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Technological Developments in Urban Transportation

The problems of urban transportation have always been with us to some degree or other wherever people have gathered together in a community. In recent years these problems have been intensified due to the large concentrations of population, not only of people, but of hardware in the form of automobiles and trucks. It is becoming quite obvious that our knowledge of technology has not been fully applied to solving these problems.

In the context of today's metropolitan transportation problem, new technology must be examined carefully and critically so that a total transportation system may be evolved for metropolitan areas. No one mode of transport will solve these problems. It is not foreseen that any new technological "breakthroughs" will individually solve this problem. Each mode must be used where it can function not only effectively but economically as well.

In future years the total social costs of transportation will likely be more important than they are today. Unless we arrest the trend, transportation will take an ever increasing proportion of our disposable income. In large part these costs are generated in urban areas, therefore, the critical need for better answers both for moving people and goods.

Before examining in detail some of the technological developments and potentialities for urban transportation, I should first like to emphasize that the principal benefits will come by applying existing technology using a systems approach so as to optimize the end result. Therefore, most of the actual hardware involved will represent "design technology". Overall transportation planning requirements, objectives and economic factors will determine the participation of each mode of transport.

Urban transportation is judged by two main factors—quality of service and cost. The dimensions of urban transportation improvement are measured by the extent to which these two factors can be improved.

The more important elements entering into *quality* are as follows:

1. Time required for travel (door to door). The longer the trip, the more important is the speed of movement.
2. Reliability—this is closely related to time, for time is lost where a service does not operate on schedule. Unpredictable delays are an especially serious impairment of quality.
3. Convenience—
   A. Frequency of service—the higher the frequency, the greater the possibility of accommodating individual needs.
   B. Accessibility—to the transportation vehicle or service.

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4. General amenities (in the case of passenger transport)—including seating, lighting, air conditioning, cleanliness, noise, loading, general riding qualities, and appearance.

The elements of *costs* are as follows:

1. Fixed facilities—the capital costs—including property acquisition, right-of-way constructions such as track or pavement; traffic control or signal systems; structures, signs lighting equipment, etc.
2. Transportation equipment—the capital cost of autos, taxis, trucks, buses, and rail equipment, required to perform the transportation services.
3. Operating and Maintenance Costs:
   - A. Of the fixed facilities
   - B. Of the rolling stock
   - C. Administrative costs

There are also other elements of cost not capable of being directly measured, such as the cost of congestion which have to be taken into account.

In a state of frozen technology, costs are opposed to the factors making for quality, most of which can be improved only by increasing costs. But advances in technology and design may make it possible both to achieve quality and reduce costs simultaneously in various combinations.

The private automobile has become the yardstick by which all other intra-urban passenger transportation systems are measured. It has won wide acceptance largely because of a generally high rating on quality. Comparisons of costs tend to be distorted by the fact that in urban transportation, the price-cost system ordinarily conceals most of the cost of an automobile trip to the individual user, while making painfully apparent all or most of the cost of a trip via public transportation.

Auto transportation does have some other shortcomings which may increase in the future. It requires a high ratio of operators to riders, although driving is not counted a hardship by most operators. Increasing congestion robs the auto of some of its quality advantages; the pressure of congestion and density have been in part responsible for the trend to smaller cars which involve some sacrifice of comfort. Passengers can read only with difficulty, and not at all after dark.

Rail transit, at least, often compares favorably with automobiles as to travel time and reliability. But transit generally needs major improvements in the elements making up quality—seating, lighting, air conditioning, noise abatement, loading and general performance and riding quality. The improvement of some of these elements, such as seating and loading, has relatively little to do with technology; improvements can be achieved simply through better design. Other elements of quality, such as air conditioning, general riding quality, and better performance, depend directly on technology for improvement. Technology now available but not yet applied would make possible many improvements. In fact, the greatest current problem is not in developing new technology, but in applying what already exists.

Finally, some elements of service quality would benefit indirectly, if not directly, from technological improvements. For instance, frequency of service is a matter of economics, rather than technological innovation, but technology, by reducing operating costs (as through automation) may make more frequent service economically feasible.

I should like next to examine each urban transport mode for possible technological innovations which might improve either the quality of service or cost factors, then the facilities required for each.

Urban Transportation Equipment

Automobiles

The automobile has become a highly developed vehicle mechanically and has provided us with unparalleled mobility, yet it is this freedom of movement which promotes the choking of our central business districts today. In the automobile area technological innovations are considered to be less needed than in traffic control and automation systems designed to increase highway capacities.

