Dual-Mode Transit Concept of General Motors Corporation

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General Motors has completed the concept feasibility study and preliminary design of a dual-mode transit system. The basic system involves a modified version of the GMC motor home operating off the guideway in a relatively conventional manner and on the guideway in an automatic mode with both lateral and longitudinal control effected by communication signals from a buried wire loop. System operation will be 25 m/s (82 ft/s) in corridors and 12 m/s (39 ft/s) in the central business district. Communication is accomplished off the guideway through ultrahigh frequency equipment and on the guideway principally through a very low frequency and low frequency link. Principal modifications to the vehicle are required to accommodate load changes due to the 17 seated-passenger capacity, a unique positive switching dèvice, and an electric propulsion unit added to the primary internal combustion engine. The propulsion system combination provides for backup redundancy as well as acceleration boost allowing reduction in kilometers of guideway. Representative approaches to guideway and station design have been developed to the preliminary design stage; however, site-dependent considerations will determine detailed design. Station configurations incorporating mode-interchange facilities, 2 to 5-berth sawtooth platforms, and accommodations for processing as many as 3200 passengers/hour have been studied. Concentration in these areas has been on cost minimization. Preliminary analytical work on control and scheduling development confirms the feasibility of the system approach.

The dual-mode transportation system (DMTS) concept has long been of special interest in the planning for future transportation needs at the General Motors Corporation, for DMTS represents the logical marriage of automatic and manual control of vehicles and is a first step toward the automatic highways of the future. Evolution of a dual-mode system, partially funded by the U.S. Department of Transportation, allows one facet of the total dual-mode concept to be developed into an operating system. Particularly, the improved service level offered by DMT can be the key to real ridership increases, thereby alleviating the urban congestion problem that now exists in most major cities. Fast, comfortable, predictable service is the combination that will attract new riders, not from other existing transit modes or on a novelty basis but from the habitual core of normal rush-hour workday automobile trips that constitute the bulk of the congestion problem. General Motors has been engaged as one of three competing contractors in the development of the dual-mode concept design. Though considerable work remains to be done in subsequent phases, an attractive yet practical, dependable yet flexible, and efficient yet reasonably achievable system has emerged.

Practically all public transportation systems, if they carry a sizable percentage of the repetitive automobile trips that now account for a large segment of the vehicle-kilometers in urban areas, will relieve congestion, emission, and energy problems. Discussions on absolute values of each solution tend to be subjectively weighted, often subconsciously, toward support of the reviewers' particular system. Probably more important considerations are the practicality and the availability of a particular approach, presuming it can be attractive. We maintain that the system concept whose development status is described briefly in the following pages offers a unique combination of these attributes.

OVERALL SYSTEM DESCRIPTION

The GM dual-mode system incorporates a modification of a 7.9-m (26-ft) GMC motor home into a 17-passenger bus, operating conventionally on existing streets for off-guideway passenger pickup and in a noncontacting wire-following mode for guideway operation. A multilevel computer and communication system uses both ultrahigh frequency for radiating off-guideway communication and very low frequency for dependable noninterfering communication through the buried wires on the guideway. The system operates in a synchronous-slot longitudinal control mode at approximately 5.7-s headways at corridor speed to satisfy the required theoretical capacity and brick-wall stopping criterion. The latter, of course, needs to be relaxed before full system potential in traffic densities can be achieved. A summary of system characteristics is given in Table 1.

SYSTEM CONFIGURATION

A baseline system network was supplied for study purposes in phase 1. GM evolved typical scenarios for system evaluation and prepared typical demand model data consistent with theoretical capacities, which were then used in dynamic simulations, cost analysis, station-sizing analysis, capacity and headway studies, and guideway design studies. Results of these investigations have been reported in detail to UMTA and are implicit in the equipment concept described in later sections of this report.

Typical corridor and CBD arrangements were devised from the initial system requirements of the phase 1 contract. For some of the aforementioned studies, rigidly symmetrical networks could be used, but concern for practicality led to the attempt to apply the DMTS concept to a specific urban area. A natural candidate, because of its proximity, size, and lack of existing regional transportation systems, was the Detroit metropolitan area. Figures 1 and 2 show the corridor and CBD arrangements that evolved. The extent of the phase 1 study did not require, nor did time allow, study of the detailed needs of the area and approaches for meeting those needs. Rather, the concentration was on the feasibility of an overlay of the DMTS on the area.

One of the critical observations made of DMTS is the value of replacing drivers for a relatively short trip. Although arguments relative to anticipated inflationary effects of labor costs can be treated in the cost analysis, Figure 1 shows that a 16-km (10-mile) corridor, in the case of a moderately large city, is scarcely half of the 1980 corridor need and probably a fifth of the length of the network corridor needed for the metropolitan area anticipated in the 1990 period. If one assumes the addition of circumferential networks (also shown in the figure) and that longer trips are more advantageous to a driverless system, then the dual-mode system in moderate to large cities, especially those still expanding, becomes increasingly attractive.

