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# 1.0 EXECUTIVE SUMMARY

When exploring alternatives for premium transit, the initial decisions are most often based on the alignment and the available right of way, not the mode. The characteristics of a mode are likely to lend it to a specific set of alignment and right-of-way conditions: where there is room to maneuver at-grade, light rail offers significant advantages; where the alignment lends itself to tunnels, rail tends to offer the best performance. But where there are horizontal constraints which could be avoided by elevating the alignment, this study has indicated that monorail could offer significant advantages over conventional rail (e.g. light rail, heavy rail.) Because of this, monorail systems should be considered a viable mode of premium transit in future studies in Montgomery County.

In 2000, Montgomery County staff asked the questions, “Are we looking at all possible modal options for the variety of alignments currently under study in the County?”; and, “Are there others?” In addition to these questions, a variety of citizen groups had begun to ask, “What about monorail?” To answer these questions, the County initiated the Monorail Technology Assessment.

Historically, transit authorities have had reservations about monorails. There is a common perception that monorails:

- lack an adequate operating history
- use too many proprietary systems
- may pose safety concerns
- may pose operational problems during inclement weather
- are incompatible with the operations and maintenance of existing services

Although these concerns must be addressed, monorails still appear to have one significant advantage over other modes: where the alignment is to be neither underground or on the ground, but to work vertically rather than horizontally within an alignment, monorail appears to operate in a more efficient manner. The lighter footprint of the monorail guideway has the potential to reduce the physical and environmental impacts of an aerial structure while providing a level of transit service comparable with other premium transit modes. The visual presence of some monorail systems may also attract the attention of visitors and improve the public perception of transit services.

The Monorail Technology Assessment was performed to investigate the concerns, impacts, and benefits of monorail systems. Montgomery County investigated the full range of monorail technologies, then selected four systems for further evaluation to determine whether monorails could be used to meet premium transit needs in the County.

There are over 30 different transportation systems in the world which could be considered monorails. Many of these are hypothetical systems under development, but there are many existing systems being used in cities, airports, and amusement parks. This study identified and evaluated two existing systems and two systems under development. While there are other monorail systems whose capabilities may be comparable to those selected for this study, the four systems chosen provide a representative cross-section of both actual operating history of monorails as well as the potential advantages of new systems under development. The four systems are:

Figure 1.1. Example of a Hitachi monorail.

Figure 1.2. Example of a Bombardier/Adtranz/VonRoll monorail.

Figure 1.3. Example of a Futrex 21 monorail.


Figure 1.4. Example of a OTG HighRoad monorail.

**Hitachi.** Hitachi uses a straddle-type system where the vehicle “hugs” the guide way. The first system used in an urban setting began operations in 1964. Currently there are five existing Hitachi systems—four in Japan and one under construction in Malaysia. Hitachi offers small, mid-size, and large-scale monorail systems.

**Bombardier/Adtranz/Von Roll.** A firm formed through the merger of three vendors, the first straddle-type system developed by this group began operation in 1971; currently, there are more than 20 systems in operation throughout the world.

**Futrex System 21.** As can be seen in Figure 1.3, the vehicles in the Futrex System 21 hang off the sides of the monobeam, allowing bi-directional service on one guide way. This can minimize the visual and physical impact of the aerial structure. Futrex built a quarter-scale model of their system in 1996. Their proposed system will be capable of carrying a maximum of 520 passengers per 10-car train, providing a capacity of 20,000 passengers per hour per direction.

**OTG HighRoad.** Another system under development, it is anticipated that this system will have a capacity of 96 passengers per train. By operating at 15-second headways, it is estimated that the OTG HighRoad system will be able to provide a capacity of 46,080 passengers per hour per direction.

Based on the review of the four systems listed above, the study team drew the following general conclusions about monorail technologies:

?? **Proven operating history.** The Hitachi and Bomardier/Adtranz/Von Roll systems demonstrate that monorails have been used in urban settings for over 30 years.

?? **Ability to operate in inclement weather.** Both Hitachi and Bombardier/Adtranz/Von Roll have constructed systems in a variety of climates, ranging from Kuala Lumpur to Vancouver.

?? **Abundance of non-proprietary systems.** With the exception of the bogie (truck), the monobeam, and some switching equipment, the majority of monorail systems can be manufactured and/or repaired by a number of manufacturers.

?? **Compatibilities with other modes.** The number of non-proprietary systems associated with monorails argues against the belief that monorail systems are incompatible with existing transit systems. Shop equipment from light rail and heavy rail operations can be used to perform work on many of non-proprietary monorail systems. This, in turn, should make it possible to draw upon the skills of the existing labor pool and minimize the need for training and/or retraining staff to maintain monorail systems. Also, as any new rail system in Montgomery County would require new yard and shop facilities, the cost of developing such facilities to meet the needs of monorails may not be as dramatic as previously thought.

?? **Lighter "footprint".** By definition, monorails only require one rail in order to operate. This helps minimize the physical, visual, and aesthetic impact of the aerial structure. Where a potential transit corridor may require significant portions of aerial structure, a monorail may be more cost-effective than heavy rail or an elevated light rail system.

?? **Adequate safety history.** While there are some concerns regarding the ability of side-straddle systems to deal with localized disruptions of service and emergency egress, the overall safety history of the straddle monorails has been good.

This technology assessment has indicated that monobeam technologies are capable of the operating speeds, passenger capacities, and reliability necessary to serve regional transportation needs in Montgomery County. Moreover, there are a sufficient number of monorail vendors with a proven history of operations to minimize some of the risks associated with introducing a new technology to the regional transportation network. In areas where at-grade alignments or aerial heavy rail alignments may pose serious physical impacts to a corridor, the lower impacts of monorail systems may offset some of the costs of building such systems.

The side-straddle systems under development pose a service reliability issue as they are unable to maneuver around disabled or stopped trains by "switching tracks" as rail and straddle-system monorails do. However, if this issue can be resolved, side-straddle monorails may offer savings in costs and impacts, since they are able to fit two guideways on a single narrow structure.

Although there is uncertainty about the reliability of the monobeam technologies still under development, the existing systems have demonstrated a sufficient record of reliability and effectiveness. Because of this, monobeam technologies should be considered as regional policy makers review technological alternatives for new transit alignments in the County.

## 2.0 PURPOSE OF ASSESSMENT

In its Scope of Work, Frederic R. Harris (DMJM+HARRIS) was charged with conducting an analysis of available technologies for monobeam guide way systems to serve in various corridors throughout Montgomery County. The analysis considers potential technologies for Montgomery County corridors including the potential Purple Line and the I-270 transit way. The DMJM+HARRIS analysis includes the identification of measures of effectiveness and the best available information on cost estimates, system capacities, capital and operating characteristics, guide way, vehicle and typical station characteristics. The assessment is initially broad and becomes more specific as representative technologies are considered in more detail. The data on representative mono-beam technologies is then compared to general data on heavy rail, light rail, and bus rapid transit technologies.

This assessment is intended to assist the Montgomery County Department of Public Works (DPW&T) and Transportation in answering the question of whether monobeam technology should be included in current and future fixed guide way studies in Montgomery County.

## 3.0 SCOPE OF WORK

The study includes the identification of monobeam guide way technologies that are currently in operation and those that are in various stages of development. The developmental status of the various technologies have been discerned and the design and performance characteristics of each of the technologies has been documented for comparison. Available information on existing systems has been obtained and where commitments have been made to install new systems, it has been noted. Once key characteristics were known for each system, the list of viable technologies was reduced so that more detailed analysis could be made.

A limited number of the monobeam technology vendors were identified to present information on their systems and provide further details on design, operation, costs and unique features. The presentations provided the members of the Project Review Team with the opportunity to pose questions to the vendors which could further discern the features of the representative systems.

In order to address the County's question about the inclusion of monobeam technology in its studies, DMJM+HARRIS has also proposed measures of effectiveness to compare monobeam technologies (families of technologies) to heavy rail, light rail and bus way modes.

## 4.0 METHODOLOGY

DMJM+HARRIS conducted a preliminary investigation on the available monorail technologies through literature searches of government and industry reports and through Internet research. A search for reports and studies through the following agency sites was conducted: US Department of Transportation – Federal Transit Administration; Transportation Research Board (TRB) Publications Index and the Transportation Research Information Services (TRIS); and the Bureau of Transportation Statistics National Transportation Library.

Internet research began with The Monorail Society Web Page. This site includes numerous references to technologies, projects and vendor sites. Other general technology sites researched include the Monorails of the World Web Page and the Innovative Transportation Technologies Web Page. Information from the web sites of each of the systems was obtained.

A total of 38 technologies (see below) were initially reviewed to determine their compatibility with the general transit needs anticipated in Montgomery County. Technologies intended for longer distance and/or higher speed travel and those considered to be small-scale personal rapid transit systems were not considered compatible. Those systems that are very conceptual with technologies that are not yet fully developed were not considered viable. Certain technologies listed are no longer marketed as separate systems.

The initial list was reduced to seventeen candidate systems on which a more thorough investigation was conducted. The investigation revealed that some vendors and companies had merged, some had established joint ventures with their technologies, and certain technologies were no longer marketed. As a result the list of seventeen (17) vendors was then reduced to eleven (11). Of those eleven, seven (7) vendors have currently operating monorail systems and the others have developing technologies, with no full sized systems or models yet operating. The individual web sites of each of the technologies were carefully reviewed, and information on currently operating systems using the technologies was sought.

A letter of inquiry was sent to the eleven vendors to verify information that had been obtained from web sites and seeking more detailed information. DMJM+HARRIS developed a comparative fact sheet for each of the eleven technologies and began compiling technical design, propulsion, suspension and vehicle characteristics data on each of the systems

The scope of this technology assessment includes providing data and information that enables a reasonable comparison of monorail technologies with alternate modes of transportation. To that end, DMJM+HARRIS proposed specific measures of effectiveness to compare heavy rail transit and light rail transit to monorails. These alternative modes of transit currently exist in the area and are generally included in multi-modal studies as the alternatives to highways.

DMJM+HARRIS presented the information gathered on the eleven technologies to a Project Review Team comprised of County, State and Local transportation planning professionals, as well as representatives from WMATA and MTA, the major transit operators in the region. The Project Review Team reviewed and critiqued the initial assessment work and identified questions and concerns that ensured that the assessment provided answers to the County's questions. They participated in the presentations from representative vendors in order to obtain more detailed information. The Project Review Team then reviewed and assessed the reasonableness of the proposed measures of effectiveness between modes of transit.

With input from the Project Review Team, DMJM+HARRIS will assess whether any of the monobeam technologies examined are viable in meeting the county's general transit needs. DMJM+HARRIS will use typical cross sections from I-270 corridor or the Purple Line to portray the application of the viable technologies.

Finally, DMJM+HARRIS will develop a brochure for the public that provides information on the monorail technology study and the recommendations developed at the conclusion of the assessment.

# 5.0 INITIAL SCREENING OF TECHNOLOGIES

The preliminary research and literature review identified 38 monorail systems. The study team then examined the systems and determined if they were viable candidates for additional research by applying three general criteria:

1. Sufficient information was readily available from which to examine the relevance of the system to the study.
2. The system is still being marketed by an existing manufacturer.
3. The system exhibits characteristics which are suitable to the needs of Montgomery County.

The following sections explain these criteria in greater detail and identifies those systems which did not meet the criteria.

## 5.1 INSUFFICIENT INFORMATION AVAILABLE FOR DETERMINATION

The study team did an extensive literature search on monorail technologies, using the following sources:

?? US Department of Transportation – Federal Transit Administration

?? Transportation Research Board (TRB) Publications Index

?? Transportation Research Information Services (TRIS)

?? Bureau of Transportation Statistics National Transportation Library.

?? The Monorail Society Web Page

?? Monorails of the World Web Page

?? Innovative Transportation Technologies Web Page

While the following systems were identified during this search, the existing literature did not provide sufficient information from which to develop conclusions about the applicability of the systems to the needs Montgomery County:

?? **Aerobus.** A suspended rapid transit technology developed originally in Switzerland and now being marketed by a company in Houston, Texas, USA.

?? **SkyTrain.** An overhead suspended light rail technology being developed in Clearwater, Florida.

?? **Airtrain**. Info no longer available.

## 5.2 SYSTEMS NO LONGER MARKETED

Initial investigations indicate that the following systems are no longer being marketed:

?? **Alweg.** The Alweg style technology is the basis for Hitachi technologies. Information obtained serves as the historical explanation for some newer technologies.

?? **H-Bahn or SIPEM.** A German GRT technology operating at Dortmund University. SIPEM technology is no longer offered as a product by Siemens.

- **SAFEGE.** A type of suspended system. Aerorail is based on the SAFEGE technology.
- **Wuppertal.** Started operating in 1901 in Germany - now carries around 50,000 passengers per day on a 13.3 km line.

## 5.3 SYSTEM CHARACTERISTICS INCONSISTENT WITH NEEDS OF MONTGOMERY COUNTY

The purpose of this study was to determine if monorails should be considered an alternative to the light rail and heavy rail technologies currently used by the MTA and WMATA, respectively. Therefore, the study team focused its efforts on higher-capacity systems capable of meeting the regional travel needs of visitors, residents, and employers in Montgomery County.

Several of the systems identified during the literature review qualified as Personal Rapid Transit (PRT) systems—automated, fixed-guideway systems capable of providing point-to-point service across a matrix of stations. Such systems were considered inappropriate candidates, as they do not appear to have the ridership capacity necessary to meet Montgomery County's needs. The following PRT systems were excluded from further consideration:

- **Cabintaxi.** A unique PRT system with vehicles suspended from and running on top of beam way.
- **Flyda.** This system provides for two-way travel on one guide way. It was devised in the U.K. in the early 1980's.
- **Higherway.** A suspended, dual mode PRT.
- **Monomobile.** A dual-mode concept that uses small electric cars that can be connected to an overhead rail for movement in a suspended mode.
- **SkyTran.** A maglev, high speed, personal transportation concept currently under development.
- **CULOR**. A computer-guided, electrically powered car traveling suspended beneath a single overhead rail.
- **MIX** A combination or "mix" of the bicycle, PRT and the electric car.
- **Pathfinder.** Pathfinder is a PRT-scale concept that features 4-5 passenger vehicles that are suspended from an elevated guideway.
- **RUF.** Individual electric/hybrid vehicle which is driven onto a fixed guideway which then delivers vehicle to preprogrammed location.
- **Skycar**. Korean version of TAXI 2000 concept.
- **Sportaxi.** Automated electric cars running on elevated tracks
- **Taxi 2000.** Personal rapid transit system of computer controlled vehicles on slim guideways operating on demand and nonstop direct to an station in the network.
- **ULTRA** Merged with Intamin.
- **Whoosh**. Utilization of Atmospheric Engine to transport passengers using a "Star Network" in small vehicles.

