which the car body rests, is subject to a variety of failures. The frame also transmits undesirable vibrations and noise to the car. Rubber tires have been used in both the Paris Metro and the new Montreal subway, and their ride and potential for quiet operation make them attractive for urban transportation. However, for use in automated systems, where failure of a single tire can cause delays on miles of guideways, the performance of present tires needs to be improved. Work also needs to be done to produce quiet tires capable of bearing greater loads without becoming too large, so that less cumbersome vehicles can be designed.

Railroad Beds: Steel wheels on steel rails are likely to continue in use for some time. Welded rails have been used for over a decade to help smooth rides in some parts of the country. Ties which distribute transient loads more effectively have been a continuing design effort by railroads for years. More recent innovations are stressed-concrete supporting structures, including prestressed ties or solid roadbeds, to replace the ties-plus-ballast combination used to transmit loads directly to the earth.

RAPID TRANSIT MAINTENANCE

Effective and economic rapid transit service depends to a great extent on the ability of the system to provide safe, comfortable, attractive, and reliable close-headway service at reasonable speeds. Such a requirement under restrictions of time and availability of right-of-way establishes a clear need for carrying

Demonstration of an abrasive belt grinding machine on the San Francisco BART test track.

out high-speed maintenance techniques concurrently with operations.

Wheel and Rail Grinders: The rapid grinding of wheels and rails by new types of maintenance machinery is one of the prime needs. The development of abrasive belt-grinding techniques for wheels and rails could eliminate costly and time-consuming lathe-turning of wheels and hard-grinding of rails. Improved and safer tracks can be achieved through the development of specialized rapid transit oriented equipment designed to detect deficiencies. The benefits of these efforts will be realized primarily in increased wheel life, reliability, safety, and in noise reduction.

Wheels for high-speed rapid transit systems are subjected to rigorous tests—including ultrasonic and magnetic particle tests—to detect cracks, flakes and laminar-type defects.

Maintenance of Equipment: One of the more costly activities of rail systems might be cut appreciably by organizing some types of car repairs on a "continuous flow" basis, involving a concept of laying out maintenance shops in a systematic way to enable greater efficiency in operations. The general approach could be adopted by most rail systems which have similar maintenance problems.

Cleaning: Rail systems also have generally similar cleaning problems at present. The car cleaning process might be improved for all rail systems (and bus systems, too) by developing standard procedures and specialized cleaning equipment. For example, the cleaning of tunnels is still a costly manual operation. Since most of the "dirt" is ferretic material, it appears worthwhile to develop a cleaning technique based on magnetic principles.

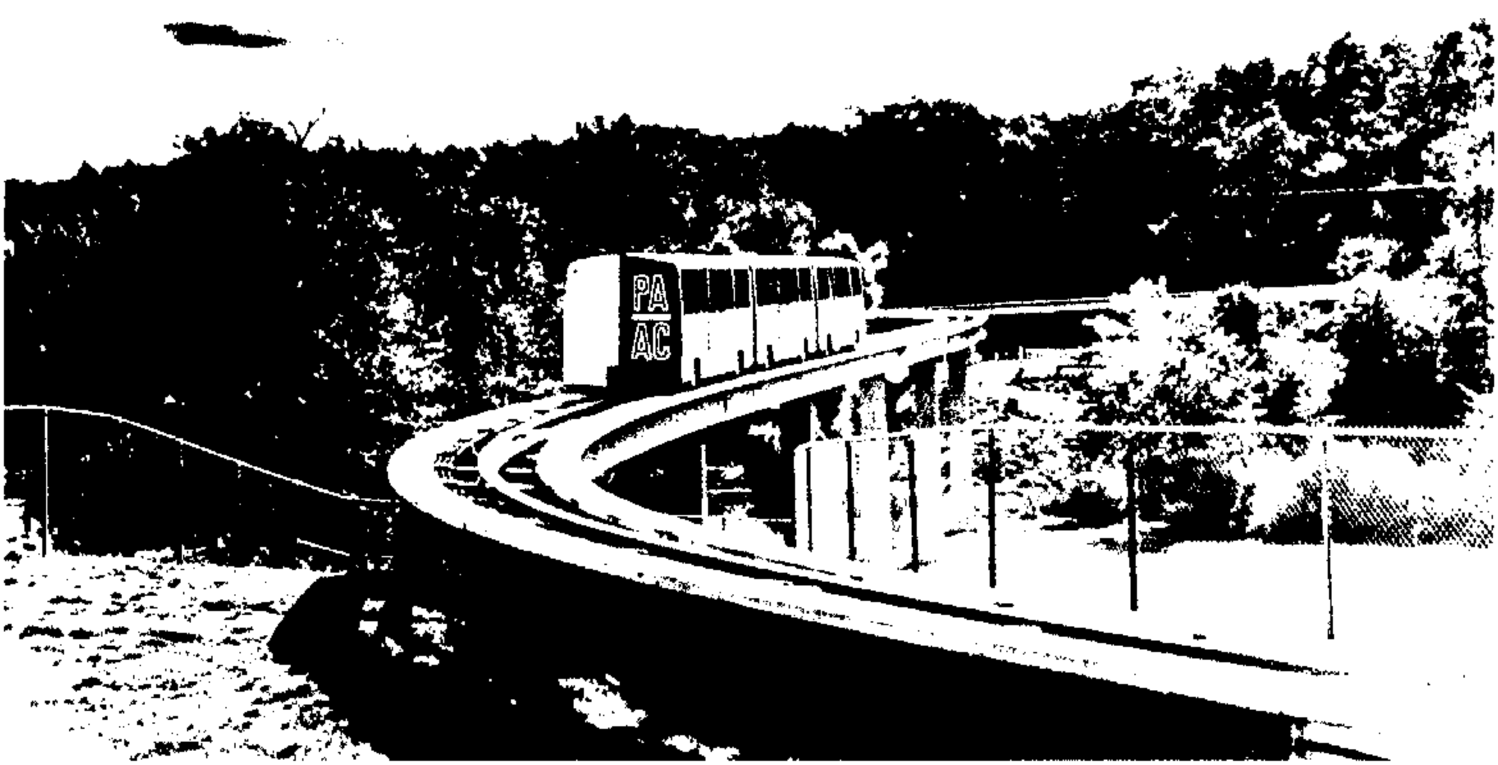
Noise Control: Improvements in operating efficiency also often improve a system's quality. For example, better cleaning procedures contribute to upgrading quality as well as cutting costs. Similarly, improved right-of-way utilization upgrades quality by reducing the crowding at rush hour. But one important area of amenity improvement—noise— will cost money rather than save it. Noise control requires attention to maintenance of rails, wheels, trucks, couplers, and interiors. Noise control also requires judicious selection of acoustical treatment techniques. The identification of the best noise reduction methods is a matter for further research.

RECENT NEW FIXED GUIDEWAY SYSTEMS

Two projects in which the Department of Housing and Urban Development has participated, the Transit Expressway in Pittsburgh and the BART system in the San Francisco Bay region, demonstrate a few of the fixed guideway features which are currently available.

The Transit Expressway system represents a fairly radical break with the past. Driverless, rubber-tired vehicles could operate over a concrete guideway on 2-minute headways at top speeds of 50 miles an hour. Using lightweight cars seating 28 persons and with room for 26 standees, the system is designed to serve peak demands of 5,000 to 16,000 people per hour one way—considerably lower than the economic ridership level of standard rapid transit systems. While further development is necessary (for example, on means of switching), systems incorporating the Transit Expressway are likely to be fully operational within a short while.

The Transit Expressway, with lightweight automated vehicles, offers the possibility of a system well suited to medium passenger travel demands with capital and operating costs below those of conventional rail systems.



Design of the San Francisco BART System has emphasized passenger comfort and convenience with wide seats and aisles, large windows, and virtually silent vibrationless operation at high travel speeds.

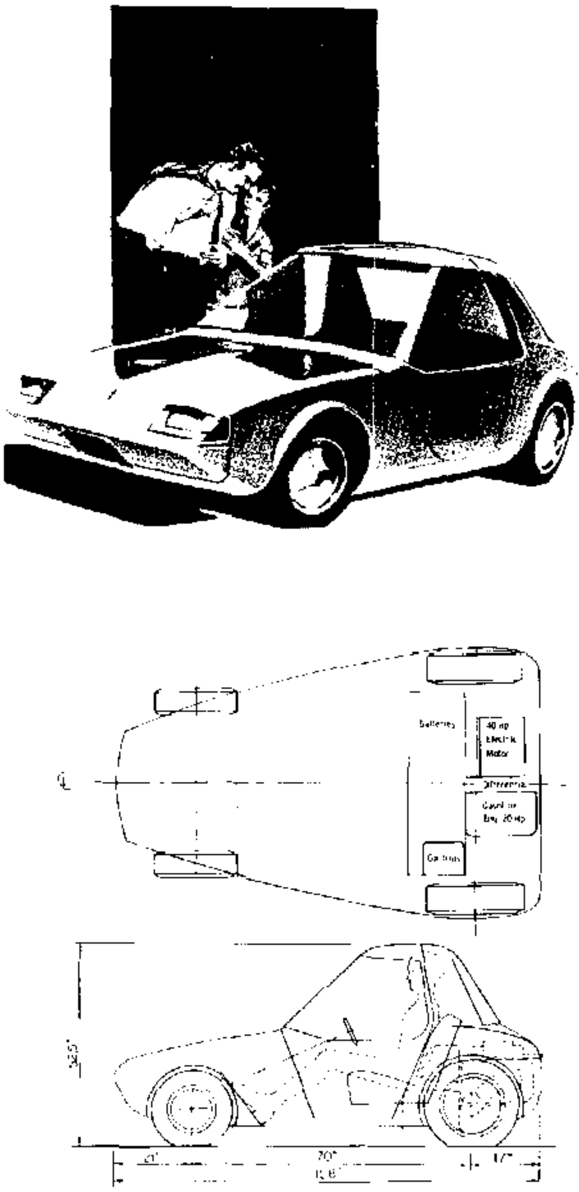
The less radical BART system is essentially a wide-gauge commuter rail system, incorporating such advanced subsystems in rail technology as automatic fare collection and automatic controls with a single attendant to handle emergencies. BART trains will have maximum speeds of 80 miles an hour, with capacity designed for 30,000 seated passengers per hour in trains of 10 cars.

URBAN AUTOMOBILE INNOVATIONS

The automobile, providing both flexibility and speed, has rapidly established and maintained domination over a wide range of trip types. The present six-passenger family car represents a compromise in design to satisfy a wide variety of travel needs. As such, the automobile intrudes in many ways. The experience of recent years contradicts the belief that traffic congestion will itself set a limit to car ownership. If there is to be any chance of coexisting with the automobile in the urban environment, a different sort of automobile is needed with improvements in the supporting systems. The evolution in the automobile and its supporting systems, road, and parking facilities has responded to personal preference as well as to public guidance and control. These systems will continue to evolve in response to such influences.

RENTAL VEHICLES FOR LOCAL USE

Many people in urban areas need the use of an automobile only occasionally; others cannot afford to own a car. Yet an automobile may provide the only means for access to a job or to public transportation. The new systems study has established the practicality of development of an urban public transit system that has the flexibility and service of the private automobile: A car rental service for short trips operated as a private enterprise or as an adjunct to public transportation. Such a system could employ a small, low-powered vehicle on a short-term, inexpensive rental basis, obtained from a terminal and



A small urban vehicle, using a hybrid engine for reduced air pollution, could provide a public automobile service for shopping, access to mass transportation stations, and perhaps for use within central business districts.

returned to it or another location for each trip. The vehicle should be available at less than fee owner costs. It would provide service to and from transit terminals, in central business districts, in low density areas (shopping centers) or on such sites as college campuses or large international airports.

A HUD demonstration project carried out simultaneously with the new systems study has developed performance criteria for a small, hybrid-engine automobile for this type of service. This vehicle will meet strict standards of controlling pollutant emissions. A chief benefit of the small size would be in parking, both adding convenience for drivers and reducing the overall cost and amount of space that must be devoted to parking. Street and expressway capacities can be increased significantly, however, only when most cars using them are small, and until then, hazards from mixed traffic can be expected.

If the feasibility, acceptability, and benefits of such a small urban car rental service can be established through demonstration in urban areas, it should be expected that private industry would further the vehicle development and expansion of this kind of service.

Automatic Traffic Control

Traffic lights in many cities today are controlled in rudimentary fashion in response to established traffic patterns. Vehicle flow can be sensed by optical devices, treadles, or loops buried in the roadway, and lights may be set to reflect traffic patterns determined by experience. More complex systems are now in operation in Toronto and San Jose and are being evaluated in several other U.S. cities. These feed data sensed at critical intersections directly into a central computer that analyzes the flows and issues commands to achieve maximum traffic flow.

Automated Parking Garages

The new systems study devoted some attention to the possibility of automating parking garages to reduce the amount of space required for ramps and aisles, and to increase the speed of operation.

While a number of designs for such garages are available, none of them offers advantages in construction and maintenance expense over conventional ramp designs. However, for the small urban automobile, the advantages may be significant. Since three or four small cars could be parked in the space of one standard automobile, automatic parking could be provided at substantial saving over the average capital cost of \$3,400 for "automated" space for a conventional automobile. For the rental car service described above, automatic parking on a "first in–first out" basis could be reduced to \$1,200 per space. Where the preponderance of automobiles is of standard size, a more fruitful line for experimentation would be the use of peripheral parking lots to serve congested areas, prohibiting business district movements by all vehicles except transit, taxis, and fleets of small cars leased for use.

IMPROVEMENTS FOR PEDESTRIANS

The importance of the pedestrian is often ignored in planning and operating urban transportation. Urban travel surveys too often have paid little attention to walking trips. Movement within the transportation terminals and stations, both intra-urban and interurban, and within other major activity centers is often difficult—rarely pleasant or efficient. In the many places in urban areas where vehicles and pedestrians must share space (street intersections, shopping centers, and airport parking lots), the vehicle is nearly always given preference.

"People-movers" operating on shopping malls free of other traffic have aided pedestrians in such places as Miami Beach.

Studies have shown that the pedestrian particularly responds favorably to improvements that reduce walking and waiting or which offer increased personal safety. Walking begins and ends every public transportation trip, thus improvements in the pedestrian's lot are necessary for a higher quality of total service. Potential innovations and applications of present-day technology offering improvements for pedestrians are described below.

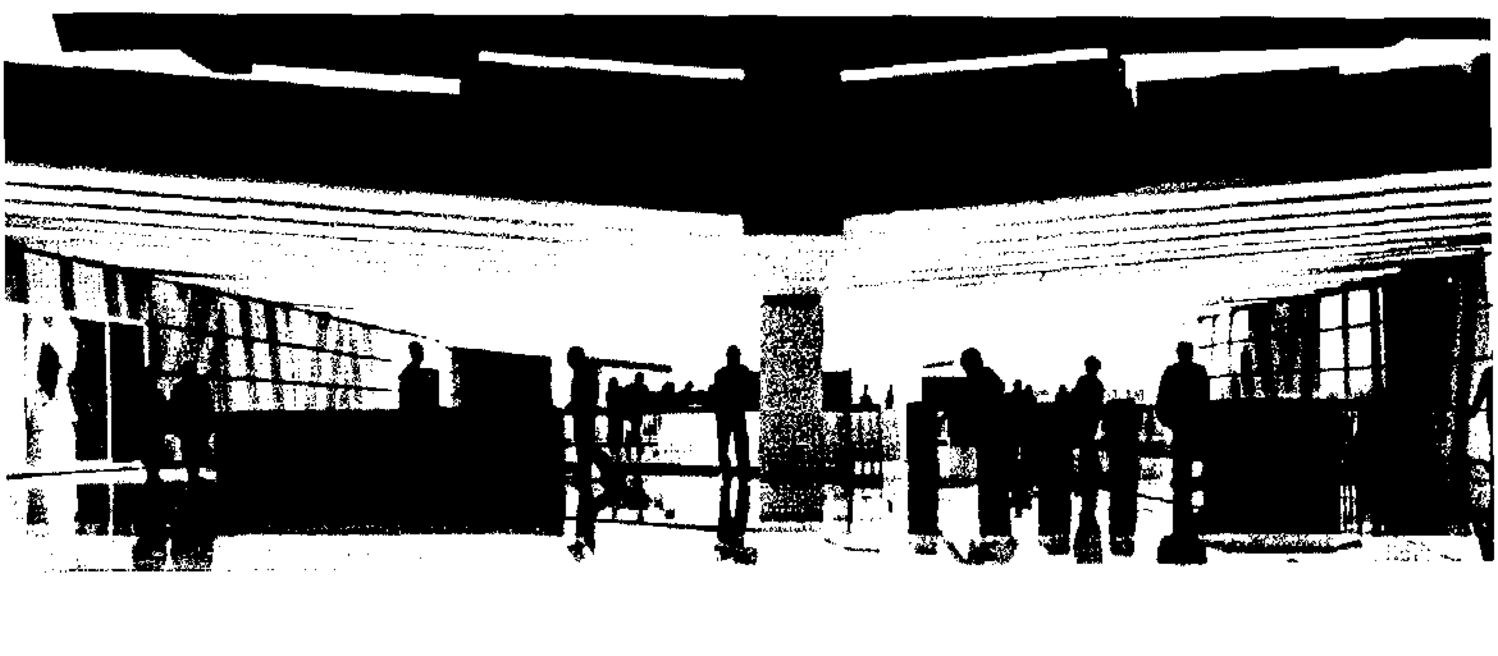
MAJOR ACTIVITY CENTER CIRCULATION

Some promising immediate improvements include improved small bus designs for more economical and convenient service in large major activity centers, improved traffic control devices to give priority to people rather than vehicles (for both pedestrian and bus passenger), modified conveyor systems for short-distance, high-volume movements, and improved commuter rail and rapid transit station designs.

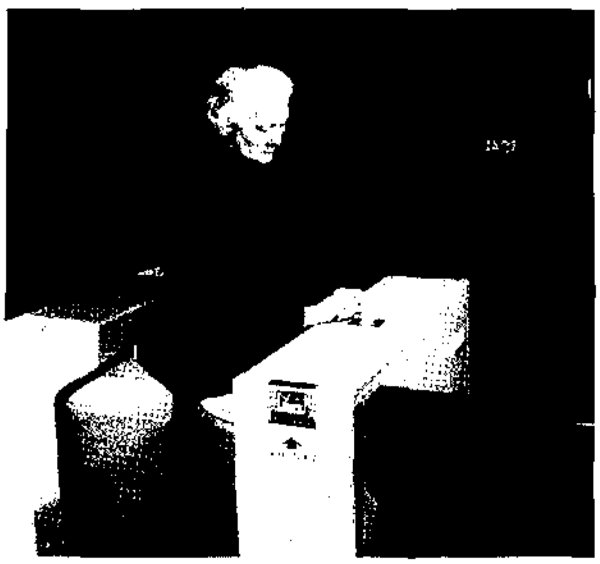
PEDESTRIAN WAYS

A particularly appealing development technically feasible in many places is the separated pedestrian walkway or pedestrian way. It may consist of elevated passages over streets and through upper stories of buildings or of underground passageways—often developed in connection with railroad and rapid

The San Francisco Civic Center pedestrian mezzanine connects shopping facilities and station access on the upper level to the Bay Area Rapid Transit cars on the lower level.



Moving belts can assist the movement of pedestrians in such major activity centers as airport terminals.



Automated fare collection can speed the traveler on his trip while making possible flexible charges and improving the efficiency of transit operations.

transit terminals. One of the most successful is the Philadelphia Penn Center subway plaza which is contiguous to the suburban station of the Penn Central Railroad. Pedestrian malls are sometimes incorporated in urban renewal projects or may be created by closing part or all of an existing street to vehicular traffic and arranging it for exclusive use by pedestrians.

Separating rights-of-way at intersections and minimizing pedestrian climbing and descending can be achieved with recently developed bridge designs using pipe and laminated wood in the structures. Ramps provide a pleasing alternative to stairs in many applications. Many mechanical devices can be incorporated into pedestrian ways to speed the flow of traffic and change it to a different level.

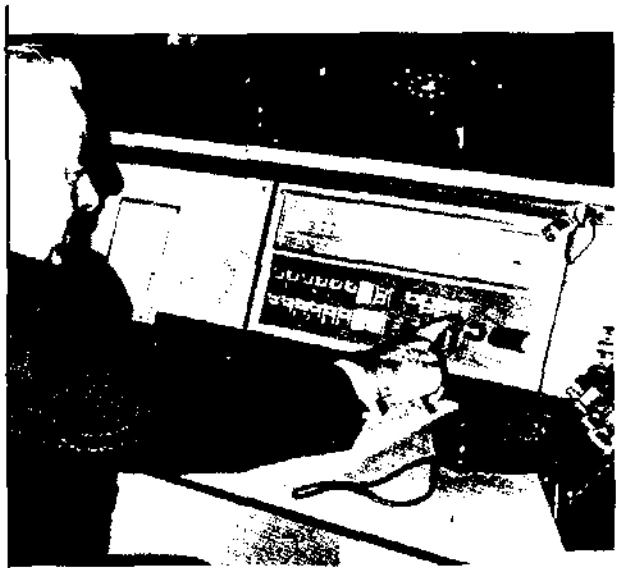
IMMEDIATE IMPROVEMENTS OF GENERAL APPLICATION

FARE COLLECTION

Fare collection is a problem for all transit systems. First, it takes time and manpower to collect and audit fares. Reductions in either would help both the systems and their riders. Second, it is awkward and expensive to collect different fares for different trip lengths and different times. Accordingly, flat fare structures now prevail on almost all city bus and rapid transit systems. This often results in high costs for some trips, discouraging the short-haul and off-peak riders.

Improved fare collection systems using current technological knowledge would make it possible for rapid transit and supporting systems to employ much more flexible charges. These charges could be based on such elements as distance traveled, time of day, frequency of travel, location of trip origin or destination, as well as personal preferences in deferred billing procedures. These have been effective in promoting the additional use of other forms of transportation by reducing the visible cost. Limited experience with automatic fare collection systems to date indicates that guaranteed collection has increased revenue by as much as 10 percent.

Where fare collection can be handled on station platforms, much progress has already been made. Much still needs to be done to improve fare collection on buses. The use of prepurchased bus passes, good for a specified period on a particular route, would facilitate fare collection, especially during peak rush hours when some "pass only" buses would be scheduled, thus reducing the delays caused by fare collection. Several rail systems are now using machine-readable tickets issued by vending machines and analyzed by a computer at the gate. Tickets have magnetic surfaces that the equipment can read and register for later billing or make appropriate deductions for the trip taken. While these systems are still crude and often unreliable, they can be improved. They eventually can also be expanded into systems that can count ridership, and may thus permit more responsive service through computerized scheduling.



Communications systems on transit vehicles can deter crime, reduce delays, and improve the safety and security for passengers and crews.

Bus route signs which clearly display schedule and destination information are essential to good urban transportation service.

SECURITY

Passenger and operator security can be increased through the use of currently available surveillance and communication technology. A Department of Housing and Urban Development (HUD) demonstration project testing two-way radio communication on New York City subways found that message delays in reaching police or other emergency aid were reduced 99 percent, to fractions of a second. The average number of train delays per month in the test area decreased 41 percent and average duration of delays decreased 9 percent. Due to the success of the experiment, the New York Transit Authority has committed itself to extend the two-way radio system to all of its rapid transit and surface divisions. A radio system with bus paging equipment is planned for the Authority's 4,200 buses. Closed-circuit TV with intercar and external security contact systems also show promise for rail systems. Such security systems are essential to restore confidence in personal safety for rapid transit riders and drivers.

MANAGEMENT AND OPERATIONS

Improvement of transit management and operations depends, of course, upon the motivation and imagination of the men who run the industry. With limited budgets and staffs, and heavy demands on management time for day-to-day operations, it is difficult for them to devote themselves to improving methods. But without improvement in the methods of management and operations, many of the proposals described elsewhere in this report will be fruitless.

HUD has recognized the need for assisting the industry in its efforts to improve management and operating practices by conducting training seminars for key personnel at West Virginia University and Kent State University in Ohio. University research, training, and fellowship programs have been established to attract promising personnel to the field.

The application of computer technology can improve cost accounting systems, aid in equipment and manpower scheduling, and improve planning through simulation of operating conditions. The development and use of better market research and marketing techniques should result in increased transit coverage, greater patronage, and revenues.

Other sections of this report describe potential improvements in operations that could show early results in increased quality and efficiency. These include assembly line cleaning and maintenance practices, automatic fare collection, automatic vehicle controls, traffic signals for bus preference, and security systems for passenger and operator protection.

STATIONS AND INFORMATION AIDS

Informing the public of its services is an essential function of urban mass transit. The basic problem is disseminating information on modes, routes, and frequency of service. Difficulty in obtaining such information discourages potential riders, and such difficulty is entirely unnecessary. Direct advertising through all media, including the mails, to inform the public about routes, schedules, fares, and the availability of special services would be an important improvement.

Conveniently located information centers should be provided with easy-to-read maps of the complete transportation system, and timetables describing the vehicle, route, and frequency of service available. There should be direct telephones to the transportation agency information service. All bus shelters and public transportation stations, old or new, should be permanently equipped with attractive maps, routes and placards displaying trip frequency, origin and destination of passing vehicles. A high standard of architecture and graphics can improve station design, and assure the traveler that he knows where he is and how to get to where he wants to go on time. Such a willingness to serve is a prerequisite in making public transit attractive and competitive.

NEW SYSTEMS FOR THE FUTURE

COMPONENTS TECHNOLOGY

The technology which underlies the development of the new transportation systems covers a wide range of subsystems and components. These include:

- command and control devices for safe and reliable guidance;
- propulsion subsystems to power the vehicles with little or no air pollution or noise;
- suspension subsystems to improve comfort and safety; and

many other mechanical and electrical components which in combination become the total operating system.

Establishing the technical feasibility, advantages, and limitations of innovative concepts and their subsystems and components is critical to advancing new systems of urban transportation. The following is a review of some of the promising technologies of components which should be explored through a program of research and development to determine their advantages for longer range systems which constitute the whole.

