

**PORTABLE WORK ZONE BARRIER- MOBILE BARRIERS
MOBILE BARRIER TRAILER (MBT-1)**

Final Report
December 2009

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In cooperation with

New Jersey
Department of Transportation
Bureau of Research
And

U.S. Department of Transportation
Federal Highway Administration

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1. Report No. FHWA-NJ-2009-021	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Portable Work Zone Barrier- Mobile Barriers Mobile Barrier Trailer (MBT-1)		5. Report Date December 2009	6. Performing Organization Code
7. Author(s) Camille Kamga (CCNY) and David Washington (NJIT)		8. Performing Organization Report No. 49777-01-05	
9. Performing Organization Name and Address University Transportation Research Center, City College of New York, Marshak Hall Room 910, New York, NY 10031 and NJIT, Newark, University Heights, Newark, New Jersey 07102		10. Work Unit No.	11. Contract or Grant No. RF CUNY-29
12. Sponsoring Agency Name and Address New Jersey Department of Transportation PO 600 Trenton, NJ 08625 Federal Highway Administration, U.S. Department of Transportation Washington, D.C.		13. Type of Report and Period Covered Final Report – Jan. 2008-Dec. 2009	
15. Supplementary Notes		14. Sponsoring Agency Code	
16. Abstract <p>This work has focused on the fabrication and implementation of the MBT-1 Beam which is a truck mounted, moveable, expandable beam that provides positive work zone protection comparable to a fixed concrete barrier. It is specifically intended to enhance worker safety when carrying out shoulder repair in work zones adjacent to guardrails, inlet repair, bridge rails, bridge deck repair, sound walls and other work where workers are normally exposed to traffic or behind cones in limited work areas for several hours. Usually the shadow vehicle or the truck mounted attenuator provides protection from rear end collisions; the new device provides protection from adjacent lane traffic.</p> <p>The MBT-1 is designed to provide positive, steel beam protection system for exposed workers who normally work behind temporary cones and barrels in limited work areas. The MBT-1 was developed by Mobile Barriers, LLC. The device is currently implemented by New Jersey DOT in East Hanover, N.J, among other states.</p>			
17. Key Words work zone safety, portable mobile barriers, short road maintenance		18. Distribution Statement No restriction	
19. Security Classif (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No of Pages 38	22. Price NA

ACKNOWLEDGEMENTS

This research project has been funded by a grant from the New Jersey Department of Transportation and the Region 2 University Transportation Research Center.

The authors are grateful to the assistance and patience of Mr. Edward Kondrath and Mr. Anthony Pellegrino of the New Jersey Department of Transportation and the other members of the Research Advisory Committee at the NJDOT who provided information and advice.

The project team also wants to express their gratitude to Mr. Kevin Groeneweg, Mr. Walter Black, and Mr. Art Kornin of Mobile Barriers, LLC, for their invaluable assistance to the research team.

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SUMMARY

The purpose of this research project is to purchase and review issues concerning implementation of the Mobile Barrier Trailer (MBT-1) at the New Jersey Department of Transportation work zone sites. The Mobile Barrier Trailer, manufactured by Mobile Barrier, LLC, is a mobile temporary barrier that is intended to protect workers and vehicles at work zone sites since workers in short-term highway maintenance-type work zones are at significant risk of being struck by errant vehicles that intrude into defined work zones. Currently, many work zone devices, such as truck-mounted attenuators (TMAs), traffic cones, and barrels are used to separate workers from the traveling public during construction and maintenance activities. Although, these devices may serve well to delineate work zones, they do not provide lateral impact protection for pedestrian workers when an errant vehicle intrudes into their area. While temporary concrete and other positive barriers can be used in long-term work zones to separate the work area from live traffic, thus protecting the workers, it is not practical to use these types of devices for short duration and maintenance-type (Short-Term Stationary, Mobile Work, Work-Vehicle) work zones due to their time-intensive and difficult deployment characteristics.

The functionality of the MBT-1 for positive protection against lateral intrusions into the work zone is state-of-the-art. Our research indicated that it far exceeds its expectations regarding the protection of workers from bodily injury due to errant vehicles and also protects the vehicle passengers from potential fatalities since it rides down upon impact. Another attractive feature is its ease in mobility both to the site and while working on the site for any given road construction project.

As part of this Study, a test setup was accomplished at the NJDOT Hanover Yard in Hanover, NJ and a single pilot implementation was performed near bridge deck on Route 17 off of Allendale Road in Saddle River, NJ. The Team observed positive and encouraging developments during these tests. Statistics indicate that there is a strong need for this type of safety precaution for road workers; however major decision factors in choosing to invest in the MBT-1 include availability of adequate resources and proper logistics such as appropriate access and egress, yard configuration, training, and appropriate auxiliary equipment, which are all essential for application of this vehicle.

Planning for deployment of the MBT-1 to work zones is a very critical step in the success of the MBT-1. Planning for appropriate yard requirements, for example, is essential because the equipment must be assembled at a yard site before deployment to the field. This is crucial for several reasons. It cannot be readily and safely converted from either a left or right side barrier to the other side at the roadway job site. Furthermore, it is recommended that the best application of the device be on straight sections of roadway without a need to use ramps, clover leaves, or intersections. Therefore the route to the site must be carefully planned. The geometry of certain

roadway systems such as access ramps and intersections, in New Jersey, required that the MBT-1 had to be setup at a yard prior to deployment.

1. INTRODUCTION AND BACKGROUND

Given that more than 40,000 people are injured each year as a result of motor vehicle crashes in work zones, the protection and safety of construction and maintenance fieldwork crews and motorists on roadways are among the top priorities of both the New Jersey Department of Transportation (NJDOT) and the Federal Highway Administration (FHWA). This need is further exacerbated by the trend that fatalities from work zone crashes have increased more than 50 percent in recent years. Workers in short-term highway maintenance-type work zones, in particular, are at significant risk of being struck by errant vehicles that intrude into defined work zones. In addition, many work zone devices that are currently used to separate workers from the traveling public during construction and maintenance activities, such as truck-mounted attenuators (TMAs), traffic cones, and barrels, might not serve well to delineate work zones because they do not provide lateral impact protection for pedestrian workers when an errant vehicle intrudes into their area. While temporary concrete and other positive barriers can be used in long-term work zones to separate the work area from live traffic, it is not practical to use these types of devices for short duration and maintenance-type (Short-Term Stationary, Mobile Work, Work-Vehicle) work due to their time-intensive and difficult deployment characteristics.

