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TRANSPORTATION
THE DEVELOPMENT OF MINIMAL DESIGN FUNCTIONS

Presidential Address by Ernest A. Herzog

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Transportation is a function, the act of moving goods not capable of self-movement and people not capable of moving as well or as fast as they desire.

Transportation's requirements, solutions, emergencies and crises are cyclical, have occurred before and will continue to occur. It is that function, not directly biological, which supports our lives more than any other function performed by us or for us.

The early tribes transported themselves and goods by their own and animal muscles in search of food. The agricultural societies transported product to trade for equipment and material or stock.

Transportation was always accommodated by the development of paths, marked routes, way stations, harbors, piers and lights for the trickle of men, animals, boats and barges that existed as transportation. Every civilization, country, region or county of low population density, with no industrial or commercial make-up, existed comfortably under this design.

As population concentrations developed, because of the efficiency of certain ports or crossroads, ORDER and ORGANIZATION became a requirement. The requirement became obvious because of chaos. Hoards of animals, men and carts pushing, shoving, shouting, destroying each other's product, pride and sometimes lives was an obvious problem that had to be solved.

Elements of the problem were broken down and solved individually. The social problems of housing, feeding, vending and marketing were basically solved by providing lines of movement and direction. Streets, roads, and docking facilities were laid out, built and explained as the first steps in organizing transportation. Secondary transportation problems developed with population concentration. The ability to carry water to the population, to carry contaminated water and surface water away from the population added to the ingredients of the overall transportation requirement, created a crisis and was solved.

The industrial revolution did not really change the problem, but it did make it more sophisticated. People and goods had to be moved in larger quantities and faster than could be accommodated by natural means. The solutions were also more sophisticated. Steam powered ships and trains, and construction equipment made the moving of people, the extension of housing and utility facilities highly efficient. The number of pounds of people or goods moved per square foot of space per horsepower was quite high in the large cities at the twilight of the industrial revolution around 1910.

Because the physical ability to move efficiently brings a sense of freedom and well-being, the period 1870 to 1915 is often referred to as GOLDEN.

With the advent of the technological revolution, in the Twenties and probably approaching a phase change in 2000, we have once again witnessed the growth of CHAOS.

The innate intellectual curiosity of man has led him – as always – to pursue the unknown. His present knowledge and tools have allowed him to discover, make use of, and build at a rate we have never before confronted. The products of this endeavor are always for the benefit or betterment of man's existence.

The by-products are not. The most intolerable by-product, normally, is frustration. We are back to pushing and shoving, destroying each other's livelihood and lives.

The required rate of change of our position, our effort, our housing, our education and our recreation has been increased by our specialization, interdependency, communication, information, wants and desires. The desire of mobility is of one revolution, and our mobility is of another.

A time lag has become apparent but the definition has not yet been attempted. The time lag is one created by the inability of the governments to communicate, or understand the warnings and proposals of the technological community.

The government is defined as that group equipped with and given the authority to make policy decisions. Technology is that element which explores, discovers and builds. The two are divergent. The policy maker has a formulated approach to policy, is conservative and dependent on statistical proof of past performance. He understands human weakness, the requirement of public relations and is more often than not a good administrator, if one considers the infinite number of problems a populace creates and demands of him to solve now.

The technologist on the other hand is of a far more radical and freer intellect, capable of and dependent on, working in those areas of no previous statistical history.

The attention span of the politician is far too short, his intellect far too formalized, his time too devoted to the present, to cope with a developing gap between private and public technology.

The governments establish technical agencies but as secondary tools. It is hard to find a technical agency which has, as its head, a capable technologist with full authority to make policy or counter a private trend.

The highway system being completed in 1972 was proposed in 1939. The recently inaugurated water shed studies, and water protection inventory build-up was a standard engineering school exercise of the Forties. The plea for balanced transportation was repeated in technical publications throughout the world during the Fifties. Warnings about pollution, noise and air corridor overloads have also been published for the last twenty years. Neglecting the proddings of the governmental technical tools the policy makers have always moved too late, have activated the studies prepared for an earlier decade or have turned to the public for a specialized solution – apparently not recognizing that the depth of the social problems and frustrations grow with man's inability to move in search of work, housing, education and recreation.

Without a proper understanding of the depth of the problems, the methods available to solve them, the scope or even the rudimentary definitions, policy makers are scattering efforts, plugging leaks, attempting to by-pass development stages, ignoring some components of transportation, halting the development of others and in general are reacting in panic, resorting to propaganda and selling partial solutions which only compound the problem.

One way to view the existing conditions in transportation is from the point of total use; the movement of all people, goods and utilities. Clearly this leads to a declaration of physical scope, international, national, corridor, intercity, commuter and intracity.

This paper is concerned only with the physical aspects of the problem, that is to say, definitions, impacts, functions, procedures, location, equipment, costs, time requirements and scheduling.

The problem is horrendous! The time and costs requirements exceed any effort previously undertaken. The challenge alone is worth the effort; the rewards should include a higher degree of physical freedom, flow of goods, and personal comfort than any of those ever-glowingly promised by the propaganda machines of the symbolic Madison Avenue or a peoples' republic.

Because we have allowed one problem to merge with subsequent problems we are faced with the requirement to simultaneously attack every facet of movement. It is necessary to look at total populations, geographical sizes, densities, physical shape and the physical interdependence between and of our population centers. A center of 1,000,000 population has an obviously different requirement than one of 50,000 regardless of density or orientation.

Concentrations of traveling population is not completely represented by a density figure. Variables of importance are the physical area which effects the time and length of travel. The proximity to a second or third population center, which influences the direction of traffic flow. The land use, residential, commercial and industrial concentrations determine peaking times and transit catchment areas. The physical shape can determine sequence; coastal cities are excluded from total radial development. Life expectancy of industry, residential area integrity, recreational facilities all contribute variables of a PROBABLE influence nature but for the most part have not played an important role in transportation planning in the past.

The population densities of most of the world's major cities vary from 5,000 per square mile to 30,000 per square mile. The areas vary from 30 square miles to 500 square miles. The day and nighttime populations of specific areas within the cities vary, due to a reshuffling of people; and this reshuffling represents the transit requirements of the city, and will hereunder be referred to INTRACITY – transportation.

INTRACITY TRANSPORTATION is the oldest crisis, and for this reason represents the prime producer of our frustrations.

We will first have to state the problems as they exist within the scope of population size and within a set of definitions.

The user of transportation who follows a reproducible pattern in direction and time for the purpose of going from his residence to his place of work we will define as a commuter. Strangely enough a commuter's definition is not confined by distance only, but by the energy he is willing to expend. It is a fact that to most people traveling more than one hour, as a commuter, is beyond the accepted standard of convenience. Time not distance is a basic factor in a commuter formula. A four-mile walk, 28-mile train ride, 180-mile flight are possible commuter distances. There are then two commuting definitions: intra- and extra-city commuting.

