Project #: D-48-809  Cost share #: Rev #: 0
Center #: T5167-0A0  Center shr #: OCA file #:
Contract#: 90-X035A  Mod #:
Prime #: Work type: PUB SER
Subprojects #: N  Document: OTH
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Project director(s): ARCH COLL

Sponsor/division names: MARTA  Sponsor/division codes: 300

Award period: 880125 to 880324 (performance) 880324 (reports)
Sponsor amount
Contract value 7,421.00
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Cost sharing amount 0.00

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Title: RAPID TRANSIT PLATFORM EDGE WARNING SYSTEMS

PROJECT ADMINISTRATION DATA
OCA contact: Brian J. Lindberg  894-4820
Sponsor technical contact
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MARTA
401 W. PEACHTREE ST., N.E.
ATLANTA, GEORGIA 30365-4301

Security class (U,C,S,TS): U
Defense priority rating : N/A
Equipment title vests with: Sponsor

Administrative comments - INITIATION OF PROJECT D-48-809
THIS IS A FIXED PRICE PUBLIC SERVICE PROJECT.
GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION/CLOSEOUT SHEET

Date 8/8/88

Project No. D-48-809 T5167-0A0 School/Arch

Includes Subproject No.(s) N/A

Project Director(s) J. Templer GTRC/GITA

Sponsor MARTA

Title Rapid Transit Platform Edge Warning Systems

Effective Completion Date: 3/24/88 (Performance) 3/24/88 (Reports)

Grant/Contract Closeout Actions Remaining:

☐ None

☐ Final Invoice or Copy of Last Invoice Serving as Final

☐ Release and Assignment

☐ Final Report of Inventions and/or Subcontract:
  Patent and Subcontract Questionnaire sent to Project Director

☐ Govt. Property Inventory & Related Certificate

☐ Classified Material Certificate

☐ Other

Continues Project No. Continued by Project No.

COPIES TO:

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Other

(2)
AN EVALUATION OF FALLS AT PLATFORM EDGES, AND A DISCUSSION OF POTENTIAL SOLUTIONS.
AN EVALUATION OF FALLS AT PLATFORM EDGES,  
AND A DISCUSSION OF POTENTIAL SOLUTIONS.  

FINAL REPORT

A study prepared for:

The Metropolitan Atlanta Rapid Transit Authority  
2424 Piedmont Road NE  
Atlanta, Georgia 30324

Prepared by:

John A. Templer Ph.D, Principal Investigator  
Jean Wineman D.Arch, Co-Principal Investigator  
Deborah Hyde  
Jessica Lehrbaum  
Jon A. Sanford

The Pedestrian Research Laboratory  
College of Architecture  
Georgia Institute of Technology  
Atlanta, Georgia 30332-0420  
Preparation of this report was financed in part by funding from the U.S. Department of Transportation, Urban Mass Transportation Administration; through the Atlanta Regional Transportation Planning Program conducted by the Metropolitan Atlanta Rapid Transit Authority, the Atlanta Regional Commission and the State of Georgia Department of Transportation.

The analysis, findings, and conclusions presented in this report are those of the Pedestrian Research Laboratory of the Georgia Institute of Technology and should not be considered to be statements of policy or otherwise of the participants in the Atlanta Regional Transportation Planning Program or the U.S. Department of Transportation, Urban Mass Transportation Administration.
Acknowledgements

We would like to recognize the assistance of Gerald Pachucki and Lynn Bruce who spent a great deal of time and energy acquainting us with MARTA's administration and operations. We would also like to acknowledge the many employees of MARTA who willingly gave their time and expertise to help us with the project.

We have corresponded and talked with rapid transit systems operators in the U.S. and other parts of the world. Without their participation, we would not have learned much about the magnitude of the problems addressed in this research project nor how others are trying to resolve them. We thank them.
This study was commissioned by the Metropolitan Atlanta Rapid Transit Authority (MARTA). Like other rapid transit systems, MARTA recognizes that, for various reasons, people occasionally fall off station platforms and are injured; and that a significant proportion of these victims are severely visually handicapped individuals.

The goal of the project is to suggest ways of remedying this problem; and then to outline methods of testing these alternatives. Several different types of interventions are proposed for each of these problems. Some of the interventions seem to be effective and practical and some are probably not; but all those that have been suggested have been examined, and evaluated to a degree.

UMTA compiles national statistics on accidents related to rapid rail transit. In 1986 there were 1,698,303,523 passengers carried in the thirteen reporting rapid rail systems in the U.S.A. The reported total of deaths from all types of accidents was 40 persons. MARTA has one of the best safety records of any rapid transit system in the U.S.A. MARTA carried 65,179,000 passengers in 1986 with only 52 injuries and no fatalities. Of these accidents involving injury, only 31 of the 52 injuries occurred as a result of a station area trackway fall. As the table below shows, the frequency of a reported fall onto the trackway is one incident per 12.1 million rail passengers.

**TABLE I**

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of Incidents (Fatalities)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1979</td>
<td>0</td>
</tr>
<tr>
<td>1980</td>
<td>0</td>
</tr>
<tr>
<td>1981</td>
<td>4</td>
</tr>
<tr>
<td>1982</td>
<td>0</td>
</tr>
<tr>
<td>1983</td>
<td>6 (1)</td>
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<td>1984</td>
<td>3 (2)</td>
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<tr>
<td>1985</td>
<td>7</td>
</tr>
<tr>
<td>1986</td>
<td>8 (1)</td>
</tr>
<tr>
<td>1987</td>
<td>2 (1)</td>
</tr>
<tr>
<td>1988 (thru Feb.)</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>31 (5)</td>
</tr>
</tbody>
</table>

Frequency: 1 incident per 12.1 million rail passengers

In order to understand the nature of the problem, we contacted transit systems in the United States and overseas. Few systems maintain a usable statistical base; and
systems do not separate out the various causes, circumstances, and specific locations for accidents so we do not know the national number of falls from the platform onto the trackway. However from the reports of some systems, it is clear that while the magnitude of the problem is not great, the consequences of these accidents are serious. Only two of the systems we contacted kept records which give a clear picture of the problem. These systems were BART and MARTA. In both instances the visually impaired accounted for approximately one-quarter of the fall victims. This means that 75% of the people who fall onto the trackway are not severely visually impaired. If you eliminate those who intentionally fall (suicides), the percentage of visually impaired victims increases to one-third of the total trackway falls. This indicates that for this group of the population the platform edge is more hazardous than it is for the rest of the population. It also indicates that the problem is not limited to those with poor vision, and that two thirds of the victims are not impaired in this way. Useful remedies must therefore resolve or reduce the problem for the general population as well as for the visually impaired. The chart below presents the data from MARTA's accident records.

**TABLE II**

**FREQUENCY OF INCIDENTS BY CONDITION OF INDIVIDUAL**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Number of Incidents (Fatality)</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inebriated</td>
<td>10 (1)</td>
<td>32</td>
</tr>
<tr>
<td>Visually Impaired</td>
<td>7</td>
<td>23</td>
</tr>
<tr>
<td>Alleged Suicide</td>
<td>6 (2)</td>
<td>19</td>
</tr>
<tr>
<td>Drugs (Legal or Illegal)</td>
<td>3 (1)</td>
<td>10</td>
</tr>
<tr>
<td>Non-Defined (Other)</td>
<td>3 (1)</td>
<td>10</td>
</tr>
<tr>
<td>Ill</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>31 (5)</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

From our survey of the literature, we find that most previous studies of falls from platforms have treated the problem as one of attempting to find ways of indicating to the visually handicapped where the edge of the platform is. These studies have focused on evaluating floor surface materials that can be used at the outer edge of the platform as a detectable cue for those who use long canes. The studies remain indicative rather than definitive; and they reveal that we still do not have any materials that are detectable by all or nearly all long cane users; and we have no evidence of any reduction in platform edge falls as a result of the installation of cane detectable cues.

In order to understand the causes of platform falls, and define the specific components of the problem, we chose to use a systems approach. This approach involved examining
the actions a person could take when using a rapid rail system. This "generic" approach allowed us to pinpoint places in the passengers use of the system where errors were most likely to occur. From this analysis of the sequence of events that may result in injury from a platform fall, we have concluded that a successful fall injury mitigation system should include all of the following.

1. HAZARD EXPOSURE REDUCTION SOLUTIONS, which reduce the probability of people falling off the platform, by reducing the amount of unguarded platform edge. These solutions may be expensive, however they are quite effective.

2. PLATFORM EDGE INFORMATION SOLUTIONS, which make it obvious to transit riders (and particularly those with visual impairments) where any unguarded platform edge is located. These solutions are not as effective as the Hazard Exposure Reduction Solutions, however they are significantly lower in cost.

3. INJURY AVOIDANCE SOLUTIONS, reduce the probability of injury from a fall. They attenuate the resulting impact forces, and prevent the train from entering the station. These solutions vary significantly in cost from relatively expensive to very inexpensive. Some of these solutions would require research and development before they could be implemented.

4. PUBLIC EDUCATION SOLUTIONS, which alert the public to the problem. The visually impaired population would be the focus of special attention since they are more "at risk" for platform falls.

All of these four parts of the fall injury mitigation system must act together to form a successful solution. In other words, ideally, a successful design should ensure that if people fall they will not be struck by a train nor severely injured by the fall itself. The design should limit the amount of platform edge that is unprotected. The location of the unprotected edge should be obvious to all; and the area in the vicinity of the edge should be off-limits to all riders when no train is in the station.

We offer several alternative solutions to each of the four parts of the system. Each solution is compared and considered in terms of its feasibility, impact on the current MARTA system, probability for success, and costs. This information is also provided as a matrix from which decisions can be made. As choices can be made from the matrix information, we have refrained from making recommendations. The industry needs to explore the alternative solutions in order to determine the best possible solution for the passengers, and the rapid transit systems.

Finally we have set out a strategy for testing solutions in the laboratory, and in stations of the MARTA system; and we have estimated the cost of this evaluation. Obviously, a full evaluation proposal will depend on the solutions that MARTA wishes to evaluate.
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AN EVALUATION OF FALLS AT PLATFORM EDGES,
AND A DISCUSSION OF POTENTIAL SOLUTIONS.

The Nature of the Problem.

We have sought statistical information on platform falls from all of the rapid transit systems in the United States, Canada, and from several foreign countries; but some of these systems have not responded to our inquiries.

In 1986 there were 408 persons injured in system-wide trackway accidents in thirteen major US transit systems, for which figures were available (UMTA, 1987). The information gathered by UMTA shows that MARTA ranks eleventh out of the thirteen systems in terms of casualties. That means that only two heavy rail transit systems had lower casualty rates in 1986 than MARTA (UMTA, 1987).

MARTA has one of the best safety records of any rapid transit system in the U.S.A. MARTA carried 65,179,000 passengers in 1986 with only 52 injuries and no fatalities. The frequency of a reported fall onto the trackway is one incident per 12.1 million rail passengers. For the purposes of this study, we will define a station area trackway fall as a fall into the station area trackway which originated from the platform or station concourse.

### TABLE IV

NUMBER OF STATION AREA TRACKWAY FALLS PER YEAR OF OPERATION

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of Incidents (Fatalities)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1979</td>
<td>0</td>
</tr>
<tr>
<td>1980</td>
<td>0</td>
</tr>
<tr>
<td>1981</td>
<td>4</td>
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<td>1982</td>
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<td>1983</td>
<td>6 (1)</td>
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<td>1986</td>
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</tr>
<tr>
<td>1987</td>
<td>2 (1)</td>
</tr>
<tr>
<td>1988 (thru Feb.)</td>
<td>1</td>
</tr>
</tbody>
</table>

Total 31 (5)

Frequency: 1 incident per 12.1 million rail passengers
The data collected by UMTA in their annual **Heavy Rail Transit Safety Report** is very broad, and determination of more specific accident facts is not possible. BART is the only system, so far as we can determine, which files reports which record the type of accident, nature and location of the accident, and any pertinent data on the victim. From their statistics, in the 10 year period from 1978-1987, there were 129 people who were injured on the trackway. Of these, only 24% were blind (BART,1987). The other victims were categorized as inebriated (13%), ill (13%), inadvertent fall or pushed (26%), and deliberate trespassers which included suicide attempts (22%) (BART,1987). These figures clearly demonstrate that the problem of falls onto the trackway is not limited to people who are blind, in fact, 74% of the victims fell due to reasons other than blindness. (BART,1987) Until BART began keeping records regarding accident specifics, the widespread nature of the problem went virtually unnoticed. Aggravating the situation is the fact that most falls result in injury. According to Roger Wood of WTMA, in their system all reported falls resulted in an injury. MARTA has had a different experience, however, several falls have resulted in only a slight injury to the passenger.

Rapid transit systems generally seem to be conscious of the number and severity of platform edge falls, but have tended to treat it as a problem for the severely visually impaired only. Many of the systems had installed, or are about to install, ‘detectable edge strips’; as we discuss later, these devices are at best a partial solution.

**Ability to Utilize Information in a Particular Form**

Environmental information is utilized with varying degrees of success by various people. For instance, written directions are of no use to a sightless or illiterate person. Braille writing is indecipherable to most sighted (and sightless) people. It is important to identify which groups can avail themselves of information in various forms. The matrix that follows allows us to see how certain types of information will affect various population groups.

<table>
<thead>
<tr>
<th></th>
<th>SIGHTLESS</th>
<th>LOW VISION</th>
<th>SIGHTED</th>
<th>INEBRIATED</th>
<th>ILL</th>
<th>SUICIDE</th>
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<tr>
<td><strong>SOLUTIONS</strong></td>
<td></td>
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<tr>
<td>VISUAL INFORMATION</td>
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<td>SURFACE DETECTIBLE INFORMATION</td>
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<td></td>
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<tr>
<td>BARRIERS</td>
<td></td>
<td></td>
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<td></td>
</tr>
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</table>

- GOOD, readily and easily use this information
- FAIR, usually use information in this form
- POOR, not usually use information in this form.
A Systems Approach Model

A fall off a platform may be the result of decisions made at some distance from the platform edge. For example, a visually handicapped person may conclude incorrectly that she is on a path that will lead to a station exit when in fact it leads to a platform edge. Another fall may result from a child running close to the platform edge or even being pushed during play, and losing his balance. This suggests that to reduce the incidence of falls, we must examine the sequence of events that may lead to a fall.