The following systems were also found to be inconsistent with the needs of the County:

?? **Flyway.** SwedeTrack in Sweden is developing a suspended vehicle that can be lowered to the ground, thus avoiding the need for station structures.

?? **Otis Transportation Systems.** This shuttle and monorail system utilizes an air cushion for suspension. It is marketed as an airport people mover. (USA)

?? **Integrated Transportation System.** A suspended pallet system (dual mode) capable of carrying a variety of vehicle types and containers. Colorado, USA

?? **MegaRail.** A system developed to place existing vehicles on an elevated guide way above roadway and propel them to destinations. Does not appear applicable to needs of County. (USA)

## 5.4 SYSTEMS RECOMMENDED FOR FURTHER EVALUATION

Having eliminated 25 systems from further consideration, 13 systems remained candidates for further evaluation. These systems are described below; fact sheets for each of these systems have been included in Appendix B.

### 5.4.1 Systems in Operation

The following systems are currently in revenue operation throughout the world:

?? **Hitachi.** The first Hitachi system was put in use in 1962. There are currently five systems operating in Japan in a transit capacity.

?? **Bombardier\Adtranz\Von Roll.** These three firms have now combined to market monorail technology as one firm. The first Bombardier application occurred in 1971 and the firm now has more than 20 systems operating in Australia, Japan, and the United States.

?? **Intamin.** Had its first application in 1986 and now has systems operating in at least eight countries.

?? **Severn Lamb.** Opened a system in Sunway City, Malaysia in 2000 and has a system in Italy.

?? **Aerorail.** First system was opened in Germany (Wuppertal) in 1901, and it now has a system open in Japan.

?? **Mitsubishi.** Opened its first full size system in Japan in 1988 and now has two systems in Japan.

?? **Titan Global Systems.** Opened a system in 1962 in Miami and has a system operating in Dallas.

### 5.4.2 Systems in Development

The following systems are under development and may meet the needs of Montgomery County:

?? **Transport Ventures.** This is a consortium of international companies promoting a "New Century Transport." Technology. This mag-lift straddle technology is under consideration by the Colorado Intermountain Fixed Guide way Authority.

- ?? **Urbanaut.** This firm is developing a straddle-type technology on which patents have been issued. A scale model has been developed but no commitments have been made for full sized systems.
- ?? **OTG (Owen Transport Group) HighRoad.** This is a side-straddle technology on which patents have been issued. No commitments have been made for full-sized systems.
- ?? **Futrex System 21.** This is a developing side-straddle technology on which patents are being sought. A scale model has been built and some funding for a prototype system is committed in Charleston, South Carolina.

## 5.5 CLASSIFICATION OF CANDIDATE SYSTEMS

The general method of distinguishing monorail types is to characterize them by basic structural types. This approach allows for a simple visual distinction.

Suspended monorail systems are those which hang suspended from a guide beam. An example of this type of system is the Mitsubishi monorail in Chiba City Japan, which is shown in Figure 5.1.

Figure 5.1. Suspended Monorail (Mitsubishi) Chiba City, Japan

Source: Monorail Society Web Page.

Straddle type monorail systems ride on the top of a guide beam. An example of this type of system is the Intamin system shown in Figure 5.2.

Figure 5.2. Straddle type monorail (Intamin)

Source: Monorail Society Web Page.

Side Straddle monorail systems have a side mounted cantilevered vehicle suspension attaching the vehicle to the beam way. The Futrex System 21 shown in Figure 5.3 depicts this type of system.

Figure 5.3. Side Straddle monorail (Futrex, ¼ scale model, Charleston, SC)

Source: Monorail Society Web Page.

## 6.0 REFINEMENT OF LIST

For each of the eleven systems under consideration, a letter of inquiry was sent to gain additional information about its capabilities. (Refer to Appendix A for sample letter.) DMJM+HARRIS received responses from all but two of the companies contacted. Based on the information collected, the study team developed a fact sheet for each of the eleven systems. These fact sheets are presented in Appendix B and summarized in Table 6.1-6.11.

While best efforts have been made to obtain information for an objective comparison between systems, it has proven difficult to obtain detailed information in certain areas. The system vendors appear reluctant or unable to respond to certain questions in the absence of a specific project setting. System costs, speed and capacity are so heavily influenced by the project setting that some vendors declined to provide a specific response. While information on currently operating systems is offered, it may not reflect the range of capability of a particular technology.

**Table 6.1. Hitachi – Straddle System**

| a. Advantages | b. Disadvantages |
|---|---|
| Several Existing systems | No existing systems in United States (decreased potential for parts availability, less potential for familiarity with design standards in U.S, few in- country skilled workers) |
| >30 years in operation | |
| Proven Reliability | |
| Existing cost data (in yen) | |
| Higher passenger capacity than most other technologies | |
| | |

**Table 6.2. Bombardier (Adtranz/VonRoll) – Straddle System**

| a. Advantages | b. Disadvantages |
|---|---|
| Several existing systems | Capacitynot given in persons per hour per direction (pphpd) or other units comparable to other systems |
| Existing system within United States | Least amount of information available from sources |
| Increased potential for parts availability | |
| Familiarity with design standards in US | |
| In-country skilled workers | |
| Proven reliability (in Disney systems) | |
| > 30 years in operation | |
| Choice of beam way materials | |
| Lower minimum turning radius than most of the other systems | |

**Table 6.3. Intamin – Straddle System**

| a. Advantages | b. Disadvantages |
|---|---|
| Several existing systems | Lower train capacity than most other technologies claim |
| Existing system within United States (Increased potential for parts availability, familiarity with design standards in US, In-country skilled workers) | Minimal amount of cost data for an existing system |
| | Most systems serve as leisure transport systems |
| > 10 years in operation | |
| Existing cost data | |
| Capable of steeper grades than most technologies claim | |
| | |

**Table 6.4. Severn Lamb SL – Straddle System**

| a. Advantages | b. Disadvantages |
|---|---|
| Existing system in operation | No existing systems within US |
| >1 year in operation | Decreased potential for parts availability |
| Existing cost data | Less potential for familiarity with design standards in US. Few in-country skilled workers |
| Lower turning radius minimum than most other technologies claim | Considered a designer/builder of leisure transport systems |
| Has an office within the US | |
| | |

**Table 6.5. Transport Ventures – Straddle System**

| a. Advantages | b. Disadvantages |
|---|---|
| Claims highest passenger capacity with respect to technologies | No existing systems |
| Headquarters could be within US (Colorado) (Increased potential for parts availability, familiarity with design standards in US, Increased potential for in-country skilled workers) | No scale model of system |
| | Utilizes several unproven technologies |
| Possible contract to build in Colorado | No proven record |
| Linear induction motor claims speed capability of up to 300 mph | No cost data available |
| | No response to request for data |

**Table 6.6. Urbanaut – Straddle System**

| a. Advantages | b. Disadvantages |
|---|---|
| Existing 10th scale model | No proven safety record |
| Claims higher passenger capacity than most other technologies | No cost data available |
| Headquarters could be within US (Oregon)<br>Increased potential for parts availability<br>Familiarity with design standards in US<br>Increased potential for in-country skilled workers | |
| | |

**Table 6.7. OTG HighRoad – Side Straddle System**

| a. Advantages | b. Disadvantages |
|---|---|
| Provided the largest volume of useful technical information | No existing systems |
| Higher train capacity than most other technologies claim | No proven safety record |
| Has already been compared in another study within the State | No cost data available |
| Uses a single beam to travel in both directions | Vehicles not connected into trains, propelled individually |
| Claims lower cost values than other technologies | As a side straddle, cannot operate around disabled consist |
| Headquarters could be within US (Georgia) Increased potential for parts availability | Short turn terminals require loops |
| Familiarity with design standards in US | |
| Increased potential for in-country skilled workers | |
| Provided maintenance/facility information | |

**Table 6.8. Aerorail – Straddle System**

| a. Advantages | b. Disadvantages |
|---|---|
| Claims lowest turning radius with respect to other technologies | No existing systems |
| Headquarters could be within US (Texas) (Increased potential for parts availability<br>Familiarity with design standards in US<br>Increased potential for in-country skilled workers) | No proven safety record |
| | Higher capital costs/mile than other technologies claim |
| Claims higher travel speed than most other technologies | |
| Has already been compared in another study within the State | |
| Contains patented technology | |
| | |

**Table 6.9. Mitsubishi – Suspended and Straddle Systems**

| a. Advantages | b. Disadvantages |
|---|---|
| Several existing systems | No existing systems within US |
| >30 years in operation | Decreased potential for parts availability |
| Proven reliability | Less potential for familiarity with design standards in US Few in-country skilled workers |
| Existing cost data | |
| Maintains longest suspension monorail system worldwide | |
| Claim that maintenance is similar to that of a railway vehicle (would be easier to develop local labor) | |
| | |

**Table 6.10. Titan Global – Suspended System**

| a. Advantages | b. Disadvantages |
|---|---|
| Had an existing system | Hasn't been in operation for >10 years |
| Claims fast switching system compared to other technologies | Not currently marketed for viable transit usage. |
| Existing cost data | |
| Headquarters could be within US (New Jersey) | |
| Claims smallest turning radius of all technologies | |

**Table 6.11. Futrex System 21 – Side Straddle System**

| a. Advantages | b. Disadvantages |
|---|---|
| Provided a large volume of useful technical information | No existing systems |
| Claims similar train capacity to that of most other technologies | No proven safety record |
| Has already been compared in another study within the State | Vehicles not connected into trains, propelled individually |
| Uses a single beam to travel in both directions | No cost data available |
| Claims lower cost values than most other technologies | As a side straddle, cannot operate around disabled consist |
| Claims all weather operation abilities | Short turn terminals require loops |
| Beam way material variety possible (steel, concrete or composite) | |
| ¼ scale system in existence (w/ full-scale model being developed now) | |
| Headquarters within US (South Carolina) Increased potential for parts availability<br>Familiarity with design standards in US Increased potential for in-country skilled workers | |

## 7.0 MEASURES OF EFFECTIVENESS

This technology assessment utilizes certain characteristics to serve as the primary basis for the comparison between monorail systems. Because it is being conducted outside the context of a specific alignment or corridor, certain factors remain unknown. Details such as the length of the corridor to be served and the number of stations needed are not known at this time. Therefore, it is necessary to consider ideal or ultimate conditions in order to arrive at measurable characteristics that can be compared. For this analysis, DMJM+HARRIS has consulted with County staff and has proposed factors of speed, capacity and cost. Speed will be measured in terms of the system's maximum operating speed. System capacity will be measured as the number of passengers per hour per direction (pphpd). Cost will be measured in terms of capital cost per mile.

It is acknowledged, nonetheless, that there are other important non-quantifiable considerations for this assessment. Some of these are as follows:

- **Safety.** Considerations include whether or not the technologies already meet applicable US safety codes, the demonstrated accident rates for those technologies already in place and the method of addressing emergency egress. This would apply to the vehicle, the guide way, and the right-of-way.
- **Expandability.** Considerations include the construction time per mile of system and the minimum size of a station.
- **Maneuverability.** This takes into account such indicators as minimum turning radius and maximum vertical grades achievable.
- **Automation capability.** This is the assessment of whether the system requires an operator for each train or whether it can operate automatically.
- **Maintenance.** This attempts to compare costs over some standard measure e.g.: costs per mile or annually.
- **Systems assurance.** This attempts to assess on-time performance, maintenance history and requirements, and weather related factors.
- **Overall compatibility.** This is the most subjective characteristic and is an attempt to assess whether the system is compatible with the environment, built and natural.

# 8.0 COMPARISON BETWEEN MODES OF TRANSPORTATION

## 8.1 OVERVIEW

The purpose of this people mover technology assessment is to determine whether monobeam technologies should be included in current and future fixed guide way studies, and if so, how they may be incorporated. This study will propose quantifiable measures of effectiveness as well as identifying other factors that should be taken into consideration before recommendations are made.

The Maryland National Capital Park and Planning Commission (M-NCPPC) defines measures of effectiveness as “criteria indicating a level of performance or result which are used to compare the differences between alternative scenarios or options.” Research into measures of effectiveness used in fixed route transit studies generally resulted in measures applicable for a comparison of alternative alignments. The measures applicable for comparing differences between modes must be more general. Those measures proposed below attempt to provide for comparison of monorail types or “families” to modes already operating in or under consideration for the region.

## 8.2 PROPOSED MEASURES OF EFFECTIVENESS

### 8.2.1 Capacity

There are numerous ways to measure fixed rail capacity but most would be based on the characteristics of the specific rail line. Factors influencing capacity measures include vehicle capacity, train length, speed and headways. In the absence of a specific alignment several factors are not known. A measure of the maximum number of passengers (seated and standing) per hour per direction (pphpd) that can be accommodated by a specific system can then serve as the basis of comparison to other modes.

### 8.2.2 Speed

There are several factors that influence the measures of speed used in fixed guide way systems. System performance is a measure of how fast the technology can move vehicles. Design Speed addresses what speed a vehicle can move through the system for a given system performance. Average operating speed is a measure of the system at a given design speed, with a specific system configuration and operating parameters including station frequency and dwell time. The maximum operating speed refers to the highest speeds a technology is able to attain.