The utilization of appropriate temporary traffic control procedures, of which the MBT-1 is one type, during roadway construction, maintenance, utility, or other activities is critical to ensure the safety of the personnel performing those activities as well as the public motorists traveling on the roadway adjacent to those activities.

This report primarily describes the activities performed during the study and proposed deployment guidelines and recommendations (to the extent possible based on a single pilot test) for future models of one type of portable barrier, the MBT-1. These were based on experience, observation, and comments received from personnel and workers exposed to this equipment. It is important to note, though, that the research team did not conduct a crash test on the device; information on the crash tests provided by the manufacturer has been accepted as de-facto.

2. OBJECTIVES

Based on recommendations from a previous study entitled, "Identification of Traffic Control Devices for Mobile and Short Duration Work Operations," commissioned by the New Jersey Department of Transportation and conducted by the University Research Center, the original primary objective of this study was to obtain the license from the California Department of Transportation and then fabricate and implement the Caltrans's Balsi Beam equipment in New Jersey. After doing this, the Team planned to assess its effectiveness to improve worker safety in mobile work zone and short-term maintenance operations and reduce delays and crashes in work zones. The Team's analysis would have focused on the fabrication and implementation of the Balsi Beam

that is a truck mounted, moveable, expandable beam that provides positive work zone protection comparable to a fixed concrete barrier. The Balsi Beam was developed by the California Department of Transportation (Caltrans), Federal Highway Administration and the Texas Transportation Institute under the Strategic Highway Research Program and was implemented by Caltrans on Interstate Route 80 in northern California. This implementation identified the ease of transporting the beam to the job site, ease of set up and ability of workers to work in the protected areas. Caltrans is able to use small front-end loaders, compressors and other such equipment in the protected area. It is reported that workers like the protection of a positive barrier between them and high-speed traffic.

The licensing of the Caltrans proprietary device to the NJDOT, however, was not successful. Therefore the research team shifted its effort to the purchasing of a commercially available mobile barrier protection system that was believed to provide the same functionality as the Caltrans's Balsi Beam. With the assistance of the NJDOT's Research Advisory Committee, the Mobile Barrier Trailer (MBT-1), manufactured by Mobile Barrier, LLC, was identified, purchased, and deployed for evaluation at a NJDOT work zone site in Saddle River, NJ. This report documents and summarizes the activities of the project and the assessment of the MBT-1 resulting from its test deployment during the project performance period. The study focused on the activities performed from the purchase of the MBT-1, but it should be noted, however, that even though it was the intent of this study to provide recommendations regarding a comprehensive set of deployment guidelines, the Team encountered unexpected impediments to extensive deployment opportunities such as lack of available personnel to escort and set up work sites and inability to locate tractors without the standard NJDOT towing winch which could pull the trailer, Therefore, the opportunities to evaluate after deployment were limited on a single pilot test run . Nevertheless, this study by addressing the pros and cons of using such a system, should help departments of transportation develop guidelines for selecting mobile barriers for use in a work zone. The obstacles encountered by the Team should serve to highlight the need for the Agency to consider these requirements as well in their investment decision-making.

3. DESCRIPTION OF THE MOBILE BARRIER TRAILER

The Mobile Barrier Trailer (MBT-1), a patented product considered proprietary, is an integrated, rigid wall, semi-trailer that is used in conjunction with standard semi-tractors to provide improved mobile and safe work environments for personnel at applicable maintenance, construction, and security sites. It serves as an extended, mobile, longitudinal barrier that provides a physical and visual wall between passing traffic and the maintenance and construction personnel.

The basic trailer is comprised of two platforms and up to three wall sections. The specifications of the trailer and tractor are as follows:

- Platforms- each 6.4m (21ft) in overall length, 2.54 m (100 in) wide and 1.22 m (4 ft) high (riding approximately 1.52 m (5 ft) high with 305 mm (12 in) of ground clearance).
- Wall sections - each 6.10 m (20 ft) long, 610 mm (24 in) wide, and 1.22 m (4 ft) high (riding approximately 1.52 m (5 ft) high with 305 mm (12 in) of ground clearance). A homogenous 6.4 mm (0.25 in) steel plate is welded to cover the outer side of each wall section. Each wall section abuts up against another of the platforms and is built the same to take an impact from either direction. There are no snag points at the seams. The outer 6.4 mm (0.25 in) plate and associated welds are ground beveled to transition from one to the other (Nicol, D. A., 2008).
- Tractor - The Mobile Barrier Trailer is very similar to a standard tractor-trailer vehicle in terms of its various safety and hookup components. The tractor used with the mobile barrier has to be a dual axle system in the rear of the cab. For the most part, the standard semi tractor can be employed, provided that there have been no modifications or add-ons to interfere with the MBT-1's trailer.
- Trailer - The Trailer can be ordered complete with integrated power, message/arrow board, safety lighting, work lighting, storage and supply areas, and other features intended to reduce the number of collateral vehicles and equipment typically needed on site. Its design allows for relatively easy visual inspection, repair and/or modular replacement in the case of an incident. One or more sections of the wall (20 feet each) can be removed for shortened configurations and/or high-speed transport. With integrated crash attenuation at the rear, a semi-tractor at the front, and a rigid wall on the side toward passing traffic, the Trailer provides approximately 100 feet (with 3 wall sections) of barrier and protected work area (Mobile Barriers LLC, 2009). This trailer is towed around by a tractor truck, which makes it highly mobile.
- Weight - The actual self weight and dimensions of the MBT-1 are considerably larger than a standard tractor-trailer, with the actual weight being dependent on the number of sections that are employed at the work zone. The MBT-1 vehicle has been rated at 85,000 pounds. In New Jersey, an oversized permit is required when the gross vehicle weight exceeds 80,000 pounds. According to the New Jersey Department of Transportation (N.J.S.A. 39:3-84 *Dimensional Restrictions*), the maximum dimensions for a vehicle that would not require an oversize/overweight permit are 102 inches wide, 13 feet 6 inches high, and uses 53 foot-long trailers. The maximum single axle weight is 22,400 pounds and tandem axle is 34,000 pounds, with a gross vehicle weight of 80,000 pounds.