If a fall occurs, it is not inevitably injurious. Injuries occur because the victim's body strikes something hard (the concrete floor or a rail), or the victim is struck by the train or the victim receives an electric shock. From this we conclude that another sensible task is to find ways of reducing injuries. This suggests that we should try to look for ways of 'softening' the area below the platform, in much the same way that the interior of a car is 'softened' to protect the passengers in the event of an accident; and it suggests that we should consider ways to reduce the probability of electrocution, and of a train striking someone who has fallen onto the tracks.

The approach taken in this study is to analyze the transit system use as a series of tasks. We consider the events that occur from the time the individual traverses the fare gate at the station of departure, travels to the platform, boards the train, exits the train at his destination, and leaves the terminal station. We look at the decisions which must be made to accomplish these tasks, the problems which may be encountered along the way, the reasons that the problems exist, and finally potential solutions to the problems (some of which may be new ideas, others which may have been utilized and/or evaluated by other transit systems).

The purpose of this approach is to identify a number of potential solutions which could be implemented; to compare their strengths and weaknesses; and to identify fall warning or prevention systems, and injury reduction systems for further evaluation by MARTA. Several methods were undertaken in order to determine these solutions. These included:

1) a manual and computerized literature search of the TRIS (Transportation Research Information Service) database as well as other relevant databases, UMTA/UMTRIS (Urban Mass Transit Information Service), The ATBCB (Architectural and Transportation Barriers Compliance Board) and other public records;

2) personal contact with the safety managers of other transit systems in the U.S., Canada, Japan, England, France, Germany and Hungary, to discuss problems and solutions implemented in other transit systems;

3) a brainstorming session with designers and engineers to discuss existing solutions and to develop potential new and novel solutions; (see Appendix C)

4) meetings with MARTA personnel to assess where there might be problems with the proposed solutions.
<table>
<thead>
<tr>
<th>System</th>
<th>USA</th>
<th>Intervention</th>
</tr>
</thead>
</table>
| MARTA      | Metropolitan Atlanta Rapid Transit Authority     | • Flame Cut Granite Edge Strip  
             | San Francisco                                     | • Evaluating alternatives                       |
| BART       | Bay Area Rapid Transit                            | • Pathfinder tile (yellow)                     |
| WMATA      | Washington Metropolitan Area Transit Authority   | • Flame Cut Granite                            |
|            | Washington, D.C.                                  | • Mobility & Orientation Training              |
| MTA        | Mass Transit Authority                             | • Flame Cut Granite                            |
| MBATA      | Massachusetts Bay Area Transit Authority          | • Pathfinder Tile (yellow)                     |
|            | Boston, MA                                         | • PA System                                     |
| MDTA       | Metro-Dade Transportation Authority               | • Currently Evaluating Pathfinder Tiles        |
|            | Miami, FL                                          |                                                 |
| NYCTA      | New York City Transit Authority                   | • Textured Concrete                             |
|            | New York, NY                                       | painted yellow 3" wide, 1 foot from edge of platform |
| SPT        | Southeastern Penn. Transportation Authority      | • Yellow lines                                  |
|            | Philadelphia, PA                                   |                                                 |
| CTA        | Chicago Transportation Authority                  | • No consistent approach                       |
|            | Chicago, IL                                        | • Evaluating pathfinder tiles                   |
| Cleveland  | Cleveland, OH                                      | • Evaluating pathfinder tiles                   |
| New Jersey | New Jersey                                         | • Evaluating pathfinder tiles                   |
| Sacramento | Sacramento, CA                                     | • Pathfinder tiles                              |
### International

<table>
<thead>
<tr>
<th>TTC</th>
<th>Toronto Transit Comm.</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTCUM</td>
<td>Montreal Urban Community Transit Commission Montreal</td>
</tr>
<tr>
<td>Stuttgart</td>
<td>Stuttgart, West Germany</td>
</tr>
<tr>
<td>HVV</td>
<td>Hamburger Verkehrsbund Hamburg, Germany</td>
</tr>
<tr>
<td>Prague</td>
<td>Prague, Czechoslovakia</td>
</tr>
<tr>
<td>Kyoto</td>
<td>Kyoto, Japan</td>
</tr>
<tr>
<td>Osaka</td>
<td>Osaka, Japan</td>
</tr>
<tr>
<td>RATP</td>
<td>Regie Automedes Transports Parisiens Paris, France</td>
</tr>
</tbody>
</table>

- Alternating yellow & black pattern
- 2-3" wide textured strip 8" from edge
- Pathfinder tiles in orange
- Evaluating cane detectible magnetic strip
- Slight color difference at platform edge
- 2" wide strip of raised dots bright yellow
- Train stops if patron crosses 2' from edge
- Yellow guidance tile w/ raised arrow and braille on handrails
- Yellow guidance tile w/ raised arrow and braille on handrails
- Raised tile with dots 420 cm wide 500 cm from the edge (see page 64 diagram)

* Only for those systems responding to our inquiry.
SYSTEM ANALYSIS

An analysis of the tasks required to use the transit system successfully, and the decisions that must be made by the traveller in order to accomplish these tasks, are shown in the accompanying chart. The task really begins with finding one's way into the station and ends with successfully finding one's way out of the station of destination. However, the primary concern of this project is with areas of the station that might potentially lead someone to the platform. So, the outline below is confined to tasks within the system, that is from the time one passes through the entry fare gate to the time one exits the gate.
## Systems Analysis (continued)

<table>
<thead>
<tr>
<th>Tasks/Decisions</th>
<th>Potential Problems</th>
<th>Environmental Factors</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Task 5. Getting off the platform.</strong>&lt;br&gt;5.1 Determine the direction of the vertical circulation.&lt;br&gt;5.2 Find the route to the vertical circulation.&lt;br&gt;5.3 Use the vertical circulation.</td>
<td>5.1 Unable to determine the route to the or go wrong way.&lt;br&gt;5.2 Unable to find the vertical circulation.&lt;br&gt;5.3 Unable to use vertical circulation or mishap in its use.&lt;br&gt;5.3.1 Elevator:&lt;br&gt;   a. failure to locate or reach call button.&lt;br&gt;   b. failure to locate or reach level button.&lt;br&gt;   c. failure to understand level designations.&lt;br&gt;   d. inability to read braille or incised letters.&lt;br&gt;5.3.2 Stairs:&lt;br&gt;   a. failure to detect top landing (going down)&lt;br&gt;   b. mis-step on the stairs&lt;br&gt;   c. failure to detect bottom landing (going up)</td>
<td>5.1 Lack of signage, poor or inconsistent placement of signage, or lack of consistent station layout, or lack of non-visual information that could be used to find the station entry.&lt;br&gt;5.2 Lack of signage, poor placement of signage, poor communication of station layout (as each station is different), or lack of non-visual informational cues.&lt;br&gt;5.3 Lack of non-visual information and poor visual contrast in design elements.&lt;br&gt;5.3.1 Elevator:&lt;br&gt;   a. poor placement (too high or low), poor visual and tactile contrast between button and background.&lt;br&gt;   b. poor placement (too high or low), poor visual and tactile contrast between button and background.&lt;br&gt;   c. poor understanding of station layout and level designations (e.g. concourse and platform).&lt;br&gt;   d. poor design of control panel.&lt;br&gt;5.3.2 Stairs:&lt;br&gt;   a. No clear visual or textural marking to delineate the top of the stairs, handrails do not project beyond the stairs.&lt;br&gt;   b. Debris on stairs, no highly contrasting visual material to delineate the edges of stairs.&lt;br&gt;   c. No clear visual or textural marking to delineate the bottom of the stairs, handrails do not project beyond the stairs.</td>
<td>5.1 a. Could become lost or confused and end up at platform edge without knowing it.&lt;br&gt;5.2 a. Could take wrong route and end up in wrong place.&lt;br&gt;5.2 b. Potential falling hazard if disoriented and end up at platform without realizing it.&lt;br&gt;5.3 Failure to get out of the system.&lt;br&gt;5.3.1 Elevator:&lt;br&gt;   a. Could become confused and need assistance;&lt;br&gt;   b. Could become confused and get stuck in elevator.&lt;br&gt;5.3.2 Stairs:&lt;br&gt;   a. Could fall down stairs and be seriously injured.&lt;br&gt;   b. Could wander back into the platform, become confused and fall off the edge.</td>
</tr>
<tr>
<td><strong>Task 6. Getting out of the system.</strong>&lt;br&gt;6.1 Determine direction of the exit fare gate.&lt;br&gt;6.2 Find the exit fare gate.&lt;br&gt;6.3 Use the exit fare gate.</td>
<td>6.1 Unable to determine the direction of the exit fare gate.&lt;br&gt;6.2 Cannot find the exit fare gate.&lt;br&gt;6.3 Cannot use the exit fare gate.</td>
<td>6.1 Lack of signage, poor placement of signage, or lack of consistent station layout (as each station is different), or lack of non-visual informational cues.&lt;br&gt;6.2 No standard location of the fare gate, no non-visual cues or detectable path to the fare gate, no non-visual information indicating which is the handicapped accessible gate.&lt;br&gt;6.3 Lack of non-visual information differentiating entry from exit gate.</td>
<td>6.1 a. Could become lost or confused and end up at platform edge without knowing it.&lt;br&gt;6.2 a. Could take wrong route and end up in wrong place.&lt;br&gt;6.2 b. Potential falling hazard if disoriented and end up at platform without realizing it.&lt;br&gt;6.3 a. Injury could result if someone is exiting wrong gate.&lt;br&gt;6.3 b. Injury could result if someone is exiting wrong gate.&lt;br&gt;6.3 c. Injury could result if someone is exiting wrong gate.</td>
</tr>
</tbody>
</table>
POTENTIAL SOLUTIONS

We can group the findings of the analysis into four areas for which solutions are needed;

- Reduce the area of danger to a reasonable minimum. Limit the amount of exposed platform edge that is uncontrolled. We have called this the HAZARD EXPOSURE REDUCTION SOLUTION.

- Provide information that will ensure that all riders can find the platform edge with confidence, and we call this the PLATFORM EDGE INFORMATION SOLUTION.

- Limit the probability of injury if anyone falls off the platform through an INJURY AVOIDANCE SOLUTION.

- Educate the public about what to do in the event of a platform fall through a PUBLIC EDUCATION SOLUTION.

Description and evaluation.

In a search for possible solutions to the problems exposed in the system analysis, we used a variety of approaches. MARTA personnel met with us on several occasions, presenting us with their ideas and evaluations. A brain-storming session was held at Georgia Tech. in which several creative 'idea people' generated ideas. Finally, members of the research team invented solutions, and considered all the ideas brought to our attention. Four types of interventions have been proposed and they are as follows:

- Hazard Exposure Reduction Solutions
- Platform Edge Information Solutions
- Injury Avoidance Solutions
- Public Education Solutions

We will now discuss each of these four types of solutions; and each solution will be described, discussed, and briefly evaluated in terms of effectiveness, initial cost (per 600 foot station platform each), cost in use, maintenance, cleaning, effect on traffic flow, ease of installation, detectability by the visually impaired, potential hazards, and back up systems needed if the solution fails for any reason. In the time available, and the limited work scope, these evaluations should be treated with caution; they are our 'best guesses' based on our own opinions supplemented by estimates from MARTA personnel. The costs are for 2 - 600 ft. edges of platform area unless otherwise noted. We view this phase of the project as preliminary in the sense that these proposals are sometimes radical and mostly speculative; nevertheless, in our opinion several of the proposals are worthy of further investigation and experimental evaluation.
Hazard Exposure Reduction Solutions.

The purpose of this first group of interventions would be to reduce to a practical minimum the platform edge that people may be exposed to, and fall from.

Type 1

Guardrail

- Install stainless steel guardrail along the length of the platform three feet back from the platform edge. Guardrails should be three feet high with rails and balusters set to restrict passage, for children, to no more than five inches on center. The guardrail will not be continuous. To permit access to the train, leave fourteen feet wide openings for each of the three doors of the eight cars. The openings will be centered on the design location of the stopped location of train doors.

Discussion

The 600 feet of platform edge exposed would in effect be reduced by 336 feet (3x8x14), to 264 feet (a reduction of 56%). The trains are designed to stop at a particular and standard location. Theoretically, the trains can stop at precisely the planned location; therefore, the doors (regardless of the number of cars) should always open at what one could call a platform door position. In practice the train may miss the platform door position by as much as five feet. MARTA reports that three feet is the usual maximum over or under run, and that at five feet the faulty unit would have to be repaired.

The car doors are about four feet wide when they are open. Allowing for a maximum of five feet over run, or under run, then a fourteen foot opening in the guardrail system would ensure that the car door opening would always open onto a guardrail opening.

People on platforms are currently warned to stay back from the three foot edge strip when there is no train in the station. The guardrail would enforce this for nearly half of the platform's length.

The resulting fourteen foot openings could be further protected by an electronic intrusion detector, and other platform edge information devices as discussed later.

Will the guardrail impede pedestrian traffic flow particularly at peak hours or in emergencies? This would require experimental evaluation. Theoretically, however, little change is likely. At the Atlanta airport rail system, where the car door openings are fixed relative to the platform, at peak periods passengers spread themselves along the platform satisfactorily.

Effectiveness

- Will reduce exposure by 56%

Initial Cost

- $300,000 (per 2 (600 ft.) platform edges
Cost in use  ● Minimal

Maintenance  ● Should seldom require maintenance

Cleaning  ● Normal

Traffic flow  ● Not likely to slow access to and egress from trains. Unlikely to reduce platform egress time during emergencies to an unacceptable level.

Installation ease  ● Easy

Detectability  ● Excellent (where there is guardrailing)

Back-up  ● None needed

Potential hazards  ● Children may climb onto the guardrail and fall

Type 2

Gates in Guardrails-

Install guardrails (as for system 1) three feet back from the platform edge, with gates in the 14 feet openings, for access to the train. There would be three gate units of fourteen feet set into each car length of platform. Access to the platform edge and the cars would only be through the gates. Gates should be similar to those used by WMATA for ticket access, but with electronic operation control. After a train leaves the station, a signal to lock the gates would be activated preventing access from the platform through the gates; an infra red beam triggering device would open the gates at all times for access from the platform edge, ensuring that no one would be prevented from exiting. A train entering the station would signal to unlock the gates.

Discussion

Although there is little, if any, research to document the effectiveness of barrier systems, there is, nonetheless, precedent for their use, particularly in light rail systems such as the one used at Atlanta's Hartsfield International Airport. However, none of the transit systems contacted currently utilize gates (or barriers) on the platforms.