### 8.2.3 Cost

Documentation on costs for fixed guide way systems must be carefully examined. Capital costs per mile of guide way serve as the best comparison; however, it is important to know whether the costs are based on existing systems or proposals, what is included in the capital costs and whether the cost information that is provided has been adjusted to a common year. Included in this technology assessment are monobeam technologies that do not yet have full-scale operations. All capital costs for such systems will be proposed costs and must be carefully compared to actual capital costs of other systems.

## 8.3 OTHER FACTORS

Other factors to be considered but which are more subjective are listed below in no particular order.

### 8.3.1 Automation

Monobeam technologies can range from non-automated, to partial automation to full automation. Operational characteristics and design features will be affected by the automation capability of the system.

### 8.3.2 Expandability

The ease with which a guide way system can be extended is an important consideration. The ease is influenced by cost as well as time to construct.

### 8.3.3 Maintenance

Maintenance costs are an important consideration in comparing technologies. It is important to know what factors are included in any maintenance costs rates that are provided by cited. Differences in the approach to cost allocations can change the actual meaning of the maintenance costs. Some argue that unique factors on monorails make maintenance costs higher.

### 8.3.4 Yard and Shop

Yard and shop requirements can vary considerably across technologies. The space necessary to house vehicles, maintenance equipment, and an operation control center can add significantly to the cost of building and expanding a system.

### 8.3.5 Safety

The NFPA 130 code must be met in order to operate a rail system in the US. Additionally, there are other standards that must be met in the United States. Another basis for comparison between systems that have been in operation would be accident rates.

In addition to the regulatory safety requirements of a system, there are two other practical issues which need to be taken into consideration:

- ?? Evacuation procedures. Both the vehicle and the guideway must allow passengers to exit the system in the case of emergency. This is an especially important point with automated systems since there may not be transit personnel on board a vehicle during the time of an accident.
- ?? Operating recovery plans. In case of a disruption of service, it is crucial for a system to have mechanisms and procedures in place which would allow regular service vehicles to bypass the affected section of the system.

### 8.3.6 Compatibility

The ability to be used in conjunction with other existing modes is a consideration as we strive for seamless services or minimizing the complexity of the transfer.

#### 8.3.7 Maneuverability

The ability to maneuver can be assessed in terms of the minimum turning radius and the maximum vertical grade achievable.

#### 8.3.8 Visual impacts

Visual impacts refer to the aesthetics of the columns, guideway, and vehicles of a system. Visual impacts are also refer to the effects of a system on the aesthetic, lnes of sight, and lighting (sunlight or other) of their surroundings.

## 9.0 PROJECT REVIEW TEAM INPUT

### 9.1 GENERAL CONCERNS REGARDING MONORAIL TECHNOLOGIES

The Project Review Team meetings generated comments on a variety of factors of concern to the various agency representatives. Those factors are noted below with a brief description of the nature of the concern.

**Proprietary nature of monorail technology.** It was believed that the specialized components needed for monorails would be hard to find or only available from a limited number of distributors. The operator of such a system would be tied to that supplier or manufacturer. Introducing new technology into the County would require a new, specialized work force or additional training for existing workers. Maintenance shops already in place would possibly not be able to provide service to the new technology if it required different parts than the existing systems.

**Incompatibility with existing systems.** There were concerns about the idea of introducing another transit mode in the region - where three rail modes already exist. In the Washington Metropolitan area there exists both commuter rail and heavy rail while in the Baltimore Metropolitan area, there is commuter rail, heavy rail and light rail in use. Stations and maintenance shops already being utilized might not be able to accommodate the new monobeam guideway easily. (LRT/HRT/Commuter rail)

**Limited capacity of monorails.** There were concerns that monorails have much smaller capacity than what might be needed.

**Safety and Reliability**. There were concerns that the safety and reliability of monorail systems had not been proven. A concern about monorail technology involved the ability of trains to execute a track switch when necessary. This raised questions about the safety of passengers in the event of an emergency and the reliability of the system in the event of a vehicle breakdown.

**Weather related reliability**. There were concerns that monorails were not proven to be reliable in climate weather.

### 9.2 EVALUATION OF MEASURES OF EFFECTIVENESS

Upon review of the preliminary data gathered by DMJM+HARRIS members of the Project Review Team had several suggestions on how the measures of effectiveness currently being proposed could be modified to improve the potential for comparison of technologies.

Speed – should take into account acceleration/deceleration and dwell time.

Cost – should include operating costs, ROW costs, equipment costs and maintenance facility costs.

Automation – should be combined with measure of reliability.

Visual Impact – should be broadened to integrate other environmental impacts as well.

Qualitative vs. Quantitative

In order to efficiently compare technologies, there are quantitative as well as qualitative characteristics of each system that must be reviewed. The Project Review Team felt strongly that qualitative factors may fundamentally be as important as the more objective and quantifiable Measures of Effectiveness (MOE's.) Visual impacts and compatibility of the system with its environment are the two factors that were noted as qualitative considerations in this type of assessment.

## 10.0 SYSTEMS REVIEWED IN DETAIL

Four monobeam technology vendors were identified for participation in a meeting with the Project Review Team, county staff and consultant team. The vendors were sent information on the nature of the technology assessment as well as a list of assumptions and questions prior to the presentation date. The following sections summarize the results of these meetings.

### 10.1 OTG HIGHROAD

#### 10.1.1 Background/System Description

The Highroad Rapid Transit System is a patented side straddle system that uses each side of a single guide way beam to provide transportation in two directions simultaneously. It employs the use of components already being utilized by the rail industry. Each vehicle is independently propelled which offers tremendous flexibility in station design.

#### 10.1.2 Existing Locations

The Highroad system has not yet been built. The vendor did not identify any specific sites where this system had been selected for installation. The system was selected for study at the Baltimore Washington International Airport in Maryland where a people mover is planned to link the airport terminal to the Amtrak station, long term parking lot, and the future off-site car rental facility. Highroad has also been presented and was short listed in Dhaka, Bangladesh for a 32-mile citywide system. Further study is expected in each of these locations.

#### 10.1.3 Vehicle/Guide way/Station Description

The HighRoad system uses relatively small, single vehicles on both sides of a two-sided T-shaped guide way beam. The vehicles have a composite body, 45 feet long by 8 feet wide by 9 feet high. Four sets of doors allow passenger ingress/egress. Windows on the guide way side providing access to the guide way would handle emergency evacuation. Each vehicle can carry 32-seated passengers, 64 standing passengers and can accommodate 4 wheelchairs.

Pre-cast, pre-stressed, and post-tensioned concrete is used to create the guide way. The modular design allows for the guide way to be transported to the construction site, for simpler, faster construction. The HighRoad design is comprised of independently propelled vehicles so the number of vehicles "trained" is technically limited only by the size of the stations being serviced. The philosophy behind HighRoad is that long trains are less efficient and require larger stations so the recommended design would have a maximum two-car consist. A typical cross-section is shown in Figure 10.1.

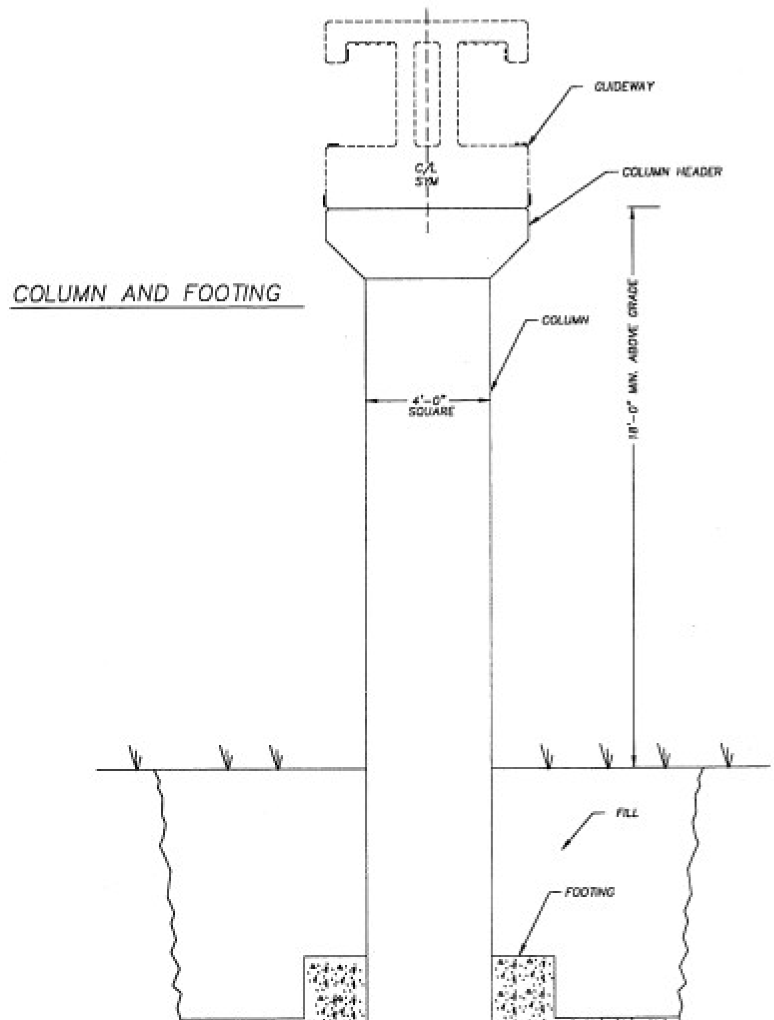


Figure 10.1. OTG HighRoad Guideway

The stations are also modular in nature to allow for easy, less costly expansion when necessary. They are designed with a platform on each side of the vehicle and initially accommodate a single car consist.

### 10.1.4 Capacity

The OTG HighRoad system utilizes individual vehicles, in no more than a two vehicle consist, in an attempt to increase the flexibility of the system. For comparison, the consultant team used the maximum speed, longest consist, and minimum headway for each system to judge capacity. Utilizing a 15 second headway and a 2 vehicle consist, the system can accommodate 46,080 passengers per hour per direction.

### 10.1.5 Costs

*Operations and Maintenance*

For the OTG system operating costs are a function of operations volume and are not related to size of system guide way. For the proposed 13.4 mile system the operating costs are about $158 per vehicle-hour of operation based on a 20-hour day and 25,000 daily riders. OTG reports that maintenance costs are included in the above cited operating cost per vehicle hour and are related more to the number of vehicles in use than to the length of system guide way. The operating cost information provided by OTG includes: guide way maintenance; station operations and maintenance; vehicles; (cleaning, maintenance) administrative staff; fuel; expendables; depreciation; insurance; advertising and payroll taxes.

The vendor discussed a desire for the OTG system to be able to operate without federal funding subsidy within a certain period of time.

*Capital Costs*

Capital costs vary according to topography. However, for a rolling terrain without unusual crossings the cost for Maryland is approximately $21 million per mile. This figure includes all non-recurring design engineering costs, and utilities allowances. It also includes maintenance and administration/control infrastructure. For overall planning, a 2001 total system estimate of $26 million a mile (plus land) may be used with some accuracy based on the postulated 13.4 mile system and the ridership estimated.

*Stations*

OTG estimates the cost of a single 50-foot long station for a single-vehicle consist at $2,951,000. For an ultimate system station for 15-second headways or two-vehicle consists OTG estimates the cost to be $6 million.

### 10.1.6 Feasibility

The HighRoad System, with smaller trains and thus, smaller stations sees its market as the built up community. HighRoad agues that because of its size, it is more easily integrated into the existing community without degrading the quality of the area. The smaller stations are conceivably easier to construct within neighborhoods. According to OTG a desirable station location is a span over a street and street widths up to 200 feet can be accommodated.

A 15-second minimum peak headway is anticipated. The HighRoad System is capable of attaining speeds of up to 70 miles per hour and has a minimum turning radius of 132 feet. The maximum attainable vertical grade is 12 % for climbing and the same grade can be attained for descending.

The design of the beam affects pier spacing. Since the guide way beam is post-tensioned, the post-tensioning can be varied to allow for longer spans. A span of 200 feet is considered reasonable for this type of construction. Longer spans may be possible by increasing the depth of the beam by use of a drop-keel on the bottom for increasing the structural moment of inertia and providing a location for additional post-tensioning cables. Supporting columns approximately 20 feet high could be spaced up to 200 feet apart.

The HighRoad system is to be composed of many parts that are already in existence by manufacturers in the railroad or related industry. Proprietary elements (patented) are guide way shape, vehicle attachment, brakes, vehicle support, column interface with guide way (seismic), dwell/headway procedure, quiet rail, power transport arrangement, emergency egress windows, cabin tilting, and cabin leveling.

In the event of a need to evacuate the vehicle a passenger can unlatch a guide way-side window and pivot the window down to a horizontal position. Unlatching the window causes the vehicle to be emergency-stopped (three braking systems) and passengers can leave the vehicle via the windows to the top of the guide way, bridging the gap between the vehicle and the guide way. Once on the guide way (6'-6" wide) the passengers can walk to safety at a station, can be picked up by a vehicle on the other side of the guide way, or can be attended by a top-of-guide way emergency vehicle. Stanchions and guidelines on the top of the guide way allow safe walking conditions in compliance with Federal handrail standards.

In the event of a disabled vehicle, OTG indicates that a turn back loop would be used. The radius for a turn-back loop is 132 feet, or 264 feet diameter, measured to the centerline of the guide way. An alternative turn-back is a rotating beam at the end of the line but OTG indicates that this would require about one minute for a 180-degree rotation with a vehicle on it. This would extend the headway such that the minimum headway would be at least one minute rather than the 15 seconds allowed by the loop.

### 10.1.7 Environmental Considerations

*Area Required for Structures*

The OTG System requires 16 square feet of area for its foundation structures and an average distance of 140 feet between structures. For a 13.4-mile segment, this would result in a total impact of 8,080 square feet being impacted by the structures of the monorail.

*Noise Impacts*

The HighRoad system with its steel on steel and rail dampening system should have less noise than a typical roadway. High speed trains have low aerodynamic noise but have no means to eliminate the wheel flange squeal on the steel rails.

*Vibration Assessments*

No information on anticipated vibration for the HighRoad System was provided by the vendor.