It is widely believed in the industry that the trend in automobile design is more toward more special purpose vehicles. Vehicles especially designed for commuting are expected to be produced within five years; and they may be powered either by high efficiency batteries or chemical fuel cells. Such a vehicle would probably seat only two people, be considerably shorter and lighter than today's compact car. Functional advantages would include maneuverability, lower space requirements, both for movement and for parking, no warm up, less noise and elimination of air pollution. The principal benefits to the user would be lower capital and operating costs. Both types of vehicles would probably employ some form of DC electric motor for propulsion which has a high degree of mechanical and electrical reliability. With DC electric drive dynamic braking could easily be used.

Taxicabs

Taxis, most of which are converted passenger cars, are probably the most inadequate of all vehicles presently on city streets (the traditional London taxicab is perhaps the most functional vehicle of its type in existence). This type of vehicle performs a very useful function in the metropolitan area in providing personalized public transportation. Yet the hardware is perhaps the most unsuited of all vehicles presently on city streets. The taxi itself rarely satisfies the owner, the driver or the passenger. This is basically a functional design problem.

The ideal cab, as it is visualized today, would be a vehicle some 30% shorter than its contemporaries and would place the driver in a centralized forward position over the wheels of a small or compact power source under the driving cab space. A large 5 foot high passenger compartment would extend to the rear with access by large sliding doors, one on each side. Such a vehicle could seat six in comfort and have ample room for luggage space. Ease of entry and exit would please the passengers, while the driver would have a far better position to view his situation in traffic. In dense metropolitan areas where the vehicle length is critical during queueing, the advantages of such a vehicle are obvious. The same vehicle could be adapted to small removable cargo containers and could do the work of small pick-up trucks during off-peak times of the day, thereby giving the vehicle operator unprecedented versatility and a further means of increasing his revenue.

One of the growing problems in many metropolitan areas is air pollution and for the permanent fleet of vehicles in the city's center the elimination of noise and fumes would be a major step forward in making the downtown area a more pleasant and attractive place to carry on one's activities.

Many technological innovations could be incorporated into such a vehicle so as to improve the various quality factors while at least arresting further increases in the cost of such services.

The Transit Bus

The modern transit bus has, through the process of evolution, developed into a very useful and reasonably comfortable vehicle, with many design innovations. Since the major cost of bus operation is labor, further innovations which either increase capacity or utilization are in order. One is the design of a larger vehicle. With lighter weight power sources, and very lightweight monocoque structures, capacity increases should be modest in terms of cost, and with reduced weights per seat.

Performance improvements ordinarily favor improved utilization, but these can only be realized if innovations are made in the facilities to permit relatively unrestricted movement.

For metropolitan transit operation where frequent accelerations and decelerations are demanded, some form of free-piston gas generator type turbine will probably be utilized primarily on account of fuel economy over a wide speed range. Further, such vehicles may take the form of turbo-electric equipment so that if private right-of-ways or tunnels are used in downtown areas such vehicles may operate electrically without the additional problem of getting rid of combustion products in tunnels. Eventually it is expected that the fuel cell type of power generation may solve this problem, but this is considered at least ten years away for buses.

The next expected development, however, will be in some form of longer vehicle which might be articulated so as to provide a higher capacity in relation to the labor cost component. A number of such vehicles have been built in Europe where the overall length has grown to some 60 feet, from the present maximum of 40 feet permitted in this country. For main line high density bus operations on freeways some form of large vehicle is certain to come about.

One present shortcoming of the bus is the relatively high floor level occasioned by the large diameter wheels and suspension design. From a passenger convenience standpoint it would be desirable to have easier access and fewer high steps to negotiate. New technology in tire design, as applied in aircraft, may permit smaller diameter, higher pressure tires allowing the floor level to be lowered. Bogie design and dual front wheels may even be necessary, but with the decreasing size of power plants, this should pose no outstanding mechanical design problems.

A logical outgrowth of the bus operating in high density areas is the concept of the bus train. This concept envisions the use of an individual bus operating in low density suburban areas which can be driven by an operator to a collection point where a number of such units are coupled together into a "bus train" for operation over a private right-of-way to the Central Business District. During operation as a train these units would be controlled by one driver on the lead vehicle or perhaps the fully automated. Further requirements of this concept are provisions for inter-communication between units so as to permit equalized loadings while operating as a train, automatic doors operating simultaneously on all units, high level—low level step arrangement, electrically controlled brakes and dynamic braking. It would be required that the vehicles have the capability of self-propulsion in the rural areas and perhaps electric propulsion during operation as a train so as to permit negotiation of sections which might be in tunnel. A turbo-electric system would satisfy the propulsion requirements. Necessarily, some form of hybrid vehicle would have to be developed having the characteristics of both the bus and the rail rapid transit vehicle. Although there are many technical problems involved in designing such equipment, there appear to be no problems which cannot be solved.