In 1987 the Washington Metropolitan Area Transit System (WMATA) conducted a survey of other systems in order to determine the extent of the problem of travellers falling off station platforms and the feasibility of using a gate system to prevent falling accidents (Wood, 1987). They concluded that, while platform/trainway gates could have positive benefits regarding the incidence at stations of suicides, trespassing and accidental falls, they may also be detrimental in other aspects. They assumed that injuries from the gates could be expected, and that they might also offer an impedance to emergency evacuation. They decided that substantial yearly operational and maintenance costs could be expected and the
disruption of service during installation would be considerable. Finally, the study concluded that the cost of retrofitting gates in the system would be substantial ($300-500 million). The study recommended that no system of gates be adopted by WMATA.

**Effectiveness**
- Should eliminate most accidental falls. Will not eliminate suicides.

**Initial Cost**
- $1,800,000 per 2 (600 ft.) platform edges.

**Cost in use**
- Unknown

**Maintenance**
- Gates will require regular routine maintenance, and repair.

**Cleaning**
- Normal

**Traffic flow**
- May slow access to and egress from train, and slow passenger traffic at peak periods, particularly if any gate fails to open.

**Installation ease**
- Retrofitting stations for wiring and controls would be necessary.

**Detectability**
- Design might have to be modified for long cane visually handicapped users.

**Failure result**
- Individual gate failure would cause delays; signal failure could prevent the whole gate system from opening, and preclude access to and from trains. This could be conveyed to the system and train driver, and the station bypassed.

**Back up system**
- System could be self monitoring; signal failure could actuate a secondary power source (if needed) that opens the gates.

**Potential hazards**
- Results from crowding in the event of system failure, and emergency evacuation.
  - Similar accidents that occur at gates presently in use.

**Type 3**

**Turnstiles in Guardrails**

The gates would be used in the same way as the gates of Solution 2, and would have similar electronic controls as the fare entry.

**Discussion**

The turnstiles would be similar to those used by MARTA in the concourses.

**Effectiveness**
- Should eliminate most accidental falls.

**Initial Cost**
- $3,000,000 per 2 (600 ft.) platform edges.

**Cost in use**
- None
**Maintenance**  
- Turnstiles will require occasional routine maintenance.

**Cleaning**  
- Normal

**Traffic flow**  
- Will slow access to and egress from train, and slow passenger traffic at peak periods.

**Installation ease**  
- Retrofitting stations for wiring and controls would be necessary.

**Detectability**  
- Should be detectible

**Failure result**  
- Individual turnstile failure would cause delays; signal failure could prevent the whole turnstile system from operating, and preclude access to and from trains. This could be conveyed to the system and train driver, and the station bypassed.

**Back up system**  
- System could be self monitoring; signal failure could actuate a secondary power source (if needed) that controls the turnstiles.

**Potential hazards**  
- Results from crowding in the event of system failure, and emergency evacuation.

**Platform Edge Information Solutions.**

The purpose of this second group of interventions is to ensure that riders will be able to know with confidence where the platform edge, and the three feet off-limits platform outer strip, are in relation to their body.

**Type 4 Bollards-**

Three foot high round posts (5" in diameter) set at intervals (approximately 42") down the full length of the platform. They would be set back three feet from the platform edge and would be spaced to accommodate a wheelchair's width, while remaining detectible by a cane sweep of a visually impaired person. They should be readily detectible by people without sight, and they would reinforce the 'off-limits' nature of the three foot edge strip.

**Discussion**  
We know of no examples where this type of solution has been used and evaluated.

**Effectiveness**  
- Should reduce exposure, and may act to reinforce the off-limits nature of the last three feet. Should be easily detected by long cane users.

- May not be affective in reinforcing edge.

- People can still bypass the bollards and fall

**Cost**  
- $100,00 per 2 (600 ft.) platform edge.

**Cost in use**  
- Unknown
Maintenance

- Minimal

Cleaning

- Normal

Traffic flow

- Could slow egress from trains onto platform.

Installation ease

- Easy

Detectability

- Should be easily detectable by long cane users.

Failure result

- None.

Back up

- Should be used with other redundant cuing devices as described later.

Potential hazards

- Unlikely.

Type 5

Detectible Strips-

A strip of a special flooring material would be placed at or near the platform edge. It should be detectable by long cane users and be discernably different from the platform floor material. Its primary function would be to warn long cane users of the hazard; it should also provide a visual contrast for people with low vision.

Discussion

There has been considerable interest in and use of this as a solution. The Architectural and Transportation Barriers Compliance Board (Federal Register, January 16, 1961) and American National Standards Institute (1980) have guidelines requiring the use of a textured warning strips at drops, and especially along platform edges.

Visually impaired people routinely use latent changes in walking surface materials as mobility and orientation aids. However, only limited empirical research has been completed on their value as overt cues in actual buildings and sites. This research has shown that changes in surface conditions can provide valuable information to cane users. For example, Aiello and Steinfeld (1979) and Templer, et al. (1980 and 1982) demonstrated that there are a range of materials that are potentially detectible by cane users. Aiello and Steinfeld (1979) found that certain materials, in specific configurations, could be detected by cane users traveling over a concrete walking surface if the material covered a large enough area. Templer, et al. (1982) identified a small group of materials suitable for external walkways that were detectably different from brushed concrete.

In addition, Templer, et al. (1982) identified a number of different materials, which depended on sound, and resiliency differences, colors (for those with partial vision), and configurations and
coverage areas, that affected detectability by the visually impaired in outdoor environments. In this study, the surfaces tested were contrived combinations of various building materials (e.g., wood, steel, concrete, and rubber), specifically configured to test the detectability of different materials which conformed to the ANSI A117.1 (1980) Standard.

To determine the detectability of materials already being specified in construction as walking surface finishes (i.e. vinyl, wood, and rubber flooring, steel grates and masonry pavers), Pavlos, Sanford and Steinfeld (1985) tested a number of off-the-shelf materials which could be utilized in contrast to concrete and other masonry surfaces. The results of this study supported the previous findings by Templer et al. (1982), in terms of the importance of sound (and, to a lesser degree, resiliency) differences rather than textural ones in contrasting a detectible cue from the surrounding walkway. It also demonstrated that readily available finishes, which did not specifically conform to the ANSI Standard, could be as effective and perhaps more effective than deliberately contrived surfaces.

This research supports the notion that visually impaired populations do not differ in their expectations of architectural space from sighted people. They only differ in the mode of sensory input. The more forgiving an informational cue is, that is the greater number of sensory qualities (e.g., color texture, sound) the cue has, the more likely that it will be detected and understood. This study tested ground surface materials, and found that they are at least as, if not more, detectible by individuals who are totally blind and use long canes as by persons who are partially sighted and use no mobility aids. This indicates that surface changes can potentially be used effectively in conveying information not only to visually impaired people, but to sighted people as well.

In a study of detectibility of tactile surfaces in a transit system, Bentzen and Peck (1987), utilized the methodologies developed by Templer et al. (1982) to test the detectibility of four surfaces in several stations in the Bay Area Rapid Transit (BART) System. They found that the Pathfinder Tile was more detectible on concrete platforms than either of two contrived PVC (hard plastic) surfaces or a Pirelli Rubber (hard rubber) surface. BART has now installed the Pathfinder Tile at platform edges throughout the system.

Obviously a small number of surfaces were tested in the BART project, and the tests seem to have relied heavily on textural differences rather than sound differences (hard plastic and rubber tend to be similar to masonry when installed over masonry). Additionally, none of the subjects approached the test strip obliquely, a case which happens frequently in real life. So, some questions remain as to whether there are other surfaces that offer greater detectability at a lower cost and that are more durable, easier to maintain, install easier etc.
A more recent study was conducted by the Miami-Dade Transit Agency which replicated much of the BART testing. They recommended the use of the Pathfinder Tile after comparing it to the granite edge at an existing station. They used 19 long cane users and conducted 151 trials. The Pathfinder Tile was detected 99% of the time and the granite edge was detected 89% of the time. This detectability rate is about twice that of any of the dozen or so surfaces tested by over 100 subjects at Georgia Tech and SUNY at Buffalo (Templer, 1982; Pavlos, Sanford and Steinfeld, 1985) where detection rates ranged from 9% to 45%. It seems likely that these high detection rates arise from the subjects increasing familiarity with the surfaces being tested. This raises questions about the significance of the test procedures for our purposes.

It should be borne in mind that the laboratory test procedures included subjects with various skills as travellers, and this may well have affected the results. However, in reality, MARTA users who have no vision will also vary in terms of their travel skills.

Experiments have also been conducted by several transit systems to find materials and techniques for creating warning strips which are durable, able to be installed and maintained at reasonable cost, and have sufficient visual and textural contrast to be readily detected by visually impaired travellers. Several materials such as the Pathfinder Tile, the Wooster Supergrit Tread and flame cut granite, are in use, and they vary in acceptability to visually impaired travellers, as well as in durability and costs of installation and maintenance. The strips also vary in width and in distance from the platform edge, (Bentzen, Jackson and Peck; 1981).

Effectiveness

- With laboratory detection rates of no more than 45%, the device seems to have limited usefulness to visually impaired people when not used in conjunction with other information sources.

- Research has raised questions about the effectiveness of strips when used in connection with certain adjacent materials. Detectability is always expressed in terms of two materials and the perceptible difference between them.

- May not be affective in reinforcing 'edge off-limit'.

- People can still bypass and fall

Cost

- $200,000 per 2 (600 ft.) platform edges.

Cost in use

- Minimal

Maintenance

- Minimal

Cleaning

- Normal

Traffic flow

- Not likely to be affected
Installation ease

- Installation would require routing out a portion of the floor surface of any existing platform.

Detectability

- 45% detectability rate.

Failure results

- None

Back up

- To improve effectiveness, should be used in conjunction with other devices.

Potential hazards

- None if carefully installed to avoid potential tripping hazards.

Type 6

Visual Contrast Edging Strip

A one foot strip set two foot from the edge of the platform would be laid with a detectible edging strip in contrasting colored bands.

Discussion

Much of the discussion on detectable edging has been directed at those with little or no vision. Those with low vision are a much larger segment of the population, devising means of emphasizing the edge for those with low vision will have a greater pay off. It will not however resolve the problem for those without vision.

Color contrasts (Templer, et al., 1982; Pavlos, Sanford and Steinfeld, 1985) may be extremely useful for people who retain some vision, and is useful for sighted travellers. While this intervention is, for all practical purposes an extension of tactile surfaces (color, like sound, resilience and texture, is a detectable quality that a material has), it is used to some extent by all of the transit systems surveyed, even when it is not accompanied by a change in surface material or texture. This seems to indicate that there is an acknowledgement that the edge of the platform does need some clear identification, at least for sighted pedestrians.

Effectiveness

- May be effective for those with low vision, and for the able bodied in delineating the 'off-limit' edge.

- May be affected by lighting conditions and cleanliness.

- Limited usefulness to visually impaired people when not used in conjunction with other information sources.

- Will not be useful to those with no vision unless the strip is also cane detectable.

- May not be affective in reinforcing 'edge off-limit'.

- People can still bypass and fall
<table>
<thead>
<tr>
<th>Property</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Cost</td>
<td>$200,000 per 2 (600 ft.) platform edge.</td>
</tr>
<tr>
<td>Cost in use</td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
<td>Minimal</td>
</tr>
<tr>
<td>Cleaning</td>
<td>Normal</td>
</tr>
<tr>
<td>Traffic flow</td>
<td>Not likely to be affected</td>
</tr>
<tr>
<td>Installation ease</td>
<td>Installation would require routing out a portion of the floor surface of any existing platform.</td>
</tr>
<tr>
<td>Detectability</td>
<td>If it is made cane detectable, it will then only be detected about 45% of the time.</td>
</tr>
<tr>
<td>Failure result</td>
<td>None</td>
</tr>
<tr>
<td>Back up</td>
<td>To improve effectiveness, should be used in conjunction with other devices.</td>
</tr>
<tr>
<td>Potential hazards</td>
<td>None if carefully installed to avoid tripping hazards.</td>
</tr>
<tr>
<td><strong>Type 7</strong></td>
<td><strong>Ramped edge strip</strong></td>
</tr>
<tr>
<td></td>
<td>At or near the edge of the platform a slight rise or 'bump' in a floor material would be made. This would be of sufficient height to be cane detectible, say one inch high at the center.</td>
</tr>
<tr>
<td>Discussion</td>
<td>From various studies, it has been shown that long cane users can detect ramps, or at least curb ramps if they are steep enough (a gradient more than 1:16). We do not know whether very short ramps, say 18&quot; long as is proposed would be detectible. Another alternative is the use of inclined surfaces. Templer, 1979 discovered that visually impaired people can use slight inclines or humped surfaces to guide their movement along a pathway. Pavlos, Sanford and Steinfeld, 1985) found that visually impaired subjects can detect both upward and downward ramp slopes that are similar to those prescribed for sidewalk curb cuts. Slight changes in level that do not pose problems to other mobility impaired travellers may also aid in providing overt information to blind travellers.</td>
</tr>
<tr>
<td>Effectiveness</td>
<td>Limited usefulness to visually impaired people when not used in conjunction with other information sources. People can still bypass the strip and fall. There may be no standard material available.</td>
</tr>
</tbody>
</table>
- It may become a tripping hazard.
- Provides no edge protection.
- May act adversely for wheelchair users.

<table>
<thead>
<tr>
<th>Initial cost</th>
<th>$250,000 per 2 (600 ft.) platform edges.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost in use</td>
<td>Unknown</td>
</tr>
<tr>
<td>Maintenance</td>
<td>Minimal</td>
</tr>
<tr>
<td>Cleaning</td>
<td>May prevent water run-off from platform, and inhibit cleaning operations.</td>
</tr>
<tr>
<td>Traffic flow</td>
<td>Not likely to be affected</td>
</tr>
<tr>
<td>Installation ease</td>
<td>Installation would require routing out of a portion of the floor surface of any existing platform.</td>
</tr>
<tr>
<td>Detectability</td>
<td>Unknown in such dimensions</td>
</tr>
<tr>
<td>Failure result</td>
<td>None</td>
</tr>
<tr>
<td>Back up</td>
<td>To improve effectiveness, should be used in conjunction with other devices.</td>
</tr>
<tr>
<td>Potential hazards</td>
<td>None if it is carefully installed to avoid tripping hazards.</td>
</tr>
</tbody>
</table>

**Type 8**  
*Pressure sensitive floor signal strip-*

At a point about three feet from the edge platform, a pressure sensitive pad could be installed which could trigger a warning message over the public address system if anyone walks on it when it is switched on. It would be in its active mode when the train is in motion.