## 10.2 FUTREX

### 10.2.1 Background/System Description

The System 21 technology is a side straddle mono-beam system that operates on both sides of a 6' wide triangular guide way supported by 16' columns. Both island and platform stations are possible and train length can go as long as 6 cars.

Futrex has taken a deliberate phased approach to the development and marketing of its new System 21 technology. Research, conceptual design, preliminary engineering and evaluation have been completed under Phase I. In May 1996 Phase II was completed with the construction and evaluation of a ¼ scale model of System 21 in Charleston South Carolina. Phase III involves taking the System 21 to commercial manufacturing and has been guided by a Consortium of individuals and firms.

### 10.2.2 Existing Locations

There are currently no System 21 revenue operations. A $1.6 million ¼-scale model was built in Charlestown, South Carolina with the help from federal funds to test the system and as a proof of concept. The Futrex representative noted that discussions continue to identify a proto-type project.

### 10.2.3 Vehicle/Guide way/Station Description

The System 21 vehicles are 28 feet long and made of a combination of aluminum and composite materials. There is a maximum ten-car consist to accommodate larger volumes of traffic. Each vehicle can accommodate 24 seated and 28 standing passengers, and there are provisions for handicapped passengers in each car.

A triangular beam carries vehicles in both directions on a solitary structure. The guide way may be constructed of steel, concrete, or composite. The modular nature of the guide way design provides portability and expandability of the system. Typically, the guide way is 6 feet wide at the base and is supported on 16 foot columns, which can be higher or lower based upon client expectations. Piers are usually spaced at 84 feet on center. A typical cross-section of a Futrex guideway is shown in Figure 10.2.

The four-car typical station requires a 12' x 120 landing for an at-grade location. As with the rest of the system, stations may be pre-fabricated off-site or built on location per client needs.

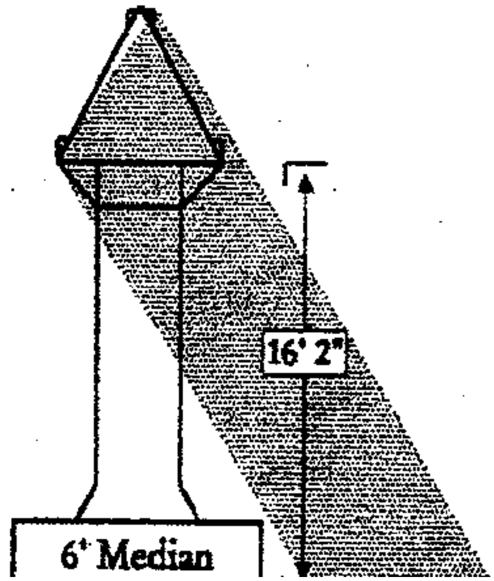


Figure 10.2. Futrex Guideway

10.2.4 Capacity

Futrex systems are to be able to accommodate Approximately 20,000 passengers per hour per direction.

10.2.5 Costs

*Operations and Maintenance*

Operating costs are entirely dependent on the installation and operating profile. The vendor indicates that operating costs will be equal to or lower than that of other fixed guide way systems carrying comparable numbers of passengers/hour /direction.

Given the parameters for the hypothetical installation in Montgomery County, the vendor estimated a total annual Operations and Maintenance cost of $16,618,768. This cost would include: personnel, labor, materials, vehicles and fuel, utilities, propulsion, contract services and insurance.

*Capital Costs*

System 21 capital costs are largely dependent on the installation profile. All-inclusive capital costs are usually stated at $20-25 million per mile (plus Futrex margin). The vendor estimates that capital costs are $6.3 million/mile guide way. Each “A” car is estimated to cost $750,000 and each “B” car is estimated to cost $500,000.

*Stations*

For the hypothetical 13.4-mile system with 18 stations System 21 would require 87 trains, with at-most a 2 train consist to satisfy the peak hour volumes. The cost of the stations needed for this system was calculated by the vendor to be $2,861,138.

### 10.2.6 Feasibility

The System 21 is marketed as able to fit into an existing urban landscape due to the relatively small footprint of the elevated guide way. The stations can be built into or adjacent to an existing structure due to their modular nature.

A train may operate at headways as short as 90 seconds, reaching speeds of up to 70 miles per hour. The minimum horizontal turning radius is 90 feet which could be ideal in an urban setting. A unique branching system, based on standard railroad switching, allows for trains to form a transit network. Switching between tracks utilizes a movable rail section for a grade-separated branch line.

System 21 offers a unique switch mechanism that allows grade separated branching in very compact areas. The ability of the system to make concurrent moves greatly reduces the impacts on service as trains do not have to wait for clearance on the opposite track tot make a diverging move across oncoming traffic. It also eliminates the queuing behind the vehicle moving through the switch. The mechanism actually takes the switching vehicle over the oncoming traffic creating a greater degree of safety in the operation.

The System 21 does not provide a typical crossover design to divert trains around a section of guide way for maintenance or emergencies. In those events a turn back shuttle on the opposite side of the guide way still in operation would be implemented to transport passengers around the outage. Other options are to use a two level bypass station design, or emergency sidings for the removal of disabled vehicles from active guide way.

### 10.2.7 Emergency Operations

Futrex offers numerous options for emergency evacuation including a guide way mounted walkway, and vehicle borne stairways and emergency slides. Passengers will also be able to move from cat to car to flee a hazard or uncomfortable situation. Over water or busy highways, Futrex may introduce an open truss beam configuration which incorporates an emergency walkway internal to the beam.

In the event of a disabled vehicle, shuttles would be utilized since there are no crossovers in the system. If this were to be a normal operating practice, a loop would be integrated into the system to get the train off the main line. The minimum diameter for the loop would be 180’.

### 10.2.8 Environmental Considerations

*Area Required for Structures*

The area required for structures is larger for System 21 than for the other technologies studied in detail—a total of approximately 41,258 square feet for the system’s structures. This is due primarily to the larger land impact per structures (49 square feet per structure) and the tighter structure spacing—an average of 84 feet between structures.

Futrex indicates that pier spacing corresponds with beam length. The maximum pier spacing possible is 110 – 120’ but would require a more massive guide way. Depending on the corridor, the aesthetic impacts of such a structure could offset the benefits accrued by using a longer span.

*Noise and Vibration Impacts*

The System 21 vendor indicated that a noise and vibration consultant is to be hired for the consortium. Sound coating on the interior is expected. No other information was provided.

## 10.3 HITACHI

### 10.3.1 Background/System Description

Hitachi has been operating straddle type monorails for 37 years. There are six systems operating and at least two more are in development stages. The longest existing system (23.8 km) is the Osaka system which opened in 1990 and carries 50,000 people per day.

Hitachi builds small, medium and large type vehicles for different service needs. The small vehicle systems are used in amusement park settings and the medium and large are both meeting mass transit needs.

### 10.3.2 Existing Locations

There are four double tracked Hitachi monorail systems currently in transit service. The largest system built for transit purposes is the Haneda line in Tokyo. The Haneda Line opened in 1964 and carries 200,000 people per day. It serves 10 stations. 114 vehicles, in 6-car consists, are used to provide their service. An 8-mile system with 15 stations is currently under construction in Okinawa and is expected to be in revenue service in 2003. The 14.9 km KL Line in Malaysia will open in 2002 with 21 stations.

### 10.3.3 Vehicle/Guide way/Station Description

Hitachi systems have a variety of vehicle styles to meet various needs. A typical large sized vehicle is approximately 45' long and can accommodate up to 50 seated and 60 standing passengers. The small vehicle is 30 feet in length. The vehicle shell is made of aluminum alloy with welded construction.

A Hitachi monorail uses the straddle beam system to carry a single direction of vehicle traffic along the guide way. The guide way may be constructed of pre-stressed concrete for standard spans and steel girders for both straight and curved sections over longer span lengths.

Hitachi's standard track beam is made of pre-stressed concrete. The beam way is 33.5" wide and 59" tall. The support structure is a T-shaped reinforced concrete column spaced from 65'-98' feet apart. Both the beam and the columns can be manufactured off site and installed. The Hitachi beam has a slim structure which makes it less of an obstruction in urban settings. A typical cross-section is illustrated in Figure 10.3.

Hitachi systems have been built in many large cities and stations are often built above roads. 120' long island platforms are typical as terminal stations with both ends of the station will have stairways and escalators. For intermediate stations two 180' long platforms are used.

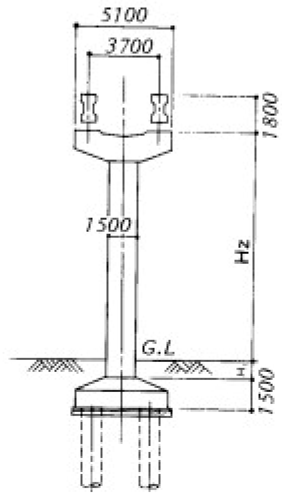


Figure 10.3. Hitachi Guideway

### 10.3.4 Capacity

Hitachi offers a variety of systems, each of which has its own capacity constraints. At present, the maximum passenger capacity of an existing Hitachi system is 49,080 pphpd (passengers per hour per direction) for a 6 car consist traveling at 2-minute headways.

### 10.3.5 Costs

*Operations and Maintenance*

In order to avoid misunderstandings Hitachi does not provide cost information until the basic configuration and operations objectives of the proposed system are provided. According to their operations and maintenance experiences with their own systems, Hitachi representatives said that the operation and maintenance costs for our monorail systems are at the same level as required for the light rail technology.

*Capital Costs*

No response was provided to the inquiry.

*Stations*

No response was provided to the inquiry.

### 10.3.6 Feasibility

*Intermodal Connections*

Several of Hitachi's monorail systems connect to HRT systems including Tokyo and Osaka. The options to interface with other systems and stations are not limited.

Hitachi systems are capable of operating at speeds of approximately 50 miles per hour and at a maximum grade of 6%. Hitachi indicates the ability to achieve a minimum headway of 2 minutes for a system if needed. Guide ways have pier spacing of between 82 and 100 feet.

The only proprietary technology utilized for a Hitachi monorail is the track switching system. The track switch designated for Hitachi monorail systems transforms the track beam itself as a switching mechanism by way of moving one end of each beam. The switching girders are supported firmly on the movable trucks. Fully automated electrical sequences operate in strict accordance with the train operation schedule and are monitored from the Operation Control Center.

The track switch is designed and manufactured in such a way as to ensure high reliability. There have been no disruptions to Hitachi service operations from the switch since 1964. Hitachi has a wide range of track switch types for the purpose of turn back, crossover, emergency rescue and train storage. There are switches that can be utilized to execute a turn back, crossover, emergency rescue or train storage. These include a two-point, three-point, five-point, crossover, or x-type of switching mechanism. A combination of these can also be employed.

Hitachi systems can be built with a minimum 180' turning radius along the main line and a 150' turning radius at the station.

Unlike other monorail vendors, Hitachi provides a walkthrough feature as a safety provision between adjacent vehicles. This enables the passengers on board to evacuate from one vehicle to other vehicle.

Hitachi provided the following explanation of standard evacuation procedures to be used in the event of system failure or incident:

- Self-propelled trains on the main line by way of the motor cutout operation, as a design redundancy, in case of vehicle with malfunction.
- Propelling a train with the assistance of another train on the main line.
- Train to train evacuation (in the same traveling direction because both end and front cab cars are provided with an evacuation door to rescue train).
- Train to train evacuation (on the opposite side of track).
- Train to ground evacuation by way of ground service car with special armed ladder, like a fire engines.
- Train to ground evacuation by slow-down facility.

Hitachi indicated that in Japan, walkway facilities along the beam are not required . The costs involved and the impact on the aesthetics form the basis for this policy.

Hitachi guide ways are supported by structures that can be spaced on average up to 75 feet apart on a curved section and up to 90 feet on a straight section.

#### 10.3.7 Environmental Considerations

*Area Required for Structures*

The average pier spacing for Hitachi support structures is 90 feet. This falls within the middle of the range for the four systems studied. The overall direct impact on land from Hitachi structures would also be in the middle range, with approximately 19,650 square feet impacted over a 13.4-mile corridor.

*Noise and Vibration Impacts*

Hitachi systems are rubber tired and have lower noise levels than steel wheeled rail systems. Hitachi reports that the target noise level for the Kita Kyushu monorail system of 70dBa at 10 meters was achieved.

Pneumatic springs in the vehicle provide a smoother ride and less vibration. Pre-cast concrete beams are cast in special molds providing high degree of accuracy which also eliminates vibration and noise.

## 10.4 BOMBARDIER

### 10.4.1 Background/System Description

Bombardier is a company that manufactures many different types of transit and recreational vehicles. Bombardier has merged with Adtranz and VonRoll in recent years and consequently some of the monorail systems currently marketed by the company were developed by these now acquired companies. Under the Bombardier framework there are several different types of systems that can be developed. This study has focused on the straddle-type monorail with which Bombardier has 30 years of experience.

### 10.4.2 Existing Locations

There are several different monorail systems currently in revenue service. Included is the Disney World Mark VI, which is the most widely known monorail in the continental United States. Bombardier also designed the mono-rails for the Tampa International Airport, the City of Jacksonville, Newark International Airport and the soon to be built Las Vegas monorail.

The Disney World system has 14.7 lane miles of track on 3 lines and a fleet of 12, six-car trains. Vonroll has built monorail systems in Germany, England and Australia.

### 10.4.3 Vehicle/Guide way/Station Description

The Bombardier representative used the Las Vegas system as the basis for presenting information and discussion since it represents the most recent company experience.

The M-VI vehicles to be utilized by the Las Vegas monorail are bi-directional vehicles comprised of a composite shell with a steel truss and plate under frame. Each 4 car train has a length of 137 feet, a width of 9’ and height of 11’. They accommodate 152 standing and 62-seated passengers per train with 2 dedicated wheelchair locations per train. Las Vegas will have four-car train consists utilizing a double tracked system. This system has an average line speed of 17.5 mph.