It becomes obvious that any intracity transit form has to provide for the reshuffling of the day and night population within its physical limits. This intracity system is a prime system. Depending on city size it can be made up of rapid transit trunk lines plus sub-rapid transit feeder systems. The trunk lines may also be fed by long distance suburb-to-urb express systems that in turn are supported by residential feeder systems. To incorporate order to this mushrooming reasoning, it is necessary then to start with a unit and expand.

Let us assume that the unit city requiring transit is a unit of 50,000 people and having an area of 16 square miles. The city is isolated, has no suburbs, but with a financial and commercial area at its core, an industrial perimeter, and an agricultural area surrounding it.

There will be a transit requirement for commercial business workers and city administration workers in one direction and industrial workers in another.

Children will have to go to school, and shoppers, messengers, service people and visitors will move into and about the core during the day. If we assume maximums as design conditions we would have the following requirements: 7,000 industrial workers, 5,500 core workers, 7,000 shoppers and visitors, 10,000 school children, and 15,000 trucks, service calls and deliveries. If the time allotment is one hour and if the city is an ideal square or circle, and if no one walked, the entire transportation requirement for maximum conditions would require 80 buses on 16 bus routes, using one square mile of the city's area. The maximum walk required by any rider would be less than 5 minutes. If schools were placed strategically the bus requirement would be reduced to 40. The above assumptions require no automobiles, indicates an ideal mix of origin and destination, and reflect the importance of the rudiments of applied land use planning.

Other elements in the transportation planning are the flow of water into the city, the flow of sewage and trash out, the flow of visitors and goods into the city, and the flow of raw material and manufactured items into and out of the industrial area; and finally the communication, power transmission and distribution systems. It is easily seen that the half-cities (port cities) have longer routes, and additional transport facilities have to be accommodated.

The society of this ideal physical setup will have automobiles and will want to travel to other cities so that the direct routes will have to exist between cities and will have to be accommodated by the core. For the buses, the service vehicles, the visitors and the pedestrians, only 25 percent of the area of the city will be required for roads, streets and sidewalks – an area of 4 square miles.

If we increase the population density from 3100 to 12400 (New York's density is 24,000) what happens? The industrial band will increase in depth and area. The housing will change in character. The bus routes will become extended and at 200,000 population under ideal planning condition, with six or seven buses per mile on every bus route, the bus as a transit system begins to break down as a reliable convenience. Frustrations produced by longer waits, delays, longer trips, and crowded housing triggers a move to housing beyond the industrial belt. Because transportation now has to be done by automobile, the new housing, related services and commercial establishments are build first along the existing intercity roads and later generate their own feeder road system. The automobile now takes over a transit function for a significant part of the population. Convenience dictates the choice of vehicle. The degree of frustration dictates the definition of convenience.

If the automobile driver were severely restricted by space or cost, when he attempted to park, he would revert to the more convenient transit system. If the automobile driver traveled at 9 miles an hour, paid $4.00 to park and understood the physical danger he was in during the 3/4 hour trip to his suburban home, and if an alternate existed providing reliability, twenty-four hours a day, he would not use his car as a transit vehicle.

If however, highways are provided, conduits into the heart of cities, which increase the delusion of convenience and mobility, the use of the most flexible, inefficient and expensive vehicle for transit, the automobile, will be encouraged. Is the automobile inefficient? As a high density intracity transit system it is idiotic. As a mainline commuter system it is inefficient. As a low-density suburban civilian system it is possible. As a family holiday intercity or inter-region conveyance it is wonderful.

The history of our present crisis is practically the history of our affluence and our car. Some would like to equate our problem to affluence, but this is nonsense. The problem is a misapplication of two good tools, the automobile and public relations. Most cities grew from a basic plan somewhat as described above. Growth developed beyond the industrial belts and incorporated them, a secondary industrial belt grew beyond that. Increase in density, and the merging of population centers are characteristic of the east coast of the United States.

Public monies were never applied to planning, were diverted to indiscriminate construction of housing, and were applied to a massive attempt to accommodate the automobile, always with the promise that new roads would bring relief. Conversely the maintenance, rehabilitation, protection and development of the existing transit systems was neglected.

The newer population centers of the west coast, saddled with no existing transit systems, were designed for the automobile, with a glistening understanding of human weakness. A living and working sprawl followed the roads.

For different reasons we now have two corridors of population concentration, San Francisco to Los Angeles and Boston to Washington. Within the boundaries of these corridors exist all the problems of transportation and all the related frustrations. Less prominent but developing are other corridor sprawls, Chicago-Detroit, Detroit-Cincinnati, Atlanta-Birmingham – future problems.

There is now, a requirement to apply our massive technological capabilities to the crises areas. Is a solution possible? How long will it take? How much money will be expended?

There is no doubt we can solve the problem. It will take at least five years to complete. We will expend 70 billion dollars. To tiptoe into the problem, to search for a maybe compromise, to assume that another study committee will somehow allow the driving commuter to make better time getting to his destination is but to continue the process that we have followed.

The solution is relatively easy once a scope of procedure is adopted. The scope should include objectives, time schedule, monies, for transit construction now for the entire problem. The scope should also include planning for new areas of transit problems making an appearance within our country. The scope should further include planning provisions for an increase in global interdependencies and the accommodation of a product of the interdependencies – a rapid rate change in global travel and exchange of commodities and manufactured goods. The fact that all things have a life expectancy and will have to be updated and replaced, precludes the thinking that what we do will be for once and for ever. The technological evolution will call for vehicle changes every twenty years.

The procedural requirements then are to provide: intracity transportation systems for all cities by classes of population and density, suburban–urban transportation, intercity transportation, and feeder systems.

The requirements for all these systems are clear, and are in effect axioms: 1. Reliability – continuous operation, 2. Frequency – convenience, 3. Accessibility, 4. Non-competing integration.

The choice of system is easily defined by the logic of arithmetic. If an important direction of travel must accommodate more than 5,000 people per hour for any hour, the automobile must be abandoned as a possible solution. If the same route has to accommodate more than 15,000 people per hour the bus must be abandoned as a solution. In short above 15,000 passenger volume per hour requirement it is necessary to consider only guided vehicles.

The often presented but neglected physical requirements are rather spectacular for each category. For 50,000 passengers per hour in each direction the requirements are: 30-ten foot lanes in each direction and 1,000 cars per lane per hour, land use is 600 feet of road, 4-13 foot lanes in each direction and 180 buses per lane per hour, land use is 104 feet of road. A precision spacing of 20-second headway is used in the bus calculation. Subway, rail or guided vehicle trains would require thirty, eight-car trains on one guideway each direction. Rail land use 30 feet.[1]

The comparison must lead one to conclude that there is no alternative system to guided vehicle trains for the traffic volumes we are required to accommodate now. This of course does not eliminate the automobile. It can play a vital part in a complete transit system.