<table>
<thead>
<tr>
<th>Effectiveness</th>
<th>May be effective in reinforcing 'edge off-limit'.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Limited usefulness to visually impaired people when not used in conjunction with other information sources.</td>
</tr>
<tr>
<td>Initial Cost</td>
<td>$400,000 per 2 (600 ft.) platform edge.</td>
</tr>
<tr>
<td>Cost in use</td>
<td>Small</td>
</tr>
<tr>
<td>Maintenance</td>
<td>Will depend on material and electronics.</td>
</tr>
<tr>
<td>Cleaning</td>
<td>Not likely to require special treatment.</td>
</tr>
<tr>
<td>Traffic flow</td>
<td>• Not likely to be affected</td>
</tr>
<tr>
<td>------------------------------</td>
<td>----------------------------</td>
</tr>
<tr>
<td>Installation ease</td>
<td>• Will require routing out the existing platform floor.</td>
</tr>
<tr>
<td>Detectability</td>
<td>• Detectible if used in conjunction with other devices</td>
</tr>
<tr>
<td>Failure result</td>
<td>• For sightless people who may depend on this warning, failure would be dangerous.</td>
</tr>
<tr>
<td>Back up</td>
<td>• Could be used in conjunction with gates/barriers and turnstiles.</td>
</tr>
<tr>
<td>Potential hazards</td>
<td>• Provides no edge protection.</td>
</tr>
</tbody>
</table>

- System may be activated by children playing on it.
- Vandalism.
- Recorded message may be ineffective as a warning.

**Type 9**

**Wind curtain in Guardrailing**

Three feet back from the platform edge, a curtain of air would be blown horizontally from between the openings of the guardrails so that patrons would feel their location in relation to the edge.

**Effectiveness**

- May be rendered ineffective from air movement when train enters and leaves a station.
- Limited usefulness to visually impaired people when not used in conjunction with other information sources.
- To be effective, it must have sufficient force to be obvious; and this may disturb people's hair or clothing.
- May not be affective in reinforcing 'edge off-limit'.
- People can still bypass and fall
- Provides no edge protection.

**Initial Cost**

- $1,000,000 per 2 (600 ft.) platform edges.

**Cost in use**

- Fan motors would consume power.

**Maintenance**

- Periodic maintenance and repair would be needed.

**Cleaning**

- Will not affect platform cleaning.

**Traffic flow**

- Not likely to be affected

**Installation ease**

- Will require ducting and fan motor installation.
**Detectability**
- Unknown. Would require training for visually impaired riders.

**Failure result**
- Would be dangerous for those who have learned to rely on this cue.

**Back up**
- Should be used only in concert with other devices.

**Potential hazards**
- See failure result.

**Type 10**

*Photoelectric beam which will trigger a recorded warning announcement when broken*

A photoelectric beam would be placed to project along the platform, three feet from the platform edge (or between the barriers openings in type 1). The beam would be activated by the system when there is no train at the platform. If the beam is in the active mode and it is broken by someone moving close to the platform edge, a recorded warning would be played over the public address system stating that they must move back from the edge.

**Effectiveness**
- May be effective in reinforcing ‘edge off-limit’
- Limited usefulness to visually impaired people when not used in conjunction with other information sources.
- People can still bypass and fall
- Provides no edge protection
- Beam may be broken by children playing with it.
- Vandalism.
- Recorded message may be ineffective as a warning.

**Initial cost**
- $1,150,000 per 2 (600 ft.) edges.

**Cost in use**
- Would require occasional servicing and repair.

**Maintenance**
- System would require maintenance.

**Cleaning**
- Would not affect existing cleaning procedures.

**Traffic flow**
- Not likely to be affected.

**Installation ease**
- Will require connection to power, and to control system (to disarm it when train enters station).

**Detectability**
- Good when operational.
### Failure result
- Would be dangerous for blind people who have come to rely on this information.

### Back up
- Should be used in concert with other systems.

### Potential Hazards
- See failure result.

#### Type 11
**Sound location beacon**

Install (perhaps with the barrier system) sound generators that produce a click or chirp at some intervals.

#### Discussion
Despite mobility training techniques which emphasize the use of sound as a latent cue (e.g. the direction of automobile traffic or the location of an escalator) and the extensive research on the auditory abilities of visually impaired people (E.g. Christian and Rossey, 1975; Curtis and Winer, 1969; and Norlund, 1975), little research has been undertaken to document the effectiveness of sound as an overt cue. Templer, et al. (1982) found that the installation of a tweeter greatly increased a blind person's ability to locate an object. A device such as this which can emit a continuous signal has excellent potential for aiding mobility in transit stations. Many Japanese cities such as Osaka, Kyoto and Tokyo use directional beepers at pedestrian crossings to aid blind travellers. However, there is no data to determine the effectiveness of this intervention. Nonetheless, this solution can have important applications in mass transit. The Mass Transit Administration of Baltimore, for example, has installed a beeper device at the central door of each rapid rail vehicle with the purpose of aiding blind persons in locating open vehicle doors.

#### Effectiveness
- Principle is known to be effective. Would need to be tested for this application so that the noise is not offensive to others, and is audible in the context. Would require power source.

#### Initial Cost
- $1,000,000 (600 ft.) platform edges, when installed in guardrailing.

#### Cost in use
- Nominal

#### Maintenance
- Would require occasional maintenance and repair.

#### Cleaning
- Would not affect present cleaning procedures.

#### Traffic flow
- Would not be affected.

#### Installation ease
- Would require connections to power source.

#### Detectability
- Detectable for those with normal hearing.

#### Failure result
- Confusing for those who have become accustomed to using the beacons.
Injury Avoidance Systems

The purpose of this third group of interventions is to reduce the severity of injuries suffered by anyone who falls off the platform. Injuries may be caused by the fall impact, by the electric current, or by the train entering the station. This would be a new approach for the industry. By applying this approach to the problem of injuries resulting from falls onto the trackway we realize that potential solutions can be developed.

Type 12 Impact absorbing foam padding

The area around the trackway would be fitted with a thick resilient padding (or perhaps water filled "sausages") installed to absorb most of the impact of a fall and therefore to reduce the probability of injury. This would probably be achieved by forming plastic covered "pillows" that could be placed along and between the track with adequate clearance from the moving equipment. The purpose of the padding would be to provide a relatively soft surface on which to fall. This is a new approach for the industry. In other words, we find ourselves in the condition that the car industry was in during the days before studies were conducted, directed at protecting the occupants of motor vehicles in the event that an accident occurs. In a recent book chapter (Templer, 1988), it has been suggested that the deliberate attempts to protect motor vehicle passengers may well be responsible for saving as many as 10,000 lives a year. If we apply this approach to the problem of injuries resulting from falls onto the trackway we realize that potential solutions can be developed.

Effectiveness

- May be quite effective in reducing injuries.
- Will not prevent injuries caused by the train, or the electric current.

Initial cost

- $300,000 per 2 (600 ft.) platform edges.

Cost in use

- Would depend on the durability of the materials.

Maintenance

- System would require minimum maintenance.

Cleaning

- Would require reconsideration of procedures for track garbage collection.

Traffic flow

- Not likely to be affected

Installation ease

- Easily installed
Failure result

- Failure would be caused by improper installation or maintenance. This might cause the materials to catch in the underside of the train, with unknown results.

Back up

- None

Potential hazards

- Could produce toxic gases in the event of fire.
- Ultraviolet light might cause breakdown of the materials
- Water resistance

Type 13

Air Bags

A series of air bags could be installed on the track area which could be activated in the event of a fall, by a fall detection beam as discussed in Type 15. The air bags would be similar to those used in automobiles, they would instantly inflate.

Effectiveness

- Could be effective if the beam system is effective. Would not protect a victim from injury by a train unless the power is cut off at the same time.

Initial Cost

- $2,000,000 per 2 (600 ft.) platform edges.

Cost in use

- Unknown.

Maintenance

- System would require occasional maintenance.

Cleaning

- Would not require special cleaning procedures

Traffic flow

- Not likely to be affected unless the device is actuated in the event of a fall, or a malfunction occurs.

Installation ease

- Will require the installation of a fall detection system, and connection to a power source.

Detectability

- Not required

Failure result

- Would fail to prevent injury.

Back up

- Could be used in concert with type 12, the foam padding.

Potential hazards

- Unknown
Type 14  

**Pressure sensitive fall warning pad**-

A pad located in the trackway around the tracks would respond to the pressure of a fall by activating the emergency systems of MARTA, and cutting off the track power.

**Effectiveness**
- Could be effective in reducing injuries caused by the train striking the victim, or from electrocution. Will not reduce fall injuries unless used in conjunction with one of the impact attenuation types.

**Initial Cost**
- $700,000 per 2 (600 ft.) platform edges.

**Cost in use**
- Will require occasional service and repair

**Maintenance**
- System would require occasional maintenance.

**Cleaning**
- Might require special cleaning procedures

**Traffic flow**
- Not likely to be affected unless the device is actuated in the event of a fall or it malfunctions.

**Installation ease**
- Will require connections to power sources and to system control.

**Detectability**
- Not required

**Failure result**
- Will close down station, and fail to operate injury reduction systems.

**Back up**
- None

**Potential Hazards**
- Unknown

---

Type 15  

**Fall Detection Beam**-

An infra-red or laser beam (or similar device) could be used in the trackway as a signalling device. When the beam is broken by someone falling off the platform, a signal would be actuated. This fall warning signal could be connected to the "blue" button that cuts power to the track, and the train (as the train's brakes are not actuated by a power cut, the system requirements for this would need to be altered). The beam would have to be located in an area that is between the platform and the car. The effect of the device would be to deactivate the live rail, and reduce the possibility of the train striking someone who has fallen onto the track.

**Effectiveness**
- May be quite effective in reducing injuries caused by the train and the electric current.
Beam might be broken by maintenance workers and cleaners (though this could be obviated by training).

Beam might be broken by birds, litter, small animals, and objects thrown from the platform.

<table>
<thead>
<tr>
<th>Initial Cost</th>
<th>$1,150,000 per 2 (600 ft.) platform edge.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost in use</td>
<td>Will require routine servicing and repair.</td>
</tr>
<tr>
<td>Maintenance</td>
<td>System would require occasional maintenance.</td>
</tr>
<tr>
<td>Cleaning</td>
<td>Not needed</td>
</tr>
<tr>
<td>Traffic flow</td>
<td>Not likely to be affected unless the power is switched off during an incident or a malfunction.</td>
</tr>
<tr>
<td>Installation ease</td>
<td>Will require connection to power source and to operation system.</td>
</tr>
<tr>
<td>Detectability</td>
<td>Not needed</td>
</tr>
<tr>
<td>Failure result</td>
<td>Malfunction could prevent train from entering station; and could be ineffective in avoiding injury</td>
</tr>
<tr>
<td>Back up</td>
<td>None</td>
</tr>
<tr>
<td>Potential hazards</td>
<td>Unknown</td>
</tr>
</tbody>
</table>

**Type 16**

*Fall detection beam encased in Compressible Plastic*

This would be another version of the previous system. In the trackway on both sides of the track (or live rail), foam pads would be installed. These pads would be hollow with a light beam shining down through them. If a body lands on the pads, the fall would be cushioned and the light beam broken, signalling an emergency, and operating the deactivating systems as before.

**Effectiveness**

- May be quite effective in reducing injuries caused by the train, the fall, and the electric power.

- If the foam cushion is not firm enough, the beam could be broken by maintenance and cleaning personnel walking on it (this may be obviated by a cautious choice of foam resilience that could only be compressed to actuate the system as a result of the force of a fall).

- Would have to be resistant to weather and cleaning materials.

<table>
<thead>
<tr>
<th>Initial Cost</th>
<th>$1,000,000 per 2 (600 ft.) platform edges.</th>
</tr>
</thead>
</table>
Cost in use
- Will require regular service and occasional repair.

Maintenance
- Would require more maintenance than current track.

Cleaning
- Might need reconsideration of track garbage collection techniques.

Traffic flow
- Not likely to be affected unless the power is switched off or the device malfunctions.

Installation ease
- Will require connection to a power source and to the control system.

Detectability
- Not needed

Failure result
- Malfunction could prevent train from entering station; and could be ineffective in avoiding injury.

Type 17

Safety Netting-
A safety netting system would be installed which would protrude from the platform unless the train was in the station. It would have to be mechanically operated to fold down when a train enters the station.

Effectiveness
- Could be effective in preventing falls. Would have to be used in conjunction with a system to prevent a train from entering the station when a fall has occurred.

Initial Cost
- $53,000,000 per (600 ft.) platform edges.

Cost in use
- Will require regular service and repair.

Maintenance
- System would require regular maintenance.

Cleaning
- Would require special cleaning procedures

Traffic flow
- Not likely to be affected unless the power is switched off, or the device malfunctions.

Installation ease
- Complex.

Detectability
- Not required.

Failure result
- Could prevent trains from entering the station; failure to deploy would fail to prevent falls and injury.

Back up
- Any of the similar systems already described.

Potential hazards
- Unknown.
Type 18  Signage in Refuge area-

Under the edge of many of the system platforms is a space that may be usable as a temporary refuge in which to retreat to in the event that one falls onto the tracks, and a train is coming. In the refuge area, stenciled signs would warn patrons to seek shelter and wait there for assistance.

Effectiveness
- Could be effective for those that see and understand the signs. Would have to be used in conjunction with an educational component.

Initial Cost
- $5,000 per 2 (600 ft.) platform edges.

Cost in use
- Nominal.

Maintenance
- Would require no special maintenance.

Cleaning
- Would require no special cleaning procedures

Traffic flow
- Would not be affected.

Installation ease
- Simple

Detectability
- Not detectible to people without vision nor illiterates.

Failure result
- None

Back up
- Could be used with fall detection systems

Potential hazards
- None

Type 19  Call button in the Refuge Area-

In the refuge area, a call button could be installed which would be highly visible. The purpose of the call button would be to alert the authorities that someone is trapped in the refuge area

Effectiveness
- Could be effective for those that see and understand its purpose. Would have to be used in conjunction with an educational and signage component.

Initial Cost
- $100,000 per 2 (600 ft.) platform edges.

Cost in use
- Would require occasional testing and service.

Maintenance
- System would require occasional maintenance.

Cleaning
- Would not require special cleaning procedures
Traffic flow
- Not likely to be affected unless the button is connected to the 'blue button' and power is switched off, or the system malfunctions.