The guide way will be composed of pre-cast concrete beams as well as some pre-stressed and post-tensioned concrete where needed. Beams will typically be spaced 100 feet apart, with a maximum span length of 120 feet where necessary. A typical cross section of the guide way is shown in Figure 10.4.

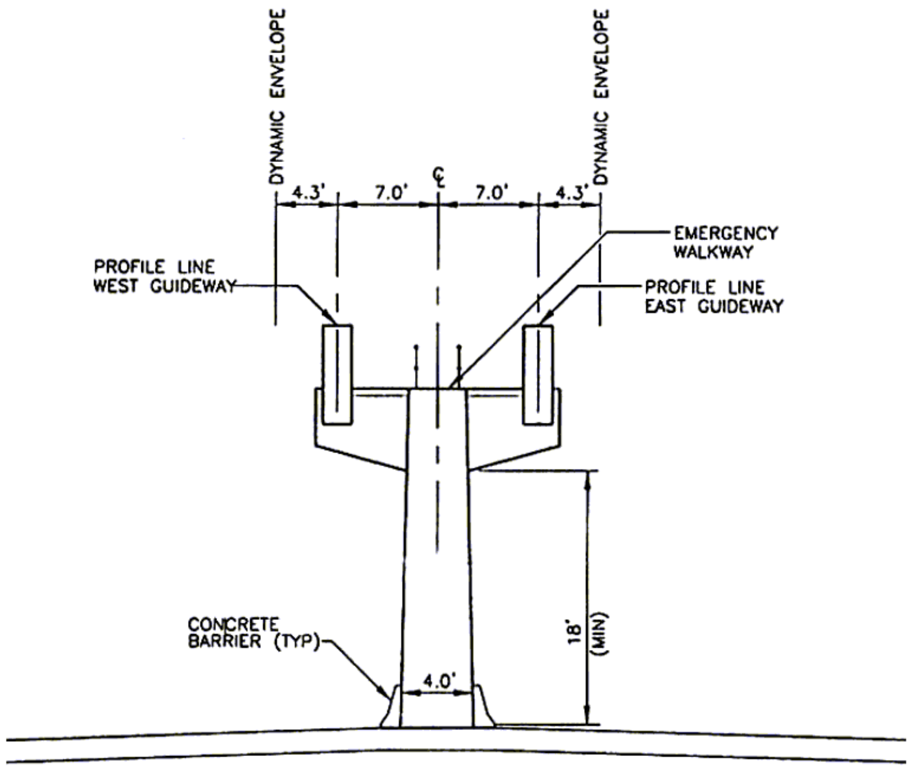


Figure 10.4. Bombardier Guideway

There will be seven elevated stations served by the system spaced an average of half a mile apart. The average platform length at the station will be 240 feet long.

#### 10.4.4 Capacity

The Bombardier system is able to accommodate up to 23,200 pphpd with a 6 person per square meter density, 8 car train, and 90 second headway traveling at 50 miles per hour.

#### 10.4.5 Costs

The Bombardier representative was reluctant to answer questions pertaining to cost without more specific information about what is to be included for comparison. Costs for the Las Vegas System were cited as examples of what recent experience has shown. The four-mile system with seven stations cost $350 million. He cited that half the cost was civil design work and half in electrical and mechanical systems. Up to 25% of the cost for a system is associated with the vehicles. Operating and maintenance costs for the Las Vegas System are $10 million annually. Each station is estimated to cost $5 million.

He did generalize by saying that an elevated monorail system would be more expensive than an at-grade light rail system.

#### 10.4.6 Feasibility

The Bombardier systems are designed with the ability to increase capacity in stages as warranted. The Las Vegas system will operate at an average speed of 17.5 miles per hour with a maximum grade of 6.5 %. Bombardier is capable of achieving a 150' minimum horizontal turning radius and operating speeds of up to 53 miles per hour. 175-200 'turning radius is preferred.

The 26" wide beam sections are prefabricated and the concrete columns are poured in place. Pier spacing is also affected by geo-technical conditions and wind and range from 90' – 120' maximum.

#### 10.4.7 Emergency Operations

Emergency egress from the vehicle is handled either by use of a recovery train or vehicle which would take passengers to the next train station or by coupling a disabled train to another train and moving the entire vehicle to the next station.

#### 10.4.8 Environmental Considerations

*Area Required for Structures*

Refer to Table 11.1. Bombardier compares favorably with the other systems studied with overall impact area equal to approximately half of the Hitachi system. This is possible because of the small footing area required for each support structure.

*Noise/Vibration Impacts*

The Las Vegas system is anticipated to have a noise and vibration impact of approximately 70-75 dBa.

# 11.0 STUDY FINDINGS

## 11.1 EVALUATION OF MONOBEAM TECHNOLOGIES

The research conducted in this report has indicated that monobeam technologies could serve as a viable alternative to more conventional modes of transportation (light rail, heavy rail) in certain corridors.

### 11.1.1 General Environmental Conclusions

While it is not possible to provide a complete assessment of environmental impacts in the absence of a specific corridor, it is possible to draw general conclusions as to the impacts of monobeam systems on their surroundings.

Table 11.1 estimates the area of land required to implement systems from each of the four vendors interviewed. These estimates were based on a hypothetical 13.4-mile corridor in Montgomery County. The table indicates that the space taken up by guideway structures would be less than an acre for each of the four systems. This is significantly less of a direct impact than would be made by an at-grade light rail or aerial heavy rail system. However, the presence of an aerial structure could still have other impacts to the aesthetic, cultural, and historic characteristics of its surroundings. Also, the construction of an aerial structure could have short-term implications on wetlands and other natural resources in the vicinity of a monobeam structure.

**Table 11.1: Area of Land Required for Monorail Technologies******

| Vendor | System Type | Approximate Area of Foundation Structure ($ft^2$) | Average Distance Between Structures (feet) | Total Number of Structures per 13.4 – mile Segment | Approximate Potential Square Feet of Impact |
|---|---|---|---|---|---|
| OTG, Inc. | Monorail (side-straddle) | 16 | 140 | 505 | 8,080 |
| Bombardier Transportation | M-VI Monorail (straddle) | 16 | 105 | 674 | 10,784 |
| Hitachi | Monorail (straddle) | 25 | 90 | 786 | 19,650 |
| Futrex System 21 Inc. | System 21 Monorail (side-straddle) | 49 | 84 | 842 | 41,258 |

** This approximation is based on typical foundation structure sizing as specified by individual vendors. Specialized foundations for switches and stations may be larger.

### 11.1.2 Monorail Cross Section Comparisons

Guideway cross sections were requested from each of the representative technologies. These can be compared with cross sections for LRT and HRT to increase understanding of how the systems differ. As seen in Figures 10.1-10.4, the cross sections of the monorails evaluated require a smaller median than typical of LRT and HRT systems. The typical width of monorail columns ranges from four to seven feet. In comparison, the MTA's light rail system requires approximately 12 feet of right-of-way for a single-track alignment, excluding additional space required for stations, traction power sub stations, and other systems. Montgomery County has a 26 foot standard requirement for right-of way on potential rail alignments.

### 11.1.3 Overall Feasibility

The Project Review Team raised five key issues which would affect the feasibility of monobeam technologies in Montgomery County. The research done for this study indicates that these may not pose as significant a problem as previously thought:

1. Proprietary nature of monorail technology. Discussions with Hitachi indicate that the only proprietary system used in their monorail systems is the track switching system. While this is a significant element of the system, the fact that the remaining portions of the system are non-proprietary indicates that the availability of parts and support for the system may not be as great as feared.

2. Weather related reliability. The presence of monorail systems in Germany, England, and Korea indicates that it is feasible to operate a monobeam technology under a variety of climatic conditions.

3. Incompatibility with existing systems. While the introduction of a new technology to the regional transit network will require an investment in new systems, vehicles, and

maintenance resources, similar investments would be required to expand any of the other rail systems into Montgomery County.

With regards to the compatibility of monobeam technologies with existing stations: where a transit line is being extended, it does make more sense to extend the existing mode rather than introducing a second mode to the line. However, where a new transit service is being used to provide an intermodal link between two or more existing transit lines, the reduced guideway requirements of monobeam technologies may make it easier to integrate a new service into the site design of existing stations.

4. Limited capacity of monorails. The systems reviewed by the study team demonstrate passenger capacities of up to 49,000 passengers per hour per direction. Used in the appropriate corridors, this should be ample for the needs of transit service in Montgomery County.

5. Safety and Reliability. There are significant concerns with many of the monobeam technologies as to how they deal with emergencies and other disruptions of service. In many cases, systems designed for use in overseas markets have not had to include emergency walkways and other features which are standard in U.S. transit services. Existing monobeam technologies may require additional research and development in order to adapt them to Federal, State, and local safety requirements.

   The reliability of monobeam services varies considerably among the technologies reviewed. The side straddle systems on the market today may require additional right-of-way for turn back loops in order to preserve service around disabled vehicles. As with other conventional rail services, the ability to preserve service will be dependent on the availability of crossovers and other system elements necessary to move around disabled vehicles.

## 11.2 MEASURES OF EFFECTIVENESS

Table 11.2 compares the four representative systems against a set of Measures of Effectiveness. As this table shows, all of the systems under evaluation exhibit operating speeds, passenger capacities, and capital costs comparables with other premium transit services used in the region.

**Table 11.2: Measures of Effectiveness**

| | System Name | Hitachi | Bombardier /Adtranz/Von Roll (M-VI) | OTG HighRoad | Futrex System 21 |
|---|---|---|---|---|---|
| **Background** | Monorail Type | Straddle | Straddle | Side Straddle | Side Straddle |
| | Years in operation | 37 | 30 | Not Built | Not Built |
| | # of Existing Systems | 5 | 20 | 0 | 1 |
| **Capacity** | Passengers/hour/direction | 33,000 | 23,200 | 46,080 | 38,400 |
| **Speed** | System Performance- max train speed (mph) | 36 | 53 | 70 | 80 |
| | Average Speed (mph) | 24 | 22 | 32 | Varies |
| | Design speed (mph) | 48 | 55-60 | 75 | 70 |
| **Cost** | Capital Construction Costs ($Millions/Mile) | Not available | $25.00 | $26 | $20-25 |
| | Operating Costs ($Millions/Mile) | Not available | $5 | $24.76 | $8.00 |
| | Vehicle Costs ($Millions/mile) | Not available | $0.75 | $1.80 | Not available |
| | Station Costs ($Millions) | Not available | Not available | $3 - $6 | Not available |
| **Automation** | Full/Partial | Yes | Yes | Yes | Yes |
| **Expandability** | Min. Station Length | Not available | Not available | 90' | Not available |
| | Prefabricated Beams/Columns? | Yes | Yes | Yes | Yes |
| **Maintenance** | ($/Mile) | Included in Operating Costs | | | |
| | Proprietary Technology (yes/no) | Yes | Yes | Yes | Yes |
| **Safety** | Emergency Egress | Car Walk through | Evac. Walkway | Windows evac. | Ladder evac. |
| | NFPA 130? Other Code? | AAA (Japan) | NFPA 130 | NFPA/ANSI 130 | NFPA 130 |
| **Maneuverability** | Min. Turning Radius | 210 | 150' @ 17 mph | 132' @ 10 mph | 50 |
| | Max. Vertical Grade (%) | 6% | 8% | 12% | 12% |
| **Noise** | Noise Emissions | 75 dB | 75 dB | Not available | <76 dB |
| **Visual Impacts** | Vehicle Size (L x W x H) (feet) | 208' x 10' x 15' | 28' x 8' x 7' | 45' x 8' x 9' | 28' x 8' x 8' |
| | Max. Pier spacing (feet) | 90 | 120 | 200 | 100 |

## 11.3 LIMITS OF THIS TECHNOLOGY ASSESSMENT

It is worth noting that there have been limitations to the type of assessment that was conducted here. Those that are apparent will be noted below.

Some vendors contacted may not have responded with complete information since the assessment was not conducted for a specific alignment. The general nature of the initial letter requesting information may not have compelled them to respond with all available information.

It was apparent in the responses that were received, that vendors were reluctant to provide too much detailed information for this assessment. This may be a result of the general nature of the assessment or because they did not think the effort would lead to an actual project.

It was difficult to compare existing systems with developing systems. The vendors of the developing systems need to estimate or project costs and operating conditions, while the vendors who have operating systems provide more cautious estimates based on their experience building systems under varying conditions.

It has been anticipated that capacity information and cost data from existing and planned LRT and HRT systems would be used for comparison with the monorail technologies. The MTA does not use passengers/hour /direction (PPHPD) as a measure for its LRT or HRT. The MTA has also been reluctant to provide estimated costs for LRT planned at grade and elevated for the current corridors under study.

**Table 11.3: Comparison of Modes**

| | Max. Speed | Max. Passengers/ Hour/ Direction |
|---|---|---|
| Straddle Monorail | 36-53 mph | 23,200-33,000 |
| Light Rail | 55 mph | 19,000-21,000 |
| Heavy Rail | 75 mph | 34,000-40,000 |

Sources: Monorails: information supplied by vendor; light rail and heavy rail:

TRCP Report 13: Rail Transit Capacity, 1996.

## 11.4 CONCLUSIONS/RECOMMENDATIONS

Table 11.3 compares the speeds and capacities of straddle monorails with those of light rail and heavy rail. As illustrated in this table, monobeam technologies are capable of providing operating speeds and passenger capacities comparable to those of other modes of premium transit. They are also have a demonstrated history of reliable operations. Moreover, there are a sufficient number of monorail vendors with a proven history of operations to minimize some of the risks associated with introducing a new technology to the regional transportation network. In areas where at-grade alignments or aerial heavy rail alignments may pose serious physical impacts to a corridor, the lower impacts of monorail systems may offset some of the costs of building such systems.

The side-straddle systems under development pose a service reliability issue as they are unable to maneuver around disabled or stopped trains by "switching tracks" as rail and straddle-system monorails do. However, if this issue can be resolved, side-straddle monorails may offer savings in costs and impacts, since they are able to fit two guideways on a single narrow structure.