If we build on 50,000 population units with densities increasing from 3,000 to 30,000, we can establish a quick transit selection index which would be useful as a capital expenditure estimating tool. The unit can be applied as an isolated city, part or parts of a suburban area, a multiple of an urban unit, or the characteristic central business district, CBD. The transit selection index should

[1] "Les Transport Urbains" – Langevin

be in a form applicable to a variety of conditions and capable of being adjusted by the obvious modification of shape and time.

We have adequate arithmetic tools in the form of statistics to examine a transit corridor first. We can examine each isolated metropolitan region, each suburban area, each city, and each central business district within the total corridor length, make simple assumptions, develop definitions and applicable equations, and determine transit requirements and then the expected costs. A second set of selection requirements are land use acceptabilities, social benefits, and expected variables that will modify the selection over a period of time. The third set of selection requirements are of a purely practical nature and are related to existing technology, and the adaptability of present technology to the expected next phase.

For purposes of defining the problem scope, let us define a corridor as a series of closely interdependent populations centers, such that the popular desires require physical linking of transit facilities, a loss or merging of region or even sectional definition, no clear cut, one directional catchment area. This merging of population centers through suburbs and road growth has been referred to as coagulated sprawl or a megopolis and is indeed in existence.

It is possible to plot the densities as contours from Boston to Washington, D.C., and they, through an interpolation, can provide us with the insight to our problem, its scope and cost. The requirement to connect these centers by a transportation means is obvious. How they should be connected is not so obvious. The connection however is intercity and establishes a definition.

Railroads, airlines and recently highways connect these centers. Highly developed highway designing techniques, vigorously pursued standards and construction schedules have resulted in a desirable, and valuable national network of intercity transit routes; but in most areas they are only valuable as routes and do not provide transit systems. A very interesting broad aspect to consider is the following development of highways.

The rural highway has developed not the urban road system. (Fig. 1) At the very basis of our problem is this simple fact – that our older cities as originally laid out, have not increased their road network areas. They have been paved, and improved, but have not increased in total area. The area within any city limits has a more or less regular grid pattern of streets and roads, originally developed to accommodate surface transport, the internal shuffling of people and goods.

Around the city grid has developed a secondary and larger but much less formalized grid of suburban areas. Through them both have come the interstate highway systems. The intercity traveler on this intercity link is joined by thousands of extracity commuters – suburban residents, and as he approaches

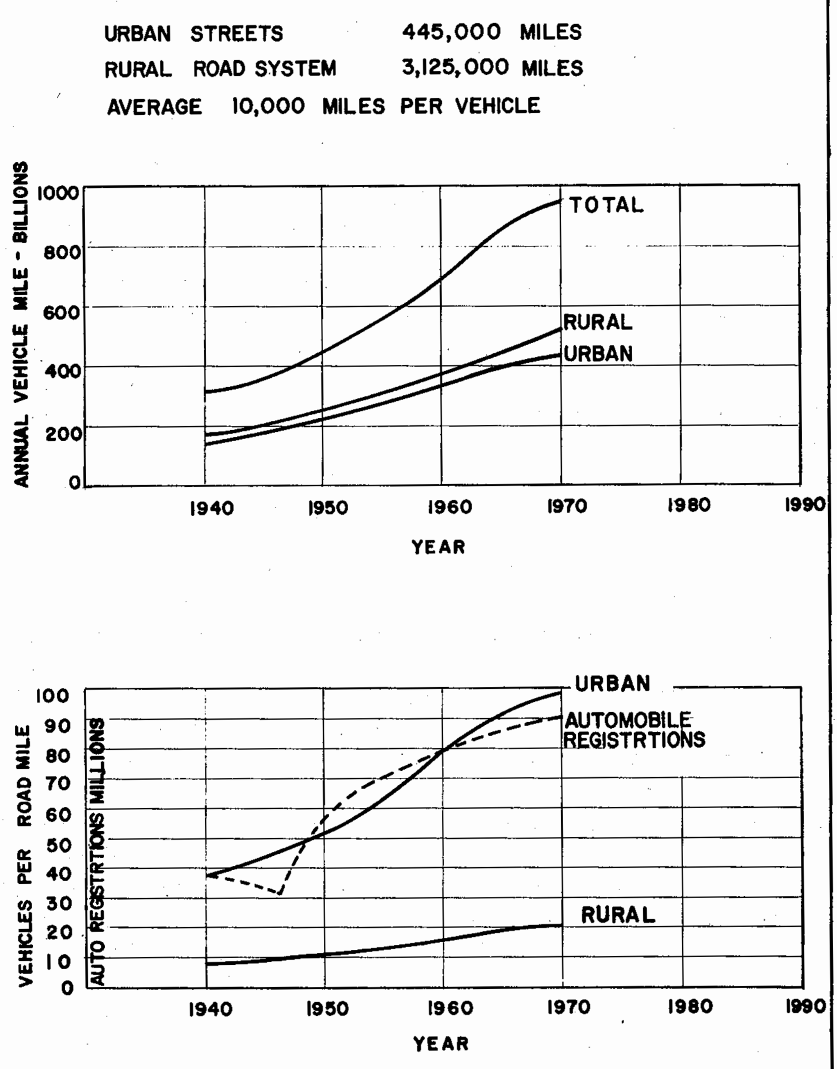
URBAN STREETS 445,000 MILES
RURAL ROAD SYSTEM 3,125,000 MILES
AVERAGE 10,000 MILES PER VEHICLE
ANNUAL VEHICLE MILE - BILLIONS
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FIGURE I

the city perimeter the volume increases. The speed of travel decreases. Crossing the city perimeter is the interstate and many arteries feeding directly from the suburbs. The objective is to get into the city grid.

But the grid has its own function. It provides the means to shuffle its own daytime-nighttime population as well as storing the automobiles of its residents – on-street parking. Worse! a great proportion of all the cars in motion have a more or less single objective – the CBD.

The actual paved area assigned to the moving of cars can be computed. The area requirement of cars moving at various speeds (the higher the speed the more area required) can be computed. The number of cars owned by the residents of the city and the percentage of these parked in the streets during the rush hour period can be computed. The volume of cars dumped by the arteries and the number of arteries entering a grid certainly can be computed.

What can we tell from these computations? When and where bottlenecks will appear on the arteries as well as in the grid; whether or not the grid can accommodate the discharge from another artery; at what point the physical dimensions provided by paved streets and those required by the automobiles are equal, or approaching equality.

When the area of vehicles equals the area of streets, the result is a zero velocity. From this we can establish an acceptable vehicle velocity which of course will be more than zero.

The initial absorption rate of the grid is directly related to the automobile ownership within the grid. This is a function of the population size and make up. If there are twelve single-family units along one side of a city block sharing three lanes of street with twelve family units across the street, there will probably be one lane available for movement if the city cars are parked on the street. There will be two lanes available if they all park in garages but use their car to go to work or school. If the number of family units increases say to 150 family units on each side of the street, the problem obviously becomes intensified and also indicates that traffic volume is a function of density and again allows a method of establishing design criteria. The computation of traffic volume can establish points of transit requirement, the nature of the transit means, as well as its direction. The street absorption capacity of the grid can tell us how many lanes of onslaught can be tolerated; how far apart the entering arteries should be at the city perimeter; when, where and how large the parking facilities should be; what we can expect in the future under constant conditions; and if we wish, how to control the direction of growth.