COMMAND AND CONTROL

Control is one area in which the technological problems of urban transportation are considerably more complex even than those of space travel; thousands of vehicles with hundreds of options for switching and stopping are involved. Without automation, few of the new systems would be economically feasible. It is important also because the large aggregates of vehicles going thousands of different places which comprise metropolitan transportation today can be handled with greater speed, and greater safety, only if electronic machines make the routine control decisions rather than individual human drivers and operators. Even the automation of apparently minor parts of the transportation function, such as fare collection, can become an enormously complex undertaking that requires the most sophisticated computer and communications equipment.

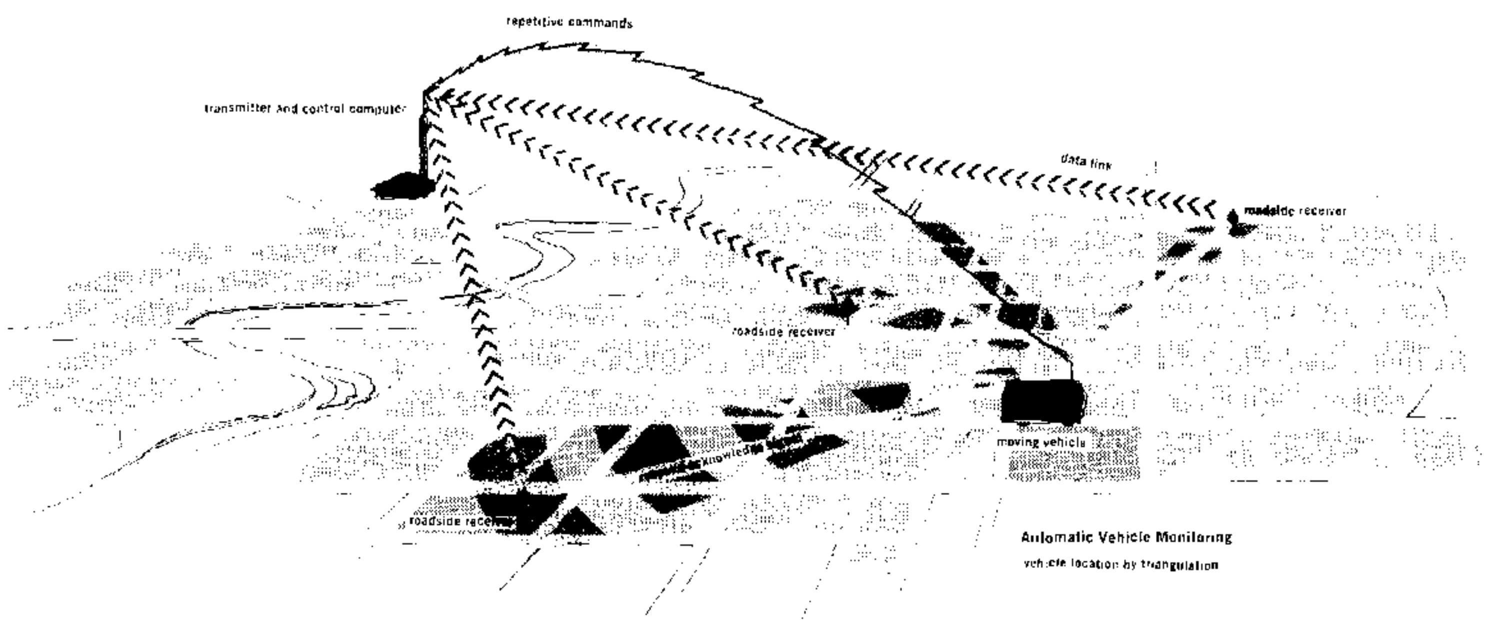
While much research and development associated with "command and control" technology must be done in connection with a specific concept, there likely will be byproducts of this work that will be useful in advancing other ideas.

AUTOMATED VEHICLE MONITORING

In order to control the movement of vehicles, one must know where they are—no problem if the number of vehicles to be controlled is small. Two-way voice radio is entirely adequate for dispatching small fleets of taxis, trucks, or police cars. But when the fleets become large, the amount of information becomes unmanageable without automation. The new systems study considered various ways of automatic monitoring for highway vehicles. Under the promising concept described below, it appears feasible to keep track of a very large number of vehicles continually and automatically, whether private fleets of taxis, commercial trucks, or public buses and emergency cars.

An automatic vehicle monitoring (AVM) system can establish the location of any vehicle within an accuracy of 100 feet, in a metropolitan area 50 miles in diameter. A central transmitter broadcasts repetitive commands. Each command in effect addresses one particular vehicle whose equipment recognizes its own coded signal among all the others.

Automated vehicle monitoring can aid the movement of people and goods over city streets by continually establishing the location of large numbers of vehicles in bus sysems, trucking companies, taxi fleets, and police departments.



On receiving the coded signal, the addressed vehicle activates a keyed transmitter which produces a respond-acknowledge (R–A) signal. At least three roadside receivers, perhaps on towers, pick up this R–A signal and relay it to the central computer. The vehicle's location is then computed by triangulation using the differences in arrival times of the R–A signal at the three roadside receivers.

The two salient features of this kind of system are that it has a very large capacity (the system can keep track of thousands, perhaps over 1 million vehicles), and that it can be "time shared" by many different users, public and private. Thus, an AVM system makes it possible to improve the urban operations of police departments, taxi fleets, and of course, transit systems and trucking companies.

The latter is of particular interest since trucks contribute heavily to the congestion of urban streets. An AVM system could be used in a central dispatch system for trucks, permitting only an optimum number to be in a given area at one time. For example, trucks serving New York's crowded garment center might be "staged" outside the area, and dispatched into it when curb space was about to become available.

PROPULSION, ENERGY, AND POWER TRANSMISSION SUBSYSTEMS

Two types of propulsion systems drive most of our present transit vehicles: Internal-combustion engines, whether gasoline or diesel; and electric, whether supplied from internal sources or by external transmission systems. With the exception of the gas turbine engine which has been developed primarily for aircraft but which has seen some recent application for ground transportation, these propulsion systems are all products of 19th century technology, with some 20th century refinements.

Internal-combustion engines, which carry so much of the Nation's transportation, also produce a major share of urban air pollution. Since preventing environmental contamination and conserving resources are important national goals, quiet, pollution-free engines are already the object of intensified research efforts. Today's gasoline engine produces less pollution than yesterday's and tomorrow's will no doubt exhibit still better performance. In the congestion of the urban environment, however, even low pollution outputs may add up to unacceptable pollution burdens. Thus, electric motors, which themselves are practically nonpolluting, give more promise as propulsion systems for the future than any type of engine which involves combustion.

Electric motors are notably quiet and efficient. Electricity is a most facile form of energy for systems operating on exclusive guideways, as well as possessing distinct advantages in automatically controlled systems. Of course, if the electricity powering a transit vehicle is produced in a power station which burns fossil fuel (or urban trash, as has recently been proposed), overall urban air pollution may still result.

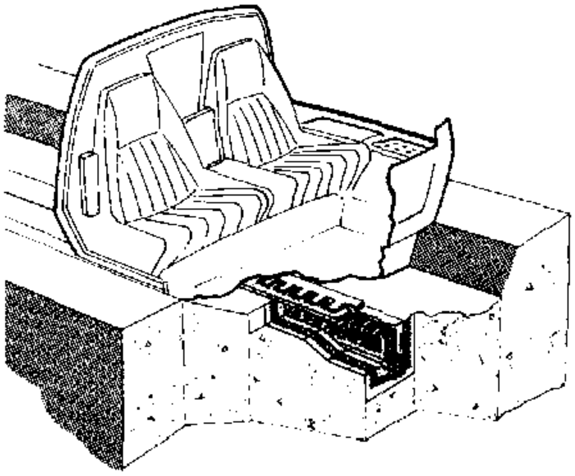
Generating plants, however, can be considerably more efficient than the small, mobile powerplants which propel automobiles, buses, trucks, or locomotives. The large stationary plants make more efficient use of the fuel, dumping fewer products of incomplete combustion into the air, simultaneously contributing to resource conservation and diminishing air pollution. Not so numerous as mobile plants, the stationary generating plants can be located to minimize adverse impacts in urban areas. Nuclear generating plants produce only vanishingly small amounts of air pollution, sometimes none at all, although there may be some water-pollution problems with these plants. The Federal Government is supporting research which will aid in designing and operating large generating plants to meet the increasingly strict standards governing urban air pollution now being developed by the national air pollution abatement program.

Propulsion: Combustion engines of various types evaluated under the new systems study included the conventional internal combustion engine, the Brayton Turbogenerator, Stirling, and steam reciprocating engines, as well as steam and organic turbogenerators. Steam engines and gas turbines are discussed above as immediate improvement possibilities. Other propulsion systems showing the greatest potential for future development are described below:

Hybrid engines have a good potential for urban transportation use. These combine an electric motor with a generator operated by some other type of engine. Hybrid engines can help to reduce pollution in several ways. They can be operated at a constant speed all of the time, charging batteries or accelerating a flywheel from which the vehicle's drive motors draw power. Constant speed operation cuts pollution considerably, since it is during acceleration and deceleration that most pollutants are emitted. Alternatively, hybrid vehicles could operate exclusively on batteries in areas such as downtown business districts in which air pollution and noise are most critical.

Electrically powered vehicles offer advantages for urban transportation in eliminating noise and pollution emissions as well as their proven adaptability to automatically controlled systems. Self-contained electric propulsion systems are relatively undeveloped for urban transportation. Lead acid batteries are now the only practical means available for storing energy to operate vehicles off of guideways. They are heavy, expensive, and cannot store and deliver energy well enough to permit battery-powered vehicles to travel very far or fast or to perform adequately in competition with internal combustion engines. For vehicles on guideways, third rail and pantograph-overhead wire systems are the only means for transmitting power.

Electric motors for both kinds of systems are far from being as sophisticated as the automated systems of the future will require. Electric motors have now been developed that are much lighter than the conventional ones used to propel trolleys and rapid transit. A 130-pound, 100-horsepower motor, for example, was recently demonstrated successfully in a small electric car. Solution of the weight problem opens the way for use of electric motors in small vehicles. The focus of development in the conventional electric motor field no doubt now will be on the engineering necessary to achieve the most efficient application of lightweight reliable motors.



Linear electric motors, shown here with the rotor or shuttle in the vehicle and stator or winding in the guideway, may have application to several new urban transportation concepts.

Linear electric motors have been experimented with for at least 20 years. Reduced to its simplest terms, a linear motor is a rotary motor cut parallel to its axis and laid out flat. Instead of a rotor spinning inside a stator, a flat shuttle passes along a controlled guideway. In transportation applications, the guideway is the stator and the rotor is on the vehicle—or in some cases, the rotor is the vehicle. Power windings can be either in the guideway or on the vehicle. Usually they are on the guideway but applying this convention to transportation guideways could be enormously expensive, since it would require tons of copper or some other conductor to "wind" a guideway. Most concepts, therefore, put the windings in the vehicle, though this requires a method of supplying it with power.

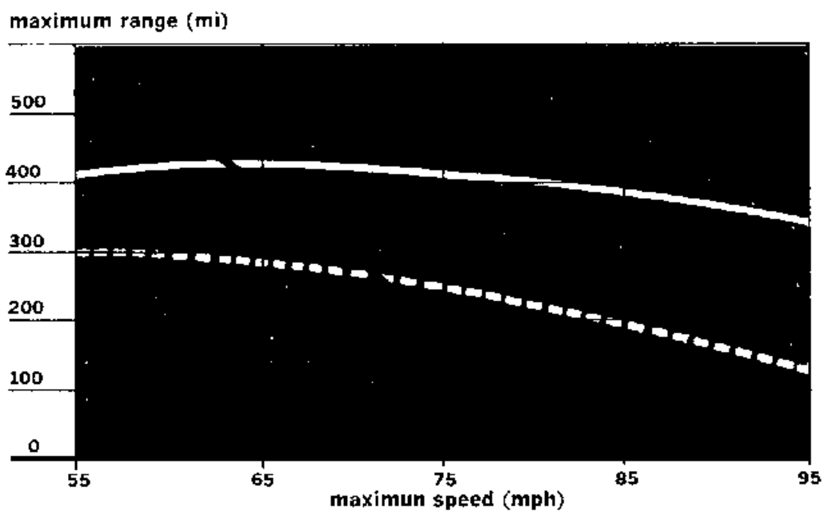
The new systems study indicates that development of the linear motor offers some advantages for the development of several new urban transportation systems. Since thrust is direct, relying on electromagnetic reaction between vehicle and guideway, no power is lost nor is weight added through gearing, and the system need not rely on tractive friction. Vehicle weight can be reduced, since in effect half the motor is in the guideway. Since the linear motor depends on a narrow gap or clearance between stator and rotor (guideway and vehicle), it may be suited to propel air suspension vehicles. Vehicle speeds can be controlled for an entire automatic system, but this introduces serious problems. The practicability and economy of "winding" a roadbed must be resolved. If power is applied to the vehicle, connections are necessary between it and some adjacent power source. To keep thrust constant, theory suggests that the air gap between vehicle and guideway must also be kept constant, though research has yet to determine the range of acceptable variations. In sum, linear electric motors, especially if used in conjunction with air bearing suspension, appear to have good potential for use in urban transportation systems. Further research is required, however, to determine whether they possess significant or unique advantages in this application.

Energy Storage: Lack of routing flexibility is one of the penalties incurred with systems which run on a guideway; this is one of the reasons most often cited for the decline of the trackless trolley bus. Attention has focused recently on energy-storage devices which would allow a vehicle to operate without being in contact with a power source, yet without producing air pollution. Such systems would be driven by electrical power produced on-board, either by batteries or by fuel cells; or else they would carry mechanical or thermal energy-storage devices.

There are several differences between batteries and fuel cells. Generally, a battery must be recharged, while a fuel cell needs to be refueled (energy is the regenerating means in the one case, matter in the other). Further, batteries possess a relatively higher power density (measured in watts or kilowatts per pound), and fuel cells possess a relatively higher energy density (measured in kilowatt-hours per pound). Thus, fuel cells might permit reasonable driving range and rapid refueling, while batteries can more readily supply peak load requirements for better acceleration but require relatively long reenergizing times.

Conventional lead-acid batteries represent a well-developed technology, and are fairly inexpensive, but their range capability is low. Newer experimental high-energy-density batteries are less well developed, currently more expensive, and may be more complex to operate. Typical of these newer batteries are the sodium-sulfur, sodium-air, zinc-air, lithium-chlorine, and lithium-organic electrolyte. None of these concepts is yet developed to a point where it would be inexpensive enough for practical urban transportation use. Nevertheless, further work will likely bring some of these concepts to a point at which they can be put to practical use. The potential range and speed of a conventional 3,000-pound automobile with battery power are compared on the graph in figure 3.1.

Figure 3.1. Battery-powered vehicles, range, and speed



Among the various fuel cell types which have been developed (largely in response to space requirements) are hydrogen-air, direct hydrocarbon-air, and some types which consume hydrazine, ammonia, methanol, or other fuels. The largest types now known have a capacity of 50 kilowatts. One truck has been designed which uses stored hydrogen and oxygen in its fuel cell; the cell develops 32 kilowatts continuously, or up to 100 kilowatts for short transient loads.

The major disadvantage of fuel cells at the moment is that they use expensive and relatively scarce fuels, and that they themselves are expensive to produce. The fuel-cell technology is one in which more research effort is needed.

A comparison of battery and fuel cell characteristics is shown in table 3.1.

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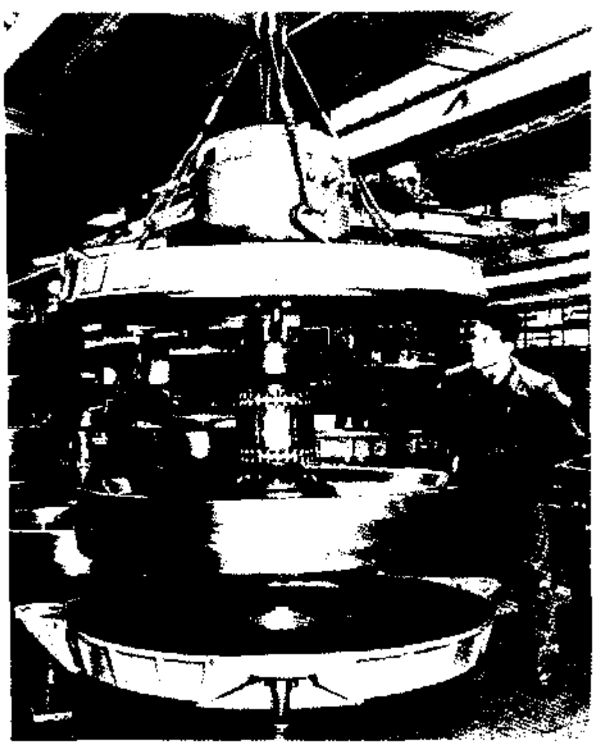
Table 3.1

Comparison of Battery and Fuel Cell Characteristics

type	energy density—watt-hours per pound		operating temperature °F
	theoretical	*practical**	
Batteries:			
Lead-acid	115	10–12	RT†
Silver-cadmium	120	27–31	RT
Silver-zinc	220	40–50	RT
Nickel-iron	138	15–17	RT
Nickel-cadmium	107	18–20	RT
Sodium-sulfur	346	204	570
Lithium-metal halides	230–745	20–80	RT
Hybrids:			
Zinc-air	500	160	RT
Sodium-air	930	480	270
Lithium-chlorine	1,050	250	1,200
Fuel cells:			
Hydrogen-oxygen	1,660	400–500	up to 400°F
Hydrogen-air	14,930	1,500–2,000	RT
Hydrazine-air	1,515	400–500	RT
Methanol-air	2,760	400	RT
Hydrocarbon-air	6,330	900	reform hydrogen at 400°F

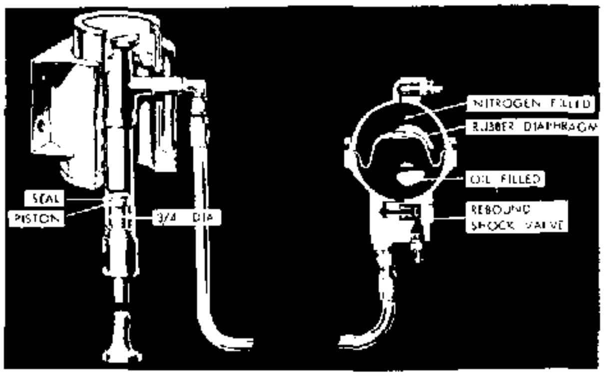
* Includes weight of battery or fuel cell structure.
† Room temperature.

Major components of the inertial energy storage system for a mechanical flywheel bus.



Mechanical flywheels have been used to store energy for buses in Europe and Japan. The flywheels are accelerated at stops from overhead electric power posts, which takes only a few moments, and operate without pollution and with very little noise. Advances in materials are possible which could permit smaller wheels and greater energy storage. If developed, flywheels could be a feasible means for propelling buses under American urban conditions. Hybrid combinations of a flywheel with an electric motor-generator and another form of engine can provide vehicle propulsion or means of accelerating the flywheel at peak engine efficiency with little or no air pollution.

Electric Power Transmission: For vehicles which stay in contact with the guideway, including those vehicles driven by linear motors with the power applied to the rotor, novel power-distribution and power-collection schemes are being explored. The standard shoe-on-power-rail or pantograph-on-catenary will probably continue in use; servo systems have been suggested so that the shoe or pantograph can follow the rail or catenary more closely without being spring-loaded. Direct-contact techniques will serve for vehicles up to the 200-m.p.h. range, even if



Active suspension systems offer possibilities for improved passenger comfort through adaptation of air-oil spring dampers.

the vehicle itself is riding on air. Power transmission techniques which involve an air gap merit further investigation for longer term application to high-speed future systems of transportation.

SUSPENSION AND GUIDEWAY COMPONENTS

Guideway and suspension methods remain a major challenge for research and development, partly because the advances needed for futuristic systems, being largely inapplicable to automobiles, have received relatively less attention than propulsion devices. They are, however, of great importance. Improvements in conventional mechanical suspension and rail guideways are required for even modest increments in speed and comfort, while for major advances new technology clearly will be needed.

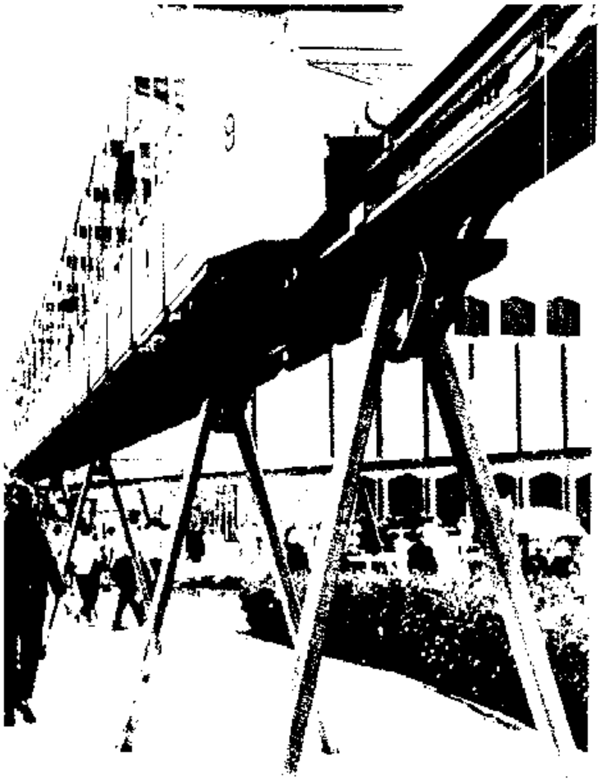
Active Suspension Devices: Performance characteristics of springs and dampers, modulated to anticipate roadbed irregularities, may be worked out through the adaptation of aircraft, military tank, and intercity rail technologies. Though there are many engineers who believe such complex mechanisms may cause more trouble than they are worth, the possibilities should be researched in terms of the potential improvements for passenger comfort, especially at urban speeds.

Air Suspension or Air Cushions: These offer some of the most promising developments in means for supporting new transportation systems. They will require, however, a great deal of further test and evaluation before problems of noise, excessive need for power, vehicle switching and steering, and operation on grades are solved. The potential advantages, however, are substantial: Wide distribution of weight on guideway and vehicle, reducing structural complexities; negligible roadway wear; elimination of wheel problems such as bearing failure, imbalance, and bounce; and simplification or elimination of secondary suspension devices such as springs and shock absorbers. Several vehicles have been designed using air suspension with high clearances, but low clearances are better from the standpoints of noise and power consumption.

The frictionless character of the air-cushion system requires that some thrust-producing device be provided to drive the vehicle, and that some method of producing either reverse thrust or frictional drag, or both, be provided for braking. Since the air gap is an integral characteristic of the system, the linear electric motor seems a logical choice as the propulsion means, and this tends to limit the use of air-cushion vehicles to routes with some types of guideway. Combinations of linear-motor propulsion and air-cushion suspension appear to offer considerable promise in the development of quiet, simple, pollution-free urban transportation systems.

ELEVATED STRUCTURE DESIGN

Artists' concepts of futuristic transportation systems so often portray graceful, airy structures soaring above the city with the beauty of a piece of sculpture. The reality, even with the kind



The quiet operation of the Montreal Expo 67 Minirail is enhanced by an unobtrusive supporting structure.

The dark, dingy, noisy intrusion of the old Third Avenue El was a marked contrast to present day structural possibilities.

of new systems discussed in this report, is not so ethereal and their deleterious effects may extend from esthetics to neighborhood property values and social cohesion.

The new systems study found that it would not be possible to design elevated structures entirely free of adverse effects. Yet new suspension methods which distribute vehicle weight more evenly than present equipment and which create fewer vibration problems would help reduce the bulk of supporting structures. Vehicles which carry smaller passenger loads, with resulting lighter weights and lower profiles permitted by new suspension techniques, would permit the design of elevated structures that eventually could come much closer to what was appealingly offered in the Montreal Expo 67 Minirail system than to the dismal designs of the old Third Avenue El or the Chicago Loop. Indeed, it may eventually be feasible to incorporate elevated guideways into adjacent buildings, passing through them or making them a part of arcades and malls separated from other city streets.

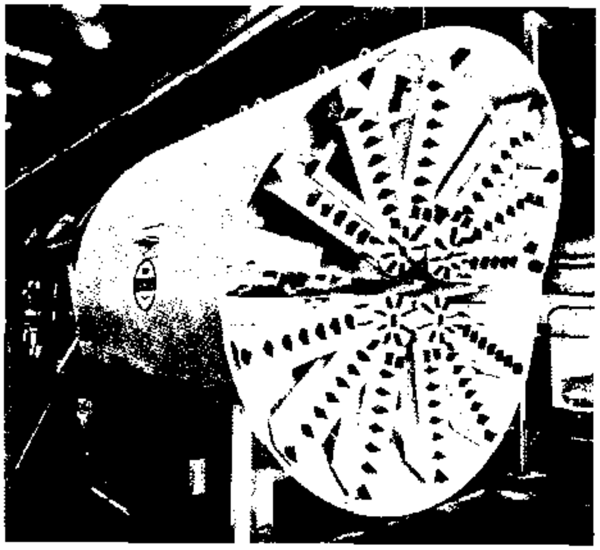
Transit construction and operation costs can be met by changes in tax laws to recover some of the appreciation in property values attributable to proximity to attractive new public transportation systems. With financing of this kind, right-of-way construction can incorporate renewal of adjacent urban areas, so that the whole project would require less land than that consumed for urban freeway rights-of-way. For example, a typical four-lane urban freeway requires about 80 feet of width with median strip and safety shoulders. For comparable construction costs, a double-tracked personal rapid transit guideway would be 17 feet wide as an elevated structure.

TUNNELING

Underground rights-of-way have obvious advantages compared to other kinds in crowded urban conditions—especially with increasing costs of urban rights-of-way, and the resulting social and economic dislocations, together with local tax losses from use of land for transportation purposes. Their great drawback has always been cost, though the trend in tunneling costs has been rather steadily downward over the past 40 years due to mechanization of excavation and hauling. Tunnel construction is slow as well as expensive, and ventilation of tunnels makes them expensive to maintain as well as to build. Research work to lower tunnel costs and to speed construction times is very important to the future of urban transportation.