Installation ease
- Would require connection to alarm and system control.

Detectability
- Not detectible to people without vision.

Failure result
- Would prevent trains from entering the station; would fail to trigger the alarm system.

Back up
- Could be used with fall detection systems.

Potential hazards
- Unknown

Type 20

Pull Cord Fall Alert-
A pull cord, similar to that found on the buses, would be installed in the refuge area to be pulled in the event of someone seeking refuge there after a fall. The purpose of the pull cord is similar to the call button. It would be to alert the authorities that someone is trapped in the refuge area.

Effectiveness
- Could be effective for those that see and understand its purpose. Would have to be used in conjunction with an educational and signage component.

Initial Cost
- $75,000 per 2 (600 ft.) platform edges.

Cost in use
- Would require occasional testing and service.

Maintenance
- System would require occasional maintenance.

Cleaning
- Would not require special cleaning procedures.

Traffic flow
- Not likely to be affected unless it is connected to the 'blue button' and power is switched off, or the system malfunctions.

Installation ease
- Would require connection to alarm and system control.

Detectability
- Not easily detectible to people without vision.

Failure result
- Would prevent trains from entering the station; would fail to trigger the alarm system.

Back up
- Could be used with fall detection systems.

Potential hazards
- Unknown
Type 21

**Body on Track Detection System on Train**

The train would be equipped with a detector on the front of the train which could detect the presence of a body on the track. In this event the system power would be cut and the brakes applied automatically.

**Effectiveness**

- Could be effective if the beam system is effective. Would not protect a victim from injury by a train unless the power is cut off at the same time.

- Effectiveness would be dependent on the equipment's ability to discriminate between people who have fallen, and people working on the line, objects detected as the train rounds a bend, and so on.

**Initial Cost**

- $500,000 per train.

**Cost in use**

- Would require regular testing and service.

**Maintenance**

- System would require occasional maintenance.

**Cleaning**

- Would not require special cleaning procedures.

**Traffic flow**

- Not likely to be affected unless the device is actuated in the event of a fall, or it malfunctions.

**Installation ease**

- Complex

**Detectability**

- Not needed

**Failure result**

- Train would stop. If system detection failed, victim might be struck by train.

**Back up**

- Could be used in conjunction with one of the other fall detection systems.

**Potential hazards**

- Unknown.

---

**PUBLIC EDUCATION**

The purpose of this final group of interventions is to inform riders of actions they can take to avoid falls, and other actions they can take if they do fall.

**Type 22**

**Signs in trains and on platforms**

A series of information signs could be developed which educate the sighted ridership concerning safety procedures on MARTA. (ex. refuge area, emergency button etc.)
Effectiveness  • Could be effective for those that see and understand the purpose. Would have to be used in conjunction with some of the proposed interventions.

Initial Cost  • $750,000 for the entire system.

Cost in use  • Minimal.

Maintenance  • System would require occasional maintenance.

Cleaning  • Would not require special cleaning procedures.

Traffic flow  • Would not be affected.

Installation ease  • Simple.

Detectability  • Not useful to those without sight and illiterates, unless accompanied by audible information.

Failure result  • None.

Back up  • None.

Potential hazards  • Patrons could become curious and attempt to find the refuge area.

Type 23

Orientation and Mobility Training Sessions

MARTA would work in cooperation with local organizations to provide the visually impaired ridership with training day to day and emergency situations at MARTA.

Effectiveness  • Could be effective for those that are willing to attend these sessions. Expert travellers may elect not to participate. Would have to be used in conjunction with some of the proposed interventions.

Initial Cost  • Negligible.

Cost in use  • Regular program.

Maintenance  • None.

Cleaning  • Not applicable.

Traffic flow  • Would not be affected.

Installation ease  • Not applicable.

Detectability  • Not applicable.
<table>
<thead>
<tr>
<th><strong>Failure result</strong></th>
<th>● Faulty training could lead to accidental falls.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Back up</strong></td>
<td>● Follow up sessions.</td>
</tr>
<tr>
<td><strong>Potential hazards</strong></td>
<td>● Only from faulty training.</td>
</tr>
</tbody>
</table>
Type 24

**Recording at Platform Entry**

A recorded message which gives patrons their location could be played at the escalators, stairs and elevators leading to the platform level. This system could be similar to that used at the Atlanta Airport.

**Effectiveness**
- Should be extremely effective, since disorientation seems to be a primary cause of falls onto the trackway.

**Initial cost**
- Minimal.

**Cost in use**
- Minimal.

**Maintenance**
- Should require little maintenance.

**Cleaning**
- None.

**Traffic flow**
- Would not be affected.

**Installation ease**
- Simple.

**Detectability**
- Would be extremely detectable except to deaf individuals.

**Failure result**
- Visually impaired person might not know they are on the platform level.

**Back up**
- None needed.

**Potential hazard**
- None.

For simplicity, we have also presented the evaluations in the form of matrices. These matrices allow one to quickly identify the solutions which seem to have the best potential. The 'best' solutions were then chosen for further evaluation.
## HAZARD EXPOSURE REDUCTION SOLUTION

<table>
<thead>
<tr>
<th>Potential hazards</th>
<th>Back-up</th>
<th>Detectability</th>
<th>Installation ease</th>
<th>Traffic flow</th>
<th>Maintenance</th>
<th>Cleaning</th>
<th>Cost in use</th>
<th>Initial cost</th>
<th>Effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guardrailing</td>
<td>1 1 1 1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1 1 1 1</td>
</tr>
<tr>
<td>Gates in guardrails</td>
<td>1 1 1 1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1 1 1 1</td>
</tr>
<tr>
<td>Turnstiles in guardrails</td>
<td>1 1 1 1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1 1 1 1</td>
</tr>
</tbody>
</table>

**KEY:**

/ not applicable

● positive: makes the item a good choice (inexpensive, easy to install, etc)

● neutral

○ negative: makes the item a poor choice (expensive, difficult to maintain, etc)

**Example:** As you read across a row from left to right, an entire row of ● ● ● indicates an extremely effective and efficient solution. Sound location beacon and recording at platform entry are two such examples.
### PLATFORM EDGE INFORMATION SOLUTIONS

#### Potential Hazards
- Back-up
- Detectability
- Installation ease
- Traffic flow
- Cleaning
- Maintenance
- Cost in use
- Initial Cost

<table>
<thead>
<tr>
<th>Effectiveness</th>
<th>Bollards</th>
<th>Detectible Strips</th>
<th>Visual Contrast Edging Strip</th>
<th>Ramped Edge Strip</th>
<th>Pressure Sensitive Floor Signal Strip</th>
<th>Wind Curtain</th>
<th>Photoelectric Beam with Recording</th>
<th>Sound Location Beacon</th>
</tr>
</thead>
<tbody>
<tr>
<td>○○○○</td>
<td>○○○○○</td>
<td>○○○○○</td>
<td>○○○○○</td>
<td>○○○○○</td>
<td>○○○○○</td>
<td>○○○○○</td>
<td>○○○○○</td>
<td>○○○○○</td>
</tr>
</tbody>
</table>

#### KEY:
- / not applicable
- ○ positive: makes the item a good choice
  (inexpensive, easy to install, etc)
- ○ neutral
- ○ negative: makes the item a poor choice
  (expensive, difficult to maintain, etc)

**Example:** As you read across a row from left to right, an entire row of ○○○○○ indicates an extremely effective and efficient solution. Sound location beacon and recording at platform entry are two such examples.
**INJURY AVOIDANCE SOLUTIONS**

<table>
<thead>
<tr>
<th>Potential hazards</th>
<th>Back-up</th>
<th>Detectability</th>
<th>Installation ease</th>
<th>Traffic flow</th>
<th>Cleaning</th>
<th>Maintenance</th>
<th>Cost in use</th>
<th>Initial cost</th>
<th>Effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impact Absorbing Foam Padding</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Airbags</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Pressure Sensitive Fall Warning Pad</td>
<td>●</td>
<td>○</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Fall Detection Beam</td>
<td>○</td>
<td>○</td>
<td>●</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Fall Detection Beam (encased in compressible plastic tube)</td>
<td>○</td>
<td>○</td>
<td>●</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Safety Netting</td>
<td>○</td>
<td>○</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Signage in refuge area</td>
<td>●</td>
<td>○</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Call Button in refuge area</td>
<td>●</td>
<td>○</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Pull Cord Fall Alert</td>
<td>●</td>
<td>○</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Body on Track Detection System on train</td>
<td>○</td>
<td>○</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
</tbody>
</table>

**KEY:**

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  (expensive, difficult to maintain, etc)

Example: As you read across a row from left to right, an entire row of ● ● ● ● indicates an extremely effective and efficient solution. Sound location beacon and recording at platform entry are two such examples.
### Signs on Train and Platforms
- **Potential hazards:**
  - Back-up: ●●
  - Detectability: ●
  - Installation ease: ●
  - Traffic flow: ●
  - Cleaning: ●●
  - Maintenance: ●●
  - Cost in use: ●●
  - Initial cost: ●●
  - Effectiveness: ●●

### Orientation and Mobility Training Session
- **Potential hazards:**
  - Back-up: ●●
  - Detectability: ●
  - Installation ease: ●
  - Traffic flow: ●
  - Cleaning: ●●
  - Maintenance: ●●
  - Cost in use: ●●
  - Initial cost: ●●
  - Effectiveness: ●●

### Recording at Platform Entry
- **Potential hazards:**
  - Back-up: ●●
  - Detectability: ●
  - Installation ease: ●
  - Traffic flow: ●
  - Cleaning: ●●
  - Maintenance: ●●
  - Cost in use: ●●
  - Initial cost: ●●
  - Effectiveness: ●●

---

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**Example:** As you read across a row from left to right, an entire row of ●●●● indicates an extremely effective and efficient solution. Sound location beacon and recording at platform entry are two such examples.
CONCLUSIONS

As we have found from the system analysis, no single solution type can provide adequate protection. We recommend the evaluation of a set of interventions, chosen from the matrix, that will in combination reduce the amount of platform edge, warn riders that they have passed onto the off-limits strip, and reduce the probability if a fall occurs.

RESEARCH AGENDA

In this section of the report, research questions related to fall and injury reduction systems will be discussed and methods to undertake and evaluate these systems suggested. The research needs fall into the three areas discussed above:

1. Platform edge information system (fall warning);
2. Hazard exposure information system (fall prevention); and
3. Injury reduction system (fall mitigation).

Research Need. The evaluations should examine the effectiveness of each particular intervention, combinations of interventions within a particular area, as well as systems of interventions that are made up of interventions from each of the three areas listed above. Questions which should be addressed relate to:

1. The acceptance of the intervention(s);
2. The ability of patrons to utilize the intervention(s);
3. The impact of the intervention(s) on incidence of falls and fall injuries;
4. The costs involved in implementing the interventions.
5. Impact of the intervention(s) on the MARTA system

Proposed Experimental Design. The research design would be divided into two phases, a laboratory testing phase and a field testing phase. Laboratory testing would enable several potential interventions to be tested quickly, reliably and cost effectively without risk to the subjects. This would eliminate solutions that are ineffective, and it would enable the researchers to refine the list of acceptable solutions that will be tested in the field research. Laboratory testing should examine the performance of visually and mobility impaired, as well as able-bodied subjects. A range of potential solutions can be tested under a variety of conditions. These conditions should be designed to simulate:

1) interior/exterior and above/below ground station and platform areas,
2) hazards such as stairs and platform edges, and
3) varying environmental conditions such as changes in lighting levels, temperature, and noise levels. From this phase of the project, the most promising solutions would be selected for further evaluation in the field.

Field testing would involve installation of interventions, and data collection, in three transit station test sites in order to cover a range of station and platform design types. The design of this phase of the testing would be a basic "before and after" design with baseline data collected on station use prior to the installation of any interventions as well as after installation.
The "before" study would use two methods for data collection. In the first, video tape observations of patron use in each of the three transit stations would be made. This would be undertaken in order to identify potential problems in wayfinding, edge violation, and general use of the system. In the second phase a sample of visually and non- visually impaired individuals would be sent on a predetermined route through the station; and these activities would be observed in order to measure wayfinding performance and edge violation.

After the completion of this baseline data collection, the interventions selected from the laboratory testing would be installed in the three stations. Using the same methods as in the "before" condition, data would be collected on transit patrons and on a group of volunteer test subjects. The performance of subjects can be compared across the various types and combinations of interventions installed as well as comparing performance in the "after" condition to the performance of subjects in the "before" condition. From this comparison the effectiveness of the interventions can be assessed.

Research Tasks.

1. Develop evaluation protocol.
2. Approval for appropriate Georgia Tech Safety Committees.
4. Develop installation design and specifications.
5. Identify criteria for subject selection.
6. Identify and recruit subjects.
7. Organize testing of subjects.
8. Identify observers.
9. Train observers.
10. Schedule observations.
11. Construct test site in lab.
12. Construct test sites in 3 MARTA Stations.
13. Conduct tests in laboratory.
14. Conduct tests at the MARTA sites.
15. Negotiation with MARTA departments for all phases.
17. Preliminary report to MARTA.
18. Write, edit and produce final report and recommendations.

Anticipated Costs. Because the types and number of interventions to be tested has yet to be determined, cost estimates for the two phases of testing are inevitably somewhat speculative. Although a typical estimate would include the costs for all of the research tasks listed above as well as materials and prototypes that need to be set up in the laboratory and the transit stations, the costs outlined below only cover the costs of the research tasks (except 11 and 12) above. In other words we have made no estimate of the costs of constructing the interventions.

Laboratory (60 subjects: 30 blind, 15 mobility impaired, 15 able-bodied)
Estimated cost: $17,000

Field (20 blind, 10 mobility impaired, 10 able-bodied at each of 3 stations)
Estimated cost: $26,000
Total estimated cost (excluding construction): $43,000

Anticipated Time. The Laboratory and Field testing activities can be completed within six months if the construction of the interventions do not delay the process; and we assume that this construction will be carried out by MARTA or its agents.
APPENDIX A

Problems of Visually Impaired Travellers

The ability of people to orient themselves and to find their way safely are two major issues which are affected by the design of the built environment. In finding their way, people use both "latent" and "overt" environmental information for orientation and safety (Pavlos, Sanford, Steinfeld, 1985; Sanford, 1985). The former includes clearly physical geographic features of the environment such as nodes, landmarks, and districts which attain consensual meaning due to their personal significance. These features are not intended to serve as specific wayfinding and orientation aids but, do in fact, have such usefulness. Their significance is ascertained by the traveller solely through experience. "Overt" information, on the other hand, is information which is specifically intended to be used for wayfinding and orientation. Examples are signs, milestones, directional traffic signals, addresses, and pedestrian markings.