Trucks and Goods Distribution

With respect to movements of goods in urban areas, aside from direct rail transport, it is expected that in the immediate future, time and vehicle productivity will become even more important than they are today due to the increased cost of labor. Therefore, higher vehicle utilization demanding higher speeds and higher acceleration capability will be designed into most truck equipment.

One of the other attacks on cost of operation will be in terms of materials handling efficiency. This will involve a much greater use of "containerization" in the near future. Here the vehicle will, over a period of years, gradually change its form so that it in effect becomes a universal carrying structure whereby various types of boxes or containers can be placed on it for shipment and local delivery or be transferred to cargo aircraft or to rail cars for long hauls. Where containerization has been utilized to date major savings in handling costs have occurred and losses due to pilferage have been drastically reduced.

By utilizing containerization systems in metropolitan areas a major improvement should be possible in reducing street congestion by substituting off-peak night deliveries and pick up of containers at the consignee's dock.

More sophisticated systems of container handling and storage must be developed to optimize goods movements in urban areas. For example, a vertical handling system and container stack 15 or 20 stories high, similar to the so-called "pigeon hole" parking facilities, could permit container storage, random selection, and delivery to either truck or rail modes. This could be operated entirely by one man at a console, with automatic weighing and accounting features. Because of the vertical storage land use could be reduced substantially compared to present rail and truck terminal facilities.

This whole area of container handling represents fertile ground for the cultivation of technological innovations. Again quality of service can be enhanced while costs can be reduced.

Rail Transit Vehicles

The principal need of the moment is application of available technology and design techniques to improve performance and reduce costs, and to increase attractiveness and comfort. This requires little new technology, but it does require abandoning many traditional concepts of rail transit equipment design. It is possible to build rail equipment with performance characteristics and comfort standards far superior to any transit vehicle now operating.

Unfortunately, rapid-transit car design is, and for half a century has tended to be, highly individualized, because of the differences in operators' preferences and requirements in such elements as loading density, tract gauge, tunnel and other clearances and many other environmental controlling factors. Because of the parochialism of design, no simple, universally accepted standards of design have developed.

Today, the rail transit industry is badly in need of modern rapid transit car designs which will permit standardization, lower production costs and set new standards of performance and public acceptance. Although the initial design work on such a car would be expensive, it would be cheaper in the long view than the cost of designing cars to specifications of individual lines and operators; such designs tend to follow precedents already established because funds are never adequate for research and experimentation with basically new ideas.

The most important elements to be incorporated in a new design are as follows:

1. Higher performance standards—faster acceleration and deceleration. This requires a higher horsepower-to-weight ratio.
2. Weight reduction. Only through weight reduction can improved performance be linked with lower costs, that is, the horsepower/weight ratio is raised by lowering weight rather than increasing horsepower and power consumption. (It has been estimated that the costs of unnecessary weight are as high as 10 1/4 cents per pound per year. It has also been amply demonstrated that the cost of track maintenance is directly related to the gross ton-miles of traffic carried, hence lighter equipment lowers track maintenance costs.
3. Improved appearance and environmental factors.

Present day "heavyweight" rail transit equipment weighs about 1,400 pounds per lineal foot of 10 foot wide car. Some new cars have been built in recent years with weights around 1,000 pounds per lineal foot, and some as low as 850 pounds. Weights as low as 750 pounds or even 500 pounds, are possible—they require the use of new high strength, low weight alloys and improved design and construction methods—and can be achieved without sacrificing safety. The London Transport System is presently involved in a major equipment renewal program for its underground and transit rail lines wherein light alloy cars are replacing the former heavier cars for the entire system. Power savings and schedule improvements are the prime incentives of this program.

Part of the answer in reducing weight is to reduce the size and weight of the running gear components by virtue of new suspension designs and secondly, to reduce the weight of power and associated equipment. Single axle designs such as the Talgo and Train-X types are now being reconsidered for a rapid transit use because of the weight and maintenance savings which appear possible.

With the use of gas turbine power plants and/or high frequency electrical propulsion systems further weight reduction not heretofore anticipated could bring the weight of rail transit equipment much closer to the weight of the conventional city bus.

Improved performance characteristics must also include acceleration capability over a wider speed range. Accelerations of 3.0 mph per second through 60 mph (to be reasonably competitive with auto performance) would require 4,132 hp for a 250 foot long ultralight weight train and would require over 6,000 hp for the lightest weight equipment currently available of equivalent length. Such power levels represent about four times the horsepower installed on today's transit vehicles. The importance of weight while preserving high performance and reducing power requirements is apparent.