"Mechanical moles" used in the construction of the Munich subway and for nonvehicular tunnels in this country appear to exhibit the greatest potential for cost reductions. These machines may cut excavation costs by as much as half, and since excavation accounts for approximately half the cost of vehicular tunnels (the balance being for lining, roadbed and utilities), this could mean an overall saving in construction costs of 25 percent.

Machine tunneling has not been successful to date in very hard rock, but here experiments with techniques for weakening rock with laser beams, ultrasonic vibrations, chemicals, and heat show promise. Different proposals for modernizing other facets of tunnel construction include the control of cave-ins and water in soft ground by injecting cementing agents, the reduction of labor costs through the automation of tunnel lining and its amalgamation with excavation in one continuous process. Many difficulties must be resolved before these techniques are even competitive with conventional methods, let alone cheaper, but they appeared, on the basis of the new systems study, to warrant further investigation.



A tunneling machine, 18 feet in diameter, will bore the twin holes along Mission Street for the BART system in San Francisco.

GOODS MOVEMENT

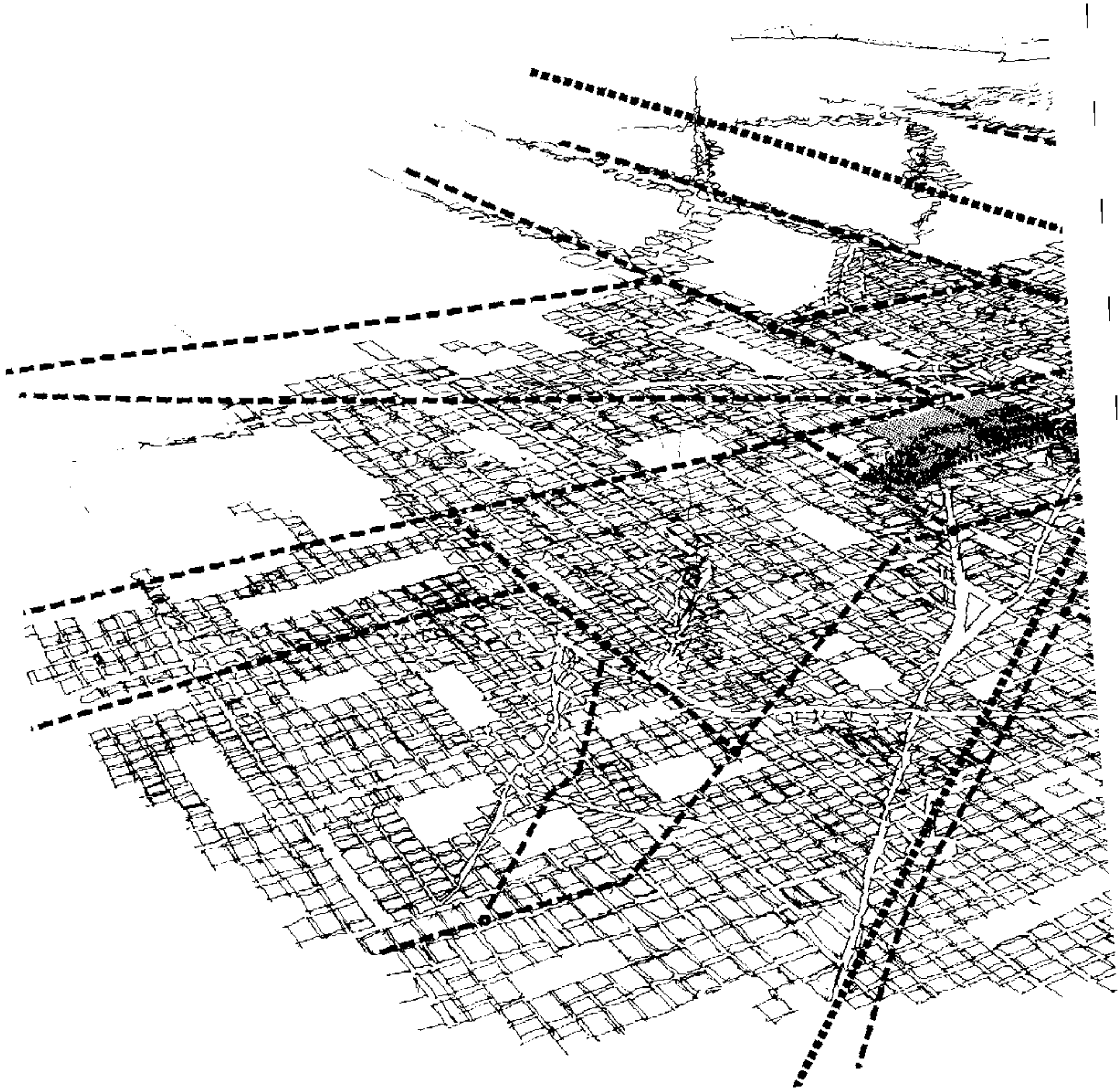
Movements of goods into, within, and through the city are essential to the economic prosperity of its citizens and the health of the city; these movements also contribute heavily to the problems of urban congestion. The goods-movement systems of the future metropolitan area should logically be encouraged to grow along with, and in relation to, the systems which are evolving for the movement of people.

Automation has been applied to materials movement of certain kinds within modern factories and warehouses, but not to goods movement between buildings and between districts of congested cities. Central business districts and major activity centers provide both the most urgent needs and the most propitious conditions for the installation of automatic goods delivery systems. The novel systems probably should be off-street as well as automatic, since a prime objective is the freeing of streets from all the congestion and noise of truck movements, truck parking, and loading-unloading operations.

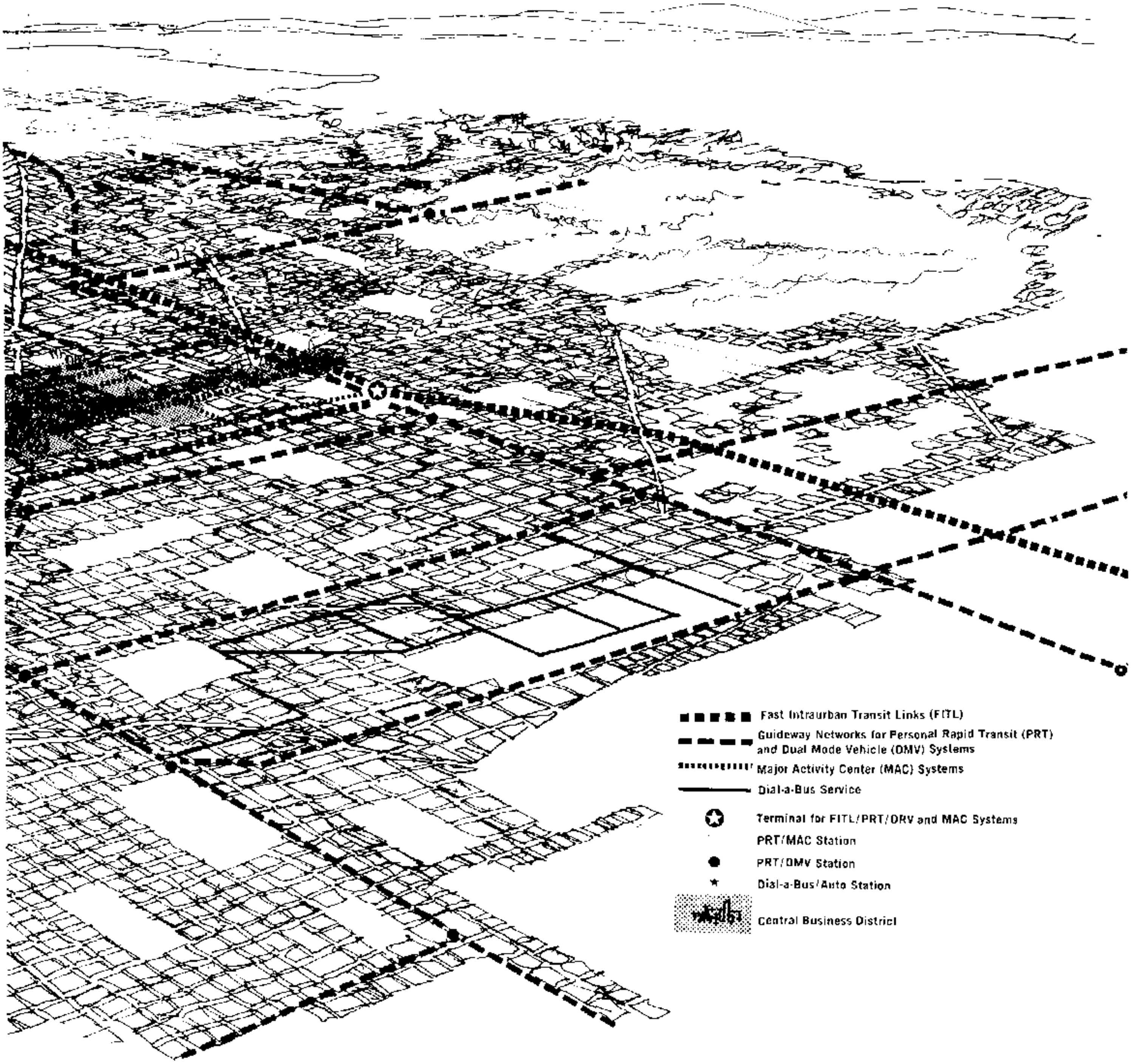
Since conveyor, pneumatic, moving belt, automatic small car, and other suitable technologies already exist in mining, manufacturing, and warehouse applications, the central problem is to select and adapt technologies which are appropriate to the complex institutional, architectural, platting, traffic, and labor relations problems of downtown districts. In less densely developed areas, such as airports and new towns, it is quite possible that the same systems of automatic small cars which deliver goods might also deliver personal baggage or passengers.

Automatic, off-street goods delivery systems could bring dramatic relief to traffic congestion, air and noise pollution, and could increase economic efficiency of doing business in major activity centers. For lack of substantive data on demand, trip origins and destinations, and the like, however, it is possible today to reach only an intuitive understanding of the dimensions of the goods-movement challenge. There is an urgent need for comprehensive data, for quantitative studies and for analyses of the problem. Only when the data are available and the analyses have been undertaken and completed, can the technology be expected to provide realistic solutions.

NEW SYSTEMS OF URBAN TRANSPORTATION *offer many alternatives for travel throughout a metropolitan area. Fast intraurban transit links can serve travel needs between major urban nodes. Personal rapid transit can automatically serve low-to-medium population densities over a network of guideways. Dual mode vehicle systems can augment personal rapid transit with small*



cars or buses which can be driven on city streets and travel on automatic guideway networks. Dial-a-Bus service can collect and distribute passengers in low-density areas on demand. Through combinations and efficient use of these new systems, people can be provided with greater accessibility to the opportunities of urban life.



RECOMMENDED FUTURE SYSTEMS

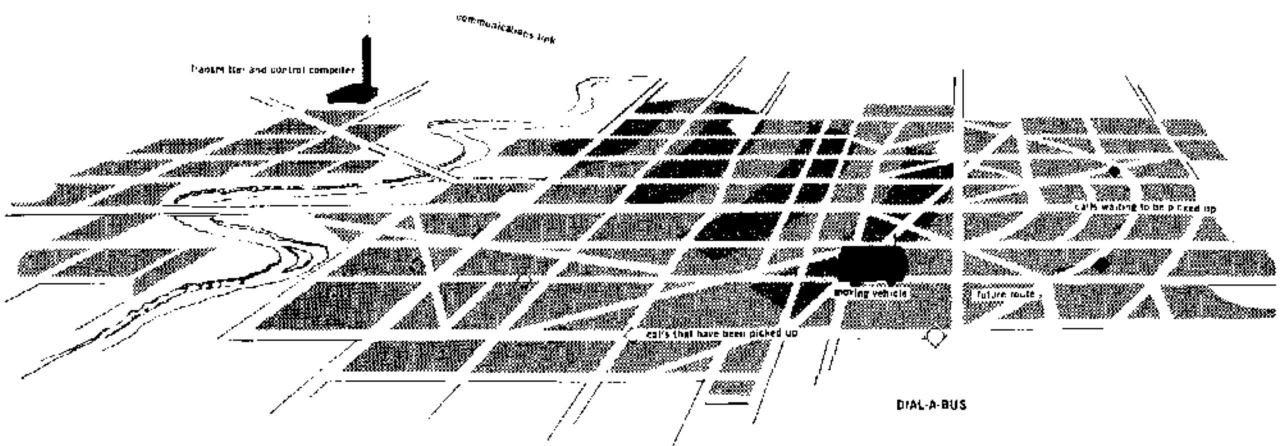
The following seven major types of new systems of all the many candidates investigated, were found to possess not only a high expectation of technical and economic feasibility but also to contribute significantly to the solution of major urban problems.

1. DIAL-A-BUS (DEMAND-ACTIVATED BUS SYSTEM)

A major failing of public urban transportation today is its inability to provide adequate and attractive collection and distribution services in lower density areas of a metropolis. In some parts of urban areas and in many small cities and towns, the travel demand is too small to support any transit service at all. It is simply economically infeasible to route and schedule present transit vehicles efficiently when only a few people want to go to and from the same places during a short period of time. Rail systems are too expensive and are technologically unsuited for low volumes of demand. Ordinary buses cannot maintain sufficiently frequent service in outlying areas to attract any but those who have no alternative. What is needed is a public transit system which can respond dynamically to the needs of these areas, that is, a system whose routes and schedules are both flexible and ubiquitous.

The Dial-a-Bus, which is a hybrid between an ordinary bus and a taxi, could be the basis for such flexibility. It would pick up passengers at their doors or at a nearby bus stop shortly after they have telephoned for service. The computer would know the location of its vehicles, how many passengers were on them, and where they were heading. It would select the right vehicle and dispatch it to the caller according to some optimal routing program which had been devised for the system. Thus, the system could readily link many origins to many destinations.

A Dial-a-Bus, with it's position established by automatic vehicle monitoring, can be routed by computer and a communication link to collect passengers who have called for service.



Customers desiring Dial-a-Bus service could telephone the controller from home and indicate their desired starting time, origin and destination. A signal on the panel might announce the approach of the Dial-a-Bus.

The diffused pattern of trip origins and destinations which this system would serve is most dominant in low density suburbs. But it also exists in a different form in the most thickly populated urban areas.

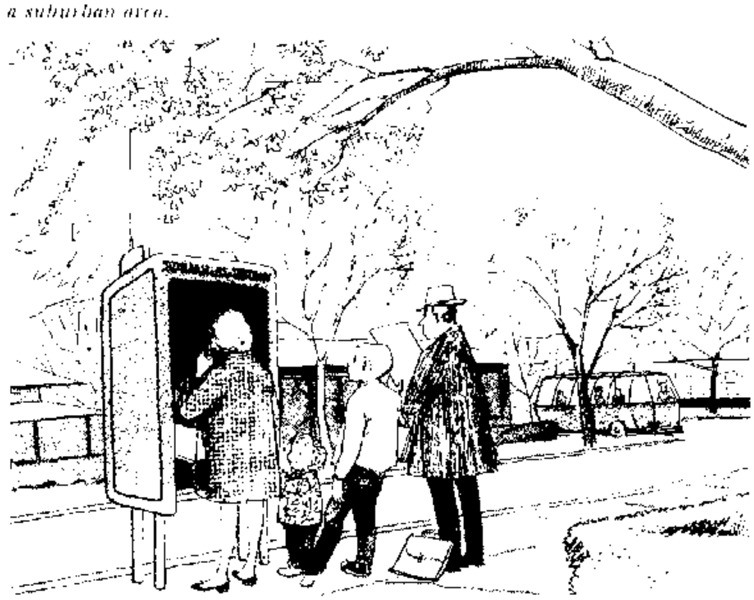
The cost of taxi rides can be driven down by sharing rides, and basically the Dial-a-Bus system is designed to accomplish this. Data from the new systems study suggest that, depending on demand, door-to-door transit can serve its passengers almost as fast as a private taxi but at one-quarter to one-half the price, indeed, at only slightly more than the fare for a conventional bus.

With its operational flexibility, the Dial-a-Bus system could be programed to give different levels of service for different fares. At one extreme it might offer unscheduled single passenger door-to-door service, like a taxi, or multipassenger service, like a jitney. At the other extreme it might operate like a bus service, picking up passengers along specified routes which could include several home pick-ups. The system might also be programed to rendezvous with an express or line-haul carrier, and in serving as either a collector or distributor, provide the opportunity to improve the complete transportation service.

The major point is that the Dial-a-Bus might do what no other transit system now does: Handle door-to-door travel demand at the time of the demand. This means that the system would attract more off-peak business than does conventional transit. And if it does attract enough passengers, the off-peak revenue would help Dial-a-Bus avoid the same financial problems of conventional transit, which is used heavily only 3 or 4 hours per day. It could also help reduce dependence upon automobiles.

Technically, there is little question that the system will work. Any number of existing vehicles can comfortably carry 12 to 24 passengers. Some of the best are now offering service to air-

Dial a Bus call stations could be located at convenient intervals throughout a suburban area.



ports. Present computers, radio communications, and telephone links are fully adequate to the major needs of Dial-a-Bus. Mathematical routing and the associated computer programing present no real obstacles. What must be done is to put these isolated elements together into a unified system. Dial-a-Bus service could be made somewhat more efficient if the buses were equipped with automatic monitors to report each vehicle's location to the dispatchers at frequent intervals. Although these monitors do not now exist, there is no technological barrier to developing them, as discussed above under the automatic vehicle monitoring subsystem.

The cost for a given level of Dial-a-Bus service is a function of many variables. These include the nature of the street system, the cruising speed of the vehicle, the distribution of demand, and the size of the area served. Perhaps the most uncertain of these variables is demand density, the number of trips generated per square mile per hour. Dial-a-Bus systems probably will be most efficient at demand densities of 100 trips per square mile per hour— a level that is barely practicable for conventional bus service.

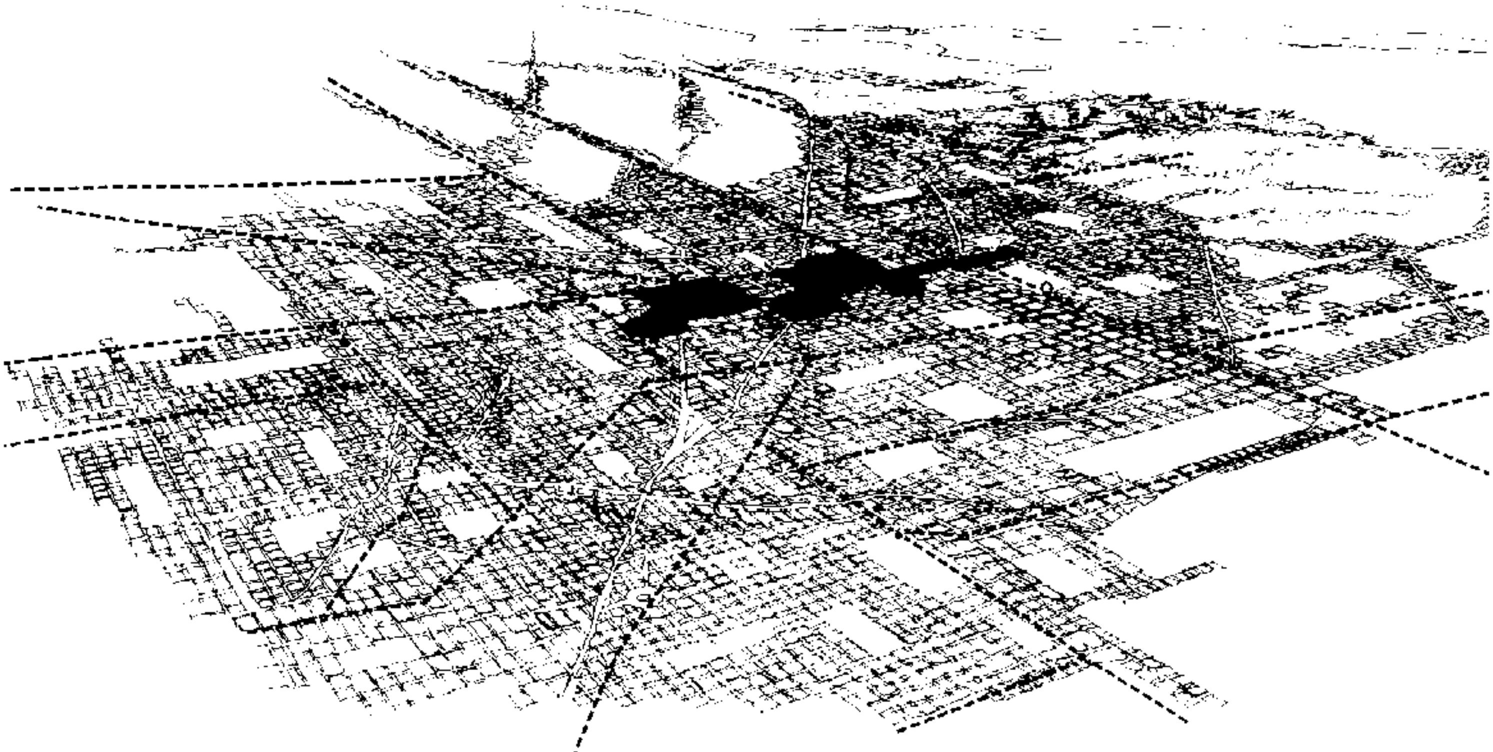
A limited demonstration of the Dial-a-Bus concept, using existing equipment, could almost certainly be achieved within 3 years at a cost of less than $1 million. A definitive full-scale demonstration of Dial-a-Bus service, using vehicles and control equipment specifically designed for this purpose to test the full range of possible benefits, probably could be completed within 7 years at a cost of less than $20 million. (Refer to app. A.)

2. PERSONAL RAPID TRANSIT

The demand for transportation in areas of medium to low population density is at the present time predominantly served by private automobiles. Public transit trunklines may traverse these areas, but collector-distributor service is poor if it exists at all. More than half the automobile travel in large cities occurs in such areas in trips longer than 2½ miles. Increasing travel demands of this kind, unmet by public transportation services, tend to encourage multiple-automobile ownership and use; often these additional automobiles can be neither afforded nor efficiently accommodated.

To provide accessibility and service to the profusion of origins and destinations in these metropolitan areas, a system is needed which can be designed to be more responsive to the requirements varying population densities and land use patterns might generate. One such concept is "personal rapid transit," sometimes called areawide individual transit or network transit. It would consist of small vehicles, each carrying about the same number of persons as an automobile. These vehicles would travel over an exclusive right-of-way or guideway network, either over standard routes, or else automatically routed individually from origin to destination at network stations.

Personal rapid transit would provide travelers the important advantages of minimum waiting time at the origin station,



Personal rapid transit would serve all but the lowest density suburbs with a network of lines such that no one in the area would be more than 2 miles from a PRT station.

and private, secure accommodations. At the heart of the concept is the premise that personal transit would serve a metropolis, except perhaps for its lowest density outskirts, with a network or grid of lines, each perhaps a mile or two apart.

Empty passenger vehicles or "capsules" would be available at each station on the network. The riders would enter one, select and register their destination, and then be transported there automatically, with no stopping. The average speed would be essentially equal to the vehicle speed. The station spacing on a guideway network for the system would have no influence on speed of travel. Passenger demand and station costs would dictate proper station spacing.

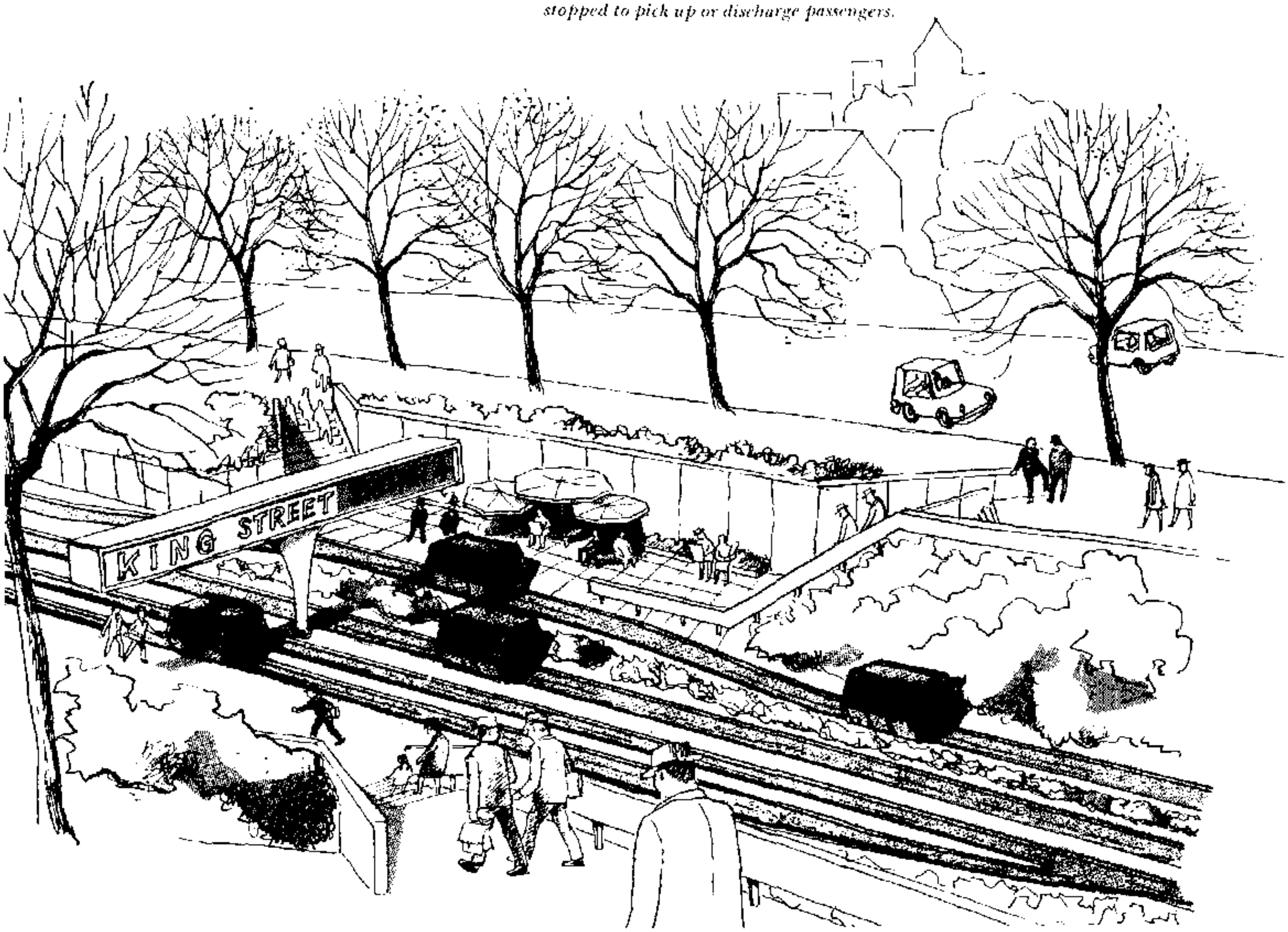
Empty vehicles would be recirculated automatically to maintain an inventory at each station, and passengers could be routed past stations without stopping until they reached their destinations. Ideally, such a system would give travelers the same privacy as a private automobile, although during peak periods in cities with particularly heavy corridor movements a traveler might have to share a vehicle with two or three other passengers.