If we look closer at the major crisis problem, the metropolitan area – city and suburbs, perhaps certain truths become apparent.

The suburban area will be defined as an area contained within a thirty mile radius of the geographical center of the city but beyond the city limits. The CBD, central business district, as that area within the city limits which has the highest destination count; or put another way, the highest daytime population. The general statement that the CBD is relatively definable, its density and area computable for most cities, is not weakened by the existence of certain cities such as New York where more than one CBD, as defined, might emerge.

This Metropolitan Area can be studied as a cell – a metro-cell, wherein certain predictable and precise physical things happen. The metrocell is also subjected to roughly predictable variables and also to those products of chance not within the behavior pattern of our mathematics, such as flat tires and breakdowns.

The suburban shell is comparable to a sponge which injects a large number of people and vehicles into the more dense nucleus. The initial target is the city perimeter, and for a high percentage the final target is the CBD. The sponge causes a reversal of the process at the end of the day. The first desire is arrival. The second desire is ease of arriving. It is not uncommon for the outer shell to inject into the city area as many people as there are people occupying the city area. It is apparent that providing easy automobile access to the city perimeter does not solve the extra-city commuter problem.

Dumping a high volume traffic load generally into the grid will absolutely reduce the area of the grid available to the city residents, the maintainers of the grid. That grid which originally (in some USA cases over two hundred years ago) was designed as a minimum requirement to provide them with order, direction and the capability to move towards the CBD. This area-available reduction will produce an increasing reduction of the rate of travel as the distance between the CBD and the driver becomes smaller. The rate of travel by car becomes ludicrous in most cities of high density. A twenty-minute period at 9 mph velocity decreasing to 3 mph is not uncommon. It is also not transit.

Certain routes are relieved for a very short period of time by a drawdown of a certain route volume. This drawdown is accomplished by the construction of parking facilities or the creation of space – parking lots – by the destruction of a building. An obvious solution to increase the travel rate would be the conversion of the bulk of the grid to parking facilities. Of course this would eliminate the reason for going to the city. Obviously illogical? But this is what we have been doing! Daily, in every city we are forcing an existing and limited intracity commuter network, road grid or transit system, to accommodate the full brunt of extracity communters, often equal in number to four times the total moving population for which the grid or system was designed. This surely has to be ridiculous!

More startling, however is the attitude of the policy makers in arriving at a solution. They have, until recently, been convinced that by increasing the accessibility of the suburban driver to the city the problem will somehow be relieved, so the area of country roads and arteries to the city perimeters has increased and been improved. Ludicrous! The interstate highways, really an interregional system very often enters cities and provides off ramps into the cities, not only where there should be none at all, but in violation of all engineering principles, at frequencies endangering the interstate user and usually located by the dictates of the ward heeler through whose immediate district the illogical structure transverses.

Recently, very recently, existing transit systems have been proposed for expansion and again the resistance to logic is monumental. In the face of technological advances we are proposing seven- or ten-mile extensions of obsolete intracity systems, which have been physically neglected, and politically overburdened. These existing systems in most cases, no longer connect the correct residential areas with the CBD. Their direction, orientation and even function were designed for other criteria. The question of even keeping some of the systems has to be addressed.

We have in fact, in those areas of high density and large population, at least three broad problems to solve. Each problem has more than one facet. Using assumptions based on population, density, area, volume computations we can establish directions, modes, and costs on a broad but reasonably accurate basis. Starting with the activity in the Central Business District only, we can expand our examination to encompass any area of interest.

In most major cities, always excluding New York as a special case, the CBD area is relatively small, of one or two square miles. It has a high daytime population, has an almost ironbound grid pattern, and provides a great diversity of activity. The movement of people and auto traffic in the CBD is a scatter pattern without usable, definable direction or volume.

The area because of its isolated transit requirements, definable physical shape and daytime density, requires isolated attention. Using a unit area of one square mile and a basic population of 50,000, an internal CBD transit system can be developed to provide complete mobility for the daytime inhabitants of the CBD.

It is proposed that in all cases where the density of a CBD reaches an arbitrary figure of 30,000, private automobiles be prohibited within the area. That an internal, automated, continuously-operating shuttle system of transit be installed, and operated at no cost to the rider. This system will be no longer than eight miles, but not reasonably less than six miles per the design unit. The cost of construction for the maximum 8 miles will vary, depending on the mode adopted from 19 million dollars to 80 million dollars, and has to be considered as a city investment. An operating cost of twenty million dollars per year must be anticipated which includes provision for vehicle replacement every twenty years plus the updating of overall plant and equipment.

The street pattern, without the private automobile, becomes available to pedestrians, the development of parks, and emergency, taxi and service vehicles. The dissolution of city-owned garages, parking lots, towing services, traffic control demands and parking meters would help defray the cost of the CBD transit operation. The physical aspects of the CBD would be greatly enhanced, the mobility of the daytime occupants would increase, the flow of goods in and out of the retail area would be accelerated; in short a form of orderliness would be added and a striking apparent waste would be eliminated.

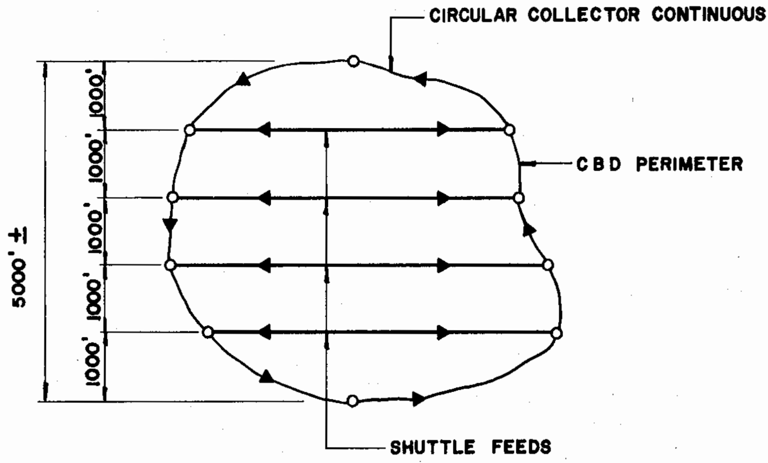
In general the orientation of the system can take two positions: a circular collector, plus shuttles having a continuous perimeter operation plus shuttle feeds. Straight shuttle dividing the CBD into four strips each direction provides a pedestrian with available transit for an average maximum walk of three city blocks. The population movement, route volume and mode selection are demonstrated at the end of the paper in the total system determination discussion.