The caboose on the rear of the vehicle has the capability to be detached from the trailer and moved over to the opposite side of the barrier. The Mobile Barrier can be easily set up in the maintenance yard before being deployed to the work site. According to the manufacturer, the initial setup can take approximately four hours when performed by an experienced work crew, however this assemblage time will vary depending on the functions and optional equipment tools that are being performed or mounted. The

Trailer can be used to provide protected areas to either the right or the left side of the road depending on which end to which the tractor is attached.

(Please refer to Table 1, Comparison of MBT-1 to a Standard Trailer Tractor for a summary of these specifications).

VEHICLE COMPONENT	WEIGHT (lbs.)	Lengths (ft.)
Legal limit of semi-tractor and trailer	80,000	48 or 53 ft. trailer
Standard payload weight of a loaded trailer	43,000 -45,000	48 or 53 ft. trailer
Payload Weight of the MBT-1	30,000	Approx. 40 ft. to 100 ft.
MBT-1 Platforms (2 of them)	20,000	40 ft.
TWO SECTIONS OF THE MBT-1 with Platforms	Approx. 10,000 (5,000 ea.)	40 ft. (20 ft. each)
THREE SECTIONS OF THE MBT-1	15,000	60 ft.
Semi -Tractor	Approx. 12,000 - 24,000 lbs	Approx. 13 ft. (not including 5 th wheel portion) for wheel base (20-22ft.)
Combination of Tractor and Unloaded Standard Trailer	Approx. 33,000 to 36,000	Approx. 70-80 ft.
Combination of Tractor and Unloaded MBT-1 Trailer (with 3 wall sections)	Approx. 65,000	Approx. 113 ft.

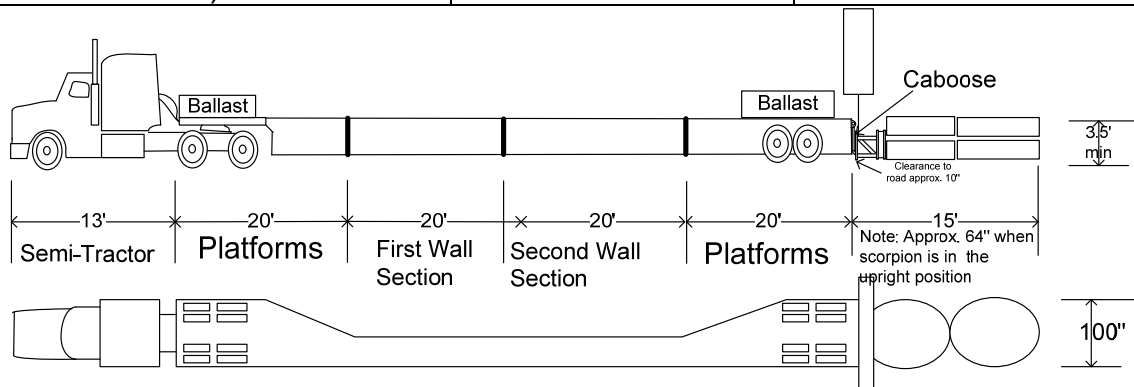


Table 1 - Comparison of MBT-1 to a Standard Tractor Trailer

The ballast boxes installed on each platform of the trailer act as a counterweight for the wall sections. They can hold between 5,000 and 8,000 pounds of sand or any other suitable material. According to the manufacturer, the ballast boxes are only needed when three wall sections are being deployed or being transported.

In order for the MBT-1 to go into production and onto various roadwork sites, a number of FHWA tests had to be performed on this device to ensure that it was in compliance

with the recommendations of NCHRP Report 350 and the new the AASHTO Manual for Assessing Safety Hardware (MASH). The safety acceptance letter B-178 (Nicol, D. A., 2008) states that this trailer has successfully performed the TL-2 or TL-3 crash test depending on the test level of the Truck Mounted Attenuator that is affixed to the rear. This was accomplished by colliding a Dodge Ram pickup at 23.5 degrees into the MBT-1 trailer at 63.5 mph (102.3 km/hr). The MBT-1 deflected approximately 2ft during the impact. The results were within the specified limits of the MASH-08. There were very minor damages to the MBT-1 as a result of the impact, and the deflection of the trailer is a benefit to the colliding vehicle, producing ride down during its deflection off the wall of the trailer.

4. FIELD DEPLOYMENT OF THE MBT-1 AT A WORK SITE IN NEW JERSEY

4.1 Maintenance Yard Considerations

The Mobile Barrier Trailer (MBT-1) with basic configurations comprised of two wall sections and two light poles was purchased by the NJDOT Bureau of Research for field trials and implementation. On July 6, 2009, the MBT-1 was delivered to the NJDOT Maintenance Yard in East Hanover, New Jersey for evaluation and deployment. The Hanover Maintenance Yard (Figure A1) was used for setup and as a training ground for potential users and drivers to become acquainted with the operations of the MBT-1. This facility was selected primarily for its large area size and its convenient access to three major interstates (I78, I287 & I80). The identification of the facility to park the MBT-1 is an important consideration in the planning phase prior to its deployment to the work zone site. Some of the factors to be considered while choosing the appropriate facility at which to park the equipment include easy access from/to the yard and to/from the main road and to/from the work site; minimum turns; the width and number of lanes of the roadway; separation of the road with physical median barriers; grade level of the roadway; and location of poles (e.g., traffic signals) at intersections.

In addition, the yard area size, the type of equipment used, and activities conducted at a facility are also important factors to be considered. The MBT-1 should be kept in a facility that will facilitate easy maneuvering in and out of the yard. In addition, the availability of other equipment vehicles, such as front loaders and special tools needed for its assemblage, must be considered. For example, at the Hanover Maintenance Yard, the MBT-1 was parked in an area that helped to avoid any conflict with regular activities and operations of the maintenance facility. It should also be mentioned that if this facility had been deemed inappropriate to house the MBT-1, the research team and NJDOT personnel were considering parking it at closed rest areas along a highway. However, the Team's evaluation of the rest stops for practical maintenance activities concluded that they were impractical for this purpose.

4.2 The MBT-1 Assemblage Requirements

For delivery of the MBT-1 to the NJDOT, the two wall sections were towed (mounted) on the platforms of the trailer and the accessories were stored in the bay compartments of the platforms during transport to the Hanover Maintenance Yard. The wall sections were removed for shortened configurations and thereby allowed for the MBT-1 to be transported almost at normal highway speed.