The guideway network covering the metropolitan area is the essential ingredient of the personal rapid transit system. Without a network of guideways the system could hardly avoid conventional heavy dependence on work trips and a radial orientation to existing central business districts. Thus, it could not provide adequate transportation alternatives in large metropolitan areas with a wide dispersion of trip origins and destinations. No matter how sophisticated the technology, transit which operates without some sort of network service pattern almost certainly will remain a marginal service in the movement of urban populations.

Network systems of personal rapid transit would perform economically with travel demand ranging from 1,000 to 10,000 persons an hour in a travel corridor—the medium to lower density conditions in which mass transit systems today usually perform inadequately. Yet these corridor travel demand levels prevail in most metropolitan areas. The network system, moreover, could have average speeds of 50 to 70 miles an hour, a substantial improvement over average urban freeway speeds.

The roadbed or guideway for personal rapid transit might consist of rails or surfaces for air bearings; the vehicles could use steel or rubber wheels or air pads. Propulsion could be in the vehicle or in the guideway itself. Each guideway would be about 5 feet wide and could be a single-lane over substantial portions of its length. The narrower and lighter struc-

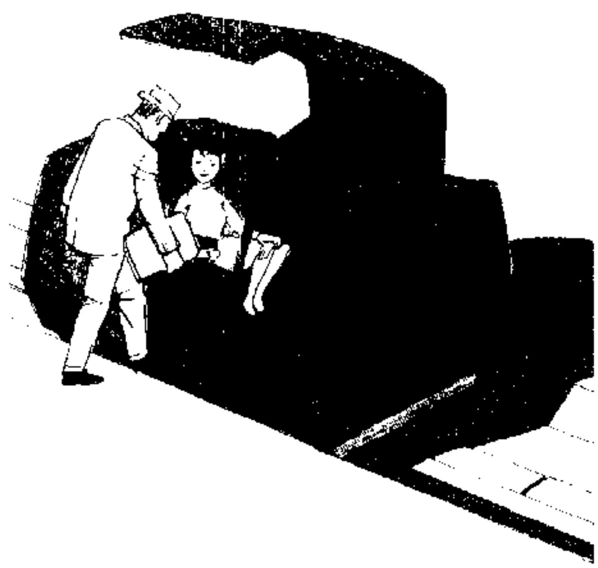
A suburban personal rapid transit station showing turnouts for vehicles stopped to pick up or discharge passengers.



Automated guideways may be depressed—as in this parkway adjacent to residential areas—at grade level, or elevated to suit the locale of the installation.

tures should require less land. They also could be more attractive than many urban freeways. All these options are open to the design engineer; no particular solution has yet been shown to be outstanding.

A personal rapid transit system having these performance characteristics is an important element in a viable urban transportation system for a number of reasons:



A four-passenger personal rapid transit vehicle.

- *An exclusive right-of-way* is essential if public transportation is to be automated and if it is to escape the congestion of general street traffic. Forced to compete with automobiles on crowded streets, other forms of mass transportation are inherently at a speed disadvantage.

- *Automation* can make transit service more competitive with the automobile, since it is the only safe and efficient way to operate a system using numerous small vehicles.

- *Small, individualized vehicles* avoid the chief delays of present rapid transit: Stops at intermediate stations for other passengers and waiting or dependence on a schedule at the origin station.

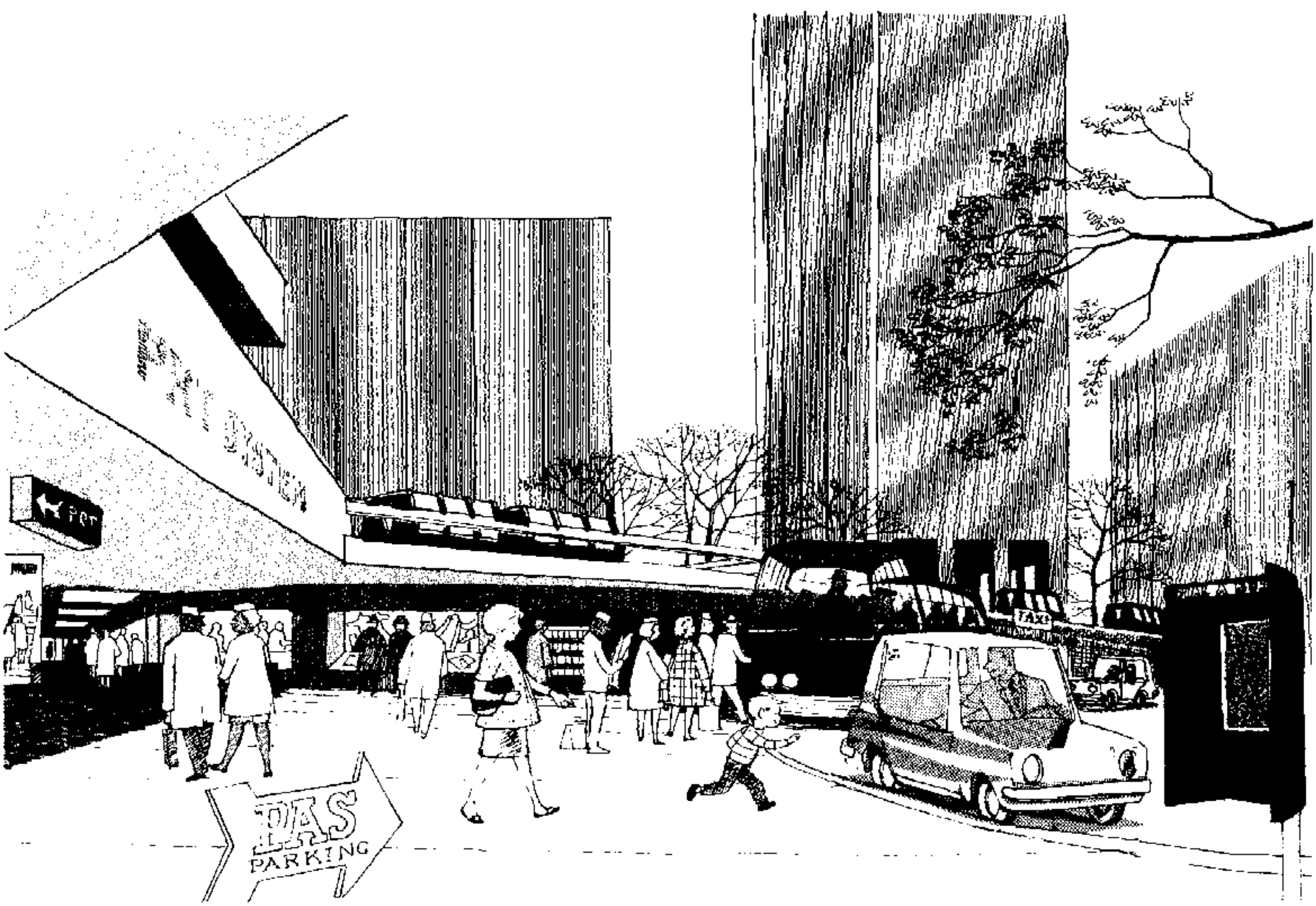
- Additionally, *use of small lightweight vehicles, with the quiet suspension and propulsion mechanisms* which can be developed, and the less massive elevated and station structures such systems would permit, would minimize the impact of the system on the environment.

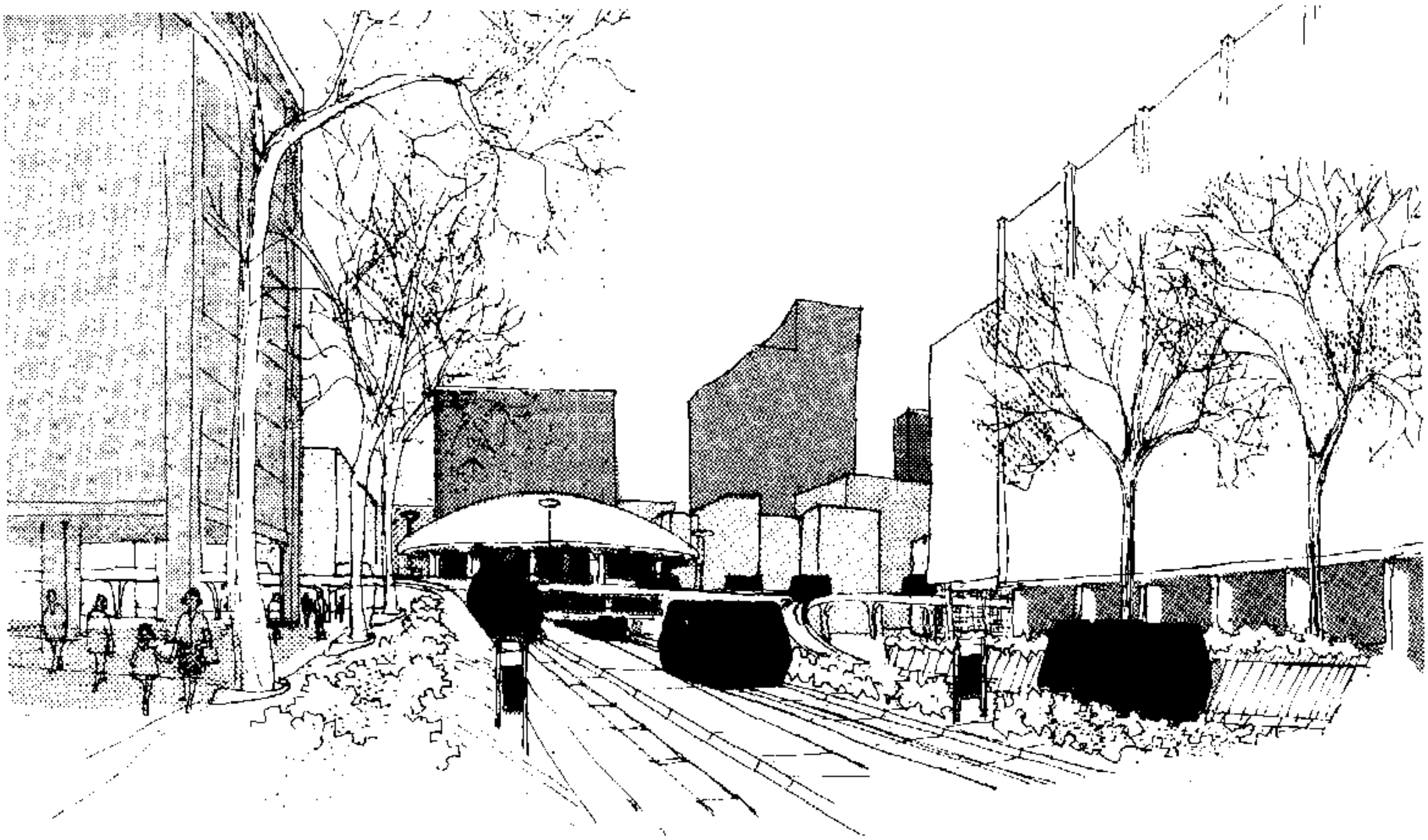
The new systems study found over 20 existing proposals for various kinds of personalized transit, most of them little advanced beyond the original concept. The greatest amount of development work is needed for automatic electronic controls. Maintaining safe headways to permit stopping in case of an emergency on the line ahead is a very substantial problem in a system using small vehicles and yet still aiming at high traffic volumes. Such operation requires vehicles to be run far closer together than they can now, but the problems involved in realizing this potential require further research.

A network of exclusive right-of-way transit on any such scale poses obvious problems other than technical ones. Clearly a major investment would be required, though costs might be reduced by running the guideways on elevated structures using the medians or margins of existing rights-of-way. Tunneled guideways and grade level or depressed guideways would be less expensive than conventional systems requirements because of the smaller vehicle size of personal rapid transit.

Personal rapid transit could probably operate at costs below 10 cents per mile if its capacity were 6,000 riders per hour and if the demand were sufficient to generate 15,000 riders per day, on the average, over each section of guideway. In sum, the real issues concerning the feasibility of personal rapid transit systems, as for all new systems, are not merely technological ones, they include the questions of cost and safety as well. These questions cannot be answered with absolute precision at this time, but indications are that personal rapid transit will be many times safer than the private automobile, and yet will cost no more than modern mass transit systems proposed in areas of low to medium volume travel demands.

Personal rapid transit stations in the suburbs would be reached by Dial a Bus and by private or public automobile service. (PAS).





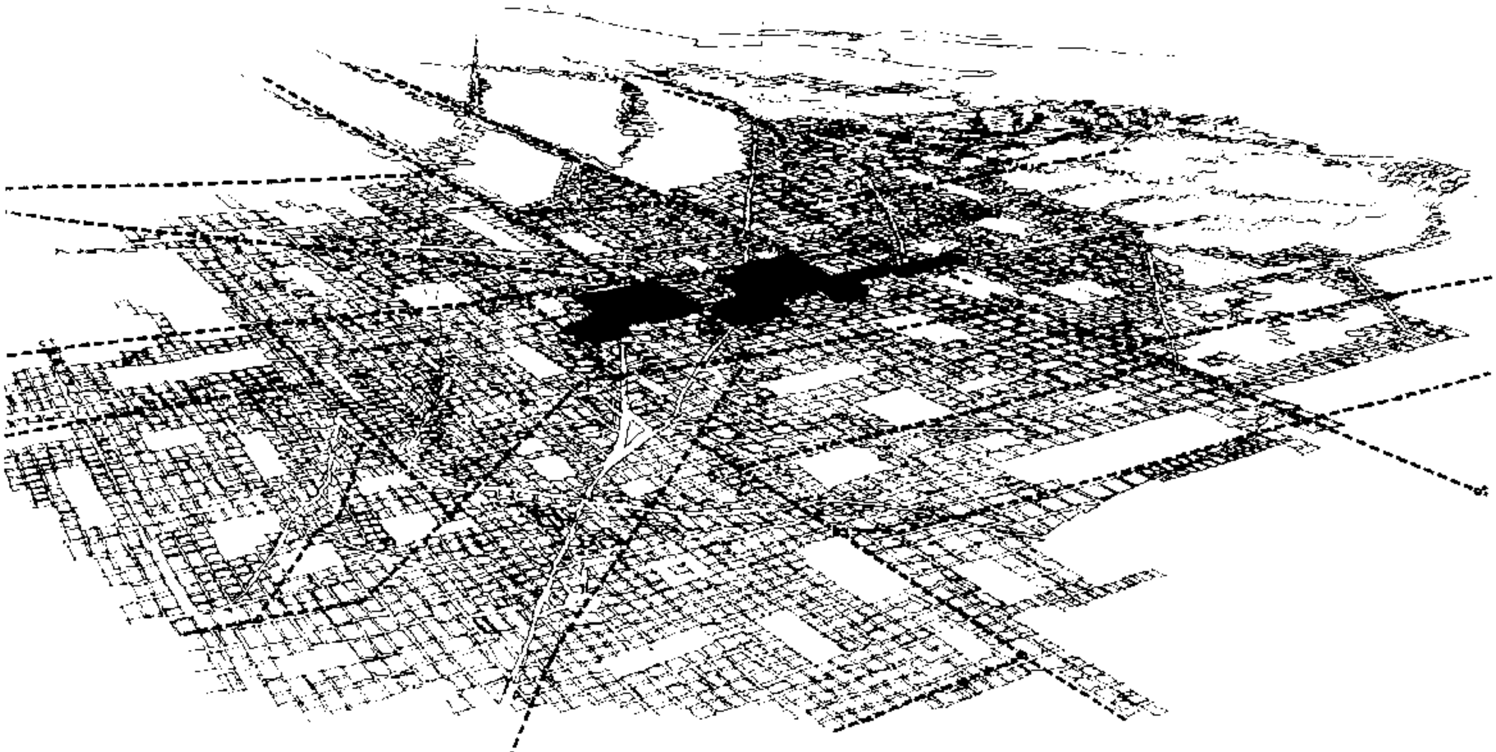
An inner city personal rapid transit station

A prototype of such a system could be developed, working perhaps from an existing system such as the Transit Expressway demonstrated in a HUD project in Pittsburgh. Such a prototype system might minimize control difficulties, for instance, by requiring passengers to transfer—a requirement that might not be too onerous in some metropolitan areas because networks requiring few transfers could be designed.

The ultimate goal should be a system that does not require this kind of temporizing. Yet control problems become even more complex in the areas of merging one vehicle stream into another and of routing numerous small vehicles automatically over a network of guideways, with provisions for switching off the line at stations, of maintaining adequate supplies of empty cars at stations, and of distributing vehicles so that congestion does not result on any line. The new systems study found that these problems are surmountable, and that a prototype system could be developed, tested, and evaluated in less than 10 years at a cost of about $250 million.

3. DUAL MODE VEHICLE SYSTEMS

On the outer fringes of the personal rapid transit system just described, the network of lines in the lower density areas, to remain economical, would probably be too far apart for convenient walking access, and unsuitable for short neighborhood or local trips. The new systems study found the dual mode vehicle system to offer a possible solution to these problems. In a dual mode system, the vehicle can convert easily from travel



The dual mode vehicle system could operate on the same network of lines used by personal rapid transit. Vehicles would drive from the streets onto the guideways at selected PRT stations.

on a street to travel on an automated network. It thus could serve as a logical extension or elaboration of personal rapid transit.

Dual mode personal vehicle systems would give the same service for persons who did not own or know how to drive an automobile as would the personal rapid transit system. They would use public vehicles on the automatic guideways, and would walk or transfer to other systems for local trips. However, the guideways also would be accessible to privately owned or leased vehicles which could be routed on and off ramps connecting with ordinary streets, and driven over the streets to the driver's destination just as in the case of an automobile. At the point of destination, the vehicles could be parked as they are today or, if they were leased for the trip, they could be turned in at local connection points for redistribution to other users. This last method has the advantage of minimizing parking problems in congested areas.

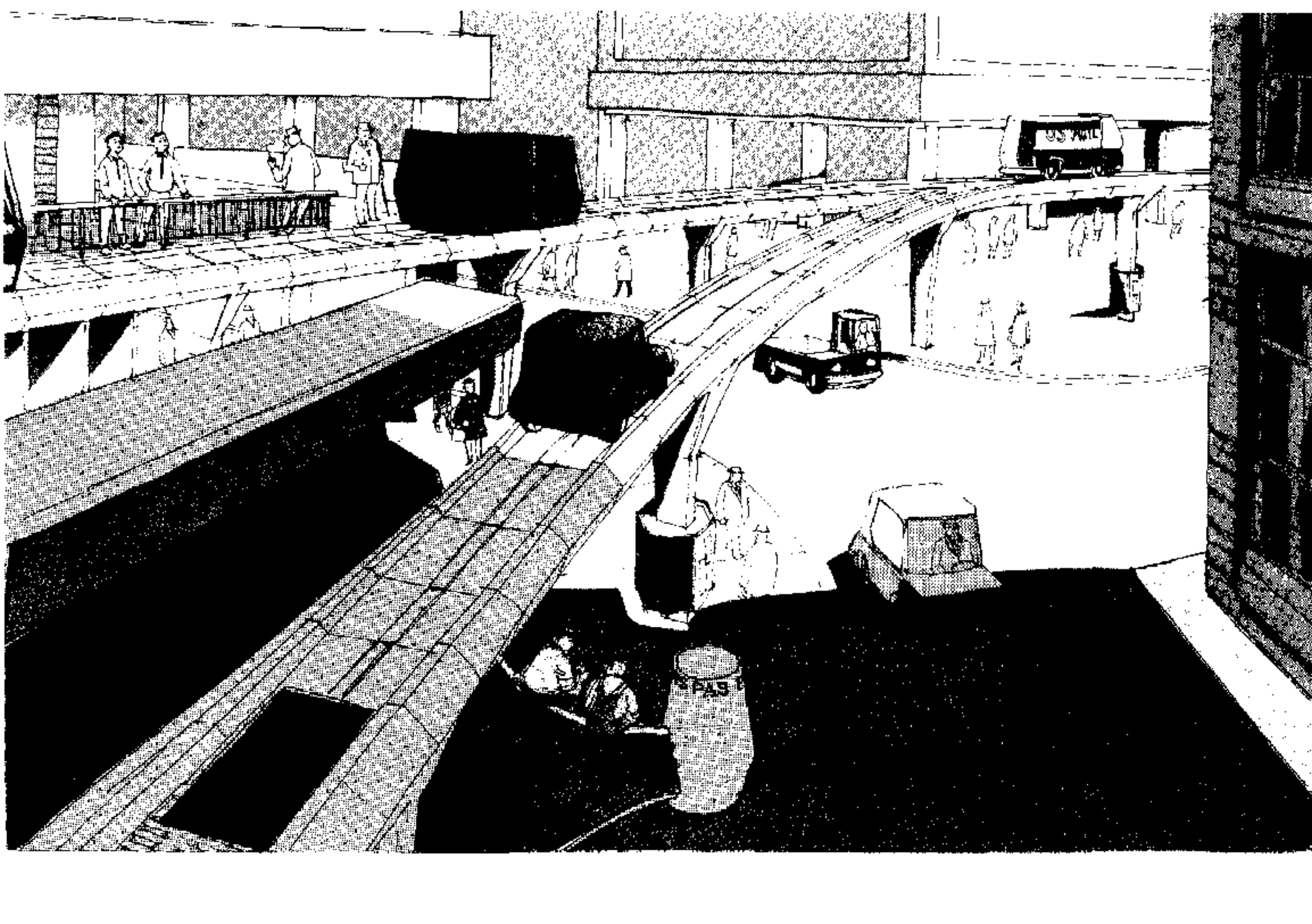
A dual mode system presents more technical development problems than the personal transit system. However, it should be possible to work on such problems simultaneously with the development of personal transit, and to so design personal transit systems for ultimate dual mode use. The earliest developmental problems will be in the adaptation of propulsion, suspension, and guidance systems for use on both automatic guideways and regular streets. None of them seems insurmountable in the light of present knowledge.

Propulsion on the guideway, as in the case of the personal transit system, would almost certainly be electric, probably using third rail power distribution in prototypes. In the final development of the system, however, propulsion might be a version of the linear motor discussed previously. Vehicles would thus need an electric motor; off the guideway they would run on batteries or use a separate engine to generate power for the electric motor.

Since these are the directions in which propulsion technology for ordinary automobiles may evolve to achieve reductions in air pollution, the propulsion problems of a dual mode personal vehicle are likely to be solved well before its other problems.

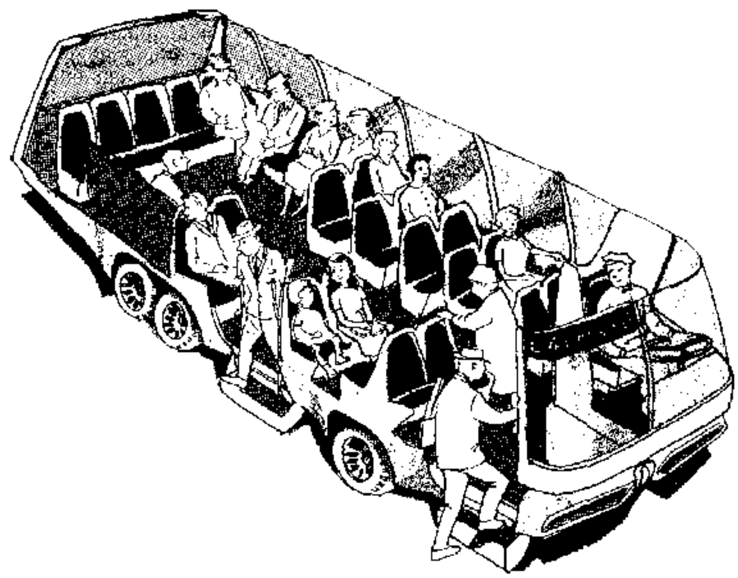
The most difficult technical problems are those associated with the development of a control system. Two different courses are possible. One is to concentrate the burden of control in the automated guideway (using equipment like linear synchronous motors and wayside computers); the other is to concentrate it in the capsules. The cost and complexity of the guideways would be reduced if the controls were in the capsule, but the controls could be damaged when the capsules were off the guideway and being driven by individuals, and there could be additional safety hazards.

A personal rapid transit dual mode vehicle station showing a small car entering the network through an inspection point, a destination encoder and an automatic fare collector.



In the automatic mode, the vehicle would be powered electrically from an external source. While in the manual or street mode, propulsion might be initially from a turbo-electric powerplant. Eventually, an all-electric propulsion system could achieve minimum levels of noise and air pollution.

Because of the relatively long headways between vehicles, the controls for intervehicle spacing, speed, switching, and stops are not as complex as those required by the personal rapid transit or small dual mode vehicle systems. Nevertheless, the controls will constitute a major portion of the research and development effort leading to a demonstration of the automated



Design of the automated dual mode bus would give particular attention to passenger comfort on the longer express trips.

dual mode bus system. Significant efforts will also be required for the design and development of the guideway propulsion system and mainline stops for passenger entry and exit while the vehicles are operated automatically. The redistribution and effective use of vehicles and drivers during off-peak and manual operating periods will require careful analysis. Consideration has been given to the possible use of some of these vehicles as a Dial-a-Bus during off-peak hours.