Major concerns in application of any new transit system are urban upset and cost. Installation of a relatively high-speed system, i.e., approximately 12 m/s (39 ft/s) in the CBD, in other than the expensive subgrade configuration is generally expected to cause considerable devastation to the urban fabric. Our application studies indicate that realistic systems can be acceptably integrated in the urban scene. Figure 2 shows an arrangement of a two-way loop and two one-way transverse sections, configured to existing streets and architecture, which would serve this entire area with average walking distances of approximately 150 m (500 ft). Though all necessary constraints were not rigorously applied (for example, no investigation was made of utility rearrangement needs), a system of this type could be designed with an acceptable impact. In fact, preliminary studies indicate that the establishment of station areas could be less disrupting if existing parking facilities are used as sites for downtown stations. The shaded areas shown in Figure 3 are parking facilities in the Detroit CBD. The reference circle around the station in the upper left area of Figure 2 has a 305-m (1000-ft) radius indicating that CBD coverage for a city as populous as Detroit can be achieved with a reasonable number of stations.

Off-line stations are used to achieve an acceptable system capacity; however, guideway length increases as a result. To minimize this effect, on-guideway acceleration and the capabilities of a secondary electric propulsion system are part of the system concept.

VEHICLE

The vehicle used in the GM dual-mode system is a modification of the concept currently in production at GM for commercially available motor homes. A standard motor home drive train incorporating a production 194-kW (260-hp) internal combustion (IC) engine features a front wheel drive allowing a lower floor and a lower center of gravity. A wide-track, 3-axle arrangement gives the vehicle greater stability, easier handling, and a smoother ride than conventional dual-axle design. An air suspension system with automatic height adjustment increases passenger comfort. The model used for the DMTS is about 8 m (26 ft) long and 2.5 m (8.2 ft) in width and height with a gross vehicle weight of 7300 kg (16 094 lb). This exceeds the expected gross weight for the 17-seated-passenger configuration envisioned for the system, allowing growth to a larger system capacity at the option of a particular operating property. Figure 4 shows an exterior view of a vehicle, and Figure 5 shows the interior seating arrangement including the optional accommodations for a wheelchair passenger. Significant redesign of critical components is necessitated by the rigid safety requirement imposed on an automatic system. Among these are the modifications required for steering, propulsion, and braking systems to incorporate redundancy and fail-safe requirements as well as to allow the automatic control system to operate.

Two major changes in the overall vehicle configuration exist in the areas of propulsion and positive switching. First, the propulsion subsystem will be a combination of the production internal combustion engine as a primary power plant, and a battery electric drive as the secondary power source. The IC engine will drive the front wheels in the arrangement used in the production motor home, while the electric drive will power the rearmost wheels as shown in the chassis arrangement (Figure 6). The secondary propulsion system, consisting of two chassis-mounted 26.1-kW (35-hp) electric motors and powered by a high-voltage (240-V) battery pack, will function in several modes. In case of a primary propulsion system failure, a speed of 12 m/s (46 ft/s) can be maintained within system nominal conditions. This speed allows full performance operation in the CBD area where system blockages are most critical. This is also a reasonable speed for removal of the vehicles in corridor areas and will minimize system down time after this type of failure. In addition, the backup propulsion system augments the primary power capability when required on or off the guideway, for example, to reduce required acceleration lane length in the severe combinations of 6 percent grade and 48 km/h (29.8 mph) headwind, which are system operating extremes, and for off-guideway, low coefficient of friction surfaces. Figure 7 shows the operating range for the propulsion combination. The propulsion system, which includes both primary and secondary sources as well as braking and steering, is under control of the vehicle computer.

Also shown in Figure 6 is the conceptual drawing of the vehicle-mounted portion of the positive switching mechanism. This device consists of a single arm that is mounted below the vehicle and engages a slot in the guideway. It is retractable for off-guideway use and, although always extended for guideway operation, only affects the vehicle movement in case of a failure of the primary lateral guidance system at a switching area. The mechanism consists of a pair of rollers on an arm suspended from a transverse shaft mounted near the center of gravity of the vehicle. When the vehicle approaches a switching point, the arm is driven along the shaft to a biased position such that, if the lateral guidance system fails, the rollers will ride along the proper leg of the slot and force the vehicle into the desired path.

Brake, steering, and suspension systems have all been modified from the production motor home systems to accommodate dual-mode requirements, particularly the fail-safe characteristics of vital functions. Brake systems, in particular, incorporate a split-system design with full redundancy through the wheel cylinders. One redundant pair of elements, including master cylinder hydraulic lines, brake cylinders, and controllers, controls the front brakes, and a second redundant set controls the four-wheel rear braking.