Although our inclination is to associate overt information with visual cues, this is primarily because designers approach the problems of orientation and safety in this manner. Unfortunately, visual information is often less useful to people who are visually impaired or blind. While some individuals who are partially sighted can distinguish between the relevant overt environmental symbols or spatial cues and other non-relevant building features (this is particularly true for cues that rely on highly contrasting colors and light levels), most partially sighted people, and those who are totally blind, cannot rely on visual information to negotiate the environment. As a result, they are dependent on latent environmental information and they tend to have more difficulty in locating places or objects, orientation, and detecting hazards than sighted people.

Environmental situations which cause particular problems for visually impaired persons include:

1. Locating places or objects:
   A. Vertical circulation: finding a stair, ramp, escalator, elevator or lift not located directly within the part of travel.
   B. Horizontal Circulation: finding a hallway, walkway, moving sidewalk, pathway, crosswalk, street or curb ramp.
   C. Entry Conditions: finding the entrance to a building, room or train.
   D. Egress Conditions: finding an exit from a building, especially if it is different from the point of entry; or, as in a theater, auditorium, or sports arena, where there are multiple exits.
   E. Transportation: finding the appropriate gate, holding area, bus stop, train track, platform, etc.; finding the door location of subway cars and rail coaches.
   F. Ceiling and wall hung fixtures and equipment: finding or detecting a telephone, water fountain, etc., which does not extend to the ground.
G. Building information: finding building information sources such as an
information booth or assistance telephone.

2. Orientation/Wayfinding:

A. Negotiating open spaces such as parking lots, public parks, and other areas, that lack pathways or shorelines.

B. Negotiating complex or meandering non-parallel streets, such as parks, pedestrian overpass crossings, transportation terminals, museums, public buildings, and other areas that are difficult for visually impaired people to understand and remember.

C. Negotiating spaces where there are repetitive, identical design elements such as corridors, landscaping, street layout, and other spaces which do not provide unique cues.

D. Negotiating places which overload auditory senses, such as a train station in which echoing sounds might mask detectable cues.

E. Negotiating non-right angle (oblique) intersections in sidewalks, streets, and other circulation routes which can cause visually impaired persons to inadvertently follow pathway.

3. Detecting Hazards:

A. Hazards created by unexpected level changes such as stairs within the path of travel, station platform edges, pools or/and other drop-offs where a person could fall.

B. Hazards resulting from pedestrian walks that are not separated physically from vehicular areas in any way readily apparent to blind pedestrians (e.g. median islands constructed flush with the street and walks located parallel to or within a parking lot).

C. Emergency egress.

In situations such as travelling in a rapid transit system, the problems of visually impaired persons are even more acute because difficulty in wayfinding or place location can be potentially dangerous. For example, once people who are in the system make a wrong decision such as going in the wrong direction from the train to the exit stair, going onto the wrong platform or getting off the train at the wrong station, they may become confused, disoriented and lost. As a result, fully capable people may either be unaware of their location on the platform or even that they are on a platform. In either case, if there are no informational cues to either warn or orient the visually impaired people, they are in a very hazardous situation which can result in a fall off the platform edge.
There is little evidence to support the stereotype that when left alone, blind travellers wander aimlessly, cautiously negotiating the environment, and continually expecting to bump into some object or fall. Through training, experience, and the provision of wayfinding information in a manner in which visually impaired persons can use it, many of them can achieve independent travel.

Transit systems routinely provide travellers with information and directions to particular lines. Much of this information is often provided as maps and signs which, although sometimes useful to partially sighted people, is not useful to severely visually impaired people. Moreover, visually impaired people may have difficulty finding many facilities which transit systems expect travellers to locate by sight, such as the station entrance, stairs, fare gates, information kiosks, assistance phones, safe places to wait on the platforms, and seats and stanchions in the vehicles (Bentzen, Jackson, Peck; 1981).

Despite the many challenges which face visually impaired travellers, they, like sighted travellers, expect and are able to travel independently and safely. This however is contingent upon the provision of enough information to enable them to use the transit system safely. If there are no overt "physical barriers" which prevent a visually impaired person from using the rapid rail system, there are many tasks required in its use which cannot be accomplished without delay, inconvenience or risk by the visually impaired traveller. At a minimum, overt information which is available to sighted travellers should also be available to visually impaired travellers through non-visual sources.

Even this may not be sufficient. Data indicate that even visual information provided for sighted travellers by transit systems needs to be augmented with information requested directly by the traveller (Abt Associates, 1974). For the visually impaired individual who is not provided with enough information to find the information booth or assistance phone, this is much more difficult. Further, the safety hazards posed by the platform edge is one which is not confined to visually impaired users. In fact, despite the large number of visually impaired travellers who have fallen off of the platform edge, accident statistics for the various transit systems that collect such data (e.g. BART) indicate that blind travellers comprise only one-third of all passengers who have accidentally fallen from the platform. Therefore, because the safety problems are not just limited to visually impaired people, any solutions must convey information which is visual as well as non-visual in order to warn or prevent all passengers from falling from the platform.

Visually impaired people, like sighted travellers, can and do use rapid transit. It is rare, however, to find visually impaired travellers who do not need, at least occasionally, to solicit information from other persons (Bentzen, Jackson, Peck, 1981). However, in public transit stations there is often no official from whom to solicit information. Without alternative information sources to aid visually impaired people in locating places, orientation and preventing falls, the tasks involved in using the transit system become difficult and potentially dangerous. In fact, unlike travellers with mobility problems (i.e. wheelchair users), tasks which require information, rather than those associated with the need for movement (Bentzen, Jackson, Peck, 1981), are likely to cause more problems for visually impaired people. They are likely to have more difficulty finding the exit stair than using it. Moreover, because locational and orientation problems anywhere in the transit system can result in disorientation and wandering, which in turn could result in
an individual unexpectedly coming upon the platform edge, the entire system is impacted by each individual wayfinding task.
APPENDIX B

Review of the Literature

Introduction -- fall warning systems, fall prevention systems, fall mitigation systems.

Types of Edge Warning Systems

In transit systems sighted travellers use their vision to distinguish the characteristic visual architecture or equipment. They may also use other kinds of latent information (Bentzen, Jackson and Peck, 1981) such as: characteristic sounds (e.g. escalator); direction of movement of other travellers; and inference or learned use of the environment (e.g. the train is usually above or below the fare gate level). The visually impaired travellers may also use some of these other latent cues; however these sources of information are often absent (e.g. the fare gate makes no sound when no one is using it); or the sound may be masked by competing sources of sound (e.g. as a train arriving in the station); or directional information cannot be inferred because of inconsistencies in the placement of building elements (e.g. the location of the assistance phones).

The appropriate latent environmental cues should be identified and intentionally installed so that they are consistently present and expected in order to assist visually impaired travellers. This will, in effect, transform latent cues into overt fall warning signals.

The purpose of a fall warning system is to inform an individual of a potential fall hazard in time to avoid the hazard. This can be accomplished by

1) the attention value or ability of the fall warning system to attract the individual's attention and

2) the interpretability of the system or the ability of the system to convey sufficient information so that the location and type of hazard as well as the danger level can be quickly recognized (Armstrong, et al., 1978).

Attention value is dependent on the contrast of a particular warning system to its environment and the number of warning systems to which an individual is exposed. Visual contrast or distinctness is primarily dependent on the brightness contrast of the device to its surroundings (Woltman, 1972; Forbes, 1975) rather than on the color of the device (Christ, 1975). For auditory systems, distinctness is primarily dependent on the intensity (decibel level) and frequency of the signal relative to the average level in the surrounding environment (McCormick, 1970; Harris, 1957). For tactile warnings, contrast is dependent on textural, resiliency and sound differences between the cue and the surrounding walkway surface.

A second factor which affects the attention value of a fall warning system is its discriminability (Armstrong, et al., 1978; Pavlos, Sanford and Steinfeld, 1985). Warning signals should be unique; as the number of similar signals increases (Christ, 1975; Hyman, 1953), the ability to recognize the intent of any particular signal decreases.

In addition to attention value, the information provided by a fall warning signal needs to be immediately understood. This implies that:
1) The signal should sufficiently contrast from the background, similar cues should not be used to mean different things and

2) The signal should not be complex as it will require more time to interpret the message (Attneave, 1957; Fitts and Leonard, 1957; Baker and Allessi, 1962).

A number of overt informational cues have been installed or are presently being considered by various transit systems to aid visually impaired travelers. These include: tactile warning strips, large print and tactile maps, architecture which facilitates orientation, consistent placement of signs within the stations, use of color codes and contrasts within the stations, and audible aids.

1. Tactile Warning Strips (Changes in Surface Materials).
   This was discussed earlier.

2. Sound Cues and Audible aids.
   This was discussed with Type 11 device.

3. Education and Training. In general, research indicates that increased exposure to a fall warning system reduces the number of accidents. For example, studies have shown that the incidence of employee accidents decreases markedly after the third month of employment (Vernon, 1945; Adelstein, 1952). This indicates that training or familiarity with the environment is perhaps a major factor in decreasing the number of accidents. Likewise, a number of studies of the abilities of blind pedestrians indicates that familiarity with routes and environments is perhaps the single most important factor in helping blind people to reach their intended destinations (Pavlos, Sanford, Steinfeld, 1985; Sanford, 1985; Templer, et al, 1982). Uslan (1987) supports this finding and presents a model for a training program in transit stations which includes blind pedestrians and mobility instructors as well as transit personnel. Although this model may be less elegant than a design solution, it may be just as necessary. Such a program was recently established by the American Foundation for the Blind at the Washington Metro and has had positive results.

4. Other Solutions. A number of studies have considered other types of interventions to aid in place location, hazard reduction and guidance. Some of these include color contrasts, specialized guidance systems and inclined surfaces.

Color contrasts (Templer, et al., 1982; Pavlos, Sanford and Steinfeld, 1985) may be extremely useful for people who retain some vision, and is useful for sighted travelers. While this intervention is, for all practical purposes an extension of tactile surfaces (color, like sound, resilience and texture, is a detectable quality that a material has), it is used to some extent by all of the transit systems surveyed, even when it is not accompanied by a change in surface material or texture. This seems to indicate that there is an acknowledgement that the edge of the platform does need some clear identification, at least for sighted pedestrians.

Another potential solution that has received much attention in today's world of high technology is the use of technological guidance systems such as the laser cane (Bionic Instrumentation, 1976) and electronic (Preiser, 1985) or magnetic (Stuttgart Transit System) tracking systems. Although most of these systems have performed well in test
situations, they are often impractical in real applications. They require prewiring large areas of the environment to generate a signal, and are therefore expensive to install. They require specialized canes to receive the signal and are therefore expensive for individuals to utilize.

Another alternative is the use of inclined surfaces. Templer, 1979 discovered that visually impaired people can use slight inclines or humped surfaces to guide their movement along a pathway. Pavlos, Sanford and Steinfeld, 1985 found that visually impaired subjects can detect both upward and downward ramp slopes that are similar to those prescribed for sidewalk curb cuts. Slight changes in level that do not pose problems to other mobility impaired travellers may also aid in providing overt information to blind travellers.

**Fall Prevention Systems**

These systems were discussed thoroughly earlier in the report.

**Gates and Barrier Systems.**

These systems were discussed thoroughly earlier in the report.

**Fall Mitigation Systems (Injury Reduction)**

Current work underway at the Pedestrian Research Laboratory at Georgia Tech. and sponsored by the National Science Foundation has been inquiring into ways of reducing injuries from falls, and particularly falls on stairs. From computer modelling of this kind of fall, it is clear that the severity of fall injuries can be mitigated by taking the approach used in automobile interiors. Society recognizes that even the safest stairs, like automobiles, are likely to be the locus of accidental falls. The interiors of automobiles have been 'softened' by the use of safety glass, padded dash boards, recessed switches and other injury reduction solutions.

For station platforms (and for stairs), injuries from falls can be substantially reduced by the use of suitable energy attenuating materials placed where body contact is likely to occur. The technology is simple and understood, but the specific application of this theory to rapid transit station design has yet to be explored.
<table>
<thead>
<tr>
<th>System</th>
<th>Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>MARTA</td>
<td>• Flame Cut Granite Edge Strip</td>
</tr>
<tr>
<td></td>
<td>• Evaluating alternatives</td>
</tr>
<tr>
<td>BART</td>
<td>• Pathfinder tile (yellow)</td>
</tr>
<tr>
<td>WMATA</td>
<td>• Flame Cut Granite</td>
</tr>
<tr>
<td></td>
<td>• Mobility &amp; Orientation Training</td>
</tr>
<tr>
<td>MTA</td>
<td>• Flame Cut Granite</td>
</tr>
<tr>
<td>MBATA</td>
<td>• Pathfinder Tile (yellow)</td>
</tr>
<tr>
<td></td>
<td>• PA System</td>
</tr>
<tr>
<td>MDTA</td>
<td>• Currently Evaluating Pathfinder Tiles</td>
</tr>
<tr>
<td>NYCTA</td>
<td>• Textured Concrete</td>
</tr>
<tr>
<td></td>
<td>painted yellow 3&quot; wide, 1 foot from edge of platform</td>
</tr>
<tr>
<td>SPT</td>
<td>• Yellow lines</td>
</tr>
<tr>
<td>CTA</td>
<td>• No consistent approach</td>
</tr>
<tr>
<td></td>
<td>• Evaluating pathfinder tiles</td>
</tr>
<tr>
<td>Cleveland</td>
<td>• Evaluating pathfinder tiles</td>
</tr>
<tr>
<td>New Jersey</td>
<td>• Evaluating pathfinder tiles</td>
</tr>
<tr>
<td>Sacramento</td>
<td>• Pathfinder tiles</td>
</tr>
</tbody>
</table>
| International | TTC | Toronto Transit Comm. | • Alternating yellow & black pattern  
• 2-3" wide textured strip 8" from edge |
| :--- | :--- | :--- | :--- |
| CTCUM | Montreal Urban Community Transit Commission Montreal | • Pathfinder tiles in orange |
| Stuttgart | Stuttgart, West Germany | • Evaluating cane detectible magnetic strip |
| HVV | Hamburger Verkehrsbund Hamburg, Germany | • Slight color difference at platform edge |
| Prague | Prague, Czechoslovakia | • 2" wide strip of raised dots bright yellow  
• train stops if patron crosses 2' from edge |
| Kyoto | Kyoto, Japan | • yellow guidance tile w/ raised arrow and braille on handrails |
| Osaka | Osaka, Japan | • yellow guidance tile w/ raised arrow and braille on handrails |
| RATP | Regie Automedes Transports Parisiens Paris, France | • raised tile with dots 420 cm wide  
500 cm from the edge (see page 69) |
| London | London, England | • no reply |
APPENDIX C
BIBLIOGRAPHY

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23B. Tactile Warnings
31 C. Gate and Barrier Systems
32 D. Education and Training
33E. Codes and Standards
38. Additional Selected References
40 I. Other Platform Solutions

I. Annotated References

A. Problem Statement and Solutions

1. Title: Improving Communications with the Visually Impaired in Rail Rapid Transit Systems, Vol. 1.

Authors: B. L. Bentzen
R. M. Jackson
A. F. Peck

Date: August 1981

Sponsor: U.S. Department of Transportation
Urban Mass Transportation Administration
400 Seventh Street, SW
Washington, D.C. 20590

Report NO. UMTA-MA-11-0036-81-1

Abstract: this report describes the results of a project to study improved communications with the visually impaired in rail rapid transit systems. The purpose of the study was: A) to analyze the problems visually impaired persons encounter as they attempt to
utilize rapid rail; B) to identify strategies that remedy these problems; and C) to suggest methods for communication with the visually impaired. Results of the study are presented in the following areas: 1) background information about visually impaired persons; 2) problems in accessibility to rail rapid transit by the visually handicapped; 3) suggested methods for improving communications with the visually impaired in rail rapid transit; and 4) estimated reactions to the implementation of solutions. The suggested methods for improving communications fall within the following categories: a) signage and other print information; b) graphic information; c) auditory information; d) textural information, e) special equipment designs; f) architectural designs; and g) operating procedures. Suggestions from these categories are presented according to a sequential trip format in which a hypothetical route from system entrance to system exit is traced.