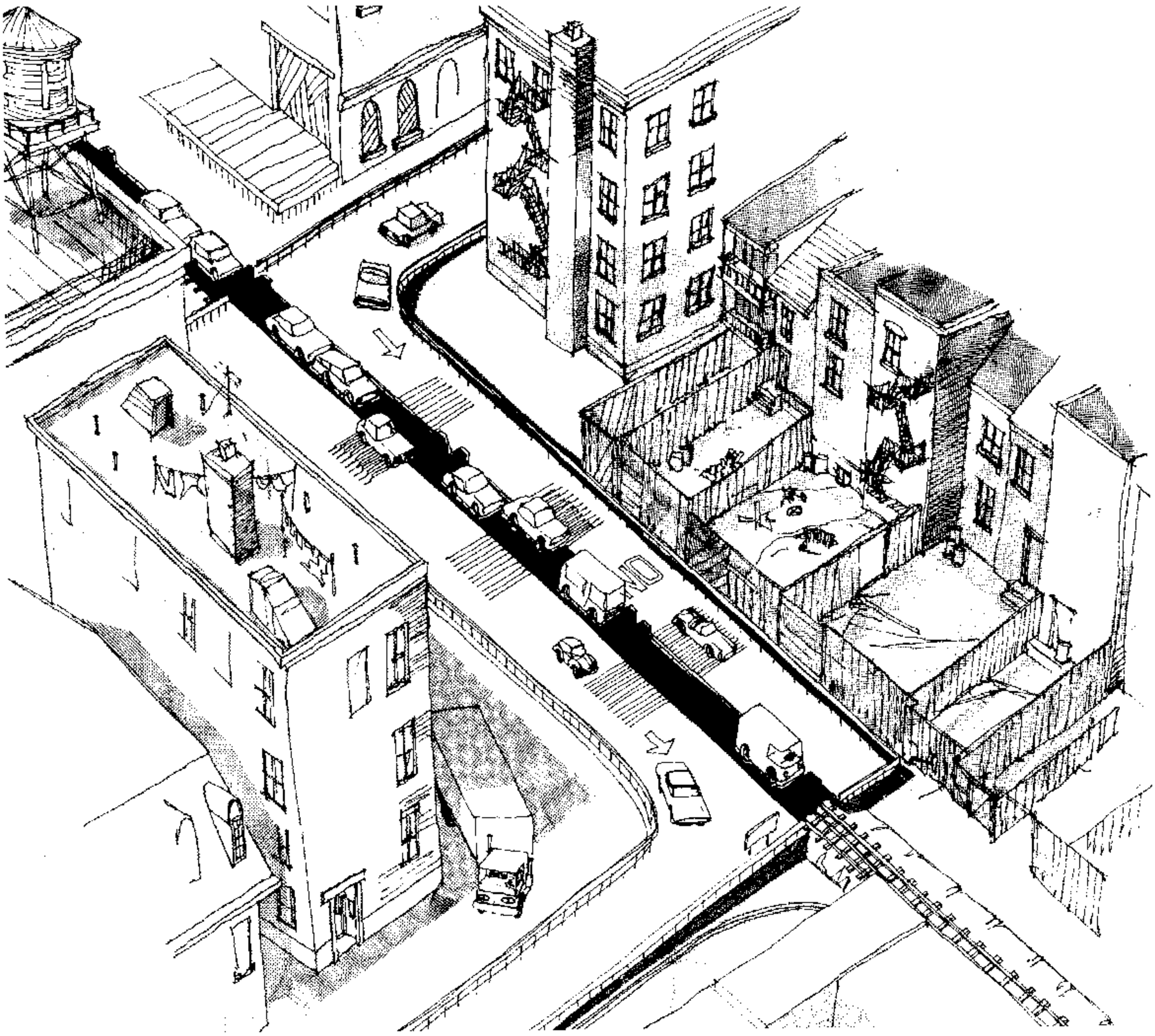
The automated dual mode bus could be developed and its feasibility demonstrated very likely within 5 years at a possible cost of less than $15 million.

5. PALLET OR FERRY SYSTEMS

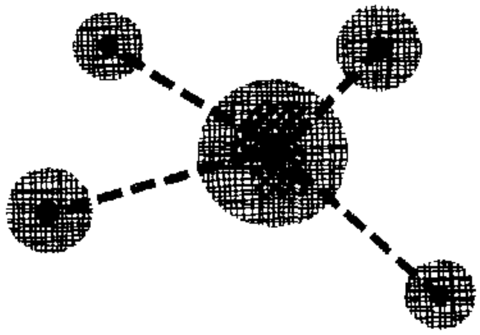
The most rapid population and employment growth in American cities today is in the suburban areas. As a result, the percentage of trips having an origin or destination in a concentrated central city area is shrinking, and the number of trips between low density residential areas and decentralized industrial and commercial areas is growing. To accommodate this growth pattern and to provide other options of urban development, modes of transportation which span entire metropolitan areas with circumferential, as well as radial links, are essential. A corollary to the dual mode personal vehicle systems which would provide this type of service would use pallets to carry (or ferry) automobiles, minibuses or freight automatically on high-speed guideways.

Pallets have several advantages. For one, the individual would not have to buy or lease special vehicles. For another, a single freeway or rail line could be converted to pallet operation; automobiles in the area could use the pallet for high-speed line-haul, thus preserving the quality of automobile comfort without the disadvantages of driving in traffic.

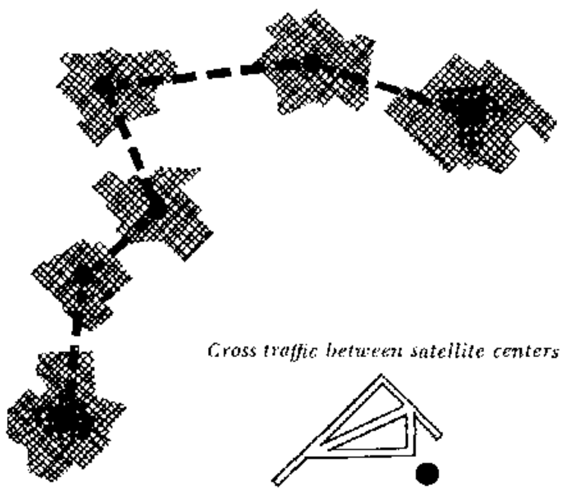
A rail pallet or ferry system could make good use of an abandoned or seldom used rail line in the city.



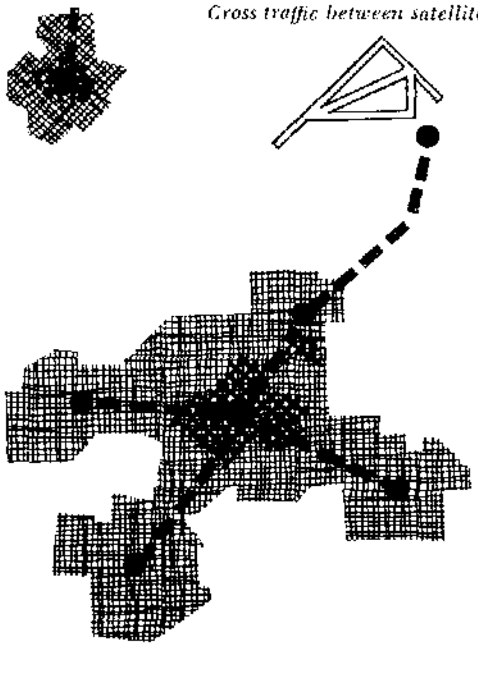
FAST INTRAURBAN TRANSIT LINKS



Central cities to suburban growth centers



Cross traffic between satellite centers



Access to regional airports

In the rail system, the traveler's private automobile, with the driver and any passengers remaining inside, would be loaded on a pallet and transported at high speed. The automobile would not need special equipment and the pallet vehicle would not need to be much more than a platform or flatcar able to carry about 10 to 12 vehicles. The concept is not limited to rail systems, but could be adapted for guideways with electrically propelled carriers.

The system would provide high-flow capacities per lane, as well as automatic operations over long route segments. Loading and unloading might be automated, although the operations would have to be restricted to terminals with transfer equipment.

A major disadvantage of the pallet concept is that it would serve only vehicles of conventional size. (It could, of course, be restricted to special small vehicles, but only by losing a principal advantage of general availability.) Thus, the pallet systems would not, in the long run, have much effect on congestion in downtown areas unless it were coupled with extensive construction of peripheral parking facilities or automated garages.

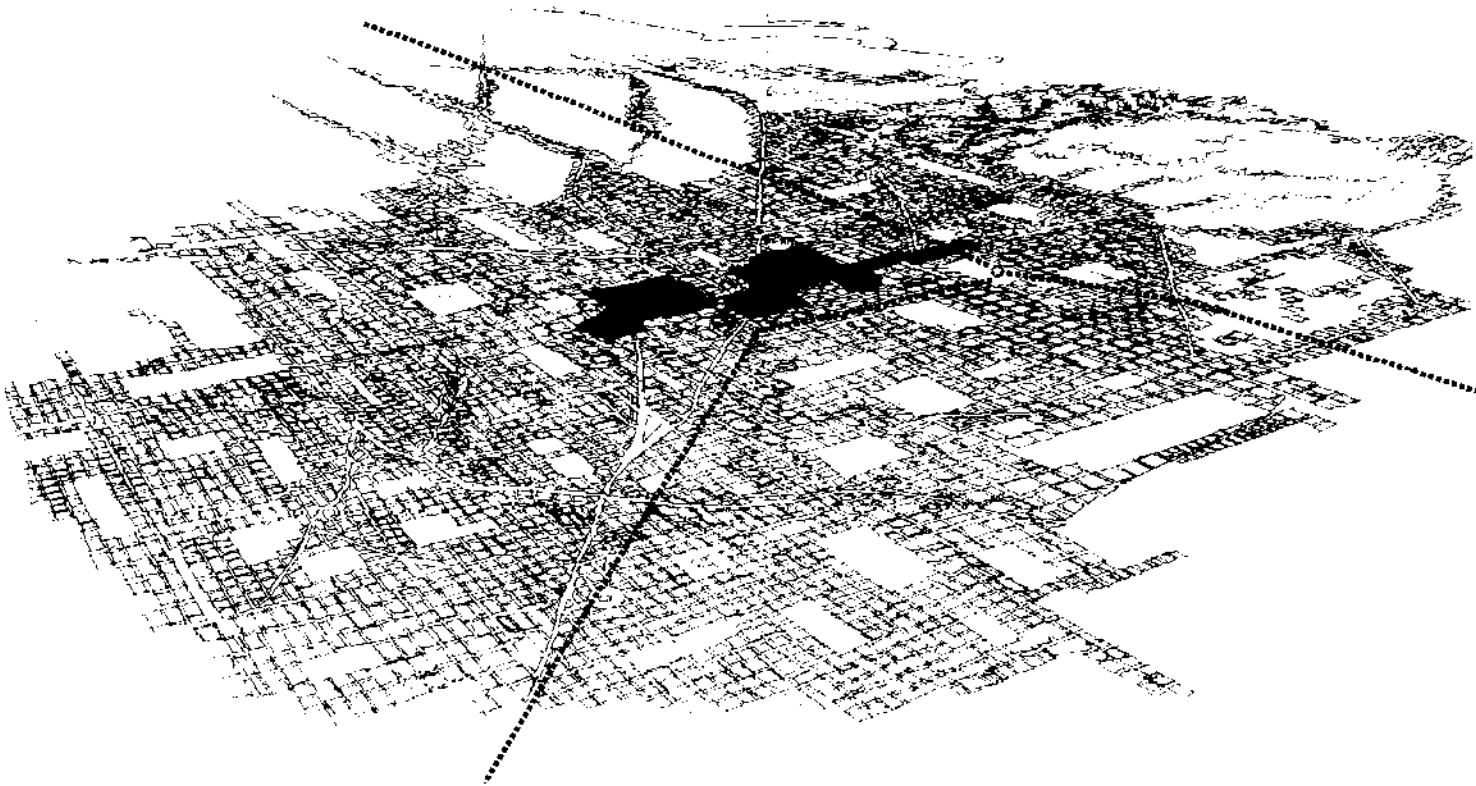
While only a limited comparison of a pallet and dual mode system was made, the new system study concluded that each had certain advantages in particular applications. A Federal program of research should examine both on the basis that a rail pallet system could initiate dual mode operation when a substantial portion of metropolitan guideways were converted. The feasibility of one form of rail pallet system could be demonstrated within 5 years at a cost of less than $25 million.

6. FAST INTRAURBAN TRANSIT LINKS

The diversification of travel in and around major metropolitan areas requires fast intraurban transit links to move relatively high volumes of passengers between central cities and suburban growth centers. Increasingly, they will be needed for line-haul travel not oriented entirely to central cities: Cross traffic among new towns, between satellite centers and international or regional airports, and as feeder-distributor systems serving the major high-speed ground lines along major regional corridors.

New systems of fast line-haul links will be essential in the development of new or renewed satellite communities. Indeed, they may be the only means to provide the focal points for future metropolitan development patterns alternative to continued regional sprawl.

The new systems study investigated all the conceivably feasible new types of fast intraurban transit links. At their best, they can be quieter, smaller, and less demanding in guideway requirements than current high speed intercity systems. Moreover, they can take less land, and can minimize adverse impact on areas adjacent to rights-of-way. For long-term development, speeds in excess of 100 miles per hour are difficult to attain economically with steel wheel suspension on steel rails because, for acceptable levels of vibration, tracks must be precisely level and in exact alinement. Further, vehicle stability requires

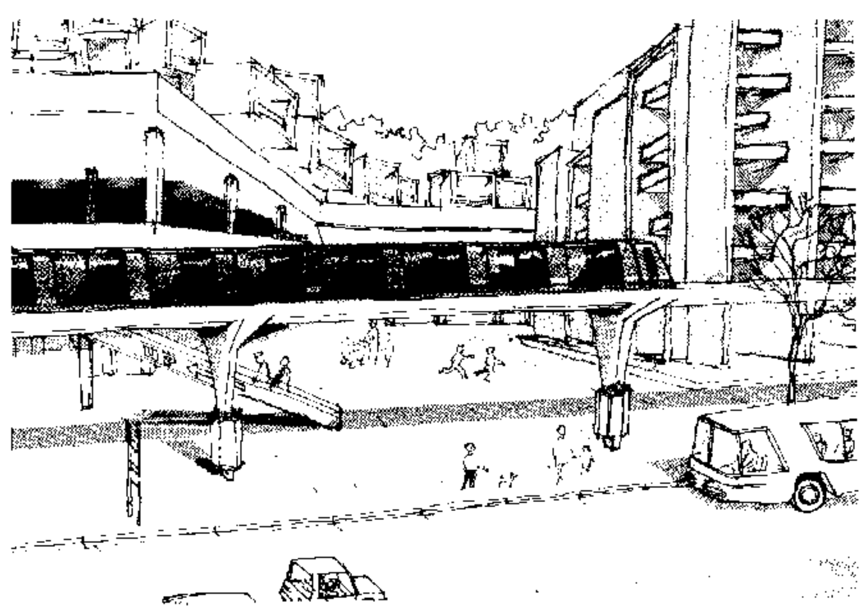


Fast intraurban transit links can provide rapid access throughout a metropolitan area between a number of distant points.

weight, which is expensive to move. Support, suspension, and guidance for several types of fast intraurban systems may evolve from the air-cushion principle.

If future intraurban link systems are to succeed where commuter lines have failed, they must be automatically controlled, with vehicles capable of operating either independently or coupled into trains. Automated systems of single-car trains would not require a large labor force to operate them, and

A satellite city fast intraurban transit link station.



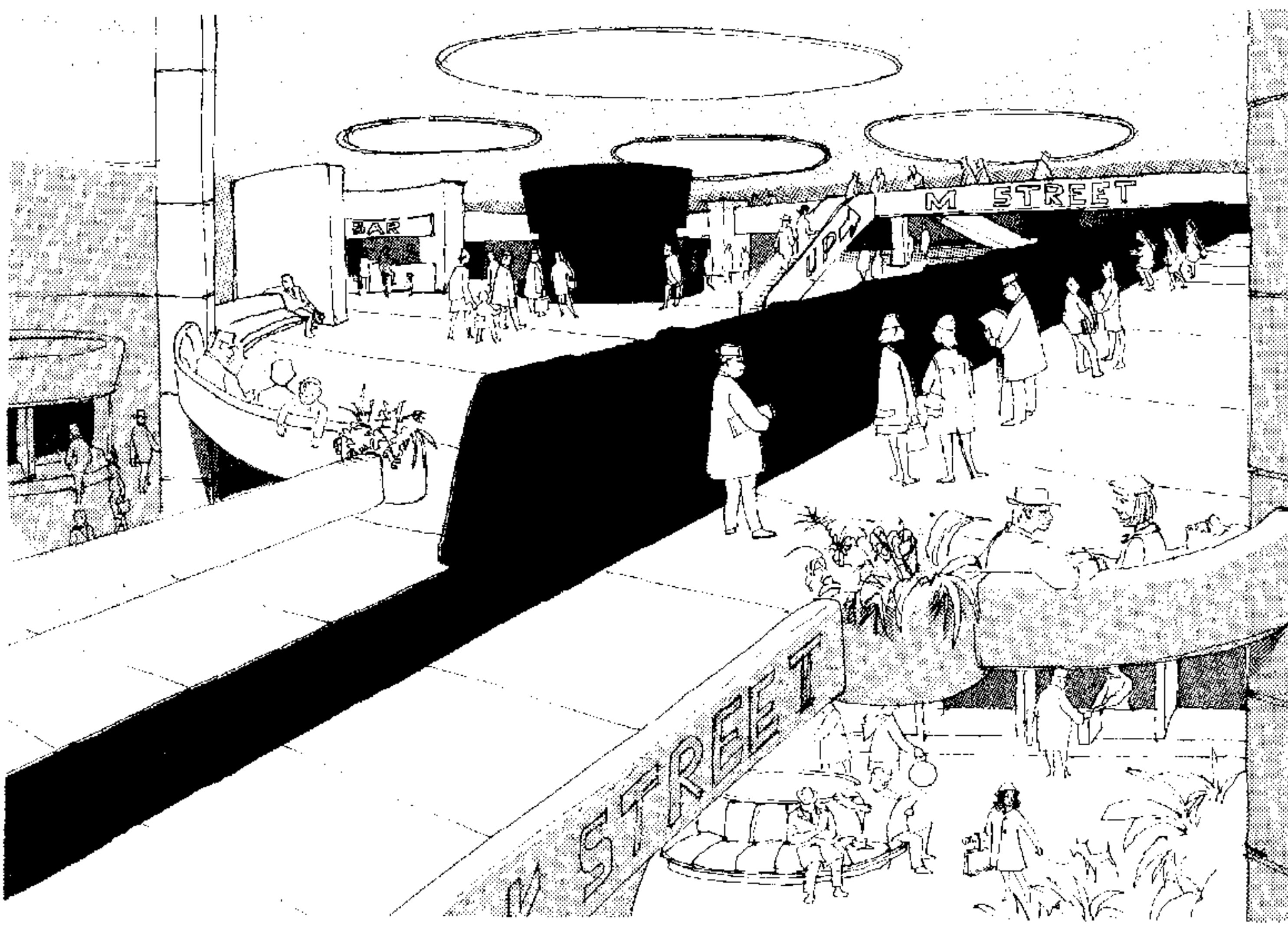
could be easily adjusted to fluctuations in demand. Linear motors for propulsion, air-cushion support and suspension for the higher speed ranges, and automatic vehicle monitoring, ticketing, and ridership counting equipment, would all contribute to safe, reliable, flexible service.

Guideway dimensions, turning radii, and support structure requirements for intraurban systems are such that fast transit links could be installed in the medians or along the edges of existing freeways. Rail rights-of-way could also be converted in many instances.

One version of an intermediate speed intraurban link would carry 80 seated passengers per car, for a system capacity of 16,000 passengers per hour. Another could carry 20 passengers per vehicle and would be able to move 6,000 passengers per hour in conditions approaching the convenience, comfort, and privacy of the automobile. Higher and lower capacities could be attained through changes in train lengths and headways. Both versions of intermediate-speed systems require extensive technological development and economic analysis.

The development, test, and evaluation of the 20-passenger-per-car fast intraurban transit link system probably could be

The main central city terminal for a fast intraurban transit link system.



accomplished in less than 10 years at a cost of less than $50 million.

The new systems study also considered other imaginative concepts for point-to-point travel systems, such as the gravity-vacuum tube design, many monorail system designs, and also various kinds of short-haul aircraft, both fixed-wing (vertical or short takeoff and landing) and rotary-wing (helicopter) types. Each of these types of systems, in their present and projected states of development, has some major problems, however, compared to other systems examined. Until these problems are resolved, such systems appear to offer few salient advantages and would have relatively limited application for travel within urban areas.

7. SYSTEMS FOR MAJOR ACTIVITY CENTERS

Multitudes of people assemble each day in the major activity centers of a city; large airports, shopping centers, industrial parks, and universities, for example. Central business districts are, of course, major activity centers. Provision must be made for an adequate circulation system to better accommodate the movement of people and goods within these centers. Currently, much of the travel in these areas is by pedestrians on sidewalks. In a few cities, trains provide service in subways or on elevated railways. In most areas, this circulation is now provided by autos, taxis, streetcars, buses, and jitneys operating on city streets, frequently under highly congested conditions.

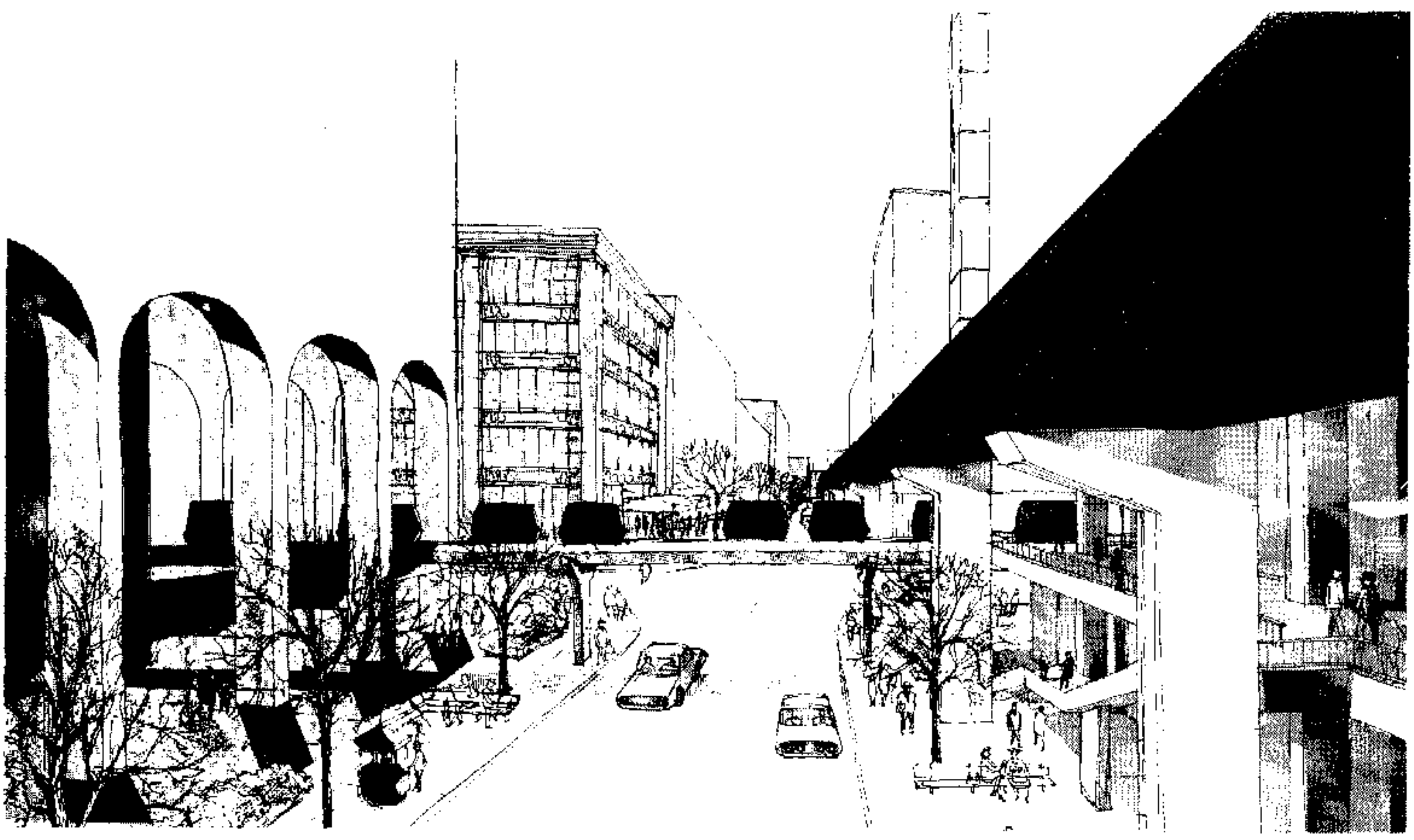
The new systems study has identified several circulation systems which offer the potential for moving large numbers of people over short trips in a relatively small area and are capable of doing so safely, comfortably, economically, and with a minimum of waiting. Because modal separation is imperative under the congested conditions of travel in activity centers, such systems must operate on some kind of exclusive guideway. Following is a discussion of the principal types of systems.

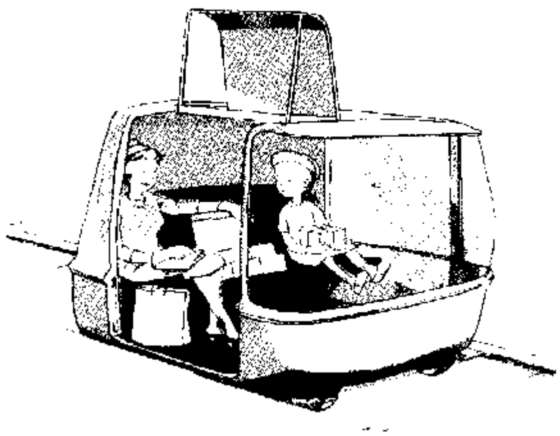
Moving Belts: Horizontal conveyor belts have been in use for a long time. They have many advantages—low cost, no waiting, no operators. A major disadvantage is their slow speed. The very old, the very young and the handicapped cannot get safely on and off sidewalks which are moving faster than about 120 feet per minute (1.76 m.p.h.). In order to permit safe loading and unloading, constant-speed belts must move at such slow speeds that they can be easily out-distanced by the average pedestrian. Previous prototype systems approached this problem by having people board faster belts from adjacent slow ones. Continuous parallel track layouts, however, are extremely expensive, cumbersome to accommodate, and involve significant safety hazards.