Figure 8 shows the cab area of the DMTS vehicle. The front compartment of the vehicle is isolated by enclosure panels and a sliding door in order to protect the controls area from access during guideway operation. It is necessary to neutralize the driver controls as well as to provide a secure area in the right front of the vehicle for the automatic control equipment. During guide-

Table 1. Characteristics of system elements.

Element	Characteristic	Amount or Type
System	Headway, s	5.68
	Operating speed, km h	
	Corridor	40.2
	Central business district	19.3
	Theoretical capacity	
	Seats per lane-hour past a selected point	10 800
	Seats in operation at one time	30 000
	Actual capacity, passengers per lane-hour	2500 to 7500
Vehicle	Capacity, seated passengers[a]	17
	Propulsion	
	Primary	Oldsmobile Toronado drive train
	Secondary	Electric motors, battery powered
	Deceleration rate, g	
	Service	0.225
	Emergency	0.525
	Braking, steering, and suspension systems	Split and redundant
Communications	Off guideway UHF[b]	
	On guideway VLF and LF, kHz	18, 29, 48
Command	System management computer	Passenger and vehicle assignment
	Sector control computer	On-guideway vehicle management
	Vehicle control computer	Vehicle control
Control	Lateral, wire following (1 of 2 frequencies)	
	Longitudinal	
	Benchmark magnets at intervals, m	12.5
	Absolute position at intervals, m	500
Guideway	Above, at, and below grade	
	U-shaped	
	Interior curbs for vehicle containment	
	Precast, prestressed concrete beams	
	Nominal elevated span, m	25
	Superelevation, max	0.12
Stations	Capacity	
	Vehicles per hour	320
	Passengers per hour	2000 to 3000
	Berths per platform (sawtooth form)	2 to 4
	Merge lane lengths, m	
	Corridor	340
	Central business district	160
	Diverge lane lengths, m	
	Corridor	190
	Central business district	80

Note: 1 m = 3.28 ft; 1 km/h = 0.62 mph.
[a]Including alternate wheelchair position. [b]Number of channels dependent on system size.

Figure 1. System network in the Detroit metropolitan area.

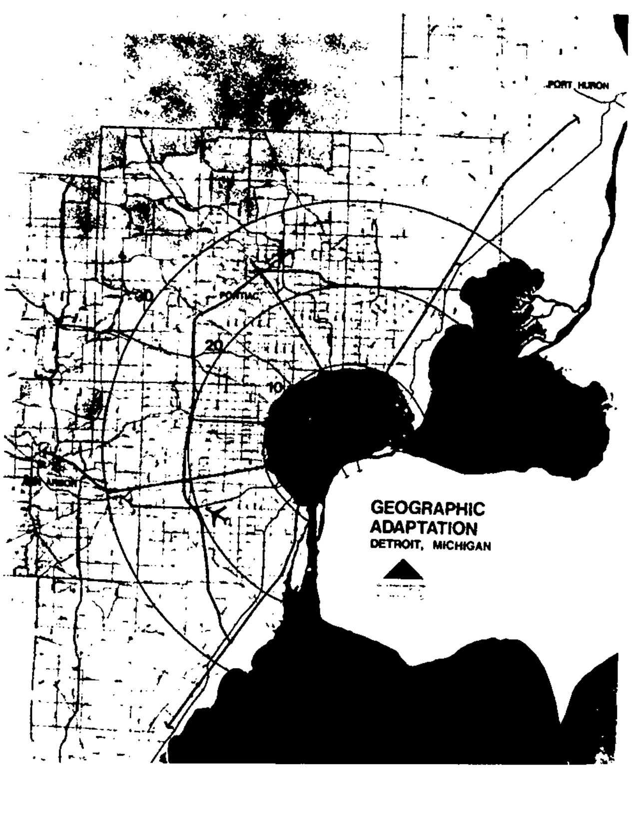
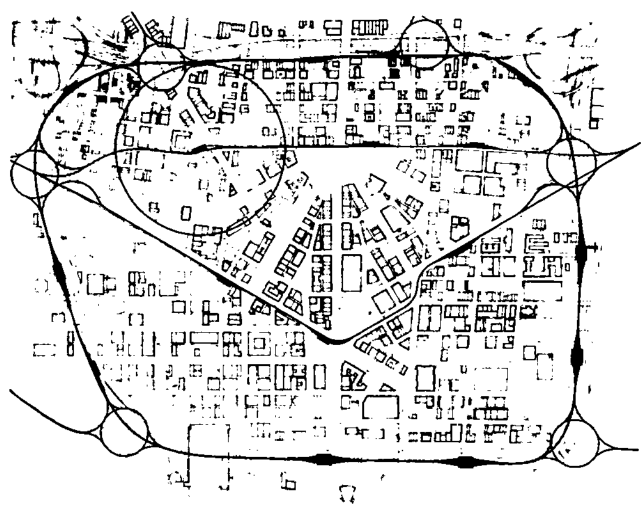


Figure 2. Loop in Detroit central business district.



way operation, all of the equipment is operative but isolated from access except for the steering wheel. Since steering wheel motion is likely to be disconcerting to the passengers and also provides a less predictable inertial element to the control system, the spline shaft will be disconnected. Figure 9 shows the combination door and step mechanisms, which can be varied in height to provide level station exit, a step for curbside operation, and a street-level elevator position to accommodate the handicapped. A minimal amount of ticketing and fare collection equipment will be provided on the vehicle and will be used primarily for trips that

Figure 3. Parking areas in central business district.