Also with increased acceleration capability better, smoother control systems will be required to optimize the rate of change of acceleration for human comfort. New power control systems are currently being studied and designed which can use digital input data for precise control.

Power sources for future rail transit vehicles will likely be central station electrical supply for higher density systems. If low level or 3rd rail distribution is used 1500 v. D.C. is likely to be used. If overhead systems are used and tied into the standard power grid probably 6600 v. to 25,000 v. A.C. would be employed using semi-conductor rectifiers for D.C. traction motors or static convertors and super-synchronous A.C. motors. For low density operations where economics determine that vehicular generated power is more desirable then some form of gas turbine power will probably be used. The energy conversion link will probably utilize a super-synchronous alternator and static conversion for super-synchronous A.C. motors. Space requirements for such power units can be kept low so that floor levels of cars can be kept low for low center-of-gravity low profile design.

One facet of the problem of low transit equipment utilization which has been explored but not fully exploited is what to do with all the excess capacity during off-peak hours. With bus equipment many operators push group charter business to fill this void but generally city transit equipment is undesirable for longer journeys. Rail equipment is much less flexible for off-peak utilization. Longer journeys are generally not possible because of equipment capability and the use of the facilities of other companies.

High speed rail transit trains could be used in short to medium distance intercity service at peak travel times which fortunately do not coincide with peak journey to work movements. Friday night, Sunday night, and holiday peaks for all modes except transit illustrate this fact.

Self-powered rail equipment would at least overcome part of the inflexibility of electrified systems so that equipment could be used for such purposes on weekends and holidays over non-electrified lines. Dual purpose capability would necessitate that equipment be of standard gauge, clearance and meet ICC safety requirements. Weekend leasing from transit operators to railroads would not be out of the question.

Future high performance transit equipment would meet all the performance requirements and most of the other requirements for short to medium distance rail service. Lack of toilet facilities and reclining seats would probably be the only shortcomings. It is possible to design a unitized "plug in" washroom which could be installed in a car by removing two seating units in a few minutes. Such dual capability could include small galley units and seating units as are presently used in mixed configuration cargo-passenger aircraft today. The increased utilization might be as low as 200 miles per week, but could cut ownership costs by 20%. Self-powered multiple-unit transit trains of the turbo-electric type would be far superior to any medium distance coach trains presently in service on American railroads today.

One of the most troublesome aspects of rail transit design is that of noise—particularly in tunnel operation. The operation of steel wheels on steel rails sometimes produces a high-frequency noise which is probably the largest single source of annoyance to transit passengers. In open air operation, where the sounds are dissipated, they are less noticeable to the passenger, though annoying to the neighborhood. It already has been demonstrated that noise can be greatly reduced; for instance, the steel-on-steel systems of Toronto and Stockholm.

This problem is a complicated one necessitating research into several areas. The wheel construction, materials, car geometry and structure of the right-of-way all play important roles. For the first time in years research is now starting to find answers.

Ventilation and air conditioning have been improving in the past few years in buses. Thus far, air conditioning rail transit cars, with large side doors which open frequently, and operate in tunnels have not been entirely successful. The problem lies partly in the vast amounts of heat accumulated in tunnels, from equipment operation and braking, solar heat on the street roofs of shallow tunnels, as well as the heat generated by the occupants of the transit cars. The cooling job is beyond the capacity of air conditioning systems produced to date. Two technical innovations may be of importance here. One involves releasing liquid nitrogen into the area to be cooled. The cost today is probably double that of conventional freon systems, but initial costs are extremely low and power consumption is zero. Another method employs the principle of the centrifuge to separate high energy (hot) molecules of air from the low energy (cool) molecules. This method, which is essentially very simple, requires a source of large quantities of low pressure air, but appears to have some potential for transit air conditioning systems.

Rail is a highly efficient guidance system. Rail transit electronic controls are being combined with improved signaling to create completely automated train control systems. These systems are presently limited to electric rail operations, but doubtless will be extended to other vehicles. By controlling the stopping, starting, speed, enroute opening and closing of doors, with special fail-safe circuitry to protect against accidents or unforeseen conditions, electronic control systems may increase capacity and efficiency of rail transit operations, partiularly during peak hours. Labor costs will be lower if the need for additional employees during peak periods is reduced.

Completely automatic operation of public transportation vehicles is not new, having been employed for years in the form of automatic elevators. Although elevator operation is somewhat simpler than most transit system operations, there is a close relationship. The automatic train now in shuttle service between Times Square and Grand Central Station, New York, is similar to an automatic elevator running between two floors. As indicated above, technology is available for more complicated operations.