The peripheral area of the CBD, still within the city confines, will be the area to collect the automobiles in parking facilities and the discharged passengers of the intracity transit system. In the spongy area of the suburbs, the automobile, in many cases, can serve as a reasonably efficient feeder system delivering the commuters to one of several backbone lines traveling express through the city perimeter and directly into the center of the CBD network. The suburban feeder system, also dependent on local densities, should vary by design, the private car, a mini-bus system, or a full scale bus grid.

These direct high-volume rapid transit systems are the extra-urban commuters' transit and must be regular and continuous in operation with a two-minute headway schedule. One of these routes will also serve as the initial leg of an intercity system, going beyond the outskirts to the next major population center and, in the case of the east coast corridor, forms the basic spine of a fast-developing requirement for corridor rapid transit.

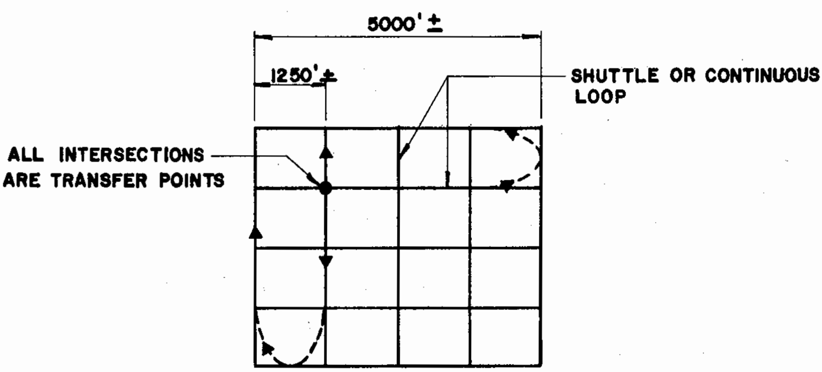
Now we have the skeletal outline of a solution: A. CBD people mover, B. Intra-city transit, C. Extra-city transit, and D. Inter-city transit. None of these systems can be competing. The automobile will of course provide some competition on the city streets and from the suburbs, but a very high cost of parking can discourage the car as a regular way of movement. More important the existence of a fast, regular and comfortable transit facility will make the auto too inconvenient an alternate to encourage its regular use.

Transit within the city limits must serve the residents of the city in two



SHUTTLE COLLECTOR GRID

FIGURE 2



STRAIGHT GRID

FIGURE 3

major ways, it must provide commuter transit, not only to the CBD, the working area of white collar, relatively high income population, it must also make mobility available to the young unskilled, generally unskilled and to the industrial workers, who travel to the city outskirts and beyond for their employment. It must allow a direct and easy access to a variety of housing to accommodate the many reasons people have, at any point in time, to change their residence.

Ideally then there should be an intracity rapid transit network designed without a target (the CBD) and providing ease of movement indiscriminately.

Depending on the densities involved, part of the system will be guided, part transit feeder, part car feeder, and part pedestrian feeder. It will be necessary to provide intracity commuters access to the extra-commuter system, at peripheral points of intersection. It will be necessary to provide catchment areas for automobiles at these same points of intersection.

With at least one concept developed we can determine specific requirements and estimated costs.

Total System Determination

Let us consider the east coast corridor for analysis based on the above concept for time, cost and mode.

By category of population and density: A. New York; B. Boston, Newark, Philadelphia, Baltimore, Washington, D.C.; C. Providence, Camden, Newark, Paterson, Trenton; and D. Hartford, Bridgeport, New Haven, Elizabeth.

Boston is at the top of the corridor, contains all facets of the problem, handles them at least as poorly as any city and for this reason is in at least the same state of transit emergency as any city. The city population is about 700,000, the area about 46 square miles, and it has a density of 15,000. A metropolitan population of about 3.5 million and a metropolitan area of roughly 450 square miles, has an average density of about 7,200.

It is a half-city and because the ocean prevented expansion eastward, the lines of travel are more concentrated and longer. The grid pattern in the CBD, the oldest part of the city, is tortuous.

The rapid transit system, one of the oldest in the world, is a combination of street cars and subway rapid transit cars sometimes operating underground, sometime on the surface and sometimes elevated – almost always poorly. It has been neglected in favor of a well-conceived highway system that brings cars into the city and the city to her knees.

The almost 100 year old transit design that extended into the early industrial areas and the commercial heart, from the residential areas of the workers and homes of well-to-do now performs according to no design at all.