There are several other ways to approach the problem of accelerating belt speed from 1.5 to 15 miles per hour that the new systems study found worthy of further development and experimentation. These include belts whose length or width can be varied during operation. Two ways of using variable length or "stretching" to produce variable speeds are to use a series of rigid plates which would overlap at slow speeds, or a "window shade" device that could produce varying speeds. This second type would be divided into sections attached at either end to a series of carts or boxes that would move along at varying speeds. The spacing between the carts or boxes would be controlled mechanically; if they were a foot apart at a boarding speed of 1.5 miles an hour, they would have to move 10 feet apart at 15 miles per hour. As they moved apart the belt material would unwind from the "window shade" reel in the carts and the passengers on the belts would be smoothly accelerated.

Capsule Transit: The complexity of moving belt designs suggests that a type of small vehicle system may be more feasible for major activity center use in the long run, if sufficiently high carrying capacities can be achieved. A large number of concepts have been proposed and several are actually being marketed or are in use. Some use small cars propelled by moving belts and are accelerated and decelerated by variable speed rollers. Others substitute variable-pitch screws for the rollers or cables for the belts. All of these proposals have technical problems of one kind or another, such as the inability to provide for an emergency—like the failure of one car—without shutting down the entire system. The new systems study recommends that investigations of them be included in a Federal research and development program.

Pedestrian movement in central cities can be aided by moving belts (as on the right and left) or by network cab transit (as shown crossing the thoroughfare).





A two-passenger network cab for trips within a major activity center.

Network Cab Transit: While traditional transit forms are applicable to downtown circulation, on-street forms suffer and contribute to congestion, while new subway systems are both very expensive and highly disruptive during installation. To meet these difficulties, the study considered narrow light-weight, low-noise systems, which can be suspended above city streets or sidewalks with a minimum of intrusion.

Two systems were proposed which consist of small automatically controlled capsules. The capsules carry one or two persons (with room for parcels) and run at about 15 m.p.h. on tracks high enough above the street level to keep from interfering with existing traffic. To use the system a person enters a capsule at one of the many sidings and pushes a start button. The capsule is automatically accelerated and merged into the mainline traffic. Deceleration to a stop is done automatically when the capsule is turned into a siding.

Capsules travel along the main lines only a few feet apart; allow capacities of about 8,000 vehicles per hour. For the speeds and loads involved neither propulsion nor suspension is a critical issue; direct-current electric motors driving steel or pneumatic wheels will probably suffice.

Many aspects of the new network cab system are similar to personal rapid transit. Principal differences are in the speeds, size of vehicles or cabs, and in spacing of the network grids. The network cab system is intended to cover a much smaller area than personal rapid transit. This similarity affords the opportunity for closely integrated development efforts which tie a circulation system for major activity centers together with fringe area transportation systems like personal rapid transit.

The most complicated part of these systems is the merging and spacing control. In the simplest type of system, operation would be in a single loop and the merging would occur only when cars left stations. Each vehicle being merged would proceed only if a slot were available; slots would not be deliberately created upstream of a merge point. Spacing would be uncontrolled except for the minimum amount necessary for emergency stops. Speed control would not be precise, but would be limited to the nominal system speed. More sophisticated versions are possible, verging on the personal rapid transit system described previously.

If developed concurrently, the feasibility of one example of these types of systems could be demonstrated during a 5-year period at a cost of about $6 million per system for a total program estimate of $18 million. In order to fully develop, test, and evaluate a series of desirable systems which could be certified safe for public demonstration, a program extending over 10 years is estimated to cost approximately $118 million.

Table 3.2

Summary Program Recommendations and Problem Areas

	Program elements	Contributions to Solutions of Urban Problems							
		1. Equality of access to urban opportunity	*2. Quality of service*	*3. Congestion*	*4. Efficient use of Equipment and facilities*	*5. Efficient use of land*	*6. Urban pollution*	*7. Urban development options*	*8. Institutional framework and implementation*
1.0	**Improved Analysis, Planning, and Operations**								
1.1	Investment, financing, and pricing	○	○	○	○			⊗	●
1.2	Comprehensive planning	○	○	○	○	●	○	⊗	○
1.3	Operating efficiency	○	⊗	○	●				○
1.4	Social impact	●	○			○	⊗	○	○
1.5	Evaluation techniques	●	○	○	○	○	○	○	⊗
2.0	**Immediate Systems Improvements**								
2.1	Urban bus systems	⊗	●	○	○		○	○	○
2.2	Exclusive guideway systems		●	○	⊗		○		
2.3	Urban automobile innovations	●		⊗		○	○	○	○
2.4	Improvements for pedestrians	⊗	○	●		○		○	
2.5	Improvements of general application	○	⊗	○	●				○
3.0	**Components for Future Systems**								
3.1	Automatic systems controls	○	⊗	○	●	○		○	
3.2	Propulsion and power transmission		○		⊗		●		
3.3	Suspension and guideway components		●		○		⊗		
3.4	Elevated structure design			○		●	⊗	○	○
3.5	Tunneling			○		⊗	●	○	○
3.6	Goods movement			●	⊗	○	○	○	
4.0	**New Systems for the Future**								
4.1	Dial-a-Bus	●	⊗		○			○	○
4.2	Personal rapid transit systems	●	○	○			○	⊗	
4.3	Dual mode personal vehicle systems	●	⊗	○			○	○	
4.4	Automated dual mode bus	⊗	●	○	○			○	○
4.5	Pallet or ferry systems		⊗	○			○	●	
4.6	Fast intraurban transit links	○	○			⊗	○	●	
4.7	Systems for major activity centers	○	○	●	○	⊗	○		○

Key: ● PRIMARY—Project areas which are primarily related to or make a major contribution to solutions of urban problems.

⊗ SECONDARY—Project areas which make significant contributions to solutions of urban problems, but which are secondarily related to the problem.

○ INDIRECT—Project areas which are indirectly related but which make substantive contributions to one or more problem areas.

SUMMARY: URBAN PROBLEMS AND PROGRAM RECOMMENDATIONS

Table 3.2 summarizes the recommended research and development program elements discussed in preceding paragraphs. The relevance of each proposed program element discussed to the solution or amelioration of eight major areas of urban problems is illustrated. The estimated costs, and the allocation of funds within the proposed research and development program are presented in Part IV of this report.

KEY TO PROBLEM AREAS LISTED IN TABLE 3.2.

1. EQUALITY OF ACCESS TO URBAN OPPORTUNITY: Present urban transportation tends to isolate and immobilize nondrivers: the poor, secondary workers in one-car families, the young, the old, and the handicapped.

   OBJECTIVE: *Transportation equity, nondriver mobility.*

2. QUALITY OF SERVICE: Public transit service too often is characterized by excessive walking distances to and from stations, poor connections and transfers, infrequent service, unreliability, slow speed and delays, crowding, noise, lack of comfort, and a lack of information for the rider's use. Moreover, the passengers are too often exposed to dangers to personal safety while awaiting service. These deficiencies lead to a loss of patronage and a further decline in service for the remaining passengers.

   OBJECTIVE: *Convenience and quality of ride approximating that of a private automobile.*

3. CONGESTION: Congestion results in daily loss of time to the traveler. Too often "solutions" are expensive in dollars and landtaking, destroying the urban environment in the process.

   OBJECTIVE: *Compatibility or separation of parking, loading, and movement in order to reduce congestion at reasonable economic and social cost.*

4. EFFICIENT USE OF EQUIPMENT AND FACILITIES: Increased efficiency and greater economy through better management and organizational techniques—including cost control, scheduling and routing, experimentation in marketing and new routes—is necessary to satisfy urban transportation requirements at minimum cost.

   OBJECTIVE: *Optimal use of transportation investments and systems.*

5. EFFICIENT USE OF LAND: Transportation functions and rights-of-way require extensive amounts of urban land, and compete with other important uses of the urban land resource. More rational urban land use patterns aided by new forms of transportation could help reduce travel demands, (as can substituting communications for urban transportation) and achieve greater total transportation service for the amounts of land required.

   OBJECTIVE: *Rights-of-way economical in land use; transportation systems unobstrusive in location and design.*

6. URBAN POLLUTION: Air, noise, and esthetic pollution from all current modes of urban transportation are far too high, degrading unnecessarily the quality of the urban environment.

   OBJECTIVE: *Quieter, cleaner, more attractive transportation systems, with drastic reduction in exhaust pollutions and in urban street noise levels.*

7. URBAN DEVELOPMENT OPTIONS: Transportation investments can be used creatively in the orderly development of urban areas. Present urban transportation is often not appropriate for the modern city. Service is generally inadequate or unavailable for low and medium density areas, for crosshaul trips and reverse commuting, and for circulation within activity centers and satellite cities. Urban transportation service should provide for choice in living styles and in locations as well as choice among modes of transportation. New town settlements, as well as other concentrations of urban growth, could be feasible options for land development patterns with improved intraurban transportation services.

   OBJECTIVE: *Provide transportation alternatives appropriate for a variety of urban development patterns.*

8. INSTITUTIONAL FRAMEWORK AND IMPLEMENTATION: An improved institutional framework—legal, financial, governmental, and intergovernmental—is needed to eliminate rigidities and anachronisms which prevent the adoption of new technologies and methods. A framework which would assist metropolitan planning agencies and would enhance the effective cooperation of local governments in solving joint transportation problems is necessary.

   OBJECTIVE: *Orderly implementation of transportation improvements through reduction or removal of institutional and regulatory barriers, by permitting a creative federalism on all levels of government, and by facilitating private enterprise and financing.*

IV a recommended research and development program

THE RECOMMENDED RESEARCH AND DEVELOPMENT PROGRAM entails a total program funding of $980 million phased over a period of 5 to 15 years. It could be a continuation and acceleration of the $25 million research, development, test, evaluation and demonstration (RDTE&D) program contained in the President's fiscal year 1969 budget. The allocation internally among the program elements shown in the example plan in table 4.1 is designed for a total funding level of $980 million over 5 years. Greater variations in the recommended funding level and the program phasing would probably affect the internal structure of the proposed program—the priorities, the selection, and the scheduling of projects—in order to maintain a maximum return per research and development dollar.

Three basic criteria were considered in structuring the research and development program recommended:

First, the program elements, or projects to be undertaken, must be of significant relevance to, and contribute towards, the amelioration of one or more of the eight salient urban problems identified by the new systems study. As indicated in table 3.1, each of the proposals, components, and systems described in this summary report are indeed relevant to the eight urban problem areas delineated. It should be noted, however, that there remain numerous projects worthy of further research and development which could not be more than alluded to in this brief summary report. The detailed information concerning such projects will be found in the forthcoming technical reports of the new systems study and in supporting materials.

Table 4.1

AN EXAMPLE PLAN FOR A 5-YEAR URBAN TRANSPORTATION RDTE&D PROGRAM

A. Example Fiscal Year Funding Levels by Program Elements, 5-Year Program

program elements	*($ million, estimated)*					
	year 1	*year 2*	*year 3*	*year 4*	*year 5*	*total*
Improved analysis, planning, and operating methods. .	$20	$20	$30	$30	$40	$140
Immediate systems improvements.	70	70	60	60	50	310
Components for future systems.	50	50	40	40	30	210
New systems for the future.	40	40	70	70	100	320
Total.	180	180	200	200	220	980

B. Example RDTE&D Funding Levels by Program Elements

program elements	*($ million, estimated)*				
	Research	*Development*	*Testing and evaluation*	*Urban demonstration*	*total*
Improved analysis, planning, and operating methods.	$40	$50	$30	$20	$140
Immediate systems improvements.	30	90	90	100	310
Components for future systems.	40	70	70	30	210
New systems for the future.	50	80	80	110	320
Total.	160	290	270	260	980

Priority is given to those projects which are most likely to yield the greatest benefits over time for the money expended on them, with benefits weighed as contributions to the solutions of significant urban problems. A problem-solving orientation has been followed throughout in order to identify the most pertinent projects. More precise estimates of the scope and amount of the benefits to be enjoyed from the recommended projects and activities must await the further information generated by the early phases of the program itself.

A second criterion of sound program structure and management, which has helped shape the recommended program, involves the concept of a *mix* of activities; a mix between relatively low-risk, near-term projects and higher-risk, longer-term proposals. The concept of a mixed strategy for an optimal program also refers to an appropriate combination between the improved planning and operating methods, or "software" program elements, and the technological or "hardware" elements.

This research and development program was influenced by the need and desire to pursue projects with early or near-term payoffs. It is essential that efforts be made as soon as possible to ease worsening urban transportation problems. At the same time, if cities are to enjoy significantly improved transportation in the future, work must be begun on those promising systems and components which likely will require years of further development. The recommended program reflects a balance between these factors.

The third criterion followed was to maintain an appropriate expenditure level among the types of program activity undertaken, whether research, development, test and evaluation, or urban demonstration. Since the meanings assigned to these terms are not necessarily everywhere uniform, the definitions of the terms used are as follows:

Research is largely applied research in the scientific sense, leaving basic research to other agencies who are now conducting such research;

Development is the development of technology to the prototype stage, leaving the product and production process development to private industry;

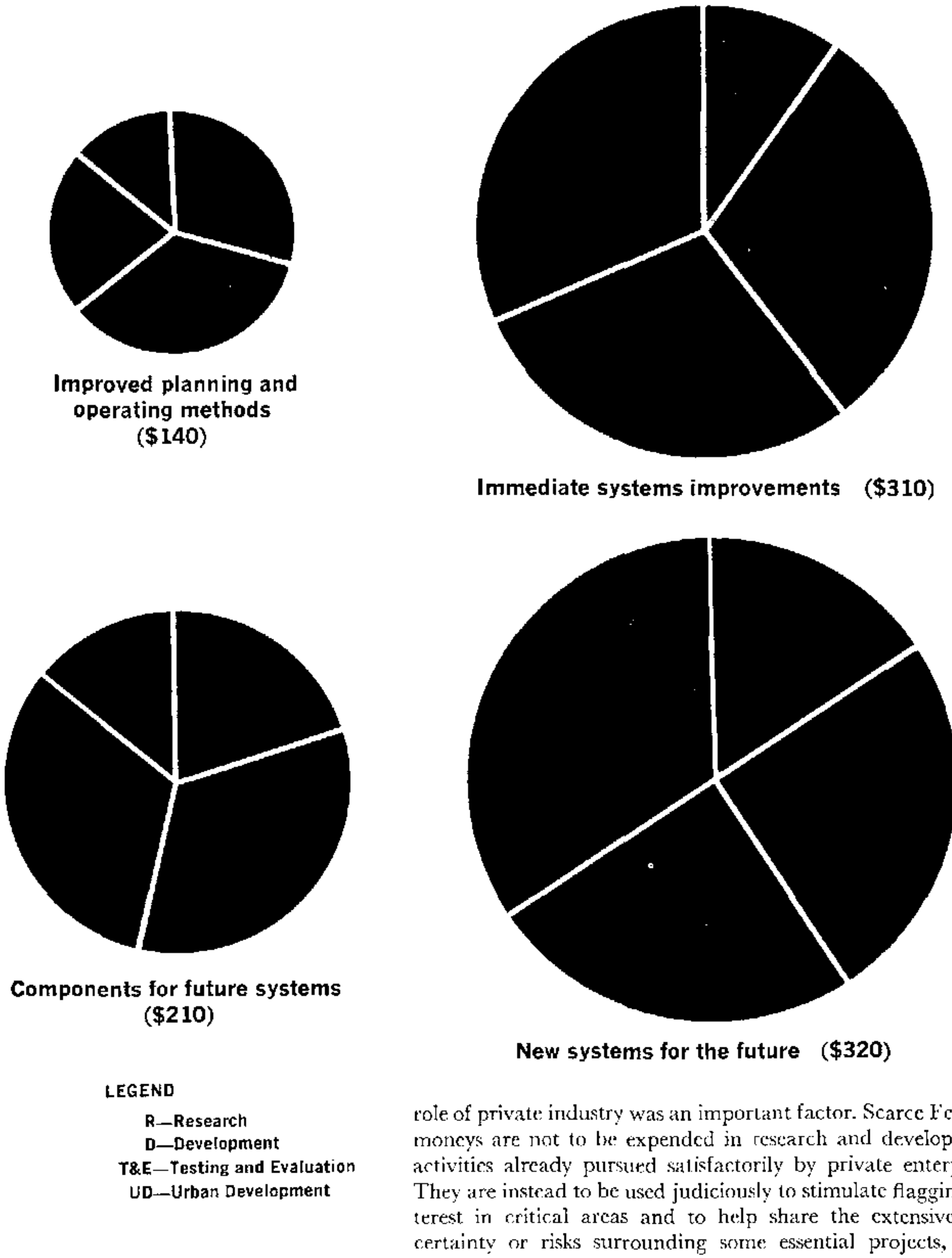
Testing and evaluation involves that laboratory work which is required to determine the technical feasibility of improvements and innovations and to estimate their social and economic feasibility sufficiently to assure that testing in the real world is warranted at all.

Urban demonstration, as used here, is the actual installation and market testing in urban areas to determine the social and economic feasibility of improvements and innovations for eventual implementation in the capital grants program. (Refer to fig. 4.1.)

Many of the technological possibilities revealed by the new systems study have already absorbed years of research and development activity, whether in private industry or in the government. Further research on these "ripe" projects is not needed, and urban demonstrations with them could begin almost immediately. The Dial-a-Bus new system is just such a case in point, and a more detailed program for the Dial-a-Bus is contained in Appendix A. On the other hand, a premature rush to demonstrate certain other of the new systems and components in urban areas would be uneconomic and wasteful pending further research and development.

Finally, in designing the program to meet this criterion of balance among types of activity, the extensive and important

Figure 4.1. RDTE&D funding levels by program elements (in $ millions).



role of private industry was an important factor. Scarce Federal moneys are not to be expended in research and development activities already pursued satisfactorily by private enterprise. They are instead to be used judiciously to stimulate flagging interest in critical areas and to help share the extensive uncertainty or risks surrounding some essential projects, risks which private industry alone could not absorb.

appendix a

DIAL-A-BUS RESEARCH, DEVELOPMENT, TESTING, EVALUATION & DEMONSTRATION PROJECT PLAN (RDTE&D)

Attached is an example of a RDTE&D project plan for a demand activated "Dial-a-Bus" system. This concept of urban transportation service has been variously called "DART" (Dynamically Actuated Road Transit), "Genie," "Demand Bus," or "Computer Aiding Routing System" (CARS). Essentially the purpose of this system is to provide a passenger collection and distribution service in a low density area with more convenience, and with shorter trip times, than a scheduled bus and at lower costs than the single-passenger taxi. The collection and distribution may be made throughout the area as an off-peak, many-to-many service, or it may provide peak-hour feeder service to and from a rapid transit station.

Dial-a-Bus service is provided by a fleet of computer-scheduled vehicles which are intended to carry a number of passengers on each trip. The service responds to demands from the customer initiated through a telephone or a push-button callbox connected with a dispatching center. A computer at the center determines the route for each vehicle to take in collecting or discharging its passengers. The routes are based on the least ride time for the passengers and the most efficient operating strategy for the system operators.

The purpose of developing and demonstrating this service concept is to answer such questions as:

What will be the public acceptance and use of the service?
What kind of operating costs will be incurred?
Can the service be used for off-peak movement of goods and mail?
What will be the effects of differential pricing policies?
What collection and distribution strategies are best?
Can equipment and vehicles tailored for this service improve performance and reduce costs?
What problems will be presented by labor union and jurisdictional questions?

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Table 4.2

DIAL-A-BUS RDTE&D PROJECT PLAN (EXAMPLE)

phases	*$ millions*	*fiscal years* year 1	year 2	year 3	year 4	year 5	year 6
DIAL-A-BUS I							
1. Limousine service	.03						
(Non-Federal share)	(.01)						
Total cost	.03						
Federal share	.02						
DIAL-A-BUS II							
1. Project preparation	.03						
2. Specification and pricing	.01						
3. Equipment and system performance testing	.06						
4. Demonstration test	.54						
(Non-Federal share)	(.25)						
5. Evaluation	.04						
Total cost	.68						
Federal share	.43						
DIAL-A-BUS III							
1. Optimal routing algorithm	.40						
2. Performance characteristics	.20						
3. Equipment and installations	2.00						
(Non-Federal share)	(1.00)						
4. Pricing algorithm	.10						
5. Test demonstrations:							
a. City A—Sole transit system	.50						
(Non-Federal share)	(.25)						
b. City B—Transit feeder system	.50						
(Non-Federal share)	(.25)						
6. Evaluation	.22						
(Non-Federal share)	(.11)						
Total cost	3.92						
Federal share	2.31						
Total Federal cost per year (Dial-a-Bus I, II, and III)		.02	.35	.61	.78	.93	.07

NOTE: Line widths are roughly proportioned to expenditure rates.

phases	$ millions	fiscal years: year 1	year 2	year 3	year 4	year 5	year 6	year 7	year 8
DIAL-A-BUS IV									
1. Requirements and systems analysis	.18								
(Non-Federal share)	(.09)								
2. Component development and test:									
a. Command guidance and control	1.20								
b. Vehicle design and development	3.25								
3. Feasibility test:									
a. Experiment design	.08								
b. Equipment design and fabrication	2.10								
c. Operation and test	.82								
(Non-Federal share)	(.41)								
4. Full scale demonstration:									
a. Equipment procurement and installation	5.50								
(Non-Federal share)	(2.75)								
b. Test and evaluation	2.50								
(Non-Federal share)	(1.25)								
Total cost	15.63								
Federal share	11.13								
Total Federal cost per year (Dial-a-Bus I, II, III, and IV)		02	.64	2.24	3.68	4.43	1.63	.50	.75

NOTE: Line widths are roughly proportioned to expenditure rates.

The following RDTE&D project plan is an example of a phased program to exploit this concept. (Refer to table 4.2.)

- *Dial-a-Bus I.* An initial demonstration would test the acceptance and feasibility of this service in a low density suburban area. Initially, the system would use two airport-type limousines, standard radio and telephone communications, and manual dispatching. This test would last 6 months and cost a total of about $30,000 ($20,000 Federal).

- *Dial-a-Bus II.* A second demonstration would evaluate demand service in a low to moderate income housing area as a feeder to a rapid transit line. This system would use 24 limousines operating in an area of about 6 square miles, special telephone and communications equipment, and computerized scheduling and routing. This test would cover a period of 27 months at a total cost of approximately $680,000 ($430,000 Federal).

● *Dial-a-Bus III.* This demonstration would test and compare two hypotheses. One is concerned with the effectiveness of Dial-a-Bus service in a large low density city where there is virtually no other form of public transportation. The second test in a different city would evaluate the use of Dial-a-Bus service as a feeder to a series of rapid transit stations not presently served with a collection or distribution system. In both tests, vehicles would be leased from franchised taxi companies. The cost of computers for dispatching and communications equipment would be shared with the local companies and public agencies. These tests and the final evaluation would extend over 4½ years at a cost of about $3.92 million ($2.30 million Federal share).

● *Dial-a-Bus IV.* This longer-term demonstration affords the opportunity to achieve a full scale demonstration using vehicles designed specifically for demand service. They would be based on NAS/NAE designs, made smaller than conventional buses to avoid obtruding into residential areas, would be quiet and essentially nonpolluting. Step 2 calls for the design and development of prototype vehicles to be fabricated and given an operational test and an evaluation in step 3. Command guidance and control systems using automatic vehicle monitoring techniques would be developed or procured specifically for this service. The full scale demonstration envisions a citywide service using two control centers, 50 new vehicles, and a monitoring system that could serve the city for tracking police, ambulance, utility, and other emergency vehicles as well. Dial-a-Bus IV would require approximately 7 years to complete at a total cost of $15.6 million ($11.1 million Federal).

Dial-a-Bus IV would provide a definitive demonstration of this type of demand service. Data obtained from these four phases would provide local government agencies, public and private transit operators, and industry with sufficient information on which to base decisions to invest in and implement Dial-a-Bus service.

appendix b

SUMMARY OF NEW SYSTEMS STUDY CONTRACTS

Opportunities for research and development within future time frames can be identified in terms of utilizing present technology, making evolutionary improvements in existing technologies, and objectively assessing distant needs to provide incentives for the development of futuristic technological solutions. Nine contractors studied these opportunities.

1. The engineering firm of Day and Zimmermann looked at ways to obtain improved results from existing transportation technologies within a timeframe of 6 months to 3 years.
2. The WABCO Mass Transit Center and Melpar, Inc., in collaboration with Wilbur Smith and Associates, and the Institute of Public Administration, undertook an evolutionary study of improvements that could be made in 3 to 8 years.
3. Stanford Research Institute conducted a futuristic study of solutions which might be developed within a period of 5 to 15 years.
4. General Research Corp., with experience in defense and space research, performed a comprehensive systems analysis, using computers, of urban transportation problems and their solutions.
5. The Battelle Memorial Institute did an early screening of the work of the major contractors and prepared evaluation monographs on a wide range of possible urban transportation research projects.
6. Because many potential benefits may be derived from a bimodal small vehicle transportation system that can travel both on ordinary streets and high-speed automated guideways, Cornell Aeronautical Laboratory was retained to analyze such a system. This concept was evaluated by applying it to a test city, Buffalo, N.Y.

7. The North American Rockwell Corp. identified advanced technologies from defense and aerospace fields which would be transferable to 1973–80 urban transportation needs. This study delineated requirements for implementing these technologies.
8. Preliminary investigations indicate that one of the critical elements of making major improvements in urban transportation is the development of electronic command and control systems. The General Electric Co. was retained to study this area.
9. The General Motors Corp. applied some of the experience and talent of the automobile and railway equipment industries to the study of a series of concepts, including low-speed air cushion vehicles for downtown areas, a "Metromode" exclusive right-of-way vehicle, automatic highways, and some radically new bus concepts. The primary purpose of this study was to evaluate the factors affecting the overall practicability and social impact of implementing these various innovative modes.