Figure 4. Dual-mode vehicle exterior.

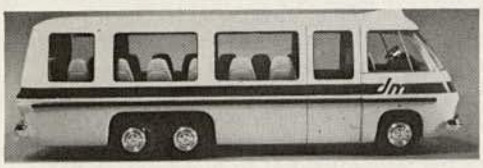


Figure 5. Seating arrangement.

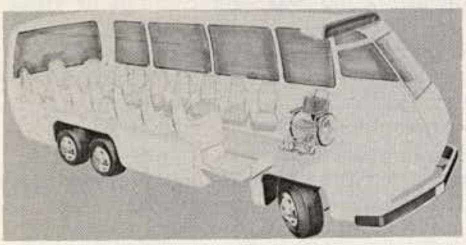


Figure 6. Chassis arrangement.

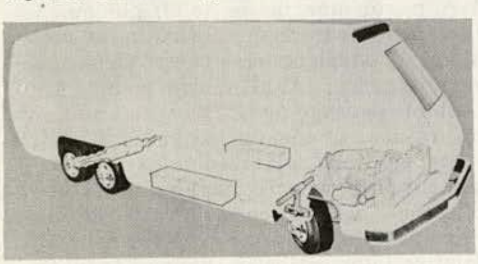


Figure 7. Propulsion operating range.

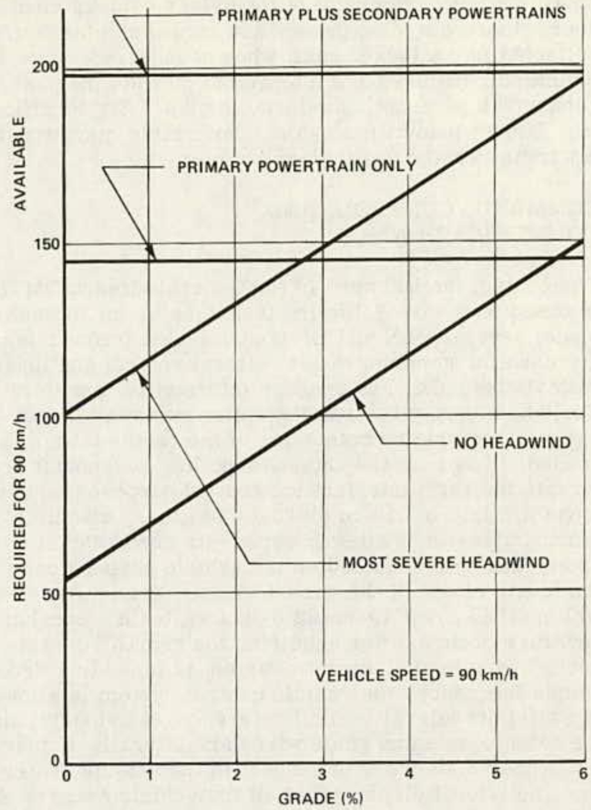


Figure 8. Cab area details.

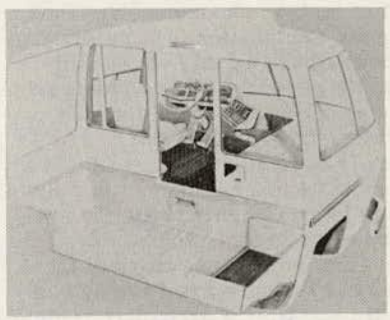
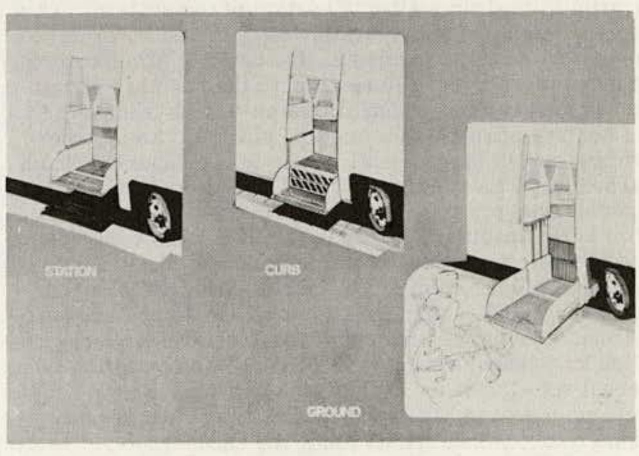


Figure 9. Door area details.



begin and end in dial-a-bus zones. Figure 8 shows the small window to the right of the driver compartment door, where boarding passes are issued and fares are collected into a locked vault when necessary.