Some present systems use a variation of programmed automation. The Paris Metro transit lines are developing an "Ordinator" system of automatic train control through which a computer-controlled train-movement program is transmitted via a special wire laid between the tracks. Signals are picked up through sensors mounted on cars. Train spacing can be continuously planned and adjusted to changing conditions by computers, making possible reduced headways and increased line capacity and service frequency. The new rail transit system for the San Francisco Bay Area, recently approved by the voters, contemplates an almost entirely automated operation.

Automatic fare collection would make possible substantial savings in manpower, and much closer adjustments of specific fares to cost of service than are possible with today's fare collection systems. The machinery for administering fares needs to be simple, so that it will minimize inconvenience to passengers; flexible, so that fares can be varied for trips of different lengths and, possibly, by time of day; and capable of construction and operation at reasonable cost. Equipment is already available which, with some adaption, will possess all these characteristics. Another possibility, already contemplated for the San Francisco system, is the use of mass data processing machinery for monthly billing of regular riders; that is, putting transit riding on a credit, as well as a cash basis.

Innovations in Facility Design and Construction

By far the largest costs are incurred in facility design and construction for transportation systems. Far more important is the fact that once the facility is built, system improvements are largely "frozen" and only marginal operating improvements can be made. Therefore, it is desirable to not only design to minimize long term costs, but to maximize flexibility. By and large, various transportation facilities have been designed, financed and constructed by organizations and agencies whose aims and motives were seldom correlated to any degree. As a result we have less than the best at a total cost of more than the best. Planning of all transportation facilities on an integrated basis is the greatest opportunity to reduce costs, progressive congestion and obsolescence.

Pedestrian Facilities

Traditionally in our CBD's we have provided sidewalks and a few underground passages (generally a part of subway facilities) for pedestrial movement. The constant surface intermingling of auto traffic and pedestrian traffic at intersections is, in most major cities, a frustration to both. We need new innovations in CBD transportation with particular attention to handling the pedestrian. He takes the least space, he is infinitely mobile and he doesn't weigh much on structures. Several design innovations have been used on a small scale, yet no large plan has ever been implemented in this country primarily because, unlike highways, sources of funds are not readily available for segregated pedestrian facilities. Yet in Stockholm today a major central city rebuilding is taking place wherein multi-level vehicle segregation is employed and the scheme is fully integrated with elevated pedestrian walkways and the new subway system. Such undertakings can be done in this country today with out technical knowledge. First aid to CBD's in the form of elevated pedestrian walks, moving belts, escalators, and carveyors could vastly improve and revitalize the economics and character of our larger CBD's.

Devices for Downtown Distribution—Carveyors and Other Moving Belt Applications

Secondary distribution of passengers, from parking lots, is now handled primarily by walking, and to a degree by local bus. One possibility is an application of the moving belt principle, by means either of the "carveyor" or the "moving sidewalks."

With the "carveyor" (which has been demonstrated only by small models) small car-units, each seating six to ten people, move on a grade-separated automated track or belt at a speed of about 15 m.p.h. At stations the cars would decelerate by moving from a high speed belt or tract to slow turning rollers; passengers would enter or leave cars by stepping from or to a slow moving parallel belt. Estimated capacity of a carveyor system is 7,000-10,000 people per hour. It is believed that operating costs would be low, primarily because of the low speeds and the low labor requirements. Capital costs can vary widely depending on subway or aerial structure costs.

Slow moving belts (moving sidewalks) operate at much lower speeds—about three m.p.h. Generally, these have been used to facilitate movement up ramps. By walking with the belt, a speed of six m.p.h. can be attained easily, making walking as fast as average bus speeds on some runs in Manhattan today. There have been several installations of these pedestrian belts; some have had difficulties because of the accident hazard in moving from a stationary walk to a moving belt, and vice versa. Much more work needs to be done in this field of secondary distribution systems, to determine the extent to which they can replace existing systems.

Roadway Right-of-Way

Concern over the enormous cost of building modern roadways in congested urban centers to alleviate urban traffic congestion has focused attention on possible ways of increasing highway capacity. New guidance and control systems offer one possibility of achieving economics by increasing the volume and speed of vehicles moving in a highway lane.

With highway guidance and control, individual vehicles, including autos and buses, could be conventionally operated on public streets in collecting and distributing passengers in light traffic areas, then operated on an "automated" highway designed to handle high volume flow only over the highest traffic portion of their run:

Several different highway guidance systems have been proposed, but they all have basic elements in common: (1) all vehicles using the highway must be equipped with guidance devices; (2) vehicles not so equipped cannot use the highway, and (3) there must be staging areas where entering and exiting vehicles can enter or separate from the system. There are unresolved questions as to how much the guidance devices would cost or restrict the usefulness of the non-equipped car or bus. Guidance systems wholly operated by electronic methods may be applied to highways. These have the advantage of not physically obstructing the highway, which can be used for normal traffic on weekends or during nonpeak periods.