It is very important to setup the Mobile Barrier in the maintenance yard before being deployed to the work site. It is easy to transport, but the assemblage of wall sections to the platforms, the setup of the TMA, the arrow board system, or the variable message system (VMS) on the rear of the trailer, and attaching the tractor cabin to the trailer, must be carefully planned in advance. According to the manufacturer, the initial setup can take approximately four hours when performed by an experienced work crew, which should be comprised of technicians (in mechanic), heavy equipment operators, and commercial vehicle licensed drivers who receive at least four hours of training prior to undertaking the setup responsibilities. It is highly recommended that the manufacturer have their representatives on-site for the initial setup of the trailer and for training purposes. It is also recommended that these personnel be on site during the entire initial setup operation before the official training begins within various departments of the DOT or any other organization.

The assemblage time can vary depending on the functions and optional equipment tools that are being performed or mounted. The Trailer can be used to provide protected areas to either the right or the left side of the road depending on which end to which the tractor is attached and the caboose on the rear of the vehicle has the capability to be detached from the trailer and moved over to the opposite side of the barrier. Regarding the caboose when it is switched around, it is strongly recommended that the lifts be raised to their highest position since the caboose will automatically raise itself to compensate for the loss of weight when the jacks are lifted off it.

Equipment such as a front loader and special tools are required for the setup of the MBT-1. The type of tractor that will pull the trailer to the worksite is also of importance. During the setup of the MBT-1, a number of NJDOT tractors were considered and tested with the MBT-1 trailer to determine if they were compatible. It was observed that most of the NJDOT tractors are modified primarily to tow other vehicles off the road for repair or maintenance. This means that a towing winch is mounted in the back of the cab, which posed a considerable problem for the turning radius of the MBT-1. However, the fifth wheel attachment to the MBT-1 seem to function well, and it is possible to adjust the king pin into position to work with the trailer.

As mentioned previously, a problem was encountered in finding operators for the tractors because there were a limited number of operators who are qualified or available to pull the trailer due to their schedules, experience and the commercial class A license requirement.

(See Table 2 for a list for a list of Concerns and resolutions associated with project setup)

Considerations or Concerns in Assembling the MBT-1Trailer	Resolutions to the above mentioned concerns
1. Finding the appropriate Tractor to pull and maneuver the vehicle	The Tractors owned by the NJDOT were used primarily for towing purposes with a winch mounted behind the cab. Another tractor had to be employed on the day of training without the winch.
2. The possibility of voiding the warranty, due to improper handling of trailer components	Any modification is allowed along as the integrity of the structural elements is not compromised.
3. Modifying vehicle with additional equipment (i.e. scorpions, generators, compressors, TMA, etc.)	Although a generator, compressors, and TMAs are needed and recommended for the modification of the trailer. The NJDOT did not have any of these devices available before the time set for the training. It was proposed that these attachments be implemented at a later date. A new TMA was attached to the caboose, however there were hydraulic safety valve issues with this new unit, which caused the TMA not to deploy correctly.
4. Finding out whether the Ballast should be filled or not	Ballast is only a concern if three sections are employed. In this study, only two were purchased.
5. Understanding what construction related items could safely be placed on the platform	Although there were no construction items transported on the platform during this study, the recesses in the platform were deemed safe for tools and supplies. These items must be safely placed in a manner to avoid them becoming a potential projectile.
6. Finding out what tools and equipment were required for assembly (i.e. torque bolts to 900 ft.-lbs.)	The assembly of this trailer based on the manual instructions, were too generic for problems that occur on the site. Especially if the equipment and tools are not exactly the same as in the instructions. (i.e. A front loader had to be modified with fork lift attachments, the caboose can be damaged if the jacks are not at the highest level, due to an automatic hydraulic lift built into the suspension of the caboose)
7. Understanding how caboose could be switched from front to back without a fork lift and the appropriate attachments.	

Table 2 - Depicts the concerns and resolutions associated with the setup

4.3 Training Considerations for the MBT-1

Table 1 depicts some of the requirements that are important to convey during training sessions prior to deploying the MBT-1 to a work zone site. These requirements are based only on the setup trial that the Team observed at the Hanover Maintenance Yard. During this session, the Mobile Barriers LLC representatives from Denver, Colorado met with mechanics, drivers and managers of the NJDOT regarding the assembly of the MBT-1. Training is very important since there can be significant safety and liability issues if the installation of the Trailer is not handled properly by adhering to the manufacturer's guidelines. This is why it is recommended that representatives of the manufacturer remain onsite during the training period. Some of the difficulties and concerns and resolutions experienced in assembling the equipment are addressed in Table 3.

REQUIRMENTS	Materials /Personnel	COMMENTS
Trained/Experienced Professional	Mobile Barrier Personnel Road Mechanics Heavy Equipment Operators Commercial Class Experienced Driver	Setup of MBT-1 requires experience and training. The commercial driver should be comfortable maneuvering oversized trailers. The road mechanic should be familiar with the equipment and tools on site. The equipment operator should be comfortable loading/unloading wall sections and connecting them with the caboose.
Tools	Forklift or Front loader Impact Wrench, Breaker Bar or Pipe Hooks and Chains (min. requirement)	There are many attachments that are required to connect sections and detach caboose. The MBT-1 provides a simple hitch, but the clamps and other requirement have to be adapted on site by an experienced mechanic
Equipment	Tractor, TMA (Truck Mounted Attenuator, Scorpion) Generator (if not preinstalled)	Road Mechanic and Fabrication within a fully equipped shop is required. Warranty will not be voided as long as equipment structural frame is not compromised. No Schematics for installation will be provided by Manufacturer
Materials	Sand	Used for Ballast Tank. Not required unless three sections are being used.
Transportation (Department of Motor Vehicles)	Registration for oversize vehicle	NCHRP Report 350 for TL-2 or TL-3 (Safety Acceptance Letter B-178 online) Oversize Permit (Vehicle is rated at 85,000#s, NJDOT has been issued an oversized permit for 80000#s) Red Reflectors on Tractor in N.J. and the MBT-1 should be in compliance with regulations
Space Required for storing the Trailer	At least area that allows MBT-1 and other vehicles to mobilize and demobilize safely and it is dependent on the number of sections installed.	Mobile Barrier cannot be disassembled in sections very easily; therefore the storage space has to be able to allow the Trailer to be easily maneuvered in and out.