Interior features are intended to provide the passengers with a pleasant, comfortable ride. Air conditioning, large window areas, and comfortable, personalized but transitworthy seating are planned.

COMMAND, CONTROL, AND COMMUNICATIONS

The control method used in the General Motors DMTS is based on a wire-following technique in the automatic mode; several VLF and LF transmission frequencies are used for communication, lateral control and longitudinal command, and position information transfer. Buried antenna wires run the entire guideway length along either side or both sides of the center trough, as needed. To break the antenna length at reasonable intervals for ratio interference control purposes, antenna loops are laid in 510-m (1673-ft) lengths. A vehicle moving along the guideway zeroes its error signal from an antenna bank mounted on the vehicle perpendicular to the length of one of the buried wires. Nominally, every 500 m (1640 ft), a 10-m (32.8-ft) longitudinal overlap of coverage occurs; after acquiring the signal from this second wire in another set of antennas tuned to a second unique frequency, the vehicle control system is allowed to switch its lateral control reference. Obviously, since the antenna sets and guide wires are laterally displaced the proper distance with respect to the vehicle centerline, no lateral displacement of the vehicle occurs. At a switch point, either for route switching or for station entry diverging, the wire configuration is arranged to allow the vehicle to select the proper switching path as commanded by the sector control computers. As shown in Figure 10, each antenna combination is a collection of phase-sensitive devices whose signals, when collectively decoded, indicate the deviation of the vehicle from its nominal path, producing an error signal that the control system nulls to achieve the proper path.

Longitudinal control of the vehicle (shown in Figure 11) is achieved by a combination of equipment on and off the vehicle. The vehicle is synchronized with the system time reference upon entry to the automatic system. The system management computer keeps track of the passage of imaginary blocks of space along the system routes as a function of time. After a particular vehicle has been assigned to one of these slots, pertinent information on its scheduled trip segment is transferred to an appropriate sector control computer, which manages traffic in real time along a portion of the system. This sector might be defined by guideway distance, switches, merge or diverge segments, or stations. The sector computer transfers information to the vehicle through the buried cables, which allows on-vehicle knowledge of desired position as a function of time. Among the succession of incremental magnetic benchmarks, which are set into the guideway at 12.5-m (41-ft) intervals, are unique markers occurring in the overlap area for the two buried cables. At this unique benchmark the system and vehicle trade identification, allowing the absolute position of the vehicle to be established. Each successive incremental marker allows an update of vehicle position. System control, however, requires a more precise knowledge of vehicle position. To accomplish this, wheel speed sensors, which also provide traction control information, are used to update position versus time on a continual basis along the entire route.

Other data are also transmitted to the vehicle as part of the interface message structure. Door commands for station operation and system control modification instruction, such as direction on which control wire to follow at a demerge to accommodate scheduling requirements, are typical of this information.

UHF communication equipment is also incorporated into the dual-mode system. In off-guideway operation, driver instructions from the system are transmitted to adjust routing or identify passengers. In on-guideway operations, the UHF equipment is used to provide emergency communications in the event of on-board incidents, vehicle failure, or system problems affecting scheduled operation. A noninterfering geometry of frequency coverage adapted to local conditions is used to accommodate anticipated load.

A hierarchy of processing equipment exists in the DMTS, as shown in Figure 12. At the highest level, the system management computer operates on requests received through telephone operators, subscriber lists, historical data, and automatic ticketing machines to schedule vehicles into the system (both for dial-a-bus and automatic operation) and passengers into the vehicle. Slot information, relative to the passage of slots and their occupancy by specific vehicles, is maintained in the management computers. The management computer also assigns passengers and monitors entry and egress from the vehicles through turnstile equipment to ensure a seat for every passenger and to limit access to a particular vehicle only to scheduled passengers. Fare structures and computations are accomplished by the management computer using stored data or ticketing machine inputs. Depending on operating policy, accounting usage and revenue information are also maintained in the management computer.

The second level of processing equipment in the system is the sector controller. At a mode interchange, the sector controller operates the vehicle through its initial entry into the system at the diagnostic bay. Then it commands the vehicle through its merge with vehicle traffic already extant on the guideway or through its diverge into a platform berth, if required, to pick up passengers arriving at the station by other means. The sector controller, after interchanging information with the management computer, which assigns a vehicle trip to a particular slot, finally determines the launch of the entering vehicle and thus allows it to merge after partial acceleration. The sector controller also monitors vehicle performance in maintaining position during its passage either to its next main-line departure point or to the sphere of influence of the next sector computer along the system path.