Both mechanical and electronic guidance systems present a difficult array of problems which may or may not be capable of practical economic solution:

1. Mechanical guidance systems require great precision in alignment to avoid shimmy and vibration at high speeds. Electronic guidance devices must constantly be "hunting" a signal. It would require a very high order of precision of steering control to keep the whole vehicle in alignment with the prescribed guide path, at higher speeds.
2. Bad weather would affect performance on open highways. For instance, vehicles might skid on a wet or icy pavement and leave the guide path. Mechanical guidance would require keeping the guiding devices free of ice and snow.
3. No simple and effective fail-safe design has yet been perfected which can operate safely in case of power failure, either in the vehicle or in the fixed roadway guidance system.
4. There are dangers of private auto breakdowns and of failures of guidance systems. Private auto breakdowns tend to be more numerous than with common carriers because of lower standards of maintenance.

In highway applications, a guidance system is of limited value unless it is combined with an automatic control system to govern the spacing, switching, stopping and starting of the guided vehicles. The following problems of control systems have to be overcome:

1. Automatic control of high-speed, closely spaced vehicles requires high standards of uniformity, including uniform rates of acceleration and deceleration. This requires either a very complex vehicle control system capable of adjusting speed to a pre-determined standard, or a uniform system of electric propulsion operated from an outside power source. Either alternative complicates the system and adds heavily to the cost.
2. With independent vehicle power, fail-safe control systems, while technically possible, are complex and expensive and are especially vulnerable to power failures.
3. There is no simple or practical means of guarding against accidental collisions with vehicles, persons or other obstacles in the road not connected with the control system.
4. So many different kinds of mechanical failures can occur on a highway vehicle that providing high reliability will be very costly.

While all of these problems may ultimately be solved, their solution at best will require a complex, and expensive control system. The first application of guidance and control mechanisms may be on buses, which can be better maintained and more closely controlled than can private automobiles.

It is also possible to increase highway capacity, by monitoring the flow of traffic to avoid supersaturation which makes the whole traffic stream vulnerable to otherwise minor incidents. The solution, over long stretches of roadway, lies in controlling access through a computer controlled signalling system so as to permit maximum movement over the highway itself. While this involves holding vehicles at entrance ramps, the overall travel time required in such a system would be much less than that required for travel on the same roadway without traffic control.

Highways can be built to accommodate transit vehicles in grade separated lanes while adding substantially to the total passenger carrying capacity available during peak hours. These can be rail or bus. If, for example, bus lanes were in the median strip, they could handle two different peak traffic loads. On weekdays the median strip lanes could be used exclusively by express transit buses carrying people to and from the CBD. On weekends the same lanes could enable motorists to travel from the central city to recreation areas in the country without mixing with heavy suburban traffic.

Another area in roadway technology which bears mention is in toll collection or some form of user charge designed to either (1) ration the product, or (2) more equitably charge various users. The rationing system could work by using variable mileage charges for different hours of the day and different days of the week, thereby tending to equalize loadings and to spread out peak-hour journey to work trips. Obviously such a complicated pricing scheme must be a mechanized operation capable of functioning in high density areas. Various systems have been proposed for this including the monthly billing feature.

Parking Facilities

Parking facilities are really terminal facilities, just as are railway or bus terminals. They are an interchange point between modes of travel; most frequently auto to pedestrian. Roadways and streets since early times have performed the dual function of transportation artery and terminal storage. Yet the parking garage does not fulfill all the functions of the curbside terminal. Obviously the complete elimination of curb parking would inconvenience many, and be a particular hardship for those people who earn their livelihood by commercial delivery and pickup. The real need is improved technology of how and where to store vehicles in our CBD's.

Location is basically a transportation planning job but such decisions are rarely the rule; rather speculative business decisions govern, rubber stamped by planning commissions whose functions are seldom more than to generalized area planning. With a good freeway system the distribution in the CBD is the major cause of freeway delays and reduced capacity. Parking facilities must be closely integrated with the arterial flow of vehicles.

Clearly there is room for improvement in the garage facility too. It can be designed to be much smaller and completely automated. Cars stored in "pigeon holes" need only have 6 feet or so between layers, saving 30% over conventional garage construction. Complicated, expensive, space consuming ramps can be eliminated. More development is necessary to increase the speed of car delivery of the pigeon hole types and to reduce costs. In CBD areas land costs favor the vertical storage concept providing suitable equipment can give the same return on investment that a more horizontally disposed conventional garage can. If we are to be better able to assimilate more autos in the parking facilities at fringe CBD locations integrated with some form of secondary distribution system (buses, belts, or conveyors), we would automatically keep much of the local auto traffic from the CBD, yet improve dependability of transit and door to door time. Even covered grade separated walkways would be a big asset and convenience.