Eight additional studies provided in greater depth the background of knowledge of demand patterns and the interrelationships of transportation with urban land use and the shape of urban life that are of such special concern to HUD.

10. Peat, Marwick, Livingston & Co. of New York, developed projections of urban personal travel demand for each standard metropolitan statistical area. This provides the broad statistical background to enable future research to be planned according to need.
11. Consad Research Corp., of Pittsburgh, studied another and most important facet of urban travel demand: The sensitivity of demand to such matters as relative investments in different types of transportation systems, technological breakthroughs and improvements, changes in income, and variations in population density. Lack of knowledge in this area has in the past left planners unprepared for the impact that shifts in other aspects of urban life have on transportation.
12. Transportation Research Institute of Carnegie-Mellon University investigated the so-called "latent demand" for urban transportation to satisfy urban and social needs unmet by existing systems. The frequent failure of present transportation to get people in the ghetto to new jobs on the fringe of cities is an instance of latent demand. So are the suburban elderly who cannot visit with friends, shop or get to recreation.
13. Battelle Memorial Institute examined the neglected area of demand for urban goods movement, with an eye to developing systems that can distribute goods from grocery bags to heavy manufactured products without the costly delays, snarls of double-parked delivery trucks, and noise of today.

14. Abt Associates at Cambridge, Mass., looked at the qualitative aspects of urban travel demand—at the effect of such things as seating comfort, temperature control, safety, and security, and at how these factors can be improved.
15. Barton-Aschman Associates of Chicago investigated the land use requirements of various urban transportation systems and their impact upon the neighborhoods and areas they cross. Barton-Aschman looked at the past experience in various cities and outlined ways to avoid conflict between transportation systems and the people and communities they are supposed to serve.
16. The Regional Economic Development Institute of Pittsburgh studied transportation in new towns, which are likely to be increasingly an answer for metropolitan development over the next 40 years. This study focused on how transportation and urban land use can be coordinated in a completely new setting.
17. The last of the eight contracts, awarded to Midwest Research Institute of Kansas City, looked at the special transportation requirements of small cities and towns. At present these communities, unable in many cases to support even the rudiments of a traditional mass transportation system, have no answer to their problems of congestion, disorderly development, and service to those who are without access to automobiles.

appendix c

BIBLIOGRAPHY OF NEW SYSTEMS STUDY PROJECT REPORTS

ABT ASSOCIATES

FINAL REPORT

Qualitative Aspects of Urban Personal Travel Demand, May 1968

BARTON-ASCHMAN ASSOCIATES

FINAL REPORT

Guidelines for New Systems of Urban Transportation, May 1968

Volume I—Urban Needs and Potentials
Volume II—A Collection of Papers
Volume III—Annotated Bibliography

BATTELLE MEMORIAL INSTITUTE

MONOGRAPHS

No. 1 "Design of Urban Transportation for the User," October 1967

No. 2 "Comprehensive Special Service Transportation Systems," October 1967

No. 3 "The Development of a Course of Instruction in Urban Transportation Management," October 1967

No. 4 "Application of Improved Management Methods to the Urban Transportation Industry," October 1967

No. 5 "Land Use Involving Transportation Rights-of-Way," October 1967

No. 6 "Operations Analysis of Augmented Guideway Systems," October 1967

No. 7 "Urban Streets and Their Environments," October 1967

No. 8 "Grouped Road Vehicles," October 1967

No. 9 "Models of Urban Transportation," October 1967

No. 10 "A Program to Evaluate Advanced Technology for Buses," October 1967

No. 11 "A Program to Establish an Urban Transportation and Analysis Center," October 1967

No. 12 "Flywheel Energy-Storage Systems for Transit Buses," October 1967

No. 13 "The Development and Demonstration of a Family of Practical Moving-Way Transportation Systems for Pedestrians," October 1967

No. 15 "An Investigation of Steel Wheel-Rail Noise and Techniques for Its Suppression," October 1967

No. 16 "Unconventional Heat Engines for Urban Vehicles," October 1967

No. 17 "A Study of the Applicability of the Linear Electric Motors to Urban Transportation," October 1967

No. 18 "Potential Application of the Helicopter in Urban Mass Transportation," October 1967

No. 19 "A Study of the Applicability of Air-Pad Support for Urban Transportation Vehicles," October 1967

FINAL REPORTS

Monographs on Potential RD&D Projects, January 1968
Urban Goods-Movement Demand, March 1968

CONSAD RESEARCH CORP.

FINAL REPORT

Transit Usage Forecasting Techniques: A Review and New Directions (1 volume), April 1968

CORNELL AERONAUTICAL LABORATORIES

FINAL REPORT

Bi-Modal Urban Transportation System Study
Volume I Final Report, March 1968
Volume II Technical Appendices, March 1968

GENERAL ELECTRIC CO.

TASK REPORTS

Survey of Electronic Command and Control Systems, August 1967

Analysis and Requirements of Electronic Command and Control Systems, November 1967

FINAL REPORT

A Study of Command and Control Systems for Urban Trans-

portation (1 volume, 3 parts), February 1968

Part 1—Introduction

Part 2—Candidate Command and Control Systems for Research, Development and Demonstration

Part 3—A Framework for Evaluation of Transportation Systems

GENERAL MOTORS CORP.

FINAL REPORT

New Systems Implementation Study, February 1968

Volume I—Summary and Conclusions
Volume II—Planning and Evaluation Methods
Volume III—Case Studies

GENERAL RESEARCH CORP.

FINAL REPORT

Systems Analysis of Urban Transportation, January 1968
Volume I—Summary
Volume II—Cases for Study
Volume III—Network Flow Analyses
Volume IV—Supporting Analyses

MIDWEST RESEARCH INSTITUTE

FINAL REPORT

Special Transportation Requirements in Small Cities and Towns, May 1968

NORTH AMERICAN ROCKWELL CORP.

FINAL REPORT

Frontiers of Technology Study, January 1968
Volume I—Summary
Volume II—Survey
Volume III—Implementation

PEAT, MARWICK, LIVINGSTON & CO.

FINAL REPORT

Projection of Urban Personal Transportation Demand, March 1968

REGIONAL ECONOMIC DEVELOPMENT INSTITUTE

FINAL REPORT

Transportation Requirements and Effects of New Communities, May 1968

STANFORD RESEARCH INSTITUTE

MEMORANDUM REPORTS

No. 1—*Future Urban Transportation Systems: Desired Characteristics,* May 1967

No. 2—*Future Urban Transportation Systems: Technological Assessment*, May 1967

FINAL REPORTS

Future Urban Transportation Systems: Descriptions, Evaluations, and Programs, March 1968

Future Urban Transportation Systems: Impacts on Urban Life and Form, March 1968

TRANSPORTATION RESEARCH INSTITUTE

FINAL REPORT

Latent Demand for Urban Transportation to Satisfy Urban and Social Needs Unmet by Existing Systems, May 1968

WESTINGHOUSE AIR BRAKE CO.

FINAL REPORT

Study of Evolutionary Urban Transportation, February 1968
Volume I—Evolutionary Improvements in Urban Transportation
Volume II—Appendices 1, 2, and 3
Volume III—Appendix 4

DAY & ZIMMERMANN INC.

FINAL REPORT

Potential Near Term Improvements in Urban Transportation, March 1968

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described. Beyond such immediate payoffs, this report projects, in summary, a systematic research and development effort designed to close the gap between innovation and application, and to accelerate the development of new urban transportation in a deliberate and careful way. The longer view must include not only the future of urban transportation but the future of urban America.

THE URBAN FRAMEWORK

Much urban transportation today is geared to the city of 50 years ago, and that city is itself largely obsolete today. The physical layout of most cities—the platting, the street design, and basic service systems—was created a century or more ago.

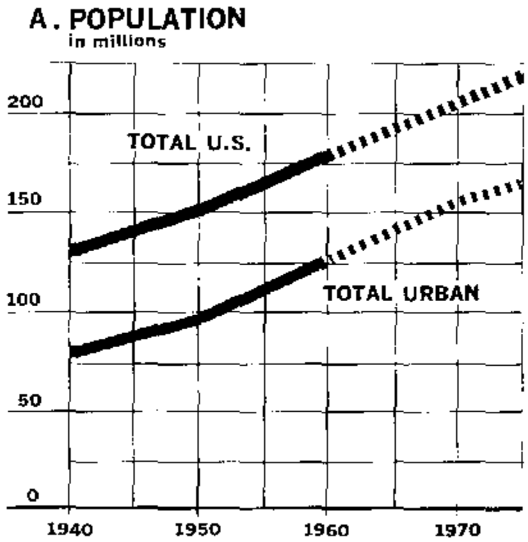
Urban areas have changed radically since their basic transportation systems were established. They have grown in population, experienced significant shifts in the location of people, industry and land uses, and have expanded substantially in area.

Between 1940 and 1960, for example, the population in urban areas grew from 78 million to 125 million, as shown in figure 1.1. Table 1.1 indicates the increase in number of major urbanized areas in the United States since 1940. In many of these, the growth took place entirely on the fringe of the urbanized area, with the central city and high density suburbs declining. For example, in Boston the city core population declined by 6 percent, the close-in, high density suburbs increased by 2 percent, while the lower density suburbs grew by 95 percent. In St. Louis, the data for the comparable areas were minus 9 percent, plus 14 percent, and plus 335 percent.

Some metropolitan areas had growing cores, as well as growing fringes. For example, in Los Angeles the urbanized area core expanded and increased its population by 60 percent between 1940 and 1960 but even in this instance, the urbanized area fringe (within and outside the city) grew by 386 percent in population. An example of the expansion in population of the urban fringe is illustrated by figure 1.2, which shows the population in the fringe of the Cleveland Standard Metropolitan Statistical Area (SMSA) increasing from 0.55 million persons in 1950 in an area of 613 square miles to an estimated 1.19 million persons in an area of 1,438 square miles in 1965.

Behind these aggregate figures lies a complex shifting of populations which has helped to intensify commutation problems. In the large, older urban areas, and in some of the newer ones as well, a significant portion of the middle class, white-collar population has moved to the suburbs. At the same time, large numbers of predominantly unskilled, rural, nonwhite migrants moved into the older central cities, as indicated in figure 1.2. The nonwhite population of central cities has almost doubled from 1950 to 1966, while the white population decreased. Finally, white collar and administrative jobs have increased in central city areas; but many industrial and unskilled job opportunities have moved from the cities to the suburbs.

Figure 1.1
Trends in urban population.



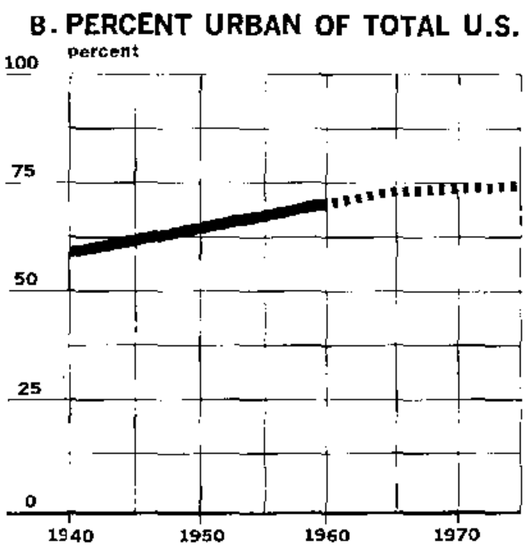
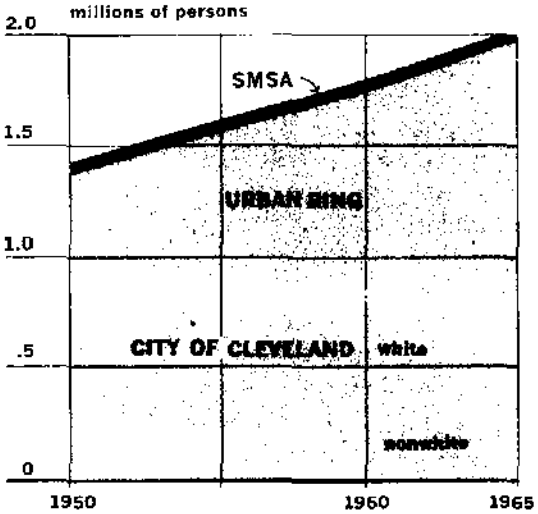
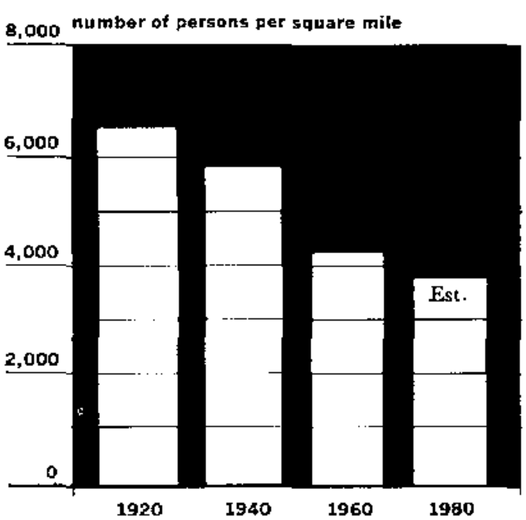


Figure 1.2
Population trend of the Cleveland SMSA



SOURCE: U.S. Bureau of the Census; 1950, 1960, and Special Census for 1965.

Figure 1.3
Decline in average population densities of U.S. urbanized areas



SOURCE: J. P. Pickard, *Dimensions of Metropolitanism*, (op. cit.) pp. 48–53.

Table 1.1

Number of Major Urbanized Areas in United States by Size Group, 1940-2000

year	total	over 1 million	500-999	250-499 (thousands)	100-249
1940	97	10	9	20	58
1960	159	16	21	30	92
1980	192	28	27	46	91
2000	221	42	29	46	104

SOURCE: J. P. Pickard, *Dimensions of Metropolitanism*, (Research Monograph 14, Urban Land Institute, 1967) table II 2, p. 19.

NOTE: Major areas are considered those with a population of at least 100,000. Areas in Hawaii and Alaska are not included.

Social Security data on employment in each county in the United States indicates that, for the SMSA's with more than one county, total employment increased 13 percent from 1959 to 1965 in the central or main county, but it increased 22 percent in the suburban counties. From 1960 to 1965, about half of the value of new construction in SMSA's for business purposes occurred outside the central cities. Percentages outside the central cities for major business categories were: Industrial, 62 percent; commercial stores, 52 percent; and office buildings, 27 percent.

The growing, shifting population of cities has also spread and thinned out. With more area occupied, the average population density of an entire metropolitan area is reduced. Suburban development is generally low density, contrasted to the high or medium density central city pattern, and thus requiries more land per person. As shown in figure 1.3, between 1940 and 1960, the average density of urban areas decreased by 1,640 persons per square mile—from 5,870 to 4,230 persons per square mile—and trends indicate a further decrease in density. Average trip length in urban areas also appears to be increasing over time, as data gathered in Boston and Houston indicate.

These figures add up to one irrefutable fact: The task of urban transportation systems in metropolitan areas in the future must be to transport more people over greater distances between where they are and where they want to go.

PUBLIC TRANSPORTATION TODAY

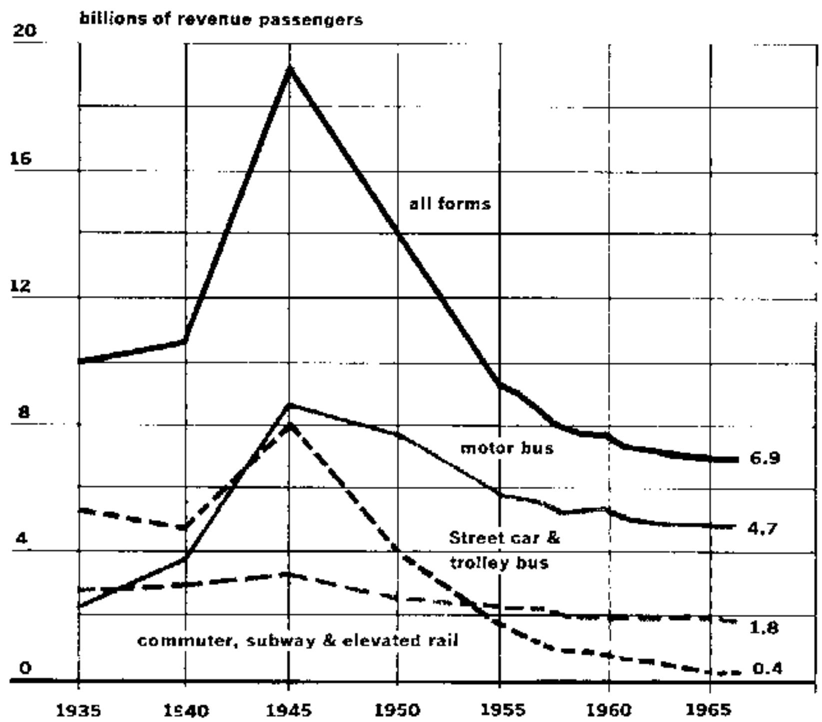
Urban mass transit systems have not developed adequately in response to changing conditions. Routes have tended to remain constant despite large population shifts and important changes in land use. Central city mass transit service often stops for no valid reason other than central city political boundaries. When transit lines were first established, few people lived outside the city. Transit charters and legal restraints further limited expansion that could have responded to suburban growth.

America's public transportation systems have been on a treadmill since the end of World War II, and they have had intensive financial difficulties during these years. Whether public or privately owned, few systems have been able to maintain service or equipment. Systems have dwindled, become overcrowded and less popular. In 1945 four cities, New York, Chicago, Philadelphia, and Boston, had rail rapid transit (subway or elevated) lines with trackage that totaled 1,222 miles. Today, even with the addition of a new line in Cleveland, the total national trackage is only 1,255 miles.

In an era of great technological advance there have been few dramatic improvements in rail rapid transit. Average speeds are about what they were years ago. So are stations and fare-collecting systems. According to American Transit Association figures, 2,891 of the 9,273 subway and elevated cars in operation in 1966 were cars that also were in operation in 1940—and as many rapid transit passengers can testify, the other newer 6,382 cars are, at most, only slightly less bumpy, better lit, or more comfortable.

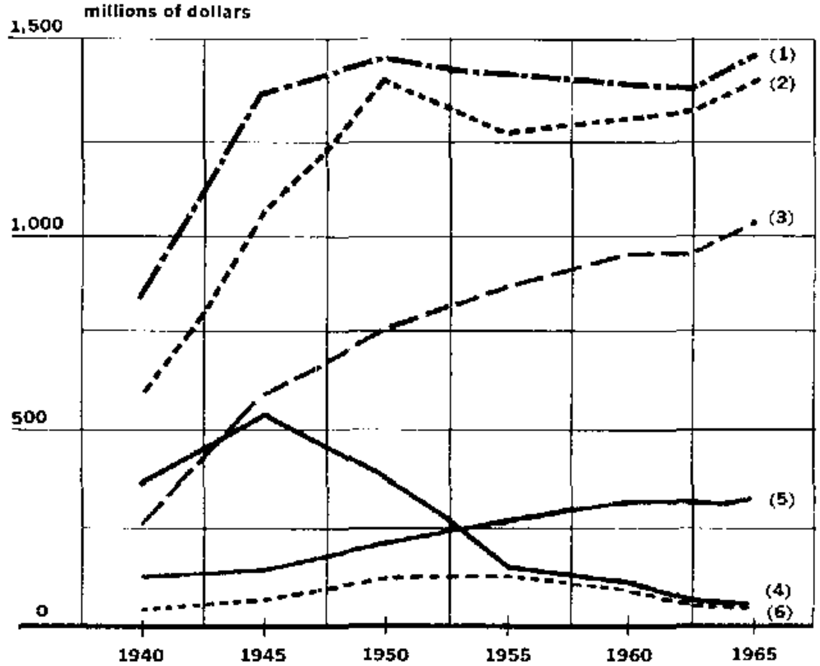
Almost 700 million fewer revenue passengers rode rail rapid transit lines in 1966 than in 1940, a 30 percent decline from 2.3 billion to 1.6 billion passengers. Partly because of increased fares, passenger revenues nearly doubled during that period, but net revenues declined by over 50 percent. (Refer to fig. 1.4 and 1.5.)

Figure 1.4. Trends in revenue passengers of urban public transportation



SOURCE: *Transit Fact Book*, 1967, American Transit Association; *Statistics of Railroads of Class I in the United States*, August 1967, Association of American Railroads.

Figure 1.5. Summary of transit operating revenues and expenses 1940–65



SOURCE: *Statistical Abstract of the United States,* 1967, Table No. 827.

NOTES:

(1) Total operating revenues.
(2) Total operating expenses.
(1)–(2) Net revenue.
(3) Operating revenues—Motorbus.
(4) Operating revenues—Surface rail.
(5) Operating revenues—Subway and elevated
(6) Operating revenues—Trolley coach.

Similarly, the long-term decline of commuter railroads is well known. In 1935, 41 of the metropolitan areas with 1960 populations of more than half a million had commuter rail service over 240 separate routes. In 1961, only 20 of those areas had any service at all, and they had only 83 routes in operation. With few exceptions, service over the remaining routes was less frequent, less reliable, and less attractive than it ever had been.

There were over 50,000 buses in local transit operation in 1966 compared with 35,000 in 1940. Route mileage of bus operations increased from 78,000 to 122,100. However, bus vehicle-miles declined from 1.7 billion in 1940 to 1.5 billion miles in 1966. Even with more buses and increased route mileage, poorer bus service has resulted in many cases, particularly during off-peak hours and on weekends, because the buses are operating over longer routes for shorter periods of the day. Motorbus revenue passenger increases of over 1 billion have been more than offset by losses in other public transit: Nearly 700 million by subway and elevated rail transit and a loss of over 4 billion by streetcars and trolley buses. During the 1940–66 period, rapid rail, streetcar, and trolley-bus transit had significant decreases in number of vehicles in operation, route mileage, and vehicle-miles. These transit trends are shown in table 1.2.

Table 1.2

Trends in Urban Public Transit Characteristics

Public Transit Characteristics (*excluding commuter rail*)	Subway & Elevated Rail	Street Car	Trolley Bus	Motor Bus	Total
Revenue Passengers (*in millions*):					
1940	2, 281.9	4, 182.5	419.2	3, 620.1	10, 503.7
1966	1, 584.0	211.0	174.0	4, 702.0	6, 671.0
Change	−697.9	−3, 971.5	−245.2	1, 081.9	−3, 832.7
Percent change	−30.5	−95.0	−58.5	29.9	−36.5
Operating Revenue (*in millions of dollars*):					
1940	128.3	327.8	25.0	255.9	737.0
1966	306.5	58.7	39.2	1, 074.1	1, 478.5
Change	178.2	−269.1	14.2	818.2	741.5
Percent change	138.9	−82.1	56.8	319.7	100.6
Vehicle-Miles Operated (*in millions*):					
1940	470.8	844.7	86.0	1, 194.5	2, 596.0
1966	378.9	42.9	40.1	1, 521.7	1, 983.6
Change	−91.9	−801.8	−45.9	327.2	−612.4
Percent change	−19.5	−94.9	−53.4	27.4	−23.6
Number of Employees:					
1940	*	*	*	*	203, 000.0
1966	*	*	*	*	144, 300.0
Change	*	*	*	*	−58, 700.0
Percent change	*	*	*	*	−28.9
Payroll (*in millions of dollars*):					
1940	*	*	*	*	360.0
1966	*	*	*	*	994.9
Change	*	*	*	*	634.9
Percent change	*	*	*	*	176.4
Vehicles Owned:					
1940	11, 032.0	26, 630.0	2, 802.0	35, 000.0	75, 464.0
1966	9, 273.0	1, 407.0	1, 326.0	50, 130.0	62, 136.0
Change	−1, 759.0	−25, 223.0	−1, 476.0	15, 130.0	−13, 328.0
Percent change	−15.9	−94.8	−52.7	43.2	−17.7
Track or Route Mileage (*miles of single track except for motor bus which is route round trip*):					
1940	1, 242.0	18, 360.0	1, 925.0	78, 000.0	*
1966	1, 255.0	898.0	676.0	122, 100.0	*
Change	13.0	−17, 462.0	−1, 249.0	44, 100.0	*
Percent change	1.0	−95.1	−64.9	56.5	*

SOURCE: *Transit Fact Book*, 1967, American Transit Association, Tables 6, 9, 11, 13, 17 and 19.

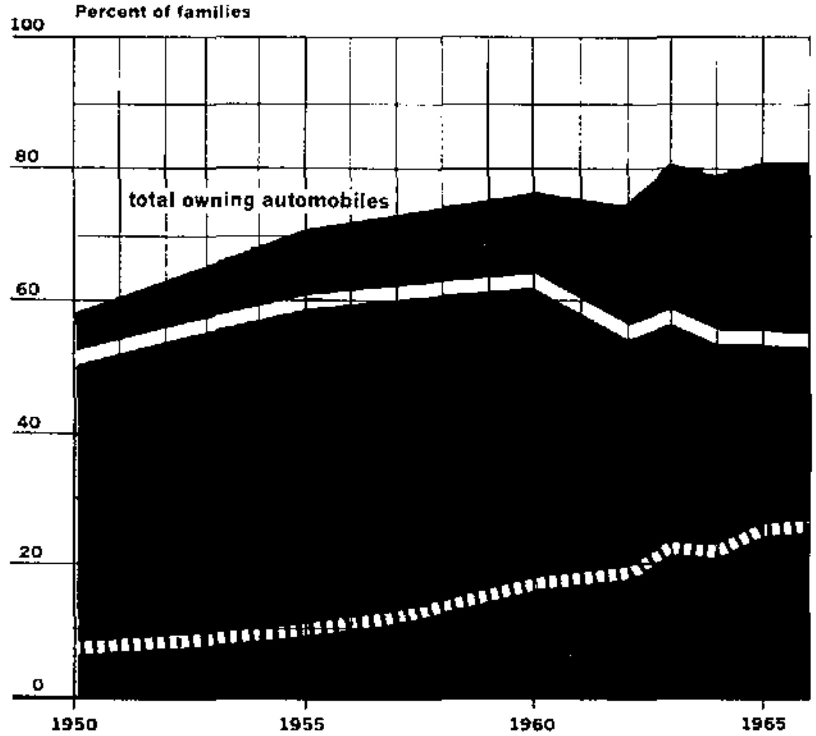
*Not available.