Key words: Accessibility; blind passengers; communications; elderly, handicapped; information systems; visually handicapped, visually impaired.

2. Title: Pedestrian Falling Accidents in Transit Terminals

Authors: John J. Fruin
Dilip K. Guha
Rolf F. Marshall

Date: February 1984

Sponsor: U.S. Department of Transportation
Urban Mass Transportation Administration
400 Seventh Street, SW
Washington, D.C. 20590

Report No. MA-06-0098-84-2

Abstract: Falls are the second leading cause of accidental injury in the U.S. Based on reports to the Federal Railroad Administration, the U.S. rail transit industry carried 7.25 billion passengers during the period 1976-1980, and these patrons experienced about 10,000 station falls. Analysis of accident reports in one system show alcohol involvement in 29 percent of all falls and 55 percent of male falls where an ambulance was called. Off-peak incident rates were higher, and the P.M. peak is higher than A.M. Most transit falls are due to personal factors. Station falls cost the transit industry an estimated $1.7 million annually in claims settlements. Societal cost for lost time and hospitalization are about the same. High industry standards of design and maintenance result in lower incident rates and settlements than the general experience. Design improvements are warranted to reduce incident rates, severity, and claims. Use of a uniform accident reporting form, and reporting threshold consistent with U.S. Consumer Products Safety Commission data is recommended.

Key words: Falling accidents, pedestrians, transit terminal design, risk management.

3. Title: An Economic Basis for Recommendations Pertaining to Fall Warning Systems

Authors: T. Armstrong
Abstract: The design and use of fall warning systems is reviewed emphasizing the effectiveness of fall warning systems. The ability of fall warning systems to provide worker protection is found to be dependent on: 1) the characteristics of the fall warning system and the surrounding environment; and 2) the physiological and psychological characteristics of potential users of the fall warning system.

The use of typical fall warning systems is discussed including signs, signal lights, delineators, audible signals, and temporary ropes and barriers. The review is supplemented by a summary of relevant technical material.

Keywords: fall warning systems, signals, signs, barriers, worker safety

B. Tactile Warnings

1. Title: Tactile Warnings to Promote Safety in the Vicinity of Transit Platform Edges.

Authors: Dr. Alec F. Peck
          Billie Louise Bentzen

Date: December, 1987

Sponsor: U.S. Department of Transportation
          Urban Mass Transportation Administration
          Office of Technical Assistance
          Washington, D.C. 20590

Report No. UMTA-MA-06-0120-87-1

Abstract: Concern for the safety of visually impaired individuals at the platform edge in rapid rail transit stations led to this study of potential tactile warnings which are designed to give the visually impaired traveller an underfoot warning as the edge is approached. The report describes three related studies: 1) initial laboratory research to identify potential tactile warning materials, in which 23 blind travellers using long canes or guide dogs attempted to locate each of four distinct edge warning materials (PVC corduroy, epoxy corduroy, Pirelli rubber, steel) which were contrasted with four base platform materials (wood, course aggregate concrete, brushed aggregate concrete, Pirelli tile); 2) in-transit research at BART in San Francisco, in which three different edge
warning materials (PVC corduroy, epoxy corduroy and "Pathfinder tiles") in four
stations having different environmental characte-...cs were experimentally
tested on 30 totally blind subjects (with an additional study of the effect of the
materials on the travel of 24 ambulatory-impaired travellers); and 3) a follow-up
laboratory study of "Pathfinder Warning Tiles" which were introduced into the
BART study and appeared to have useful warning properties.

All three surfaces were highly detectable when contrasted to the masonry
platforms therefore any of them could be used in transit stations. A minimum
width of 24 inches and maximum of 36 inches is also recommended.

Keywords: tactile warnings, surface materials, transit systems, BART

2. Title: Detectable Tactile Surface Treatments.
Authors: Elliot Pavlos
Jon A. Sanford
Edward Steinfeld

date: October 1985
Sponsor: U.S. Architectural and Trans. Barriers Compliance Board
330 C. Street, SW
Washington, D.C. 20202

Abstract: The purpose of the research was to provide the ATBCB with
sufficient information to establish, technical and usage requirements for surface
treatments at stairs; curb ramps; platforms; means for egress and other locations
where it may be necessary to provide additional information for orientation and
safety. Laboratory testing of selected surface materials was undertaken in
order to determine a range of materials that are detectable; field testing was
completed in order to determine the effectiveness of surfaces as warning and
orientation devices.

The findings of this study indicate that tactile surface materials are useful to
visually impaired people as mobility aids when they contrast to the walking
surface. Materials which rely on sound and resilient cues are more detectable
by blind and low vision people than those materials which rely on textural
cures. A recommendation was made to include common flooring materials in the
code (as opposed to just plastic, rubber, raised strips or grooves) as detectable
surfaces when the material was suitable for the maintenance, construction and
durability requirements of the specific installation. Thirty-six inches was the
maximum width necessary to provide information before the edge is reached.

Materials Tested against a Brushed Concrete Walkway:
Asphalt
Artificial Grass
Brick Pavers
Vinyl Asbestos Tile
Linoleum (Armstrong, padded and unpadded)
Rubber Mat - wide rib (3M, Anti-slip Mat)
Rubber Mat - narrow rib (Warp Brothers, Plast-O-Mat)
Antique Wood Parquet Flooring - rough (Harris Flooring Co.)
Wood Parquet Flooring: smooth (Perma Grain Products)
Safety Tread (Wooster Supergrit Warning Tread)
Stainless Steel Grate (Kadee Industries, SSS Clean Tread)
Epoxy Non-slip Coating - non resilient (3M, 1420 Coating)
Epoxy Non-slip Coating - resilient (3M, Scotch Clad Decking)
Cushioned Plastic Mat (3M, Nomad Mat)
Steel Checker Plate with 3M Conformable Anti-slip material
Resilient Thermoplastic Strip (3M Safety Walk)
Resilient Rubber Floor - smooth (Forbo, Sheet Flooring No. 14079)
Resilient Rubber Floor - Texture (Biltrite Corp, Endura Tile)

Keywords: tactile warnings, sound cues, resilient cues, textural cues, surface materials

3. Title: Ground and Floor Surface Treatments

Authors: John Templer
          David Lewis
          Jon Sanford

Date: March, 1983

Sponsor: U.S. Architectural and Trans. Barriers Compliance Board
         330 C. Street, SW
         Washington, D.C. 20202

Abstract: The purpose of this study was to determine what was known about floor and walkway surfaces in order to be able to specify surfaces that do not cause mobility difficulties, impediments, barriers and hazards for disabled people. The study consisted of an overview of the literature on: slippery surfaces, roll resistance, walk-resistance, joints and detectability. The study examined these potential mobility impediments in terms of both the context in which they were used (e.g. the nature and characteristics of the material from which the surfaces are made; the effect of the micro-environment in terms of weather, wind, ambient temperatures, etc.; the effect on maintenance) and the types of disabilities which might be affected (e.g. wheelchair users, visually impaired, cane user, mobility impaired, etc.).

Keywords: floor and walkway surfaces, surface materials, slip resistance, roll resistance, walk-resistance, detectability

4. Title: Accessible Buildings for People with Severe Visual Impairments

Authors: James Aiello
          Edward Steinfeld

Date: 1979

Sponsor: U.S. Department of Housing and Urban Development
         Washington, D.C. 20202
Abstract: The purpose of this project was to determine whether the useability of buildings for people with severe visual impairments could be enhanced through design. Subjects were asked to walk a route through a building in order to test average pace, stopping distance and tactile floor cue recognition. Tactile floor signal factors - the level of the noise signal, size of the signal, pattern of the noise signal, size of the signal, pattern of the material and resiliency of the material were tested.

The study concluded that traveller disorientation resulted from: large undefined areas and where there were irregular route paths; hazardous and difficult to negotiate situations because of overhanging objects, irregularly spaced objects lining walls and irregular sound patterns which masked or distorted sound cues necessary for easy travel; and poor directions.

Keywords: blind, visually impaired, tactile warnings, disorientation

5. Title: Provisions for Elderly and Handicapped Pedestrians, Vol. 1
   Author: John a. Templer
   Date: January 1979
   Sponsor: Offices of Research and Development
            Federal Highway Administration
            Department of Transportation
            Washington, D.C. 20590
   Report No. FHWA-RD-79-1

Abstract: This summary presents the results of the investigations that were developed to isolate the problems and hazards experienced by elderly and handicapped pedestrians. The study was concerned with the use of tactile surface materials for visually impaired pedestrians. Several materials were evaluated to determine which were easily detectable by visually impaired pedestrians. Of special interest were materials which could be applied to existing sidewalks and walkways.

Using normal mobility techniques applicable to the outdoor environment, most blind subjects were able to detect certain resilient cues, particularly thermoplastic and exposed aggregate such as pea gravel.

Keywords: pedestrians, accidents, handicapped, elderly, hazards, barriers, accessibility

   Development and Evaluation of Countermeasures.
   Authors: John A. Templer
   Sponsor: Offices of Research and Development
            Federal Highway Administration
            Department of Transportation
            56
Abstract: Presented are the results of a study on tactile surfaces for environmental cuing for the visually impaired. Subjects were asked to follow a route approximately 100 feet (30.5m) in length, on which a textured strip was installed, and then to continue along the sidewalk for a distance of equal length without the strip, to serve as a control.

Test subjects were able, without exception, to follow the textured strip and use it to maintain a safe and direct course without encountering street furniture. However, at the control area, all but one of the subjects wandered off from a direct course and had to change direction after encountering street furniture.

Keywords: pedestrians, accidents, handicapped, elderly, hazards, barriers, accessibility

7. Title: Design Guidelines to Make Crossing Structures Accessible to the Physically Handicapped

Authors: John A. Templer
Jean D. Wineman
Craig Zimring

Date: 1982

Sponsor: Offices of Research and Development
Federal Highway Administration
Department of Transportation
Washington, D.C. 20590

Abstract: The slip resistance of 12 typical paving materials and 32 test panel materials was tested. The testing was performed on dry and level surfaces. A correction factor was utilized for various gradients (slopes 1:10 through 1:16) because of the limitations of the test machine, the NBS/Brungraber machine.

In addition to slip resistance, an analysis of walkways that would be detectable by visually impaired, long cane users was conducted. The main test involved cane-detectable qualities of materials for long cane users; and a sub-test involved the effects of visual contrast on partially sighted subjects. Three potentially cane-detectable qualities were studied: surface texture (which was broken down into groove width, spacing and depth), resilience and impact sound. Visual contrast was tested by painting the test surfaces with various colors and patterns.

Although the test showed that sound was the primary factor in determining deductibility, other factors also played a part. No conclusions could be made as to the most effective combination of width, depth and spacing of grooves. Finally, specific colors were not found to be an important factor in visual detection, rather it was the degree of visual contrast based on color value that was important.
8. Title: The Feasibility of Accommodating Physically Handicapped Individuals on Pedestrian Over - and Undercrossings.

Authors: John A. Templer

Date: 1980

Sponsor: Offices of Research and Development
Federal Highway Administration
Department of Transportation
Washington, D.C. 20590

Abstract: The objective of this study was to determine the feasibility of accommodating the physically handicapped on over and undercrossing structures. Based upon the evaluation of 124 crossing structures, 86% had at least one major access barrier. A particular problem was uneven or irregular surfaces and expansion joints. Micro-climatic factors, weather and pollution, especially high winds, ice and snow were pertinent concerns.

The recommendations for future research concerning surface materials were: 1) to identify the type and amount of surface which may become a barrier if the user must travel considerable distance over them, 2) to identify a standard for a walkway slip-resistance because slippery surfaces are hazards for all pedestrians and, 3) to test a wide range of materials under various microclimate and contextual conditions.

Keywords: pedestrians, handicapped, elderly, hazards, bars, ramps, accessibility, overcrossings, slip resistance


Author: R. S. Weule

Date: May 1986

Abstract: this report, written by the safety manager of BART reviews the research conducted by Peck and Bentzen and concludes that the Pathfinder Tile should be the standard edge material on the BART transit system platforms. This recommendation was based on the following findings:

1) the Pathfinder Tile performed better statistically;

2) the Pathfinder Tile was easier to clean;
3) it would be more difficult and expensive due to the type of installation, to replace either of the two "corduroys";

4) a large number of slips were associated with the PVC raised strips;

5) low vision evaluation indicated that the yellow tile was a satisfactory stimulus;

6) the Pathfinder Tile is significantly less expensive to install; and

7) The synthetic rubber composition of the warning tile provides an additional benefit as it provides insulation between the train and the platform. This significantly reduces the car side touch potential associated with the traction power negative return.