Rail Transit Right-of-Way

Rail and other grade-separated transit systems require large initial investments; carrying costs are a major part of transit operating costs. The same is true of urban highways where the right-of-way costs per unit of capacity, tend to be much higher than for transit. New design, materials and construction methods offer opportunities to reduce transit (as well as highway) right-of-way costs.

With rail transit, there is no need to build lines to standard inter-city railroad weight and clearance standards. The use of lightweight transit vehicles permits the construction of lighter weight (and therefore less costly) tracks, bridges and other supporting structures. By combining lighter weight-carrying requirements with welded rail, the use of concrete ties with absorbent pads, new-design bridges, overpass and elevated structures, substantial capital savings over conventional construction methods are possible.

On lines which involve any considerable amount of tunneling or must do much underpassing, the cross-section profile of the vehicle in part determines cost by establishing the size of tunnel or the height of bridge required. Car designs calling for lower heights make possible lower construction costs.

Some innovations in track structure have been developed in Europe. These include various types of pre-stressed concrete ties and a new zig-zag steel and concrete design with short precast concrete ties under each rail attached diagonally each to the next opposite tie by a bolted steel angle. Such an arrangement is stable under all conditions of temperature and loading and promises to maintain line and surface much better than conventional track.

Clearly any penetration of the city areas will require either tunnels or complete grade separation and a large number of bridges or aireal structures. New technology is needed to minimize the enormous capital costs of such elevated structures.

There are several advantages to using an all elevated system in the CBD:

(a) Land use is largely unaffected.
(b) No appreciable tax loss on existing property
(c) Utilities are largely undisturbed
(d) Construction entails a minimum disruption of normal activities
(e) Construction costs in CBD are minimized.

There are, however, misgivings in some people's minds about the shadows cast upon the ground and surrounding buildings; the noise and the urban blight which might result.

New design technology is required for bridges and elevated structures for all types of public transit vehicles. The slim graceful, elegant look can, with new materials and design concepts, be given to such structures and the results need not be confined to monorail. With new high strength steels, prestressed concrete, and aluminum, new design opportunities are possible. Longer spans are possible without the penalty of beam depth if lightweight equipment is used exclusively. Single column design of double lane or track structures can make for minimum ground obstructions over existing streets.

New opportunities lie ahead in designing for reduced maintenance, both as to corrosion free materials and in terms of better geometric design to eliminate elements which collect dirt and debris. Other elevated structures such as stations and passenger platforms need much design attention also to reduce weight and improve appearance. Reduced structural weights minimize foundation requirements.

Tunneling in built-up urban areas is an extremely costly procedure. But there are many circumstances where it is the only practical method of constructing an effective grade-separated transit system. For this reason, there has been considerable interest in faster lower-cost tunneling methods. There are basically three types of tunnel construction: (1) Open "cut and cover" excavations which are usually practical only for shallow depth; (2) driven tunnels using shields or boring machines; and (3) solid rock tunneling requiring no shields.

The new "Milan method" is a variation of the open excavation methods. Two parallel trenches are dug in the ground and filled with concrete to make the sides. The tunnel roof is cast on the ground, the earth is excavated from within the walls and roof, and the floor is poured. A short subway section has just been constructed in Toronto (where no utility lines interfered) using this method.

Deep tunnels can avoid utility lines or make possible routes which do not follow street alignments. Several new machines have been recently developed for boring deep tunnels. The British "Mittry Mole" was used on the Oahe Dam to drive 26′ diameter tunnels in shale. The device is a self-propelled rotating cutter rig and is reported to have effected large savings. Another similar type machine, a "drum digger" suitable for use in clay only, has been developed for experimental tunnel construction by London Transport. This machine is operated by one man and the excavated material is removed by belt conveyor.

Recently a new mining machine known as the "boot-strap miner" has been built and demonstrated. This device is also operated by one man and involves a pilot cutter and tube arrangement which eliminates the necessity for bracing the shield or cutting machine against the walls of the tunnel and permits rapid advances (3 to 5 feet per minute). This particular machine was developed for mining bituminous coal but it has been used in other types of material ranging from hard rock to such soft materials as mud rock. Utilizing this same principle, its makers have designed a large machine for boring circular tunnels which presumably can be utilized for subway construction.