Table 3 - Depicts the various considerations for setup and deployment

4.4 Considerations for Deployment of the MBT-1 to Work Zone

Taking the MBT-1 to the workzone site also requires thorough planning and possible special treatments. The roadway width, ramp widths and configurations, number of lanes, configurations of intersections and median separation, and the roadway grade, are some factors to be considered upon transporting the MBT-1 to/from work site.

Planning is also necessary to ensure the safety of the worker, which is always a major concern. In fact, the smaller projects can carry tremendous liability for contractors and other parties involved. In this regard, when forming the crew, assessment of individuals' qualifications takes on tremendous importance including the review of the driver's credentials, which must qualify him or her to operate the MBT-1.

Also for safety, escort vehicles to accompany the MBT-1 may be necessary due to the configuration of local streets and to the oversize classification of the vehicle. Traffic conditions on local roads encountered in towns and populated cities may have tremendous safety implications for the workers. Due to its size, maneuvering the MBT-1 within towns could be very restrictive for passing vehicles. Permits for overweight vehicles may also be required; the NJDOT has obtained an oversize permit due to the heavy weight and length already discussed in Section 3, Description of the Mobile Barrier Trailer.

Other planning issues involve assessment of the configuration of the work site, which must match the features of the MBT-1 capabilities, particularly regarding size and weight.

These types of issues must be assessed prior to deciding to deploy an MBT-1. Table 4 depicts other cases where MBT-1 may or may not be favorable for the project in consideration.

ROAD CONFIGURATION	MOBILE BARRIER UNIT	COMMENTS FROM NJDOT MANAGERS
Consistently moving work zone	Very Favorable	MBT-1 does not require any stands to setup or stabilize it barrier system
Sound Barriers	Depends	Sound Barriers may not always allow for much shoulder room along the highway, requiring additional lane closures
Guide Rails	Depends	Similar to Sound Barriers, guide rails can restrict other equipment from getting into work zone
Overpasses	Depends	By nature overpasses have fix boundaries to work within.
Bridge Abutments	Depends	Bridge work is favorable for MBT-1 for high speed traffic and for short maintenance projects. Size and weight of the MBT-1 may be a factor for lighter bridge projects
Local streets in towns and villages	Not Favorable	Narrow roads and car parked on corners may pose problems with mobilization. The best application is on straight sections of roadways without a need to use ramps, clover leaves, nor intersections.
Congested City Streets	Not Favorable	Although the greater safety implications are more favorable for the MBT-1 deployment, its size may be restrictive to traffic flow
Long Term Construction	Not Favorable	Concrete Barriers are employed normally in this case.
Other Equipment inside the work zone	Depends	The Colorado DOT was able to get a Backhoe in and out of the positive work zone from the shoulder when transporting materials. The NJDOT Contractor was able to easily transport materials into the workzone.
Two or more Lanes	Favorable	The width and size of this vehicle suggest employment of multiple lane highways (two or more lanes) Note: the average lane is 10-12 ft wide and the trailer is 100 in (8.3 ft. wide). Also the width and availability of service lanes is a consideration as well. Getting materials into the work zone for patching will be a problem without an extra lane.
Length of Construction Zone	Not Favorable	Based on the TTI report (2004), construction project smaller than 20 ft. can be protected by smaller vehicles following each other
Lateral movement across the lanes in a sequential manner	Favorable	i.e. loop detector installation or short-line striping. Although MBT-1 cannot maneuver laterally, it can protect the outer lane laterally
Multiple work crews	Depends	Multiple work crews are favorable, but it may not be feasible in cases where work exceeds workzone
Variable Speeds	Favorable	MBT-1 can handle high speed traffic

Table 4 - Depicts Road Construction Conditions and Applications which are favorable for the MBT-1 Deployment

Several detailed Issues and considerations for deployment of the MBT-1 To Work Zone will be discussed in the following paragraphs. These include:

1. Hanging up or Bottoming Out
2. Turning Radius
3. Marking and Traffic Control Requirements
4. Land and Equipment Access Requirements

4.4.1 Potential for Hanging up or Bottoming out of the MBT-1

As already discussed, road configuration is an important consideration in preparation for deployment of the vehicle to the work site. Slope issues on the roads, which will serve for access and egress to/from the work site, are particularly crucial to deployment. For example, the decision to rely on a local road, Eden Lane, near the Hanover site, as the entrance/exit to/from the yard was due to the fact that the other possible exit which would have led directly to I-287 had too steep of a slope for proper use of the MBT-1. In addition, the trailer would have been angled into a position that would have required at least three lanes to be closed on the Highway (refer to Figure A1).

Of the configuration issues, the slope of the ramp to I-287 or vertical clearance was the most critical case for the issue of hanging up or bottoming out. However, off/on ramps to the jobsite were also important considerations. The clearance at the lowest point of the caboose, where the TMA (or Scorpion) plate is mounted can range anywhere from 9 to 12 inches depending on the configuration of the vehicle (Nicol, D. A., 2008). This clearance places a restriction on the ramps and inclines that the trailer can access with the Scorpion raised to its upright position. It is estimated that the ramp angle of inclination would be limited to about a 9 degree pitch across the length of the trailer before the back end of the Scorpion would bottom out (hang up) on the street surface. This restriction is confirmed elsewhere in the literature as well. Vertical angle curvature was reviewed in a study of another barrier system (Texas Transportation Institute (TTI), (TTI 2004), which stated that the vertical curves required that a mobile barrier protection system be designed to accommodate small changes in elevation through appropriate hinged connections to anchor vehicles. The minimum clearance heights to the bottom of the barrier were based on a review of the AASHTO design standards which suggests that a mobile barrier 50 feet long will need to accommodate only about 6 inches of elevation change (i.e., will need at least 6 inches of ground clearance) over a vertical curve, regardless of the operating speed of the roadway.

In addition to simple vertical curves, other studies address the issue of severe vertical alignment changes during barrier transport, which appears to not be problematic in the MBT-1. Recent studies on “hang-up” problems of certain types of vehicles were conducted for both railroad crossings and driveways where significant differences in grade exist (French et al, 2003) & (Eck, R.W. and Lang, S.K., 1991). Researchers in those studies identified vehicles and equipment with overhangs greater than 15 feet and wheelbases 40 feet or longer as being more prone to hang-up problems. The MBT-1 hangover is less than 15 feet when the attenuator is in its upright position, making it much less susceptible for a hang up to occur on a highway ramp due to its vertical curvature.