Although there is uncertainty about the reliability of the monobeam technologies still under development, the existing systems have demonstrated a sufficient record of reliability and effectiveness. Because of this, monobeam technologies should be considered as regional policy makers review technological alternatives for new transit alignments in the County.

# APPENDIX A: SAMPLE LETTER

December 29, 2000

Mr. Ken Jowaiscas
Severn-Lamb USA Inc.
Director of Marketing & Sales

P.O. Box 149
Westwood, NJ 07675

Dear Mr. Jowaiscas:

Montgomery County, Maryland is a fast growing and densely populated county in the State of Maryland. Located adjacent to and north of the District of Columbia, the county is in the heart of the vibrant Washington, DC metropolitan region. The county is served by Washington Metropolitan Area Transit Authority's (WMATA's) Bus and Rail System, MARC Commuter Rail system, Maryland MTA bus system, and its own Ride-On Bus System. The transit needs of the county are great and in response to the growing transportation challenges the County has undertaken a technology assessment of viable monorail technologies for consideration in several of the densely developed corridors.

DMJM+HARRIS, Inc. is conducting this evaluation of monorail technologies for the County for consideration as a component of their regional transit system. We are writing to inquire about your SL Series monorail system as well as other monorail systems that you are currently developing. The Internet has been a good starting point for obtaining basic information on the technology, but now we need to acquire more in-depth information about these systems.

The specific information that we seek includes:

- Patent number and/or Pending Patent confirmation
- Vehicle passenger capacity information (seated and standing)
- Vehicle Dimensions
- Maximum number of cars per train
- Maximum passengers per hour
- Station requirements (size, location)
- Station dwell time based upon passenger activity
- Maximum and standard operating speeds
- Acceleration/Deceleration rates
- Automation capabilities
- Emergency egress systems (specifically NFPA 130 compliance)
- Switching/Crossover Methods
- Minimum turning radii

?? Maximum/Minimum grade maneuvering

?? Beam way information (materials, dimensions, etc.)

?? Location(s) where system is already in existence

?? Historic and/or projected capital and operating costs (including a breakdown of these costs)

?? Long term durability and performance expectations (or record for existing full scale systems)

?? Maintenance accommodations and requirements

Once we have assembled a basis of comparison we intend to invite those vendors whose technologies show the greatest potential viability in the corridors to make presentations of their system to the review team which consists of ourselves, county, and state transit senior staff. We intend to involve the Maryland Mass Transit Administration, WMATA, and other local transit agencies as appropriate. This is a great opportunity to show your system's applicability for one of the most prominent locations in the United States.

Please forward this information to us at the above address, by January 26, 2001, to the attention of Ms. Christine Wells, along with any other information that you believe to be pertinent. Also, please indicate the name and telephone number of a contact person for further information. We look forward to your interest in this exciting project.

Best Regards,

Bryan P. Mulqueen, PE

Vice President

# APPENDIX B: TECHNOLOGY FACT SHEETS

HITACHI

| | |
|---|---|
| System Type | Straddle |
| Manufacturer<br><br>Address<br><br>Phone number<br>Web site | Hitachi<br>Hitachi Overseas Marketing Dept.<br>Transportation Systems Sales Division<br>6, Kanoa Surugaoai 4 Chrime<br>Chiyoda-Ku Tokyo 101-8010 Japan<br>http://www.keppelhitachizosen.com/Opening.html |
| First Full Size Use | 1962-INU Yama Amusement Park Japan |
| Existing Location(s) | 5 Japanese systems (Tokyo Haneda, Kitakyishi City, Osaka, Tama, Okinawa) |
| Committed System Location(s) | Kuala Lumpur Malaysia, Tokyo Disneyland, Naha Okinawa |
| Beam way Material | Concrete |
| Wheel/Tire Material | Rubber |
| Emergency Egress<br>(Design, operation, etc…) | -Tokyo Disneyland trains include a door at front cab<br>-Walkthrough between vehicles |
| Switch | Segmented and new high-speed crossover switches operate every few seconds. Reliable for 30 years. |
| Special Features<br>Unique designs, etc… | Bogies under floor in new models. Most successful manufacturer of ALWEG monorails. |
| Costs<br>Capital<br>Operating/Maintenance<br>(Indicate actual or estimated) | Contact vendor for information |
| Capacity<br>Per Car<br>(seated/standing)<br>Max Train Length<br>Max Train capacity | 40 seated /60 standing per car<br>4 cars/train<br>49,080 pphpd (passengers per hour per direction) |
| Minimum turning radius | 164' |
| Notes: | |
| Sources: | The Monorail Society web page, www.monorails.org<br>Hitachi |
| Other Information: | |
| Status: | Received data from manufacturer |

BOMBARDIER/VON ROLL/ADTRANZ

| | |
|---|---|
| System Type | Straddle |
| Manufacturer<br>Address<br><br><br><br>Phone number<br>Web site | Von Roll / Adtranz / Bombardier<br>Wendy Ruch, Corporate Communications<br>Daimler Chrysler Rail Systems (North America) Inc.<br>1501 Lebanon Church Road<br>Pittsburgh, Pennsylvania 15236-1491<br>+1 412 6 55 53 35<br>www.adtranz.com; www.bombardier.com |
| First Full Size Use | 1971 Disney<br>1988 MR III Sydney Australia |
| Existing Location(s) | More than 20 systems operating. Darling Harbor-Sydney, Australia; Canada; Japan; Singapore; Newark International Airport (opened 1995); Disney; Las Vegas |
| Committed System Location(s) | 1.6 km extension to Newark system, M-VI Las Vegas (2004) |
| Beam way Material | Steel; Concrete |
| Wheel/Tire Material | Rubber (Nitrogen filled) |
| Emergency Egress<br>(Design, operation, etc…) | Evacuation walkway added to M-VI design |
| Switch | Radial; pivot |
| Special Features<br>Unique designs, etc… | Pneumatic tires, track, and counter wheels provide a good ride and make derailment impossible. Air springs with automatic load leveling are provided. The load/drive tires are special, heavy-duty tires with run-flat rims. |
| Costs<br>Capital<br>Operating Maintenance<br>(Indicate actual or estimated) | <br>$50 Million/mile (actual)<br>$14 Million/mile (actual) |
| Capacity<br>Per Car (seated/standing)<br>Max Train Length<br>Max Train capacity | <br>30 passengers/car<br>6 cars/train<br>360 passengers |
| Minimum turning radius | 65.6' |
| Notes: | In 1994, Von Roll sold their technology to Adtranz, now a part of Bombardier. Before being purchased by Adtranz, Von Roll developed monorails in: Sydney, Australia; Jupiter-Oasis/Gold Coast, Australia; Sea World/Gold Coast, Australia; Sentosa Island, Singapore; Alton Towers, England; Europa Park, Germany. |
| Sources: | www.Monorails.org and www.adtranz.com |
| Other Information: | Max grades 4.6% up 6.6% down; Max speed 33 km/hr |

*This company represents the unity of Von Roll, Adtranz, and Bombardier. Therefore, data provided on this sheet will reflect the largest system in existence for the combined company.

INTAMIN

| | |
|---|---|
| System Type | Straddle |
| Manufacturer<br>Address<br><br>Phone number<br>Web site | Intamin Ltd.<br>P.O. Box 284<br>Millersville, MD 21108<br>301-987-5404<br>www.intaminworldwide.com |
| First Full Size Use | 1986 – Busch Gardens Florida |
| Existing Location(s) | Tampa, Florida; Stuttgart, Germany; Taejun, Korea; Bangkok, Thailand; Seoul, Korea; Shenzhen, China; Rio, Brazil; Gelsenkirchen, Germany; Manila, Philippines; Magdeburg, Germany |
| Committed System Location(s) | None |
| Beam way Material | Steel |
| Wheel/Tire Material | Not available |
| Emergency Egress<br>(Design, operation, etc…) | Contact vendor for information |
| Switch | Hydraulic |
| Special Features<br>Unique designs, etc… | Capable of 7-10% grade |
| Costs<br>Capital<br>Operating /Maintenance<br>(Indicate actual or estimated) | Contact vendor for information |
| Capacity<br>Per Car (seated/standing)<br>Max Train Length<br>Max Train capacity | Contact vendor for rolling stock information<br>140/car<br><br>>10,000 pphpd |
| Minimum turning radius | Contact vendor for information |
| Notes: | Incomplete data available<br>Additional information requested by e-mail.<br>Low speed people mover |
| Sources: | www.Monorails.org and www.intaminworldwide.com |
| Status: | Received data from manufacturer |

## SEVERN LAMB SL SERIES

| | |
|---|---|
| System Type | Straddle |
| Manufacturer<br><br>Address<br>Phone number<br>Web site | Severn-Lamb USA Inc.<br>P.O. Box 149<br>Westwood NJ 07675<br>201-666-2800<br>www.severn-lambusa.com www.severn-lamb.com |
| First Full Size Use | Sunway City Malaysia (opened 2000) |
| Existing Location(s) | Sunway City Malaysia (opened 2000)<br>Savio-Mirabilandia Revena, Italy |
| Committed System Location(s) | None |
| Beam way Material | Fabricated steel |
| Wheel/Tire Material | Rubber |
| Emergency Egress<br>(Design, operation, etc…) | Contact vendor for information |
| Switch | Contact vendor for information |
| Special Features<br>Unique designs, etc… | Contact vendor for information |
| Costs<br>Capital<br>Operating /Maintenance<br>(Indicate actual or estimated) | <br>Sunway City $10 million |
| Capacity<br>Per Car (seated/standing)<br>Max Train Length<br>Max Train capacity | <br>184 passengers/train<br>6 cars |
| Minimum turning radius | 66' |
| Notes: | Considered to be a designer and builder of leisure transport systems |
| Sources: | www.severn-lambusa.com www.severn-lamb.com<br>www.Monorails.org |
| Other Information: | |
| Status: | Received data from manufacturer |

## TRANSPORT VENTURES

| | |
|---|---|
| System Type | Maglift* Straddle |
| Manufacturer<br><br>Address<br><br><br><br>Phone number<br>Web site | Transport Ventures (a consortium of international companies NCT, {New Century Transport})<br>CIFGA (Colorado Intermountain Fixed Guide way Authority)<br>P.O. Box 377<br>Dumont, CO 80436<br>303-567-2200<br>NCTransportation.com |
| First Full Size Use | None |
| Existing Location(s) | None |
| Committed System Location(s) | None (CIFGA in Colorado to connect Denver Int'l airport along I-70 to Eagle Co Airport in phase 1) |
| Beam way Material | Contact vendor for information |
| Wheel/Tire Material | Steel Wheels |
| Emergency Egress<br>(Design, operation, etc…) | Contact vendor for information |
| Switch | Contact vendor for information |
| Special Features<br>Unique designs, etc… | LIM (linear induction motor) Capable of 300 mph,<br>Magnetic propulsion yet wheels stay in contact w/rails for stability, no flanges on wheels reduces friction, no wheel intrusion into vehicle allows for segmenting. |
| Costs<br>Capital<br>Operating Maintenance<br>(Indicate actual or estimated) | Contact vendor for information |
| Capacity<br>Per Car (seated/standing)<br>Max Train Length<br>Max Train capacity | 2-20 segment trains (metro version)<br>24 seated and 17 standees per segment = 54 total<br>Segment = 19.8' length<br>1080 passengers |
| Minimum turning radius | Contact vendor for information |
| Notes: | Capacity of intercity and metro versions vary<br>Intercity version carries 7600 passengers/hr/direction<br>**System being evaluated as a combination of the technology developed by Eurotren Monoviga and TransPort Ventures Corporations.** |
| Sources: | www.nctransportation.com and www.monorails.org |
| Other Information: | * mag lift = hybrid of monorail/conventional rail/maglev |
| Status: | Received no data from manufacturer as of 02/15/2001 |

URBANAUT

| | |
|---|---|
| System Type | Straddle |
| Manufacturer<br>Address<br><br>Phone number<br>Web site | Einar Svensson<br>19686 Sunshine Way<br>Bend Oregon 97702<br>Fax # 541-383-8855<br>svensson@empnet.com |
| First Full Size Use | None; 1:10 scale model |
| Existing Location(s) | None |
| Committed System Location(s) | None |
| Beam way Material | Concrete on steel box-single prefab rail, column to beam drop in |
| Emergency Egress<br>(Design, operation, etc…) | “Special” vehicle escape devices are provided in case of emergency evacuation |
| Switch | Central stabilizer (fin) can be made into a switch; flexible center guide rail |
| Special Features<br>Unique designs, etc… | Rides on top of runway on rubber tires, guided by central rail on a stabilizer fin, efficient switching |
| Costs<br>Capital<br>Operating /Maintenance<br>(Indicate actual or estimated) | Estimated costs for single guide way<br>Guide way 6.3 million /mile<br>Maint. Yard 1.05 million, signals 0.9 million<br>Rolling stock 3.75 million |
| Capacity<br>Car (seated/standing)<br>Max train length<br>Max Train capacity | <br>18 seated /54 max capacity/car<br>7 cars<br>378 |
| Minimum turning radius | Contact vendor for information |
| Notes: | Vehicles shorter, lighter |
| Sources: | Faculty.washington.edu/~jbs/itans/urbanaut.htm<br>www.monorails.org |
| Other Information: | Patent # 5,845,581; and Patent # 3,719,727 |
| Status: | Received data from manufacturer |

## OTG HIGH ROAD

| | |
|---|---|
| System Type | Side Straddle |
| Manufacturer<br>Address<br><br><br>Phone number<br>Web site | OTG Owen Transport Group Inc.<br>Whitlock park center<br>707 Whitlock Ave. Suite F-2<br>Marietta Ga. 30064<br>707-428-0183<br>Otg-inc.com/mainframe.html |
| First Full Size Use | None |
| Existing Location(s) | None |
| Committed System Location(s) | None |
| Beam way Material | Concrete |
| Emergency Egress<br>(Design, operation, etc…). | Guide way windows |
| Switch | Swing beam switch |
| Special Features<br>Unique designs, etc… | Uses each side of a single beam simultaneously in 2 directions. |
| Costs<br>Capital<br>Operating /Maintenance<br>(Indicate actual or estimated) | Guide way=$15.13m/mile<br>Admin/maint=$13.68m/mile<br>Vehicle=$1.6m/mile<br>Typical 25 mile = $22.3m/mile |
| Capacity<br>Per Car (seated/standing)<br>Max Train Length<br>Max Train capacity | 96 passengers/vehicle 32 seating<br>64 standing<br>46,080 passengers/per direction/per hour<br>Vehicles not connected into trains, they are propelled individually |
| Minimum turning radius | 132 ' |
| Notes: | “Quiet-Rail” Technology<br>Patent # 4,690,064 |
| Sources: | See web site above |
| Status: | Received data from manufacturer |