The last of the elements in the processor hierarchy is the vehicle processor. Along with controlling acceleration and deceleration to maintain proper position during launch, merge, demerge, and constant speed segments, the vehicle processor also monitors vehicle diagnostic sensors, operates traction control devices during acceleration and deceleration, and exchanges data with the sector controller for performance verification. Antilock braking is controlled by the vehicle processor both on and off guideway. Steering is fully controlled by the vehicle processor on-guideway but reverts to a standard power steering mode off-guideway.

Several smaller processors are included in the control system equipment, which provide independent monitoring for safety assurance. At all merge points, a set of passive, vehicle passage sensors operate in a logical "flip-flop" manner to ensure that, when a vehicle is in one of the merging links, other vehicles are commanded to remain out of the second merge link. This action is controlled by a second processor also as simply mechanized as possible to ensure greatest reliability. If the modulating information is removed from the carrier signal on the buried communication loops, intruding vehicles are stopped.

Since much of the system safety responsibility and availability potential depends on the automatic control system, substantial redundancy and cross checking pervade the design. The system management computers are fully redundant, for the loss of this function would require complete system shutdown. Safety is not adversely affected by this loss, for the sector computers control the system to a safe stop; however, system availability would be severely affected by anything other than a negligible frequency of occurrence. The sector computers operate in pairs; each has primary responsibility for one sector, yet has monitoring and full takeover control for the functions of its mate. Redundancy of VLF and LF antennas and receiver-transmitters as well as of actuators and electronic drivers is also provided. In addition, since redundancy does not normally improve safety performance of controllers, cross checking and monitoring by the various process levels and built-in reasonableness checks are used.

GUIDEWAY

The cross section of a typical elevated guideway section is shown in Figure 13. The basic guideway running surface is formed by two symmetrical segments, which can be precast for elevated sections but can be poured in place for on-grade lengths. The slot extending down the center of each lane for the full guideway length is required to accommodate the mechanical arm that ensures positive switching in the event of the loss of primary lateral guidance control at the switch areas. At other than switching areas, containment of the vehicle is effected through the use of curbs, which are shown in the figure along the side of the running surface. For further protection of the vehicles, side walls or rails are provided along the guideway length to ensure containment of the vehicles in the guideway envelope if, for example, a rollover should occur. The walls further serve to reduce noise and minimize entry of extraneous material to the guideway.

In an automatically controlled system of the length anticipated for reasonable DMTS installations, environmental conditions would be extremely difficult to monitor to the extent necessary to guarantee proper track performance throughout the entire system length. Clearly, even intermittent loss of traction (for example, a single ice patch or a snowdrift on a curve) could cause considerable damage and stop service in a transit system of this type. Since monitoring equipment is not now available that would allow us to modify speeds according to widely varying road conditions, the generally acceptable solution in this case is to provide for melting ice and snow and draining the water. Studies were performed for the GM dual-mode system on guideway snowmelting and drainage techniques. Figure 13 shows a heated-liquid, snow-melting system just under the running surface. This technique proved to be the most economical, both in cost and energy consumption.

The center slot, which is included to accommodate the positive switching mechanism, is also expected to include water collection and drainage facilities. This should ensure that rapid drainage occurs, obviating both the refreezing and hydroplaning problems that would otherwise result.

Alongside the center on either side are the buried cables used for command, control, and communication. One segment of the loop appears just below the running surface. At loop ends a vertical or horizontal run removes the closing segment of the loop from the vicinity of the vehicle to minimize interference problems.

Though the backup mechanical guidance is only intended for use in the positive switching areas, a slot is provided throughout the length of the guideway to minimize the engage and disengage operations. The slot is made as wide as possible while still allowing full, free movement of the vehicle in its allowable lateral track. This allows elimination of as much material as possible from the supported elevated structure. As the vehicle approaches the switching area, the slot is narrowed in width and split into through and diverge segments. This occurs sufficiently in advance of the actual switching barrier so that, if failures occur in both the primary guidance and the mechanical switching device, safe stoppage of the vehicle can still be effected.

STATIONS

Two general categories of stations are anticipated for the dual-mode system: (a) a corridor station that includes passenger-processing facilities and a mode interchange for entering vehicles and (b) a CBD station that has no mode-interchange capability. No more than every other vehicle may enter a particular station. This allows a station with three or four berths to handle more than 300 vehicles/h depending on the efficiency of vehicle-processing time through the station. Figures 14, 15, 16, and 17 show typical functional areas of a corridor mode-interchange station. With careful design, even a relatively large demand station can be configured in a reasonable area. In this typical design the mode interchange, including entering diagnostic and departure lanes and ramps, is located in the lower level. The station passenger entry is also on the lower level, which has accommodations for kiss-and-ride, bus, and walk-in passengers as well as ticketing and fare-collection machines (Figure 15). Figure 16 shows the mode-interchange area of the station. Figure 17 shows the berthing and platform areas on the upper level, including passenger information displays, waiting areas, transfer equipment, and vehicle guideway lanes. Some measure of station requirements can be derived from the following sizing elements. Two to four-berth stations that can process as many as 320 vehicles/h and 2000 to 3000 passengers/h and diagnostic bay facilities that can process 180 vehicles/h could be included in a station that with mode-interchange facilities would occupy approximately 8094 m^2 (2 acres). CBD stations, generally one-lane arrangements not requiring a mode interchange, can process the same number of passengers in less than half the area.