4.4.2 Considering Turning Radius for Deployment

Horizontal curvature will affect the turning radius of the vehicle. According to the TTI report on Mobile Barriers (TTI, 2004), the most significant implications of horizontal curvature upon a mobile barrier protection system are in terms of the lateral encroachment over the adjacent lane that will occur as the work convoy traverses a curve, and in the possible worse-case impact conditions that can develop between the barrier and an errant vehicle approaching the work convoy positioned on a curve.

The TTI report found that encroachment values would be minimal at all but the very sharpest of horizontal curves if the barrier system length is kept to about 50 feet. Such minor encroachments would still allow traffic to continue to operate in the adjacent lane. If the barrier length requirements approach 100 feet in length, however, significantly larger encroachments can be expected. In fact, it is likely that a work convoy would need to vacate traffic from the adjacent lane and send the vehicles into the next lane over or possibly onto the shoulder. This was the case during the mobilization of the MBT-1 to the work site.

Fortunately, during transport of the MBT-1 (with two wall sections) to the work site, there was no difficulty encountered in maneuvering off and on ramps and clover leaves that led to the highways and local streets during its mobilization and demobilization. The advantage in this case was due to the fact that the MBT-1 made all left turns on local streets to enter the highway, which are easier to make for larger vehicles than right turns. Also, traveling on the return route from the site was facilitated by the fact that jug handles eliminated the need for most right turns. . Time of day is also an important consideration; during the pilot, the hours for return were during the early morning hours, which minimized traffic control issues.

The angles of the turns in the jug handles were not critical for this vehicle. The critical turn was during a right turn (90 degree turn, approx. 49 ft. turning radius) while the traffic lanes were filled with vehicles (see Figure A1). To accommodate this situation, four NJDOT vehicles escorted the MBT-1. The research team estimates that for this situation, three vehicles are the minimum number required for escort as shown in the figure. The figure shows that at least one escort (shown as escort #1) would have to block on - coming traffic in the 90 degree right turn. The second escort (shown as escort#2) needs to keep traffic from moving in case the light changes. The third escort (shown as escort#3) would have to stay behind in the center of the two-lane road to ensure vehicles do not try to pass on either side of the trailer. During the field trial, the four escort vehicles were able to successfully transport the MBT-1 to and from the work site without incident. The vehicles were used to block the traffic at intersections to permit the MBT-1 to safely make the turns.

4.4.3 Marking and Traffic Control Requirements for the MBT-1

Designing the work zone can be a challenging task due to the infinite number of scenarios that are encountered and a limited number of existing standards and specifications for work zone layouts for this type of barrier. Even though the Federal Highway Administration (FHWA) has developed standards for work zone layouts in the Manual on Uniform Traffic Control Device (MUTCD), they do not include any detailed information regarding the use of barriers or positive protection devices. According to a study performed for CALTRANS (Ravani and Ortolano, 2006) on its barrier, however, all barriers either move on impact, as with concrete barriers, or deform, as with metal barriers. The expected deflection of the barrier is the key in determining the placement of the barrier in the work zone. This expected deflection allows for the work zone designer to create an adequate buffer zone for workers' and motorists' safety. Accordingly, if used to protect work zones, all barriers require a buffer zone between their placement and the area they are intended to protect.

At NJDOT's field trial, the work zone area was configured per the NJDOT work zone safety guidelines (NJDOT, 2004), which were written as if a trailer barrier was not utilized. The NJDOT Work Zone Safety manual is explicit with regards to advance signing requirements, channelizing device design and placement, and pavement delineation for temporary traffic control situations, but requirements for vehicle and equipment delineation are less defined. The MBT-1 was deployed in the area where the workers were present to add direct positive protection to these workers. Because of this, a few traffic cones used to delimit the work zone lane were removed and replaced along the MBT-1 to give way to the trailer and in a way, to minimize the disruption on the standard setup configuration approved by NJDOT.

The Team observed that the MBT-1 worked well for the job in question, a nighttime bridge deck repair and bridge joint maintenance, but a minor problem was encountered when the lighting was found to be incompatible with the generator. The MBT-1 lighting, which mounts onto the platform, was designed for a generator capable of running a 240-volt lamp. This was not the case with the 110-volt generator that was used by the contractor at this site. However, there was ample lighting provided to the work zone by the contractors' generator and portable light towers. Proper planning in the future may rectify this issue.

4.4.4 Consideration for Lane and Equipment Access Requirements

One of the drawbacks to the MBT-1 trailer system is that it occupies eight feet of lane width and does not allow large equipment access into the work zone directly from the rear. According to the TTI report on the development of functional requirements for mobile barriers (TTI, 2004), an adjacent lane or shoulder must be available for vehicles to access the protected work area. While deployed, the system must allow rolling equipment such as thermoplastic and bitumen heaters and hand equipment to be

brought into the work area. The system must also continue to allow workers to access truck-mounted equipment and materials (i.e., air compressor hoses, pothole patching material, etc.) normally used in mobile maintenance operations. The access of such equipment may possibly become a problem only in such cases where two-lane conventional highways or freeways with very narrow shoulders are the chosen project locations.

At the field trial work site at a bridge deck on Allendale Road in Saddle River, New Jersey, the work zone was setup as illustrated in Figure A3. The shoulder was also employed in addition to the working lanes and two lanes out of the three-lane roadway were closed to traffic. The maintenance and construction work were done in the fast and middle lane and the maintenance was performed in sections and repaired with Fast Track concrete. Bags of “quick set “ cement were brought on to the site in trucks and mixed in-place with a mixer on the bed of the truck for use within the trailer work zone. The work crews found the MBT-1 to be a very valuable safety asset, as it provides a high level of confidence in protecting them from potential intruding vehicles while working within a few feet of live traffic.