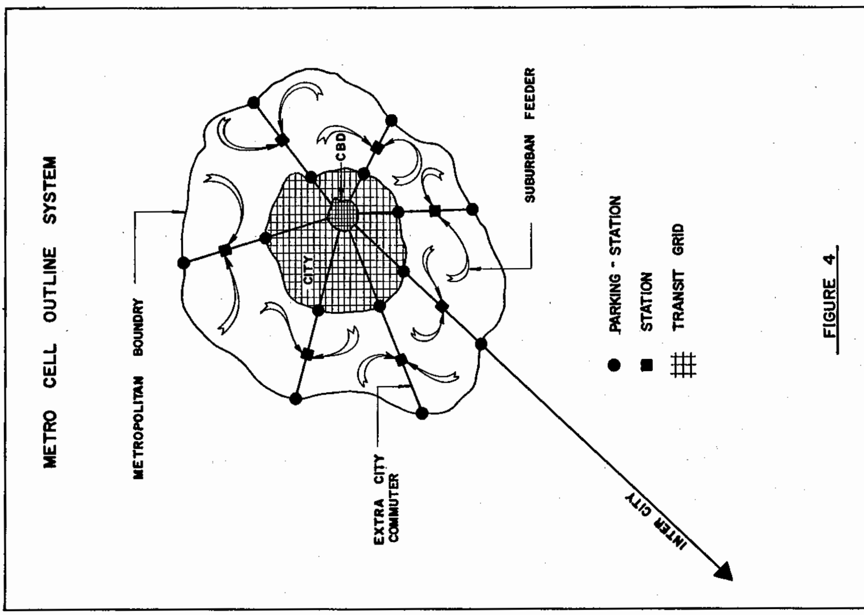


FIGURE 4

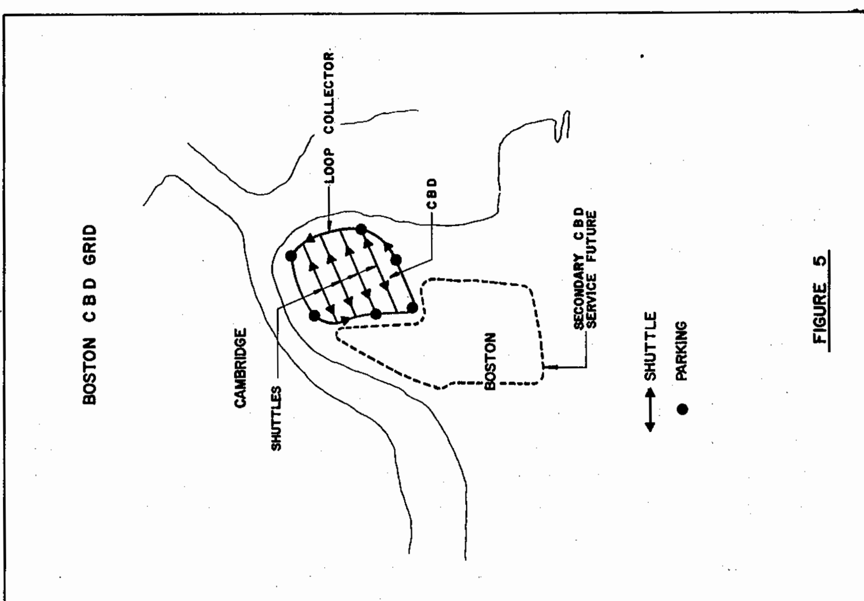


FIGURE 5

Large portions of the city occupied by the unskilled and the poor are serviced by a system which will bring them to the CBD where they are unemployable either by training or desire. They cannot get to the areas beyond the city where much of the industry has moved or developed. For a large portion of the population movement in one direction is useless and in the other direction almost impossible. The forces to make large portions of the population stay-put are enormous. If staying-put denies access to work, education and better housing, frustrations naturally develop. The denial of mobility also concentrates present-day social problems into the so-called ghetto.

A complete transit system must be designed for the Metropolitan Boston Area. It is not possible to contemplate the reliance on the present MBTA to perform anything but a holding action while a new system is built.

Boston Design Assumptions

CBD:

Area	1 Square mile
Population	150,000
Density	150,000

Dimensions of CBD Automated People Mover:

Loop collector 3.2 miles
4 shuttles @ 0.9 mile average each = 3.6 miles
Six parking facilities on the loop collector
Parking capacity 2400 automobiles.

The CBD mover can be an elevated guided system. The exact route as well as the mode can be argued – the requirement, however, cannot. For the Boston CBD, a collector route from South Station to North Station along and serving the emerging residential waterfront, from North Station through Government Center to Stuart Street, and thence to South Station, supported by, more or less, parallel shuttles, operating free and continuously above a street pattern void of automobiles, is at this point in time almost a requirement.

City Grid:

Area	46 Square miles
Population	700,000
Density	15,000

System Dimension:

F_T Transit flow directions $=\sqrt{\text{area}}$ = 6.4, say 3 routes
fL Load factor = 4÷6 = .67
City-only volume per flow direction

V_T = .06 x 700,000 x .67 = 28,000
L_T Length of each flow direction = $0.5\sqrt{A}$ = 3.2
Total length of rapid transit requirement = 19.2 miles

Feeder system completing the intracity grid dimensions. Buses using restricted streets would shuttle on a parallel street pattern, in individual loops. Transit stationing at one-mile intervals. Each bus loop would intersect each transit line once at a station, and the theoretical city boundary twice in each mile per side parallel to the transit line. A simplified possible formula could then be:

Length of one city side $\sqrt{A}$ miles
Number of bus routes per side = $2\sqrt{A}$
Length of each bus route = $(\sqrt{A} + 1/4)$ miles
Total length of bus routes = $2\sqrt{A} \ (\sqrt{A} + 1/4)$ miles
$L_B = 2 \times A + 0.5\sqrt{A}$ For Boston L_B = 2x 46 + 0.5 x 6.4 = 95.2 miles

Using a headway of 1 minute and average velocity of 20 mph there would be a maximum requirement of 300 buses to complete a total city grid system.

City Grid Summary:

Transit system	19.2 miles
Buses	300 units
Stations	21
Parking	5,000 cars

Boston Metro Cell Design Assumptions

1. Use Route 128 as a collector.
2. Population 3,600,000 less Boston = 2,900,000.
3. Area = 450 square miles less Boston = 404 square miles
4. Average metro density = 7,200

F_T = $\sqrt{Area}$ = 20, 10 routes
f_L = $4 \div 20 = .2$
V_T = .06 X 2,900,000 X 0.2 = 34,800
L_T = $0.5\sqrt{A}$ = 10 miles
Total Length = 20 X 10 = 200 miles rapid transit.

Extra Urban System. 2 lines are inter-urban extensions, three tie into intra-city system. The collector system can be computed for estimating purposes

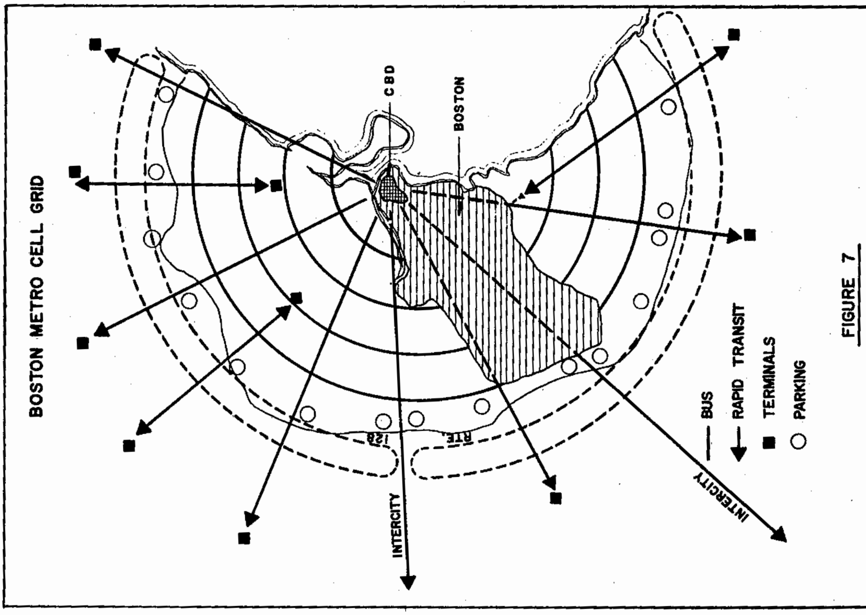


FIGURE 7

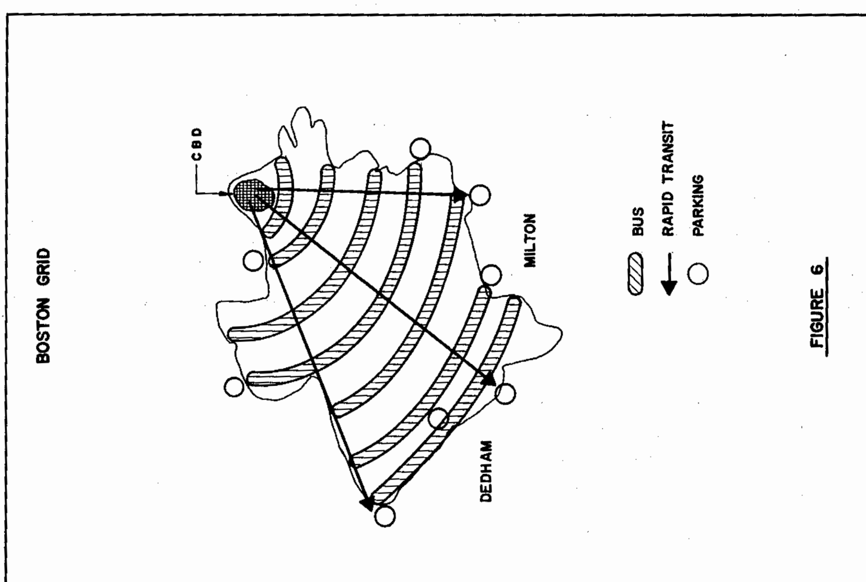


FIGURE 6

as a bus system with a main collector on a lane of Route 128, the circumferential highway now existing as a rough bisector of the basic Boston suburban area. Bus route computations for suburban grid.

$$L_B = 2 \times A + 0.5\sqrt{A} = 810 \text{ miles}$$

At 5-minute headway and 30 mph, the total number of buses required for the collector system equals 324 units.