STUDY RESULTS

A number of studies were conducted to establish reasonable functional concepts for system operation, for example, the establishment of vital functions, safety philosophy, and maintainability goals, including the basis for failure mode and effects analysis. In addition, a number of studies were able to establish quantitative values for system parameters such as headways, particularly as applied to the fully deployable system. A study was conducted to evaluate the achievable availability goal that could be applied to the full system. A tentative goal was selected. After apportionment of reliability and maintainability budgets was made, the projected system availability was calculated. Several iterations of this technique and reconfiguration of hardware were attempted when it was evident that a significant gain could be attained. For the assessed reliability and maintainability goals, the projected system availability became 99.8 percent. An example of the iterative nature of the process is the reconfiguration that occurred for the propulsion system. Originally, it was expected that a backup propulsion system would be needed to operate the system, since the potential of system shutdown due to a failed vehicle seemed intolerable. The cost of a secondary propulsion system was then evaluated, and its removal was considered as a cost-effectiveness measure. In the design process it became evident that the standard motor home IC engine might not be able to accommodate the system extremes in grade and headwind that were specified. Estimates of guideway costs indicated that adding additional lane-kilometers for acceleration with less propulsion capacity could outweigh the cost of added vehicle equipment even on a large complement of vehicles. Finally, the vehicle configured without secondary propulsion system did not offer the reli-

Figure 10. Lateral position sensing.

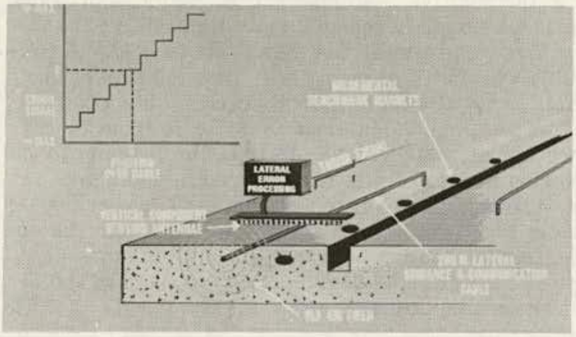


Figure 11. Longitudinal position sensing.

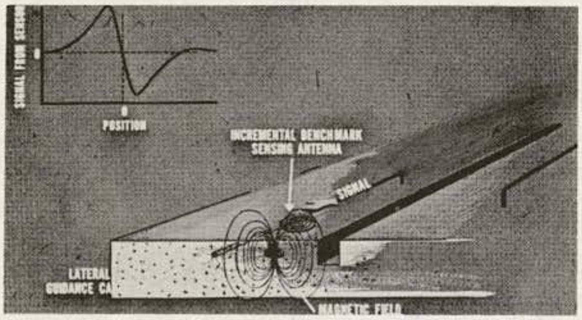


Figure 12. Hierarchy of processing equipment.

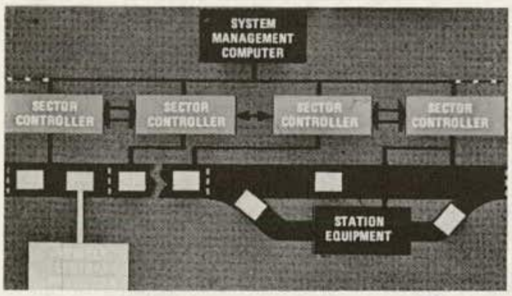


Figure 13. Typical guideway cross section.

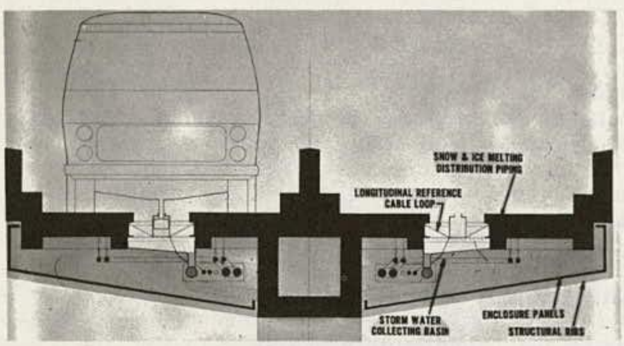


Figure 14. Dual-mode transit system station.