Keywords: transit systems, tactile warnings, Pathfinder tile

10. Title: Wayfinding and Orientation by the Visually Impaired.

Authors: Craig Zimring
          John A. Templer

Date: 1984

Sponsor: Journal of Environmental Systems

Abstract: This paper addresses wayfinding and orientation by visually impaired people. First, the characteristics of visually impaired people and several common orientation and mobility strategies are reviewed. Then, two research studies are discussed. In study 1, an indoor test track was developed to explore what qualities of paving materials make them detectable by long cane users. Twenty-four visually impaired people were tested. It was found that the noise that the cane made when it struck the surface was the best predictor of detectability. Study 2 was a field study in which sixteen subjects traversed a one-half mile (800m) test route both before and after various countermeasures were added. It was found that six countermeasures improved the subject performances: wooden shoreline, tweeter, metal plates, wooden plate, rubber mats and carpet mats. Several problems and solutions are proposed.

Keywords: blind, visually impaired, wayfinding, orientation, mobility

11. Title: Designing for Orientation and Safety.

Author: Jon A. Sanford

Date: March 1985

Sponsor: Proceedings of the International Conference on Building Use and Safety Technology
          National Institute of Building Sciences
          pp. 54-59
Abstract: The Architectural and Transportation Barrier Compliance Board has reserved technical and usage requirements in its "Minimum guidelines and Requirements for Accessible Design" that are intended to provide environmental information in order to protect and assist blind and low-vision persons by alerting them to hazards and by providing directional and locational assistance. The purpose of this research is to provide the Board with sufficient information to establish, as needed, technical and usage requirements for surface treatments at stairs; curb ramps, ramps, edges of streets and platforms, means of egress and locations where it may be necessary to provide additional information for orientation and safety. Laboratory testing of selected surface materials was undertaken in order to determine a range of materials that are detectable; whereas field testing was conducted to determine the effectiveness of detectable surfaces as warning and orientation devices. This paper presented only the findings of the laboratory testing.

Keywords: blind, visually impaired, wayfinding, orientation, safety, tactile warnings, hazards, surface materials

C. Gate and Barrier Systems

1. Title: A Special Study on the Feasibility of Platform/Trainway Barriers.

Author: Roger Wood, Office of Safety and Fire Protection, WMATA

Prepared for: Washington Metropolitan Area Transit Authority Board of Directors, Safety Committee

Date: March 1987

Abstract: This study determined the feasibility of using some form of platform/trainway barrier to preclude unauthorized persons from getting onto WMATA's trainway from station platforms. Particular emphasis was placed on methods to preclude or minimize the attempt by individuals to commit suicide, trespass; or persons accidentally falling or being pushed from stations platforms to the trainway.

A survey was distributed to the major rail transit properties in order to gather information on incident statistics in each of the systems and the general benefits and liabilities of platform/trainway gates (these responses may be considered somewhat subjective). In addition, an order-of-magnitude estimate of the costs for installing and maintaining these devices was obtained from WMATA's engineering office.

The study concluded that:
1) platform/trainway gates could have positive benefits regarding the incidence at stations of suicides, trespasses and patrons falling off the platform;

2) while gates may improve some aspects of safety, they may also be detrimental in other aspects. Injuries from the gates can be expected. They may also offer an impedance to emergency evacuation between an incident train and the station platform.
3) substantial yearly operational and maintenance costs could be expected because of implementing platform/trainway gates.

4) the cost of retrofitting gates in the system would be substantial ($300-500 million);

5) industry experience and attitudes reflect that gates do not offer any overwhelming rationale for their usage.

The study recommended that no system of gates be adopted by WMATA.

Keywords: transit systems, platforms, barriers, gates, safety

D. Education and Training

1. Title: A Training Program for Visually Impaired Travelers in the Rapid Rail Environment

Author: Mark Uslan
National Consultant in Orientation and Mobility
American Foundation for the Blind
15 West 16th Street, Ny, NY

Date: 1987

Sponsor: Presentation at APTA Rapid Transit Conference

Abstract: Few rapid transit planners today are not aware of the importance of finding physical design solutions to make rapid rail travel safer and more accessible to the visually impaired person. While public education and training may be less elegant of an approach, it is just as necessary. This paper reviews how to organize a training program and relates the experiences of the program that was established at WMATA.

Keywords: blind, visually impaired, orientation, wayfinding, education, training, transit, travel, mobility training

2. Title: How blind people learn to use public transport facilities in Copenhagen

Author: Holger Holm

Date: January 1986

Sponsor: UD & SE, the Danish State Railway magazine

Abstract: The Institute for the Blind (Statens Institut for Blinde of Svagtseende) is a governmental institution and is located close to the Hellerup Station, a busy junction in north Copenhagen. Here, blind people are given
instruction on how to cope as passengers. As a case study, UD & SE followed one blind person as he made his way through the system. In the system he used landmarks such as the ticket-punching machine, the waiting room and the metal covers to tell him where he was. All the time he used his cane so that he would not fall off of the platform. Two serious shortcomings of the system were that not all of the station stops were announced and the lack of information as to whether the platform is to the right or left of the train. An acoustics signal would be of immense help. In addition, the gap between the train and the platform should be narrowed.

Keywords: blind, visually impaired, mobility training, education

E. Codes and Standards


Abstract: Specific references to the avoidance of visual noise and the elimination of glare are included. When discussing the need for and characteristics of warning strips, the standard states that exposed pea gravel aggregate or a surface that contrasts in resiliency is a satisfactory surface and that another acceptable technique is the use of 3/4" to 2" wide raised or grooved textured strips. The strips should be perpendicular to path. All grooves are acceptable in interior application. Lastly, the location of the warning strips should be at the edges of hazardous areas not protected by railings.

Keywords: tactile warnings, textures, grooves


Abstract: Proposed minimum guidelines and requirements for accessibility and usability of Federal & federally funded buildings and facilities;

Keywords: tactile warnings, textures, grooves


Abstract: The book presents both written and illustrated provisions for accessible site conditions. Two notable components of the book are (1) a classification of walkway surfaces along with comments upon their level of accessibility, and (2) a matrix comparing physical limitations versus site elements.

No justification is provided for recommendation.

Keywords: accessibility, walkway surfaces

Abstract: This article is a comparison of the Architectural and Transportation Barriers Compliance Board Final Rule 1190 and the American National Standards Institute A117.1 (1980). The following are the variations concerning floor and ground surface treatments as noted in the report.

Maximum Carpet Pile Height. The A&TBCB Guidelines and Requirements state that the combined thicknesses of the pile, cushion, and backing height shall be less than or equal to 1/2". The ANSI Standard limits the height of a carpet pile to only 1/2".

Warning Textures for Curb Ramps. The A&TBCB has reserved all specifications for tactile warnings pending further research. The ANSI Standard requires tactile cuing on curb ramps.

Keywords: tactile warnings, textures, grooves


Abstract: This article describes standards based on the standards issued by the American National Standards Institute, ANSI A117.1 1961 (R1971), and the General Services Administration. The following list of components which pertain directly to blind and visually impaired people was discussed: floors, tactile floor signals, warning systems, gratings, acoustic characteristics and exterior walks.

In general, the standards or guidelines were not substantiated or were nebulous or incomplete.

Keywords: tactile warnings, textures, warning systems, floor surfaces


Abstract: This paper presents the results of the Codes and Standard Workshop on Life Safety and the Handicapped. The two areas of specific relevance were under:

Movement Problems: (1) Handicapped individuals can have problems moving from a threatening situation. This occurs because they are obstructed by certain conditions or elements that become barriers because of their specific handicaps. These are conditions or elements which are not currently addressed in relevant code provisions and include floor coverings, grates, mats, hardware, illumination, sills, protruding objects, and level changes. (2) the length of time that it takes a handicapped individual to move away from a threatening situation can be seen as a function of their particular disability. No current code provisions take into account this type of time and distance information for handicapped persons.

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Codes and Standards: To be credible, codes and standards should be based on adequate, reliable data.

Keywords: mobility, movement problems, barriers, accessibility, handicapped


Abstract: This third volume in a series of three reference documents for landscape architects and designers presents domestic and international examples of legislation, guidelines, standards and criteria for constructing and redesigning buildings to make them barrier free and therefore accessible to handicapped and disabled persons. Examples are included of federal, state, and local laws and guidelines, as well as British, Canadian, and Dutch legislation and standards. Specifications for walkways, floor surfaces are presented.

Keywords: accessibility, standards, legislation, barrier free design


Abstract: The guidelines presented are concerned with surface treatment and site planning, such as, walks, surface treatment, drainage structures, outdoor ramps, and maintenance.

Guidelines presented are concerned with surface treatment and site planning, such as, walks, surface treatment, drainage structures, outdoor ramps, and maintenance.

Guidelines are generally not specifically defined or substantiated by research.

Keywords: surface treatments, site planning, ramps, maintenance


Abstract: The article describes the surface treatments and standards for site planning. The trail surface should be firm and clear of debris or obstructions; materials such as soil cement, compacted trap rock dust, or asphalt are suitable for light or moderate traffic; textured paving may be used to warn of imminent hazards such as abrupt changes of grade, stairs, ramps, walk intersections, etc., and to signal the locations of special information.

Standards are not substantiated.

Keywords: surface treatments, site planning, textured paving, hazards

Abstract: Sweet's catalog includes a comprehensive listing of flooring and ground surface treatments. The catalog is organized by material within a purpose heading, for example, under flooring there is wood flooring, plastic flooring. Volume One discusses the characteristics of the materials, such as initial cost, compression strength, tile thicknesses, sizes, carpets, pile height variations, pitch. A source to locate empirical data about materials and manufacturers of the materials. The only reference to specific flooring materials and the handicapped population may be found in the volumes with product advertisements.

Keywords: flooring, gates, barriers


Pertaining to floor and ground surface treatment, the guidebook references standards for changes in level, surface conditions, drainage, and carpeting.

Important terms such as stable, firm, slip-resistant and irregular are not specifically defined, making guidelines vague.

Keywords: tactile warnings, surface textures, accessibility, level changes


Abstract: A reference manual wherein the author provides some detailed solutions to keyword mobility problems. Along with the solutions, the source for the solution and the research status -- whether the solution has been substantiated with formalized research or it is simply a recommendation by the author of the solution -- are provided.

The list of surface treatments discussed included carpets (travel distance, metal transition strips, use of shag carpets), caution strips (entrances, ramps, stairs), floor characteristics needed, floors at entrances and landings, floor finishes, floor (noisy and resonant), non-resilient floors, polished floors, resilient floors, non-slip cement surfaces, non-slip terrazzo surfaces, ramp surface materials, walkway surface treatment, surface textures for plazas, stair surface treatment, sliding door thresholds, toilet room floor thresholds, and tile.

Keywords: mobility problems, surface treatments, tactile warnings, floors, floor finishes, slip resistance

Abstract: A building code for accessibility for the handicapped, the Illinois code presents both performance and prescriptive requirements for the following surface treatments: concrete (pavers and exposed aggregate), wood decks, cobblestones, soil cement, general walkway requirements, joints (widths), metal grating, door mats, thresholds (variations in heights), brick pavers, and carpeting (carpet pile height, edging, and location of use).

Adjacent to the respective guidelines is a rationale for describing the premise behind the guideline or a description of a potential hazard. Although not referencing research projects, a practical reason is given.

Keywords: accessibility, handicapped, surface treatments, hazards


Abstract: This manual is the second of a three-volume set and it is divided into three parts. Part I is directed at identifying the major hazards experienced by the handicapped. Part 2 looks at the environmental barriers and problems. Field studies surveying the difficulties experienced by handicapped people are described and a typology of barriers and problems is developed. Part 3 considers the federal and state legislation that covers access to the pedestrian environment.

The field studies were performed to collect data from a representative sample of elderly and handicapped people. The methods were interviews, panel discussions, and field observations. With respect to surfaces, both interior and exterior, the question, "When walking/wheeling around, I often find that..." elicited a series of user responses. During the panel discussions, the panelists were asked to prioritize a list of eighteen research topics. The design of materials used for walkways ranked fourteenth, yet safer and easier ways to cross streets was first.

Keywords: pedestrians, accidents, hazards, accessibility, surface treatments


Abstract: This report summarizes information and research in the area of stair use and provides design guidelines for improving stair safety. These guidelines are directed toward seven major categories of stairway design and construction: (1) structural integrity and quality of stairs, (2) physical attributes of stair surfaces, (3) appearance of stair surfaces, (4) handrails, (5) physical attributes of the surrounding stairway environment, (6) appearance of the surrounding stairway environment, and (7) signs and symbols.

In general, the recommendations offered in this report derive from the premise that stairway accidents are caused by human perceptual errors which are frequently triggered by some flaw in the design or construction of stairways themselves. Evidence describing the severity and frequency of residential stairway hazards and supporting premises underlying design guidelines were
obtained from epidemiological, experimental, exploratory, and survey research sources.

This report includes some recommendations for stair surface treatment. To provide proper foot-to-stair interface, stability and slip-resistance should be adequate for the slope, climatic exposure, and traffic conditions but not so excessive as to prevent the user from pivoting or sliding his foot where necessary. There should be adequate provisions to dissipate surface moisture to prevent hydroplaning, and provisions to prevent the accumulation of ice or snow. Moisture, ice, and snow not only reduce traction but also interfere with seeing the stair.

Keywords: slip resistance, hazards, falls, surface conditions


Abstract: Section C: Protection of open sided floors platforms and runways (1) every open-sided floor or platform or more above adjacent floor or ground level shall be guarded a standard railing or equivalent (3) regardless of height, open-sided floors, walkways, platforms or runways above or adjacent to dangerous equipment,... and similar hazards shall be guarded with a standard railing and toe board. Section E: railing, toe board.

Keywords: platforms, barriers, railings

II. Additional Selected References


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III. Other Solutions

1. Solution: Moving Platform
   System: NYCTA
   Station: South Ferry and Lexington-14th St. Station
   IRT Line

   Description: Station is a curved end-of-the-line station with excessive platform gaps due to the curvature. Mechanical "Gap-closers" are used to bridge the gaps at car doors, with loading channelized by stanchions and chains.

2. Solution: Grab Bars
   System: NYCTA
   Station: Wall Street Station
   IRT Line

   Description: The platform is very narrow. About half of the platform is equipped with vertical stanchions and overhead grab bars.

3. Solution: Laser Canes


4. Solution: Inclined Surfaces