## AERORAIL

| | |
|---|---|
| System Type | Suspended |
| Manufacturer<br>Address<br><br>Phone number<br><br>Web site | Aerorail Development Corporation<br>3310 Fairmount 9E<br>Dallas, TX 75201 USA<br>214-526-1830<br>ttrenary@airmail.net<br>www.aerorail.com |
| First Full Size Use | None |
| Existing Location(s) | None |
| Committed System Location(s) | None |
| Beam way Material | Ductile carbon steel 5'6" wide- 7'6" height<br>Dual beam |
| Emergency Egress<br>(Design, operation, etc…) | Ladder in floor can be lowered in case of emergency evacuation |
| Switch | Track transfer, rotary crossover, and moveable rail section switches |
| Special Features<br>Unique designs, etc… | Steel wheels on steel rails to improve speed, eliminate "tire sing", uses off the shelf technology<br>Bogies in hollow box beam-sealed from elements,<br>All equipment above car for safety |
| Costs<br>Capital<br>Operating /Maintenance<br>(Indicate actual or estimated) | <br>$32-34 million/mile |
| Capacity<br>Per Car (seated/standing)<br>Max Train Length<br>Max Train capacity | <br>60 seats seated<br>100 seats standing<br>Contact vendor for other rolling stock information |
| Minimum turning radius | 50 feet |
| Notes: | Car dimensions 60' l x 11' w x 12'-0.6" h<br>Patent # 5,381,737; Patent # 5,450,798 |
| Sources: | ttrenary@airmail.net<br>www.aerorail.com |
| Other Information: | Car weight 60,000 lbs<br>*SAFEGE (Societe Anonyme Francais d'Etude de Gestion et d'Enterprises) |
| Status: | Received data from manufacturer |

MITSUBISHI

| | |
|---|---|
| System Type | Suspended |
| Manufacturer<br>Address<br><br>Phone number<br>Web site | Mitsubishi Heavy Industries<br>2-3 Marunouchi, 2-Chrome<br>Chiyoda-Ku Tokyo 100 Japan<br>03-325-6471<br>http://www.mhi.co.jp/e_hq/e_machi2.html |
| First Full Size Use | 1988 Chiba City Japan |
| Existing Location(s) | Chiba City and Shonan Japan |
| Committed System Location(s) | None |
| Beamway Material | Hollow steel box beam 6.08'w x 6.18' h |
| Emergency Egress<br>(Design, operation, etc…). | Contact vendor for information |
| Switch | Movable Switch blade |
| Special Features<br>Unique designs, etc… | Chiba is the longest suspension monorail in the world<br>Worlds only dual beam SAFEGE system in the world |
| Costs<br>Capital<br>Operating /Maintenance<br>(Indicate actual or estimated) | Contact vendor for cost information |
| Capacity<br>Per Car (seated/standing)<br>Max Train Length<br>Max Train capacity | <br>50.5'(L) x 8.69' (W)<br><br>Contact vendor for other rolling stock information |
| Minimum turning radius | Contact vendor for information |
| Notes: | |
| Sources: | www.Monorails.org<br>Mitsubishi web site has no monorail info |
| Status: | Received data from manufacturer |

## TITAN GLOBAL SYSTEMS

| | |
|---|---|
| System Type | Suspended |
| Manufacturer<br>Address<br>Phone number<br>Web site | Titan Global Technologies LTD.<br>P.O. Box 617<br>85 Chestnut Rd.<br>Montvale N.J. 07645<br>www.jetrail.com |
| First Full Size Use | Miami Seaquarium Monorail 1962 (since removed) |
| Existing Location(s) | Love Field in Dallas Texas |
| Committed System Location(s) | None |
| Beamway Material | Steel I Beam |
| Emergency Egress<br>(Design, operation, etc…). | Contact vendor for information |
| Switch | Swift beam replacement device<br>7 second lock-to-lock switch |
| Special Features<br>Unique designs, etc… | Small turn radius for complex sites (15')<br>Uses linear induction technology |
| Costs<br>Capital<br>Operating /Maintenance<br>(Indicate actual or estimated) | Contact vendor for information |
| Capacity<br>Per Car (seated/standing)<br>Max Train Length<br>Max Train capacity | 3 system sizes<br>"PRT" 4-20 passengers<br>"Jetrail" 30-50 passengers<br>"Astroglide" 75-112 passengers<br>Contact vendor for other rolling stock data |
| Minimum turning radius | 15' |
| Notes: | |
| Sources: | www.jetrail.com<br>www.monorails.org |
| Status: | Received data from manufacturer |

## FUTREX SYSTEM 21

| | |
|---|---|
| System Type | Side Straddle |
| Manufacturer<br>Address<br><br>Phone number<br>Web site | Tom Waldron,<br>5300 International Blvd., Suite 100,<br>N. Charleston, SC, 29418 USA.<br>843-760-4500;<br>www.futrexinc.com |
| First Full Size Use | None; ¼ scale model |
| Existing Location(s) | A $1.6 million one-quarter-scale model of System 21 was completed in 1996 and is operational in Charleston. South Carolina. |
| Committed System Location(s) | FUTREX next plans to build and test a full-scale 1.25 mile operational prototype to conclusively demonstrate ride quality, evacuation characteristics, low noise output, reliability, maintainability, ease of fabrication and installation and cost. The 36-month, $35 million program is expected to get underway in early 2000. $6.2 million in prototype funding has been earmarked by the U.S. DOT, with the remainder to come from the State of South Carolina, utility, strategic and private sources |
| Beamway Material | Triangular steel, concrete or composite |
| Emergency Egress<br>(Design, operation, etc…) | Being developed<br>-Vehicle-borne stairways,-Emergency slides<br>-Cantilevered guideway, mounted walkway w/handrail; -Car to car people migration |
| Switch | Moveable rail section |
| Special Features<br>Unique designs, etc… | All weather operation (-40F to 120F)<br>Design wind load is 150mph w/vehicles on guideway |
| Costs<br>Capital ($/Mile)<br>Operating Maintenance<br>(Indicate actual or estimated) | <br>$25 Million/mile |
| Capacity<br>Per Car (seated/standing)<br>Max Train Length<br>Max Train capacity | 24 seated<br>28 standing 10 cars/train<br>Contact vendor for other rolling stock information<br>520 passengers<br>20,000pphpd |
| Minimum turning radius | 90' |
| Notes: | Patents being sought. Old patents expired. |
| Sources: | www.futrex.com |
| Other Information: | |
| Status: | Received data from manufacturer |

# APPENDIX C: PROJECT REVIEW TEAM MEETING NOTES

March 1, 2001

**Subject:** Meeting Notes Montgomery County Technology Assessment

**Present:** Rob Klein, Henry Kay, Bryan Mulqueen, and Chris Wells

This meeting was arranged because Henry Kay was not able to attend the March 2nd meeting of the Project Review Team. Klein informed Kay that the input he provided today would be summarized for the Project Review Team members tomorrow. A copy of the power point slide show to be used for the Project Review Team meeting was provided to Kay.

Klein described the impetus for the County having DMJM+HARRIS conduct the monorail technology assessment. He noted concerns about the viability of other transit modes (LRT, HRT) in the studies that MDOT has underway (I-270 Corridor Cities transit way and Beltway Studies) given the preliminary data on speed, ridership and cost that have been produced.

Klein noted that the data does not meet the FTA cost effectiveness criteria.

Klein noted that the state had dismissed monorail technologies from further study in the Beltway study noting ---,--, and – as the basis. Kay said he was not as concerned about the preliminary ridership or cost effectiveness data on the I –270 transit way. He thinks it is an issue that will need to be addressed later. He also noted that the environmental impacts are the biggest issue for the Georgetown Branch study and that cost effectiveness is not the biggest issue.

Rob explained that the purpose of the study is to determine whether monobeam technologies should be considered in current and future corridor studies in Montgomery and Prince George's counties. He generally described the scope of the study.

Kay admitted that he is skeptical about monorail technologies and thinks that their incompatibility, limited capacity and potential safety questions provide adequate basis to MTA refrain from further consideration.

Mulqueen noted that the outcome of the study will be recommendations on whether or not monobeam technology families should be included in future studies. It was emphasized that it is not the intent of the study to recommend a specific technology.

Mulqueen discussed the proposed measures of effectiveness that will be used to compare monobeam technologies to LRT/HRT and BRT. Cost, capacity and speed. Following these there was discussion on the list of Other Considerations. Kay noted that these "considerations" can be fundamentally as important as the more objective and measurable MOE's. He noted that what becomes critical is whether or not they are mitigate-able. How these other considerations are defined is important (does visual impact = environmental impacts?)

Kay thought the MOE's offered are reasonable and noted that the "Other Considerations" are equally important. Fatal flaws for many projects are based on environmental visual and safety considerations.

Klein mentioned that some near term advances in technology may address questions about safety that exist. Kay was skeptical about the ability to overcome problems in the near term noting that LRT technology advances have not been that great.

There was discussion about monorail system reliability especially regarding weather. Kay noted the ice build up problem on the LRT as an example of an unanticipated problem.

Kay discussed the proprietary nature of monorail technologies as being a problem. Limited availability of parts and vendors is a real issue.

The compatibility of monorails with the existing HRT and LRT systems is a concern.

Kay noted that the transit options in state's beltway MIS study will focus on the peak hour needs as will other transit studies. The peak period transit needs will be the focus of MTA studies in the future (in contrast to non-peak circulator type transit needs)

Kay noted his personal skepticism about new technologies such as monorails. He sees a big hurdle for monorails to overcome and wonders whether they will make sense--ever.

When looking at the pictures of various technologies he posed some specific questions about how the vehicles and side straddle technology works. He said he knows Disney is able to do whatever it takes to assure reliability for its theme park monorail systems -but that is not reasonable posture for MTA.

Klein summarized Kay's comments.

Kay said he expects that if one or more viable technologies are identified through the County's consultant study that the county would be recommending that monorails be included in future state corridor studies.

Kay said that he understood why Montgomery County would pursue this task and said he would do the same thing in their place.

To answer the question of whether mono-beam technology should be included in current and future fixed guide way studies in Montgomery County and Prince George's County

**Project Review Team Meeting Notes**

March 2, 2001

Present: Rob Klein, Howard Benn Montgomery County DPW & T, Larry Marcus City of Rockville, Rick Hawthorne MNCPPC, Jim Raszewski Prince George's County DPW&T, Glenn Orlin, Montgomery County Council Staff, Bryan Mulqueen, Christine Wells, DMJM+HARRIS

Invited but not present: Marsha Kaiser, MDOT Planning, Royce Drake, WMATA Engineering, Henry Kay, MTA Planning (separate meeting held with Henry)

Introductions were made.

Howard Benn welcomed everyone and discussed the general context for the technology assessment. The Transportation Policy Report and the work of the policy committee was cited as valuable and important for the County but not intended to address questions of technology.

Rob Klein cited concerns about the outcome of transit options in state MIS and corridor studies in particular the I-270 and the Capital Beltway Corridor Transportation Study. He noted that monorails had been eliminated from further consideration in the Beltway Study. He noted concerns about the preliminary data on ridership, speed and costs for the LRT alternative in the I –270 study. Klein's particular concern is in comparing the preliminary data to the FTA's cost efficiency criteria for new starts. **This technology assessment is intended to answer the question of whether monobeam technology should be included in current and future fixed guide way studies.** Klein reviewed the scope of the study. (refer to handout)

Klein explained that a separate meeting with Henry Kay had been held yesterday since he could not attend this meeting. Klein summarized Kay's key comments as follows:

Kay has skepticism about the introduction of a new technology since it is not compatible with existing HRT and LRT. He has particular skepticism about monorails noting proprietary technology, capacity and reliability as concerns.

Kay is not as concerned that the I-270 data looks bad in terms of cost efficiency, ridership and travel speeds. He thinks these issues can be addressed later.

Kay noted that he understands why Montgomery County would pursue this technology assessment and said he would do the same thing if he were in the County's position. He understands that if a favorable recommendation results from the assessment that the County would be advocating the inclusion of monorail technology in future state studies.

Kay noted that the Other considerations items listed can be as significant as other measures of effectiveness.

Raszewski commented that to convince the state to consider monorails, the emphasis in this assessment must be put on addressing the question of compatibility with other technologies. This term "compatibility" must be carefully defined and addressed.

Orlin said that mono rail technology would have to prove itself as comparable in performance to LRT/HRT . Then, the question of compatibility becomes an issue. He said that if mono rail technology could be built at significantly lower cost, then a decision to pursue it as a new technology might make sense.

Wells mentioned that DMJM+HARRIS has conducted preliminary research into technologies. Project Review Team members were sent a list of the 38 technologies considered with some initial conclusions about whether further research appears warranted. DMJM+HARRIS has contacted 11 of the vendors with specific requests for more information. Draft fact sheets on the eleven vendors were sent to Project Review Team members. Wells said that it has been difficult to obtain some of the desired information. She noted that some of the vendor provided information may be biased and that there is some inconsistency between information found on various internet sources and that provided by vendors. Follow up will be required. She also noted that despite that specific questions were posed to vendors for certain factors (e.g.: cost, capacity) many responded that the specific characteristics of the corridor would be needed in order to respond with information costs, speed.

Mulqueen began the discussion of the proposed measures of effectiveness. These would be used to compare monobeam technologies to existing transit modes. He noted capacity, speed and cost as measurable. He then said there are "Other Considerations" listed : Automation, maneuverability, expandability, visual impact, maintenance, compatibility, and safety.