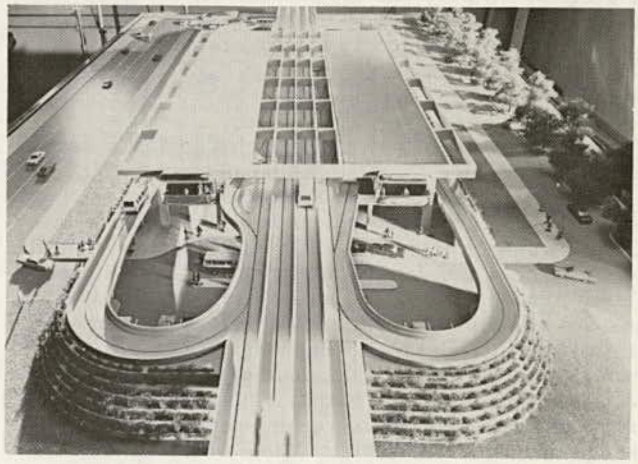


Figure 15. Kiss-and-ride area.

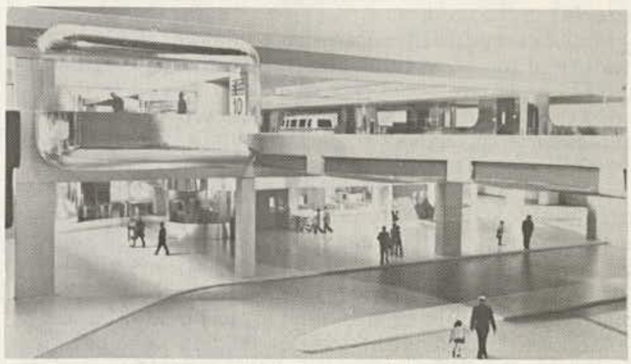


Figure 16. Mode-interchange area.

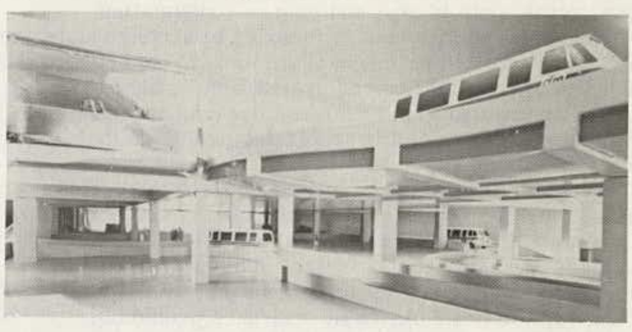


Figure 17. Platform area.

ability necessary to achieve the projected availability goal. The consequence of all of these separate factors led to the final configuration, which was described earlier in the paper.

Station sizing studies were made to establish planning figures for required area and system throughput. The system headway philosophy combined with a desire for minimum deceleration lane length led to a system operating decision that, at most, every other vehicle slot could be emptied into a particular station. With reasonable vehicle delays at the station, estimated station sizes of two to four berths were derived. A station with at least three berths will process 320 vehicles/h. Similarly, station passenger processing requirements were analyzed and reported. Typical throughput of 2000 to 3000 passengers/h could be accommodated with a reasonable station size and number of ticketing machine positions. These analyses are interdependent as well as site dependent. Relative to station capacities, only typical configurations can be described, since specific design is also site dependent.

An extensive study was conducted to determine projected system costs for a full-scale, deployable system in a medium to large-sized city based on the referenced system configuration that was developed from the guidelines supplied by UMTA. Although an exact cost of a system is meaningless without site-dependent assumptions, the intention of the cost study was to scale system cost in such a way that variations from the basic reference parameters of the system could be estimated by planners considering the dual-mode system as one of the transit options for a particular location. It is expected that a study of this sort becomes a dynamic document throughout the development life of the program, becoming more valuable to the planners as the system concepts develop and evolve. Estimates were made subject to the study assumptions. For example, land acquisition costs were not included in the study, and system loading figures cannot be verified until complete network simulations are prepared in phase 2. Under the conditions of the study, a system capital cost of approximately $350 million was determined for a system including 225 route-km (140 route-miles) of guideway, an operating fleet of approximately 2300 vehicles, 50 corridor and CBD stations, and ancillary facilities. Also, an economic fare of 66 cents and operating costs of 48.5 cents/vehicle-km (78 cents/vehicle-mile) and 3.9 cents/passenger-km (6.3 cents/passenger-mile) were estimated.

PROGRAM STATUS

We are completing the concept definition phase of the dual-mode program. The concept feasibility has been evaluated with the conclusion that the dual-mode concept is a potentially competitive system offering significantly more attractive service and therefore presumably having wider potential clientele than do existing systems. Hardware proposed for the system has not been designed in detail or tested as yet. In addition, extrapolation of small-scale system concepts into a full-scale system can be subject to error brought about by problems of system size. Hence, a large-scale simulation and software development effort have been identified during which a representative set of area requirements will be defined, demand data will be collected, solution configurations will be proposed, testing will be performed against the anticipated demand models, and decisions will be made about rules for system application. Finally, to avoid the problems that arise from applying the system without preparatory development and planning, an extensive study program will be followed to anticipate the break-in problems and development requirements to evolve from phase 2 tasks to phase 3 and beyond.