Further refinements of tunneling machines appear to be in the offing including one which pulls movable concrete forms behind the machine, allowing rapid concreting of the tunnel lining as the excavation work proceeds.

Until more experience has been gathered utilizing these machines and schemes, it is difficult to fully assay their potential effects on tunnel construction. It does appear, however, that substantial cost reductions can be expected.

Another important consideration relating to tunnel construction is their potential utility as fallout and bomb shelters. During World War II it is well known that the London Underground saved hundreds of thousands from being killed or injured, due in large part to the deep tunnels and high protection factor. With nuclear weapons the job is more difficult but substantial protection can be easily and effectively afforded at low cost.

The principle requirement is to provide doors which can close off tunnel entrances, ventilating shafts, and station entrances to prevent the entry of radioactive dust and debris. This practically requires that the entrances, doors and structures be blast resistant for overpressures of perhaps 10 p.s.i. Such protective construction can be provided at a small incremental cost when the original design criteria includes such features.

The principal advantage of using deep tunnels for shelter installations is the interconnection of shelter access points. Individual buildings or shelters generally lack this vital emergency physical communication link. The use of the underground transit facility could provide about the only transport possible after an attack where fallout and blast damage would make evacuation of survivors very difficult. Russian subways in Moscow, Leningrad and Kiev are all deep tunnels and said to be suitably outfitted for survival.

Station Structures

Stations are collectors and distributors of passengers. The necessary gathering of numbers of people together in one location for conveyance to another location requires a functionally efficient operation.

Tomorrow's operations, wherein automated trains can provide frequent service without a high labor cost penalty, will require smaller station facilities. Frequency spreads loads better and prevents large groups gathering at any time. This also helps in another way—the trains can load and unload faster if the station platform is not so crowded. The shorter trains also equalize their loadings better whereby no cars are overloaded while others are half empty. All the station design factors optimize with short frequent train service.

For stations and other building structures above the ground improvements and savings can be achieved in first costs largely through new design techniques. The use of lightweight prefabricated building components can provide substantial economies. In fact, a unique feature which can be incorporated in such "Erector Set" construction allows structures to be dismantled and moved as required by changing traffic requirements.

The concept of maintenance free materials is not new, but it is particularly important to utilize these in the most appropriate way for transit structures so as to reduce operating costs over the years. Design is important so that surfaces may easily be kept clean and provide for mechanized cleaning operations.

The track and platform area can be materially improved in design so that a special cleaning vehicle could vacuum up all the litter normally thrown down onto the tracks, and could clean tunnel wall surfaces with rotating brushes and a water spray. Such operations could take place in the early morning, would require a minimum of personnel, and make transit facilities clean and attractive at a low cost.

Unconventional Urban Transportation Proposals

With the possible exception of the various monorail schemes, other unconventional equipment proposals such as the Autoline, Hydrofoil Craft, ground-effect machines, helicopters, VTOL and STOL aircraft offer little in meeting the various demanding requirements of urban transportation.

The monorail has captured much popular attention as a panacea yet it is only a variant on a conventional rail vehicle. Actual high speed transit type performance has not been demonstrated to date and serious problems remain —both technical and economic. It appears that more growth potential exists within the context of standard rail systems if new technology is fully applied.

Research and Experimentation

There are, we have seen, numerous technological developments either available now or soon to be available, which can both improve quality and reduce costs or urban transportation. Potential improvements apply both to private motor vehicles and to various forms of transit.

One thing is quite clear; ground transportation research and development expenditures in recent years have concentrated largely on the private automobile. The amounts spent are in the hundreds of millions. We have not been able to determine how much is going into transit research, but the amount is relatively small, probably less than $1 million per year. There is no program for systematic application of various technological innovations and for testing new products and designs. Carveyors have been in the model stage for years, but no one has ever produced a full scale model to test in a working situation. The use of high cycle AC motors in both rail and bus transit offers exciting possibilities, but their use is not being contemplated by any of the new rail transit systems now being planned. The reason for this lack of progress lies in the fact that transit, a shrinking industry for years, has furnished no inducement for private research and development expenditures on the scale required.

As things stand, only a vigorous Federally-sponsored program will supply present and prospective transit systems with the information they need for making decisions respecting new equipment.

Efficient and effective urban transit is now essential in many areas, and in the future will be needed in a great many more, simply to keep highways functioning efficiently. Maintaining and building up transit patronage will avoid corresponding jams on the highways. Transit's main function, after all, is to haul people to and from work, and in this function it can relieve highways at the hours when they are most jammed.

It should be emphasized that improved public transit does not necessitate penalizing automobile movement or cost more money. On the contrary, the benefits of overall urban transportation improvement will benefit all urban travelers, and shippers.