The Project Review Team decided to spend more time discussing the proposed measures of effectiveness since some people had time limits. The slides showing existing and developing monobeam technologies were reviewed after the MOE discussion was completed.

There was considerable discussion on the proposed MOE's.

**Capacity** measure is proposed as passengers/hour/direction (pphpd)

**Speed** measure is proposed as maximum operating speed.

Comments: Speed measure should take into account acel/decel and dwell time.

There is a point at which greater acceleration/deceleration is ergonomically uncomfortable for passengers.

A list of technologies meeting or exceeding a maximum operating speed of 50 mph was shown as was a list of those with maximum operating speeds less than 50mph. The 50 mph cut off should be reconsidered since so many technologies do not meet it and it may be too high.

**Cost** measure is proposed as capital cost /mile.

Comments: operating costs should also be a measure.

Cost of R.O.W., equipment, maintenance facility

What magnitude of cost difference would be meaningful?

Other Considerations

**Automation**: was proposed as whether or not the system was capable of full or partial automation.

Comments: Isn't this actually a substitute for reliability or part of a measure of reliability? It was argued that reliability is the real consideration rather than automation;

**Maneuverability**: was proposed as the turning radius and maximum vertical grade.

Comments : depending on the type of alignment, this could become more of a concern-radial vs. cross county vs. a downtown type of alignment. Discussion followed on whether CBD -urban type environments were anticipated and the answer was that yes they should be anticipated for the purpose of this assessment.

**Expandability:** proposed as the cost and complexity to extend the system.

**Visual Impact:** proposed as pier spacing and vehicle size

Comments: this should be broader addressing noise and other environmental impacts

The footprint of the system is important.

**Maintenance:** proposed as a cost for annual maintenance

Comments: proprietary technology is a concern; maintainability is really the issue including the cost and availability of parts; maintenance facility site needs are important

Needs for short corridors might be significantly different than for longer corridors.

It may be necessary to proposed hypothetical systems

**Compatibility:** proposed as compatibility with other modes and stations

Comments: introduction of a new technology in the region is a concern; there would need to be good basis for this; it was argued that this consideration should be addressed in a narrative fashion in the introduction to the report rather than in a comparative way.

**Safety:** proposed as meeting the NFPA standards also performance records are available for systems in operation but what about developing technologies?

Comments: NFPA and emergency evacuation are the key considerations;

**Evacuation**: proposed as evacuation of the train and evacuation of the right of way. Passenger safety is key: grade separation is a factor.

New Considerations recommended:

Passenger accessibility: ease of access at stations –at grade or not?

Intermodal connections

Replace automation with Reliability

Replace visual impact with environmental impacts

There was general discussion on how to present the MOE's and the "Other Considerations". The challenge is for this assessment to present meaningful documentation that allows for a comparison of monobeam technologies to other modes (LRT/HRT/BRT).

Marcus argued that several of these considerations could be presented as objectives.

Summary of Project Review Team recommendations :

Discuss the issue of technological compatibility in the introduction to the assessment.

Propose three components for the comparison of Monobeam to other modes

those clearly measurable; (MOE's)

factors for which minimum thresholds can be assessed

factors that can be gauged as good, fair or poor in comparison with other modes.

MOE's

Capacity, Capital costs, Operating Costs, Speed Maximum operating speed (for a given condition)

Minimum thresholds

Maintainability,

maintenance facility space needs

minimum number of sources for parts

Safety

NFPA yes/no

Other codes? Yes/no

Accident rates

Reliability

Documented performance

Redundancy in systems back up

Maneuverabilility

Min Turning radius

Min Vertical grade

Geometrics of crossovers

Factors for comparison

Environmental Impacts

Noise dBa at given distance

Minimum Station Footprint

Visual Impacts

Pier size

minimum pier spacing

Beam way dimensions

Passenger Accessibility

Intermodal connections

It was generally agreed that in order to get more specific responses from the monobeam vendors DMJM+HARRIS would have to provide them with assumptions on which to base their responses. Assumptions on system length, number of stations and probably the number and type of intermodal linkages should be provided to the vendors.

<u>Next steps</u>

DMJM+HARRIS had proposed inviting 4 vendors to present their technology information at a meeting of the Project Review Team and county staff. Initial thinking was that two of the presenters would discuss systems currently in operation and two would be systems in development.

The Project Review Team members discussed whether any systems in development should be studied further. Some argued it was not warranted to study totally new technologies, as the risk is too great. Others argued that since the County's anticipated timeframe is 10 years out, and if the analysis indicates that a developing technology is very near to being available and it meets the need then more should be learned about it.

The question of which vendors to invite does not have to be resolved immediately.

DMJM+HARRIS will present a proposed short list of vendors for further consideration after the systems have been compared using the revised comparison.

**Project Review Team Meeting Notes**

June 5, 2001

**<u>Marsha Kaiser</u>** felt that the monorail technology should be studied further and that the costs and connection of the new technologies is unclear. The appeal of monorail is that it seems less obtrusive than heavy and light rail systems.

**<u>Larry Marcus</u>** felt that the flexibility of the systems needs to be further investigated, especially Bombardier and Hitachi. The cars need to be looked into also so that they may suit the needs/desires of the community.

George Cardwell felt that the costs for introducing new technology needs further review. His concern is that custom cars come with custom costs and that transit sharing capability should be investigated.

**<u>Dan Hardy</u>** noted that monorail systems are more tested than he expected. However, he doesn't believe that Montgomery County wants to be in the practice of endorsing a system that has not yet been built.

**<u>Henry Kay</u>** stated that he was amazed at how theoretical systems are much more willing to provide costs than existing systems were. He also noted that the team must always keep in mind the market that is trying to be served as there are a particular set of factors that apply to each type of technology. He feels that is it important to be open-minded but that there is a need to apply the same level of scrutiny to new systems as there is to older systems.

**Rob Klein** felt that he was motivated by the potential cost savings and the possibility of reducing/improving the impacts to the surrounding communities. He was more intrigued by the Futrex type of system and the proposed changes.

**Bryan Mulqueen** stated that it remains to be seen if Futrex can really deliver on the plans that they have, even though they've developed the scaled down model. There are no effective means to show benefit/means of comparison of monorail versus light rail and heavy rail. Coming in to the meetings, safety of egress was of major concern to him and he didn't really see any good solutions provided by any of the vendors although they could all probably develop them if forced to do so.

**Howard Benn** stated that he also went into the meetings with concerns about egress but that he felt less concerned after hearing all of the presentations. He doesn't feel that the team saw anything that would immediately discount any of the systems from further investigation in particular applications. (He felt that the OTG and Futrex systems were uni-directional and not really usable beyond 3 or 4 mile one-way applications.) He thought that operation concerns could become a major hindrance to their utility as the inability to run around a problem is significant. Furthermore, no individual would want to be stuck on any of the other systems for the long term. Adding one of theother vendors (Hitachi and Bombardier)would not be a major hindrance to the existing transit system in the county because they are basically variations of the same concept. The addition of a mode is not the most significant concern. He wants to request additional cost work be done by Hitachi and Bombardier since they already have multiple types of systems developed (i.e. – they do both monorail and conventional steel rail).

# APPENDIX D: EVALUATION OF PRESENTATIONS

| Vendor Name | Potential For Consideration | Reasonable Costs | Reasonable Capacity | Reasonable Speed | Evaluator | Comments |
|---|---|---|---|---|---|---|
| Bombardier | Yes | Yes | Yes | Yes | Bryan Mulqueen | Costs seemed reasonable based upon historical data |
| Futrex | Yes | Yes | Yes | Yes | Bryan Mulqueen | |
| Hitachi | Yes | Yes | Yes | Yes | Bryan Mulqueen | Limited applications on high density, fully grade separate applications; costs are demonstrated by service history; higher speeds appear achievable |
| OTG | Yes | Yes | No | | Bryan Mulqueen | Must substantiate capital and operating costs and technolgoy concepts in practical application; no basis/background for costs provided; 15 second headway doesn't seem reasonable; average speed seems reasonable; no easy way to clear a disabled vehicle |
| Bombardier | Maybe | Yes | Yes | Yes | Dan Hardy | Some applications seem applicable and other seem out-of-scale; use of actual historical data is helpful in understanding costs but additional literature would be helpful |
| Futrex | Maybe | Yes | Yes | Yes | Dan Hardy | |
| Hitachi | Maybe | Yes | Yes | Yes | Dan Hardy | Good to see successful applications -applications seem like more urban settings; need more follow up about costs; need to calibrate system capacity for acceptable US crush load densities; good follow ups on flexibilty to increase speed |
| OTG | Maybe | Yes | Yes | Yes | Dan Hardy | Not qualified to judge costs; seems fast, assumptions on acceleration/deceleration/dwell time need further study |
| Bombardier | Maybe | Maybe | Yes | Yes | George Cardwell | Speed going to be based upon station spacing, alignment, etc. |
| Hitachi | Maybe | Maybe | Yes | Yes | George Cardwell | Questions about travel patterns and connections to other modes will impact choice; construction costs not easily transferable to US markets; speed will be dictated by station spacing, track alignment, and grades |
| Bombardier | Maybe | No | Yes | Yes | Henry Kay | The potential for consideration depends upon setting; question whether the guideway would be accepatble in all settings but it would in some!; helps that systems are already operational |
| Futrex | Yes | Yes | Yes | Yes | Henry Kay | Concerns regarding emergency evacuation |
| Hitachi | No | N/A | Yes | Yes | Henry Kay | Much too infrastructure-intensive; capacity is similar to Metrorail which is a KNOWN technology; Speed info seemed reasonable based on extensive experience; helpful that system is existing so it doesn't appear to be a sales pitch |

| Vendor Name | Potential For Consideration | Reasonable Costs | Reasonable Capacity | Reasonable Speed | Evaluator | Comments |
|---|---|---|---|---|---|---|
| OTG | Yes | No | Yes | Yes | Henry Kay | Need more detail on costs; need breakout costs for all components-vehicles, guideway, design to be adequately compared; not satisfied with response about switching; appears switching wasn't really considered in design |
| Bombardier | Yes | Yes | Yes | Yes | Howard Benn | Only system which discussed weather |
| Futrex | Yes | Yes | Yes | Yes | Howard Benn | Unidirectional; short turns; emergency bypass? (building fire, collapse, etc.) |
| Hitachi | Yes | Yes | Yes | Yes | Howard Benn | May be slow |
| OTG | No | No | No | Yes | Howard Benn | Has not though about/out customer interface |
| Futrex | Yes | Yes | Yes | Yes | Larry Marcus | |
| Hitachi | Maybe | Maybe | Yes | Yes | Larry Marcus | Need to develop/display smaller scale application; Not enough cost info provided |
| Hitachi | Yes | Yes | Yes | Yes | Larry Marcus | Could be tailored to needs; expensive; slow but accurate |
| OTG | Maybe | No | No | Yes | Larry Marcus | Not enough cost information; too tight for seating |
| Bombardier | Yes | Yes | Yes | Yes | Marsha Kaiser | Good that technology is proven; safety issues seem similar to light/heavy rail; aesthetics present a challenge |
| Futrex | Yes | Yes | Yes | Yes | Marsha Kaiser | May have minimal community impact but still needs to be explored for acceptance; thorough cost information |
| Hitachi | Yes | No | Yes | Yes | Marsha Kaiser | At least monorail is a proven technology in other countries; disappointed about cost information since other systems have already been built |
| OTG | No | | Yes | Yes | Marsha Kaiser | No prototype ever built; not proven; would be difficult to sell to county and citizens; would like a breakdown of costs; who makes up the consortium and how long have they been together? |
| Futrex | Yes | Yes | Yes | Yes | Rick Hawthorne | Lots of development already completed; small cross section helps; credible technology for 5-10 year application |
| OTG | No | Yes | No | Yes | Rick Hawthorne | Not developed enough; costs are hard to evaluate; 15 second headway?! |
| Bombardier | Yes | Yes | Yes | Yes | Rob Klein | |
| Futrex | Yes | Yes | Yes | | Rob Klein | Hoping for higher speed |
| Hitachi | Maybe | Yes | Yes | Yes | Rob Klein | |
| OTG | Maybe | | Yes | Yes | Rob Klein | too little detail to judge information on costs |

| Vendor Name | Potential For Consideration | Reasonable Costs | Reasonable Capacity | Reasonable Speed | Evaluator | Comments |
|---|---|---|---|---|---|---|
| Bombardier | Yes | Yes | Yes | Yes | Sandra Bowen | Appeared to be more costly but the multiple options seem more able to accommodate needs |
| Futrex | Maybe | Yes | Yes | Yes | Sandra Bowen | This potential for consideration would depend upon the corridor and the potential impacts from the foundation placements |
| Hitachi | Maybe | No | Yes | Yes | Sandra Bowen | Seems to be a higher number of supporting structures used compared to OTG/Futrex presentations; costs not clearly defined |
| OTG | Yes | Yes | Yes | Yes | Sandra Bowen | Although damping of noise and vibration is mentioned, it would be helpful to know anticipated levels |
| Bombardier | Maybe | Yes | Yes | Yes | Stan Doore | Large turning radius needed; not modular system; heavy, with high cost and slow to build; unprotected safety mechanism |
| Futrex | Yes | Yes | Yes | Yes | Stan Doore | Definitely has potential in corridor; concerned about single door for entrance/exit; double sided ingress/egress decreases seating capacity |
| Hitachi | No | Yes | Yes | Yes | Stan Doore | Turning radius too large; Weight too heavy; track span too wide to fit easily between buildings and other tight spaces; Height taller than Metro; Monorail better than heavy rail but less suitable than single beam applications |
| OTG | Yes | Yes | Yes | Yes | Stan Doore | Solid engineering, solid concept and design; modular construction using current technology is good; automated system similar to current aircraft flight systems seems practical |

REFERENCES

The Monorail Society Web Page – located at www.monorails.org

Monorails of the World Web Page – located at
http://faculty.washington.edu/~jbs/itrans/monolink.htm