5. ASSESSMENT AND EVALUATION OF THE MOBILE BARRIER TRAILER

During the period of the project, the MBT-1 has been deployed only once to an actual work site. Therefore, it has been difficult to conduct a comprehensive assessment of its functionality. However, based on the experience of the investigators and NJDOT personnel, short interviews with the work crew at the work site, and the literature on the mobile barriers, the following assessments have been made:

According to a study performed by the TTI, there is a need to provide lateral protection for workers in a work zone on high volume roads and multiple lane highways. Generally, safety concerns about doing work on high-volume facilities are mitigated through the addition of positive protection (i.e., barriers). It was recognized by NJDOT personnel and work crew members that the MBT-1 is favorable in this type of work zone environment, characterized by the speed of the traffic, the volume of vehicles, and the number of lanes of converging traffic resulting from closures. TTI states that, “the number of travel lanes on a roadway segment is a factor in defining the potential side impact condition of an errant vehicle into the work area; due to the greater the number of travel lanes present, there is a greater potential initial offset or lateral separation between the vehicle and the work area and that increases the possible impact angle into the mobile barrier” (TTI, 2004). In both of the case studies related to the NJDOT and CDOT projects, the crews working within at least a 40 feet work zone reiterated their appreciation for being encapsulated from the immediate danger of vehicles traveling in excess of 60 mph in some cases. There was no fear of these vehicles hitting workers. In addition, the lighting and enclosure on MBT-1 is designed to keep the distraction away from traffic as well.

While assessing the MBT-1, the general consensus from NJDOT personnel was that it is not always feasible to utilize the MBT-1 on certain types of projects due to their characteristics such as insufficient number of traveling lanes, lack of field personnel to escort and drive the vehicle, vehicle volume on the roadway, or traffic speed of vehicles.

Though MBT-1 may be generally favorable on road projects, it may not always be feasible or economical to mobilize and maneuver this trailer when other NJDOT vehicles can be deployed to accomplish the same purpose. A TTI assessment relating to this issue mentioned that each work crew (not including litter pickup or bridge clearance measurements) typically utilizes a workspace 20 to 50 ft long. The upper end of this range reflects situations where the work area is created by two work vehicles following each other, with the work crew positioned in between. Consequently, it is possible that the specific actions taken by each work crew in those situations could be accomplished in a somewhat smaller distance. In addition, the replacement of work crews without the qualifications and experience of a commercial driver due to the use of MBT-1 is of concern and has been mentioned in several instances.

When comparing the MBT-1 with the functional requirements of a highly mobile barrier system as set by TTI, the MBT-1 assessed very well. When compared to other vehicles developed for the same purpose, the MBT-1 reflects many advantages over the existing technology that is available. Table 4 depicts a comparison between the Balsi Beam, fabricated by Caltrans, and the MBT-1.

FEATURES	BALSI BEAM	MOBILE BARRIER UNIT	COMMENTS
240 Volt lights mounted on equipment	No Lighting	Entire assembly carries lights no platform	240V gives lights double life
Tractor for equipment	Standard Tractor	Standard tractor can be used	Balsi tractor must be aligned straight
Locking mechanism once mobilized on site	Required	Not needed	Mobile Barrier absorbs impact free-standing
Standard vs. Proprietary accessories	Mostly Proprietary	Standard accessories that can be purchased w/o manufacture	Mobile Barrier uses standard lights, electric components, & generator
Lights are 90 degrees to work area	None –requires separate equipment normally parallel to traffic	All lights face into work area	Mobile Barrier does not require additional trucks for generators or lights (if they are preinstalled)
Special permit requirements	Do not required special permit	Required of special permit	The Balsi Beam can be pulled at normal highway speeds and without the need for any special permits.
Length of protected work area	30 feet	Up to 100 feet (in 20 ft wall section increment)	
Side of road protected	Capable of protecting either side (left or right, depending on the lane where work is occurring) of a work area. In addition, capable of protecting work the middle lane with traffic on both sides.	Capable of protecting either side (left or right, depending on the lane where work is occurring) of a work area.	
TL-2 & TL-3 Acceptance	Equivalent to TL-2 Test	Both TL-2 and TL-3 tests	Mash-08 Test 3-11
Ride down of vehicles upon impact with barrier	None- The Balsi Beam has to be locked into place when setup.	Yes – The walls deflect upon impact	The ride down is to prevent colliding vehicles from experiencing the full impact.

Table 5 - Comparison Between Balsi Beam and Mobile Barrier Trailer (MBT-1)

The research team has attempted to assess the MBT-1 based on the desirable functional requirements for a highly mobile barrier system that researchers at TTI have prepared (TTI, 2004), and Table 6 illustrates the results of this assessment.

Dimension	Minimum Requirement	MBT-1 Assessment
Spatial	<ol style="list-style-type: none"> 1. The system must be capable of allowing workers to access the entire width of a single travel lane. 2. The system must adequately protect the typical work area lengths required for mobile and short duration construction and maintenance activities. Limited observations indicate that these activities are currently accomplished within 20 to 50 foot lengths. 3. The system must be capable of protecting either side (left or right, depending on the lane where work is occurring) of a work area. 	<ol style="list-style-type: none"> 1. Yes 2. Yes 3. Yes (Note: the system is not capable of being configured so as to protect both sides of the work area when activities occur in the middle lane of multi-lane roadways.)
Accessibility	<ol style="list-style-type: none"> 1. While deployed, the system must allow rolling equipment such as thermoplastic and bitumen heaters and hand equipment to be brought into the work area. 2. Once deployed, the system must continue to allow workers to access truck-mounted equipment and materials (i.e., air compressor hoses, pothole patching material, etc.) normally used in mobile maintenance operations. 	<ol style="list-style-type: none"> 1. Yes 2. Yes
Mobility	Once deployed, the system must have the ability to protect a work area that progresses continuously or intermittently along the roadway.	Probably yes (not tested)
Transportability	When configured in its “transport” mode, the system must operate within the design template of a WB-50 (semi-tractor trailer) design vehicle with regards to horizontal and vertical clearances, turning path radii, vehicle hang-up potential, etc.	No. The MBT-1 requires a special permit to be transported on typical roadways.
Traffic Control and Illumination	<ol style="list-style-type: none"> 1. The system, when deployed, must comply with <i>the Manual of Uniform Traffic Control Devices</i> (MUTCD) with regards to delineation and warning light requirements for on-roadway work equipment. 2. The deployed system must have rear-ended crash protection. 	<ol style="list-style-type: none"> 1. Yes 2. Yes

Table 6 - Functional Requirements of a Highly-Mobile Barrier System assessed to MBT-1

6. RECOMMENDATIONS

In addition to the advice and recommendations already highlighted in the previous sections of the report based on the researchers' observations during the limited field work opportunities,, additional recommendations are discussed below based on observations and comments received from potential stakeholders (crews, NJDOT staff, etc.) In general, the MBT-1 has been positively accepted by work crews as providing lateral protection from live traffic, but they have noted improvements that can be made in both the physical and functional designs of the MBT-1. Comments were received on the following topics:

Equipment Maintenance

The maintenance of the MBT-1 can be improved by allowing adequate drainage from its platform to the area over the tires during the cleaning operations and with weathering conditions. Currently, the holes on the platform are over the cargo area and mechanical connections, where water damage can increase the need for maintenance of these parts and other components stored in this area.