Parking for 20,000 cars at twenty parking facilities.

It is assumed that the automobile will be an effective collector adjunct for the suburban areas; and the buses, in addition to providing collector services for the extra-city transit system lines, will also be the transit system for some of the cities within the metro cell.

Suburban Grid Summary:

Rapid transit system	200 miles
Buses	324 units
15 parking facilities	15,000 cars

Summary of total requirements for Boston metro cell

A.	All Rapid transit systems	225.8 miles
B.	Buses	624.0 units
C.	Parking facilities	22,400.0 autos
D.	Stations and terminals	59.0

Cost per mile by mode varies greatly, from 1 million dollars per system mile to 21 million dollars per system mile. For purposes of ascertaining the money magnitude of the east coast corridor transit solution, I am certain that the most desirable transit mode falls well within the estimated figure of $5,000,000 per mile. The rapid transit system cost is based on this $5. million per mile.

A.	$1,129,000,000
B.	31,000,000
C.	20,000,000
D.	59,000,000
	$1,239,000,000

Preliminary estimated capital cost = $1,239,000,000, for Boston Area, or

$350.00 per person. The corridor to Washington D.C., has eleven major areas of transit requirement and a total effected population of 40 million people. A rough estimate of what we need is simply

$$4.0 \times 10^7 \times 3.5 \times 10^2 = 14 \times 10^9 = \$14 \text{ Billion}$$

The design must be controlled on a corridor basis. This is simply a matter of plotting the density contours along the corridor. Connecting the density contours provides an inter-metro cell line which can serve as a rough route for estimating purposes and master plan development. Within the high-population, high-density metro cells, suburban, city and CBD grids can be layed out, initially by formula, then by geometry again to provide rough solutions for master planning and estimating.

To make the transportation projections a proper positive tool, international transportation should be superimposed on the corridor spine. Harbor designations and most important international airports should be made. Land use designations, following along and guided by the transit links, governing industrial housing and recreational growth makes far more sense than altering transit to accommodate indiscriminate building patterns.

International freight and passenger airports should straddle rapid transit facilities. Of prime concern has been the overloading of the air routes. However, with the advent of the large 500 passenger jets, the air route congestion could decrease – while the ground traffic to and from the airports becomes impossible. It is a distinct probability that there will be a passenger discharge rate of 30,000 per hour at our major airports by 1977. They must straddle or be accommodated by acceptable rapid transit.

Transit mode selection, based on system comparisons is a subject of study in itself. But the elements affecting a selection are rather clear cut.

CBD

1. The system should be underground – any mode can operate underground.
2. The speeds should be low.
3. The system – because of its simplicity – can be automated.
4. The rides should be free of rider charge.
5. The luxury items of privacy and extra comfort design should be minimal, because the use time per passenger is minimal. A CBD people mover is no more than a conveyor or horizontal elevator. Our present technology and

design capability would guarantee far more acceptable vehicle comfort than the existing operating transit systems, even on a minimal basis.

City Grid

1. Any city with a density of 5,000, a city population in excess of 200,000 and a suburban population of at least 200,000 must resort to rapid transit arteries extending through the suburbs, connected by a bus collector system. the grid should be truly a grid which results in any destination within the city being reached by one transfer only.

The transit mode can be underground or elevated guideway. But the system should be designed to accommodate both modes.

2. The bus collector system should travel on restricted street patterns, and on continuous elongated loop schedules.

3. The rapid transit vehicles should be designed for maximum accommodations. If the design was to be interchangeable with the suburban and even intercity systems, a pattern of maintenance and operational procedure could be initiated that would greatly simplify design, planning repairs, replacement and most important provide for future innovation.

Maximum accommodation requires low noise levels, frequency, personal physical comfort and peculiarly a feeling of privacy. This means, merely modern industrial design, comfortable seats, air conditioning, simplified fare collection, and a form of quasi-compartmentalization of the vehicles. The speeds of a city system are more or less fixed and cannot begin to approach the nonsense headlined in many proposals.

One convenience of a system is its accessibility. An intracity system requires about a one mile station spacing. This limits the maximum speed to 60 miles per hour. At this speed and 2-minute headways, a maximum trip in a city like Boston would mean less than 20 minutes including a transfer – certainly acceptable, compared to the impossible one hour requirement by automobile.

Extra Urban Grid

1. Should be an extension of the city transit lines, plus one intercity line plus filler transit shuttles, with a collector system of bus, mini-bus and automobile feeding the peripheral grid ties.

2. The vehicle accommodation should be the same as the intra-city system.

3. The mode, again can be underground or a guided elevated system.

4. Speeds, because the suburban station spacing can be at four-mile intervals, can be increased to eighty miles an hour. There cannot, however, be

any consideration given to surface transit which includes operations at grade intersections. The extra-urban transit system must maintain rapid transit frequencies which eliminate, signal controlled at-grade intersectional vehicle mixtures of guided vehicle and automobile.

Inter City Systems

1. Speed is the only design change advanced above the extra-city urban commuter system. Station spacing of twenty miles would allow speeds of one hundred and twenty miles per hour, within the scope of our related technology governing passenger psychology, physical comfort, guideway and vehicle dynamics.

In considering the transit modes there are several basic elements that must be evaluated. Any long distance, high-speed system requires an exactness of horizontal and vertical alignment. For at-grade dual-rail systems this must mean a structure of significant proportions. A roadway, in the conventional sense, would require cut and fill construction resulting in the familiar highway-railway embankment design. The speed requirements would refine this criterion so that, in my opinion, this structural system, enjoying a two thousand year history, is beyond consideration for the following reasons:

1. Right-of-way requirements and land taking are beyond reasonable acceptable standards. The existing railroad rights-of-way are not applicable to the high speed design or operational criteria.
2. The roadbed, contrary to general belief, is not stable and would require almost unattainable maintenance and repair.
3. The embankments required would form a very positive land divider as have our highways, but to a far greater extent.
4. The construction of embankments, particularly those of considerable length (400 miles) absolutely affect the surface environment. Water courses, regional water sheds, storage, estuary and river interaction would be halted or changed. The embankments are dikes, to the psychology, to the population, and to the behavior of our regional water shed areas.