In sum, during the last 25 years of unprecedented urban population growth and areal increase, public transportation, excluding commuter railroads, has lost almost 4 billion revenue passengers. Because of the failure of public transportation to respond either to an increased demand or to new types of transit requirements, and because the automobile has distinct advantages over mass transportation as it is now known, for most adults the private automobile has become the primary mode of travel within urban areas.

TRENDS IN AUTOMOBILE USE

Almost 80 percent of all American families owned automobiles in 1966 as compared with 59 percent in 1950; 25 percent of all families owned two or more automobiles in 1966 as compared with 7 percent in 1950. (Refer to fig. 1.6.) The total number of registered motor vehicles rose during those 16 years from 49.3 million to 94.2 million. In 1967, this number increased to 98 million.

Figure 1.6. Automobile ownership, 1950–66.



SOURCE: *Statistical Abstract of the United States*, 1967, Table No. 820.

Under the interstate highway program alone, some 14 percent of the highway mileage constructed and 45 percent of the money spent has been or will be spent in urban areas which occupy only about 2 percent of the Nation's land area.

Figures on trips by types of vehicle dramatically illustrate the heavy dependency on the automobile. According to the 1960 census, 67 percent of all employed persons living in the Nation's metropolitan areas traveled to work in automobiles. It is estimated that in every metropolitan area, more than 75 percent of all trips are made by car. In some, the figure is 90 percent or higher.

The causes of the present heavy reliance on the automobile are complex, but this development is impossible to separate from scattered low density suburban development. The automobile made possible widespread and rapid suburban growth; in turn, low density communities away from central cities fostered increasing dependence on the automobile.

Automotive vehicles are the source of most of the air pollution in American cities.

The automobile has a flexibility that urban mass transportation *as it now functions* lacks: The automobile permits one to travel directly wherever and whenever he chooses, and serves as well for shopping as for business trips.

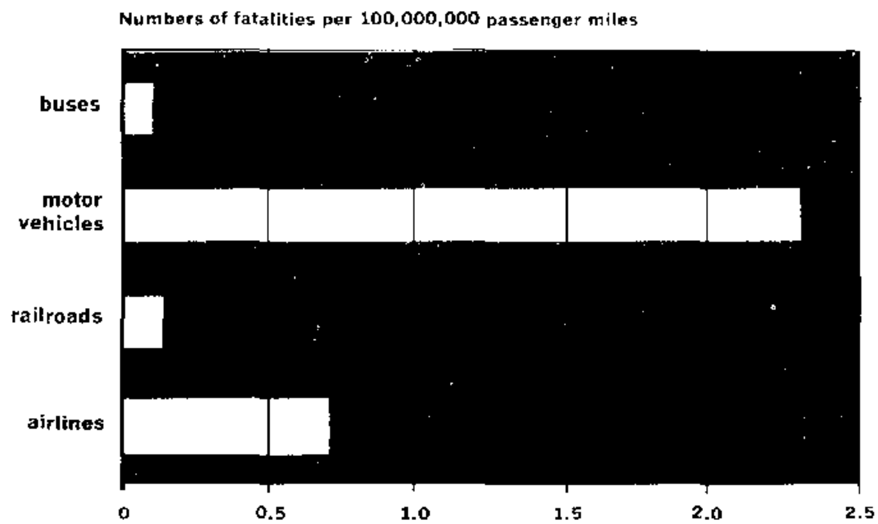
In many ways, the private automobile has served the urban area well. It will continue to have a crucial place in the total urban transportation system. For long-range intercity trips it doubtless will remain paramount, as it will for most trips in low-density urban areas. Indeed, the automobile has been on the whole such a remarkably useful technological and economical device for a wide variety of travel requirements that significant costs accruing from an unbalanced reliance upon this one mode of travel have too often been hidden. Two such major costs are:

- The automobile now produces more air pollution than all other sources combined;
- Automobile accidents now result in more than 4 million injuries annually (including 52,000 fatalities), and this number has increased at a rate of more than 5 percent a year. (See also fig. 1.7.)

Among many other "hidden" costs are the esthetic and economic costs of extensive vehicle parking requirements, automobile-oriented crime control, and further degradation of pedestrian travel.

The total cost to society of continuing to rely almost wholly on the automobile as its major source of urban transportation for the entire range of types of travel demand is already high. It will almost certainly continue to grow at an increasing rate. Only recently has the urban public become aware of the underlying economic and social costs of too heavy a reliance upon a restricted range of transportation service. Most present sys-

Figure 1.7. Average passenger accident fatality rates, 1960–65.



SOURCE: *Accident Facts*, National Safety Council, Chicago, Ill.; *Statistical Abstract of the United States*, 1967, Tables No. 834, 853, 855.

tems of urban transportation cost too much and often do not work or do not work well. Present patterns and modes of urban transportation service too often are accepted complacently as the only ones possible, and the present proportions and types of transportation service and modes are too readily accepted as inevitable for the future.

THE URBAN TRAVELER

Costs such as those described above harm urban society as a whole and neglect very real needs of the individual, the urban traveler and citizen.

The Unserved: Ironically, metropolitan transportation systems too often leave unserved those who most need service: The poor, the handicapped, the secondary worker, the elderly, and the young.

Typically, the poorer people are, the more dependent they are on public transportation. Car ownership statistics document this strikingly. According to a recent survey, 76 percent of households with annual incomes of less than $1,000 owned no car; in the $1,000 to $1,999 class, the percentage was 69; it was 24 percent in the $4,000 to $4,999 class, 11 percent in the $6,000 to $7,499 class; and 4 percent in the over $10,000 class. (Refer to table 1.3.) Less than half of all families with incomes under $4,000, half of all Negro households, and half of all households with heads over 65 years old own no automobiles.

Table 1.3

Automobile Ownership Within Income Groups, 1966

	*percentage distribution of spending units**		
	owns 1 automobile	*owns 2 or more*	*owns no automobile*
all spending units	54%	25%	21%
money income before taxes †			
under $1,000	21	3	76
$1,000–$1,999	28	3	69
$2,000–$2,999	51	3	46
$3,000–$3,999	61	6	33
$4,000–$4,999	65	11	24
$5,000–$5,999	68	16	16
$6,000–$7,499	68	21	11
$7,500–$9,999	63	30	7
$10,000–$14,999	50	46	4
$15,000 and over	35	60	5

*A spending unit consists of all persons living in the same dwelling and related by blood, marriage, or adoption, who pool their income for major items of expenses. Some families contain two or more spending units.

†Money income for previous year.

SOURCE: *Survey of Consumer Finances*, conducted by the Survey Research Center of the University of Michigan.

If a man cannot afford a car, and public transit is both inadequate and too expensive, and his job has shifted to a suburb, while racial and economic segregation prevent him from following the job—that man is effectively isolated from earning a living. Further, the 40 percent in the under $4,000 income group who do own a car must bear the heavy financial burden of operating and insurance cost automobile ownership today entails.

Even within families owning a car, wives, children, and youths are often immobilized because the family's sole vehicle is committed to a home-work trip. Forty-nine percent of white families have two or more wage earners, but only 28 percent have two cars; 55 percent of all Negro families have two or more wage earners, but only 10 percent have two cars. While substantial numbers of the disadvantaged ride as passengers in automobiles, their freedom to change jobs (which increasingly are located in the urban fringe), or to take advantage of even the basic social amenities of metropolitan living, is seriously hampered, almost as much for those with no access to automobiles at all.

The beeline distance between South Central Los Angeles and Santa Monica, a center of employment, is 16 miles; to make the trip by public transportation takes an hour and 50 minutes, requires three transfers and costs 83 cents one way. The Department of Housing and Urban Development (HUD) demonstration project in Watts has shown that when direct transportation service was provided for residents of that district to jobs and other opportunities in other parts of the city, ridership increased from 800 to 2,800 daily in 3 months. Many of the new riders were bound for work.

From central Brooklyn, it is easier and faster to reach certain areas of the Bronx some 15 miles away than nearby industrial districts only 4 miles away, if the traveler must use public transportation. Also, certain poverty areas, while theoretically in the "one-fare" zone, require a double transit fare to reduce walking and travel time to a reasonable level. And this is in a city with the best public transit system in the United States.

As more central business district jobs become white-collar, and an ever larger proportion of unskilled and semiskilled jobs move to outlying sections, poor people are more disadvantaged than ever by public transportation systems which focus on central business districts and also stop at city limits. A New York study reports, "The employment in suburban areas of both poverty and nonpoverty workers residing in the areas studied in New York City (poverty areas) appears to be almost insignificant." One reason is an often cited figure: It would cost a resident of central Harlem in New York some $40 a month to commute by public transportation to an aircraft factory in Farmingdale, Long Island.

The poor are not only isolated from jobs, but also from social and health services, recreation areas, and social contacts outside the immediate neighborhood. A HUD demonstration project in Nashville, Tenn., has provided bus service for out-

patients and employees linking nine major medical centers with downtown Nashville and a hospital connecting service. In the first 2 months of actual operation, the medical center express service line showed a 61-percent increase in passengers, while the hospital connecting service line showed a 73-percent increase in ridership.

In poverty areas, children typically have never traveled more than a few blocks from their homes. This confinement not only penalizes the poor, but it perpetuates and assures their isolation.

The poor are not the only nondrivers. The handicapped, the elderly, and the young also suffer from a transportation system that makes the individually owned automobile almost a necessity unless they are able to pay for someone to drive them. Today, 19 million Americans are over age 65; of these, over 6 million live in poverty. As shown in table 1.4, by 1980, over 100 million persons will be under 18 or over 65 years old.

The problem of the unserved is not limited to central cities. In suburban areas there is frequently no public transit. For all but two- and three-car families, intrasuburban transportation to shopping and to recreation is almost impossible. Even where there are two cars, someone must always assume the burden of driving for the rest of the family.

Table 1.4

Total Population, Population Under 18, and Over 65 Years of Age, 1940–80.

(thousands)

	total	*under 18*	*over 65*
1940	132, 165	40, 359	9, 036
1960	180, 684	64, 561	16, 659
1966	196, 842	70, 675	18, 457
1980	235, 212	79, 241	23, 063
Increase, 1966–80	38, 370	8, 566	4, 606

SOURCE: U.S. Bureau of the Census, Population Projection Series C., *Statistical Abstract of the U.S.*, 1967.

Nearly one-third of the urban population suffer serious disadvantages from being served inadequately or not at all by the vast auto-based systems on which the Nation has come to depend. These are the "captives" left to use the transit systems, or do without. If transit service continues to be reduced, many of these nondrivers will be destined to be isolated more and more in their narrow neighborhood worlds while all around them the advantages of automobile mobility benefit the relatively affluent majority more each year.

To serve the nondriver, it is not enough to provide more of the existing transportation facilities. Although new bus routes and more buses in poverty areas significantly increase the mobility of the residents, most trips are still unnecessarily long, tiresome, and expensive. Buses limited to fixed routes, and stalled by traffic congestion, and rapid transit systems crowded

and noisy, will not meet the minimal transportation needs of urban areas.

The Poorly Served: A second irony of the auto-based transportation system is that, despite the vast amount of public and private money spent on cars and roads, a large number of auto users are poorly served.

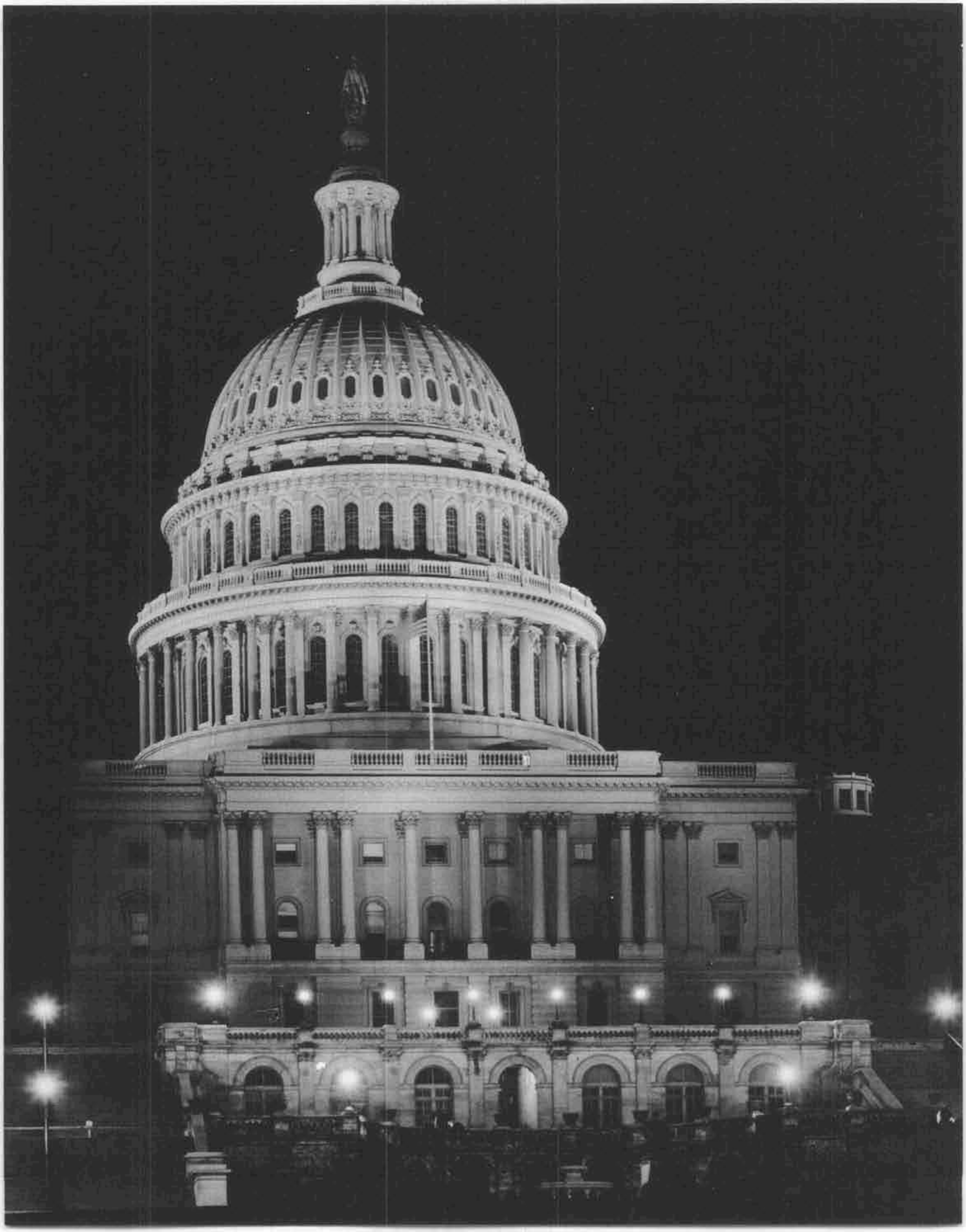
Most large urban areas experience massive congestion during peak hours. Yet the number of automobile registrations continues to expand rapidly: By 1975, the United States will have well over 120 million vehicles for a population of 220 million. Is the only answer to traffic congestion more and wider roads? Clearly in many localities, it is not. The dislocation of people and businesses, the distortion of land use, the erosion of the real property tax base, and the dollars and cents cost, make this an increasingly unacceptable solution. If carried to its illogical conclusion, an ever-increasing population, building more and bigger highways, might produce a city of freeways with hardly any room for people or buildings.

A TIME FOR ACTION

This new systems study has provided two valuable insights affecting possible approaches to solving urban transportation problems.

First, action is possible. Although the urban mass transportation industry has had difficulty in supporting extensive research and development, technology in related fields is available for direct transfer and application to the needs of urban transit. Other new technological advances have been devised in laboratories around the country. American industry and business are ready to respond to the great domestic challenge of the cities. The scientific and technical community, both as individuals and as companies, has expressed a readiness to attack the challenge of metropolitan transportation—given leadership, direction, and adequate funding.

Second, action at this time is likely to be fruitful. After decades of trying to solve their transport problems by building only highways, cities across the Nation are beginning to realize that public transportation is an absolutely essential balancing component of sensible urban planning. The Model Cities program, the production of 6 million units of low and moderate cost housing called for in the President's state of the union message, the building of new communities and an adequate infrastructure for rebuilding the second America and preserving the quality of urban life—all depend on adequate urban transportation systems. The cities, in short, now want to act.



II the federal role and responsibility

THE EXTENSIVE FEDERAL INTEREST AND RESPONSIBILITY in assisting American cities—as evidenced by programs of urban renewal, construction and modernization of hospitals, public housing, model cities, water and sewer facilities and waste treatment works, and urban planning assistance, among others—depend heavily for maximum social benefits upon sound investments in urban transportation systems. While the Federal Government has a long history of involvement with transportation—from the railroads of the 19th century to the airports and interstate highways of today—this piecemeal involvement has been predominantly concerned with intercity travel. Until recently, the Federal Government has not assumed a substantial role in encouraging the innovative development of intraurban transportation technology.

Recognition that urban mass transportation involves unique problems requiring special treatment became explicit with the Housing Act of 1961 and with expansion of that program in the Urban Mass Transportation Act of 1964, under President Johnson's urging that "the proper mixture of good highways and mass transit facilities should be developed to permit safe, efficient movement of people and goods in our metropolitan centers." It has been the Department's experience in administering urban transportation programs under the above acts, that, while application of some present technology could help with the present needs of urban areas, more intensive, longer range efforts are required in order to have available technology capable of meeting the future demands for urban transportation.

There are several reasons why the Federal Government can and must now establish an expanded, comprehensive research and development program in the field of urban transportation. Not least is the inability of a fragmented industry facing declining revenues to undertake such extensive, long-term investment. But there are other salient reasons:

- Over the next decade, nearly $50 billion will be invested in urban freeways and mass transit systems. It is simply not prudent to make such heavy investments without a thorough examination of potential technologies and a rapid development of those alternatives which appear most promising.
- Even the largest and strongest municipal governments, public authorities or private operators, cannot "take chances" on novel, unproven "new systems" of urban transportation. Their commitment of funds is too great, and for too long a period of amortization, to entertain the risks involved. Yet more than just marginal improvement to existing systems is needed if substantial benefits are to be received. The breakthroughs needed for "quantum jump" advances involve a degree of risk that the Federal Government can underwrite.
- Even if there were no risk, the cost of developing and demonstrating the operation of a new system will be large and will benefit many urban areas. Only the Federal Government can both organize and help finance a research development program which would give all cities and metropolitan areas real alternatives in new urban transportation investment decisions.
- Competition by large numbers of cities for scarce resources, such as research and management skills, private capital, and public funds, could tend to bid up prices. The Federal Government, by acting on behalf of many or all cities, will help maximize the use of these valuable resources, and thus save on total national program costs.

It should be clear, however, that an appropriate, constructive role will not intrude upon the prerogatives of municipal or State governments, regional authorities, or private industry. The utilization and implementation of the new transportation technology remain in their hands.

It should not be the Federal Government's business, for example, to specify, design, build, or operate the transit systems in Chicago or Cheyenne. It *is* the Federal Government's responsibility to see that resources of this country are devoted to providing alternative tools which those cities can use if they wish. The role of the Federal Government in urban transportation should be to:

- stimulate the technological community to respond to the special needs of urban areas in order that technology will be consonant with the social goals of urban areas, such as wider access to service by all persons;
- help communities work together across jurisdictional boundaries in planning transportation systems which truly and efficiently serve entire regions, as part of the sound development of those regions;

- help build new institutional contexts in which public transit systems can be economically viable;

- foster development of skills essential to improving urban transportation by attracting more scholars, scientists and urbanologists to the study of transportation problems, especially as they pertain to urban problems, and by training the cadres of people needed to foster further improvements; and to

- inform the public of the full range of possible transportation options and their probable social consequences in order that choices can be made with knowledge of the full social and economic costs.

Broader examination of the direct and indirect costs and benefits—social and economic, environmental and technological—will provide a better perspective from which to consider the whole role of the Federal Government in improving urban transportation, and what the appropriate contributions of industry, the scholarly and research communities, and other levels of government should be.

Few local public bodies concerned with the problems of social welfare raised by urban transportation—equal access to service, reduction of urban land consumed, elimination of noise and air pollution, and improved urban design—have the capability to sponsor and supervise research and development of new transit systems. On the other hand, these problems cannot be left solely to private enterprise unaided, for it is unlikely to have the incentives or experience necessary to take these social needs and costs into account, together with the needs of the transportation user. Moreover, large-scale private investment in transit research and development is not likely to occur unless future market opportunities are clearly identifiable, and until uncertainties surrounding future government investment decisions in this area are lessened.

As President Johnson has said,

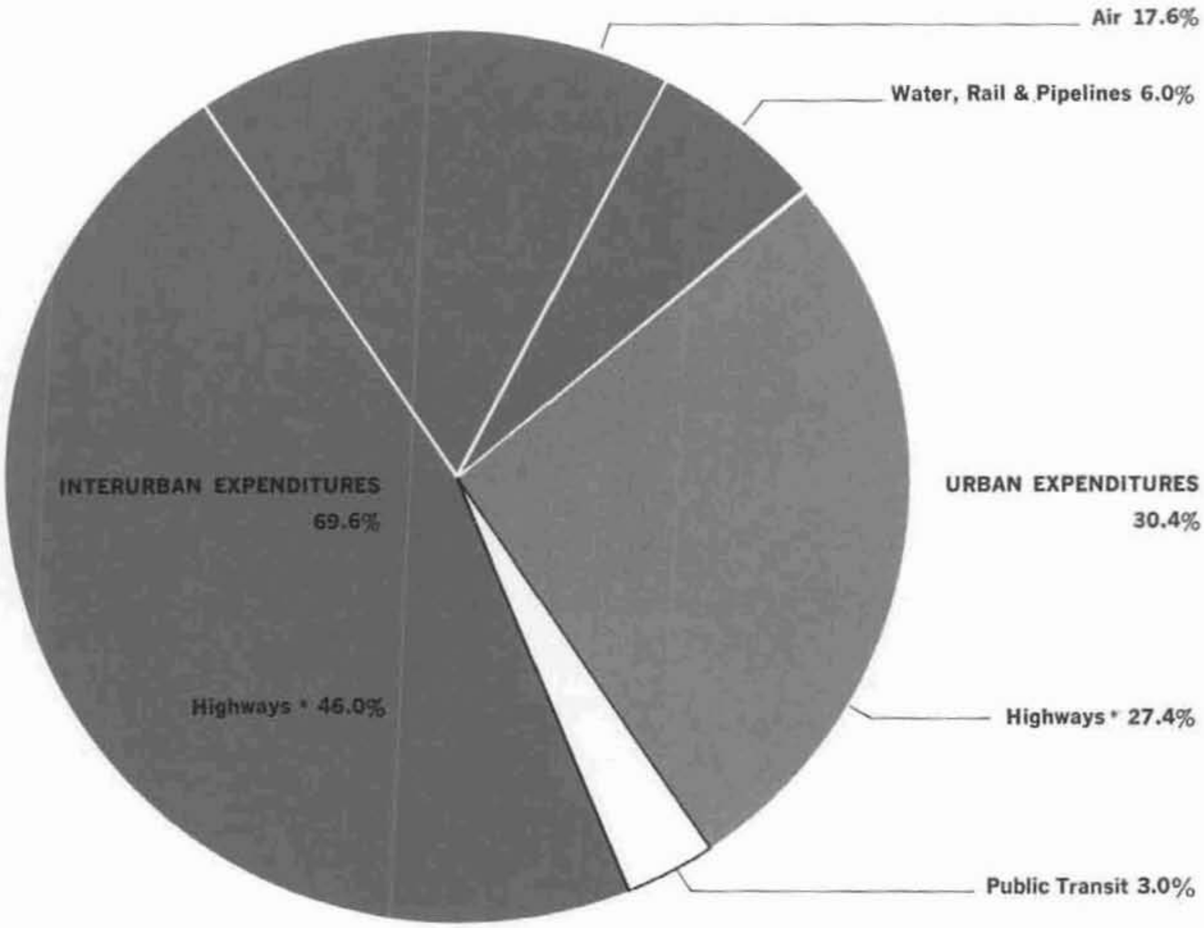
> Under our system of government, private enterprise bears the primary responsibility for research and development in the transportation field. But the Government can help. It can plan and fashion research and development for a total transportation system which is beyond the responsibility and capability of private industry.

Implementation of such a leadership role may require not only augmented funding but redirection of much of the present effort at the Federal level.

Over 70 percent of Americans now live in urban areas (and the percentage will increase), yet until now, only a small fraction of Federal research and development expenditures has been devoted to a systematic, concerted attack upon all urban transportation and related problems. The Department of Defense annual research and development budget has remained relatively constant over the last 5 years at about $7 billion. It is against such magnitudes that the increasingly significant research and development needs of urban transportation must be compared.

Although urban travel accounts for more than 80 percent of the national total, out of the fiscal year 1967 Federal budget expended for urban and interurban transportation, only 30 percent was allocated for *urban* transportation. Of this amount, 90 percent was for urban highways and only 10 percent was allocated to public transit, as shown in figure 2.1.

Figure 2.1. Allocation of fiscal year 1967 urban and interurban transportation expenditures by the Department of Housing and Urban Development and the Department of Transportation.



TOTAL EXPENDITURE: $5.35 BILLION

SOURCE: The Budget of the U.S. Government, 1969 — Appendix.
*Allocation based on proportions in Bureau of Public Roads data.

Current Federal programs of urban transportation assistance to cities are meant essentially to show what existing technology can do. The industrial and research activity stimulated by the present new transportation systems study has been exploratory so far rather than developmental. Studies of social, economic, jurisdictional, legal, political, as well as technological aspects of transportation—including research into future demand characteristics—have only begun to identify some of the questions.

It is important, therefore, that the Federal Government take on a broader, more positive role, involving the continuous assessment of the research and development needs based on the contributions being made by the private and public sectors, and that it fill in existing gaps to assure a balanced and effective national program. A summary of the findings of the most promising technological possibilities, upon which the proposed program is based, follows.