There is then a choice to go underground or above ground. This choice is restricted by cost considerations. Our present construction technology indicates that we can build certain types of elevated structures far cheaper than we can underground structures. This, of course, is completely dependent on the choice of the structure. The smaller the structure, the lower the cost, and the more acceptable it is to the sensitivity of the viewer. The elevated guideway has another advantage. It can accommodate the advent of the next generation of transit vehicles.

At present we have operating transit tools that include trains, rapid transit cars, a variety of bus characteristics, vehicles on elevated roads, suspended and supported monorails. Figure 8 indicates a profile comparison of the structural requirements.

The next generation (15 to 20 years) vehicle will be either the tracked air cushion vehicles or the magnetic levitation vehicles. The structure requirement we select now should be able to accommodate this anticipated replacement. If our future track requirements can be accommodated by the smallest, the least expensive and the most experienced guideway system for the next fifteen years, it seems contrary to logic not to employ the advantages of the supported monorail.

Financing of the east coast corridor system in its entirety at 14 billion dollars, of course, presents a problem – but strangely enough not of money. The project will require no more than 6 billion dollars in any one year and will take five years to build.

If we consider the east coast corridor, the west coast corridor, the mini-corridors of the middle and southwest and south, the total expenditures would equal no more than seventy billion dollars, over a minimum period of 5 years, or 14 billion dollars a year.

I would suggest the following program for money appropriation.

Money Sources

A. Gasoline tax, 4 billion dollars per year. This leaves, at present rates, ample funds for highway maintenance.

B. Military budget, 10 billion dollars per year. The entire program design and construction to be administered by the U.S. Army Corps of Engineers. The logic here is the military has the capacity to get the money and the Corps of Engineers has not only the experience and the precedence, but the capability beyond any other national organization to undertake and complete a national civilian project of this magnitude, if their sights can be elevated above a railroad concept.

C. All but the city-sponsored CBD would be capitalized federally.

D. A system not burdened with capital debt-reduction could operate at a profit if it were not politically overburdened or sabotaged in some other way. To preclude or at least postpone this likelihood, I propose that the transit systems be turned over to legally formed cooperatives made up of the transit employees – trainmen, operators, dispatchers and bus drivers to operate as their business within each regional jurisdiction, but subject to operating and physical requirements established by the United States Department of Transportation

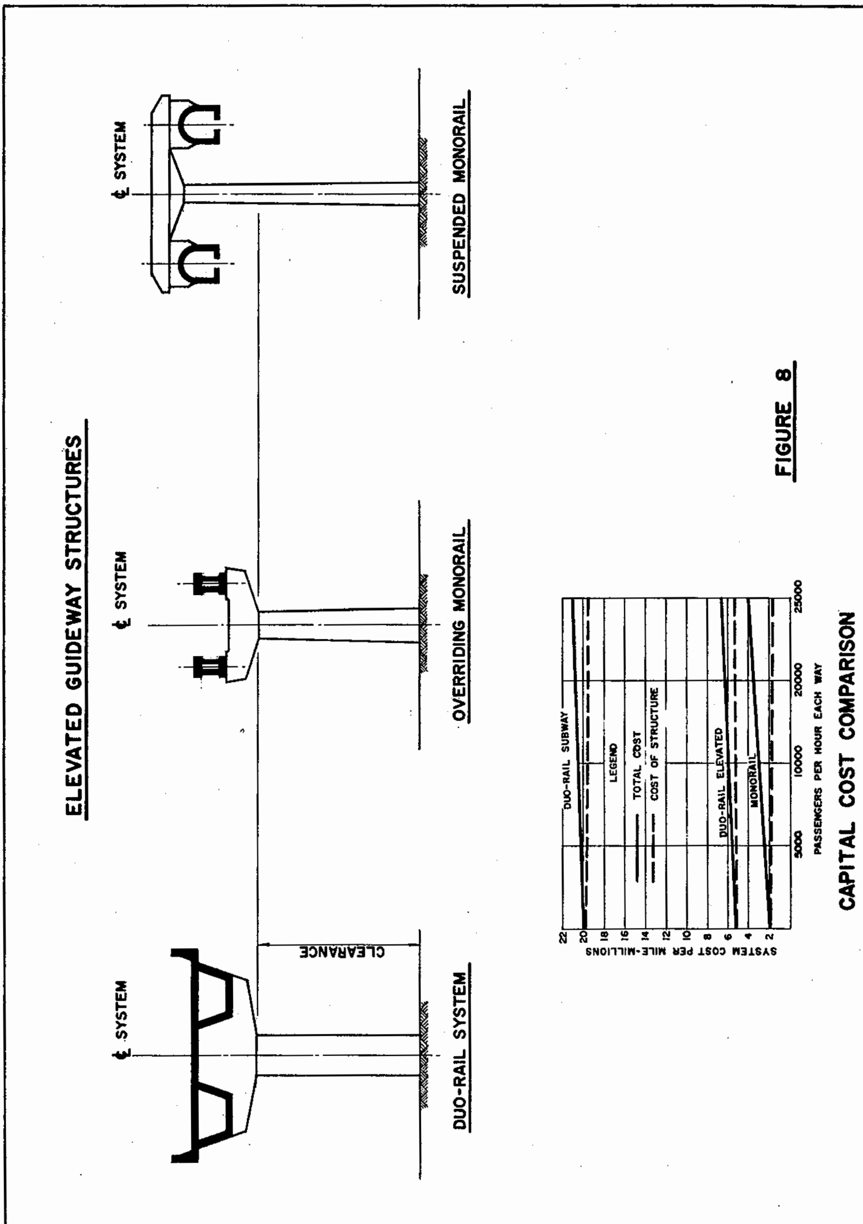

ELEVATED GUIDEWAY STRUCTURES
℄ SYSTEM
℄ SYSTEM
℄ SYSTEM
CLEARANCE
DUO-RAIL SYSTEM
OVERRIDING MONORAIL
SUSPENDED MONORAIL
DUO-RAIL SUBWAY
LEGEND
TOTAL COST
COST OF STRUCTURE
DUO-RAIL ELEVATED
MONORAIL
SYSTEM COST PER MILE-MILLIONS
22
20
18
16
14
12
10
8
6
4
2
5000
10000
20000
25000
PASSENGERS PER HOUR EACH WAY
CAPITAL COST COMPARISON

FIGURE 8

whose functions will include passenger comfort, research and development.

While the expenditures are great, they are no greater than what we now experience, the military might find their funds easier to allocate if they consider the value of such a system in the case of a national emergency; the turmoil over busing would be solved, the intra-extra city congestion would be alleviated, the frustration and the erection of symbolic ghettos due to immobility would wane; and while Snow's law – the inability of the administrator to plan ahead – would be violated, we would alleviate the future shock and provide, with a minimum of frustration – mobility.