Functionality

Even though the MBT-1 assembled with three wall sections was not observed nor deployed during this study, all the drivers were skeptical about its capability to make turns and maneuver while transporting it to work sites. With the three wall sections and the trailer-mounted attenuators attached at its rear, the trailer system will be more than 120 ft of length. With two wall sections, it has also been difficult to maneuver the MBT-1 system when making turns at intersections. The installation of a transverse beam assembly in the rear caboose may improve its maneuverability and allow a better control of the trailer while making turns. A newer design of the caboose by the manufacturer will be required to achieve this maneuverability improvement.

Safety

It was also observed that additional vehicle lighting must to be affixed along the sides (and not recessed), especially in the rear of the vehicle due to the visibility of backing up a very long trailer in the dark.

It is highly recommended to provide escort vehicles for the MBT-1 when transporting it to work site. Vehicles serving as escorts may also be utilized to carry other supplies and equipment to the site as well as blocking off other vehicles to allow a safe transport of the MBT-1 to the work zone

Design and Components

The Mobile Barrier Trailer can be ordered complete with integrated power, speed radar, message/arrow board, safety lighting, work lighting, storage and supply areas, and other features intended to reduce the number of collateral vehicles and equipment typically needed on site. Other optional tools such as generators and compressors are also available (see Table 7). It is recommended to purchase these devices while ordering the trailer because they will be handy at the site and will reduce the number of collateral vehicles and equipment typically deployed on site. The illumination of the lights mounted on the MBT-1 is adequate for road maintenance requirement within the work zone, (Hallowell, et al., 2009).

Work Zone Issues

During the field trial of the MBT-1, it was observed that some maintenance activities will tend to encroach into the adjacent travel lanes and typically need a larger space, since the equipment works right next to the edge of the travel lane and the operation includes trucks delivering materials, large equipment, and several crews of workers in the immediate vicinity of the equipment. Therefore, it is recommended that the MBT-1 is deployed to work area that will have enough space to allow easy access to materials and equipment by workers. Deploying the MBT-1 on multi-lanes roadways or on roadways with wide shoulders should not cause this type of concerns.

The selection of work zone sites as recommended in the Caltrans study (Ravani, 2006) for the deployment of the Balsi Beam would apply to the MBT-1 as well. According to this study, the work zones that are protected by the mobile barrier must be chosen based on specific parameters that evaluate the amount of worker exposure and the potential risk of serious and fatal injury in the work zone. The selection of a particular work zone is based on a number of factors that act as measures of worker exposure. These measures include efficiency of the mobile barrier in the specific work zone, the speed limit of the roadway, traffic volume of the road segment, the presence of an escape route for workers, driver visibility, and roadway history.

ASSESSMENT	COMMENTS FROM INDIVIDUALS
Getting materials into the work zone for patching will be a problem without an extra lane	The width and size of this vehicle suggest employment of multiple lane highways (two or more lanes) Note: the average lane is 12 ft wide and the trailer is approximately 8.3 ft wide. Also the width of service lanes available is a factor as well.
Maintenance - Drainage design	The removal of debris and water that gets on the deck of the trailer will be very difficult to remove due to the drainage design. Water runs into the bay compartments inside trailer instead of over the wheels.
Getting materials within work zone	Only small equipment can be used inside work zone such as backhoe or else it must be wheeled in on a wheel barrel
Concerns regarding using other construction equipment in conjunction with the MBT-1	NJDOT currently uses compressors mounted on beds of trucks. The MBT-1 application would require extra lengths of compressed air hoses to get into the work zone. Material trucks used by NJDOT cannot get within the work area. Therefore, placing material safely within platform of MBT-1 is recommended (i.e. in the ballast)
Modifying MBT-1	MBT-1 can be modified for the trailer so that a generator and other electronic devices could be employed on the trailer that is used by the NJDOT. Mobile Barriers, LLC allows for modification of the trailer to be frame out for generators and compressor, control panel (fuses, switches, etc.) to be self-installed.
Work zone lighting in multiple lanes	MBT-1 contains adequate lighting for multiple lanes
Arrow Board or Message Board	The DOT personnel recommended the arrow board, but the message board was not deemed a necessity.
Work Lighting	A few lights were already on board the NJDOT's MBT-1 and additional lights were brought to the sites by contractors. The CDOT had all of the lights on board their MBT-1 and deployed additional vehicles with lights as a precaution
Generator	Was not on board the NJDOT MBT-1 and truck-mounted generators with portable generators were used on the road sites. The portable generator did not work with the MBT-1 lights due to its voltage requirement

TMA (Truck Mounted Attenuator)	NJDOT and CDOT deemed that this option was a requirement with the use of this vehicle. NJDOT mounted their own Attenuator onto the MBT-1. Recommended that this component be purchased with the MBT-1. NJDOT had difficulty with safety valves and connections when attaching their own equipment. Maintenance recommended that the Scorpion not be moved with the wheels on the ground, due to the excessive repairs from damaged and bent wheels in the field.
Wall Sections	Transporting the MBT-1 Trailer with three wall sections was commented as a major concern in regards to the ability to handle clover leafs on N.J. roads or to make regular turns out of the yard and off/on ramps
Vehicle Lighting	More vehicle lighting needed on the sides (and not recessed), and in the rear of the vehicle. Difficulty with visibility backing up trailer in the dark

Table 7 - Assessments based on observations and comments of individual working with NJDOT and researchers

7. CONCLUSIONS

The researchers conclude that the MBT-1's functional requirements are the state-of-the-art in positive protection against lateral intrusions into the work zone. It far exceeds its expectations in protecting the worker from bodily injury from errant vehicles and also protects the vehicles from possible fatalities with its ability to ride down upon impact. This deflection of the walls when the impact occurs is only one of the advantages of this equipment. It has also been mentioned that its mobility both to the site and on the site is another attractive feature when considering the implementation of this equipment on a given road construction project.

An important conclusion is that planning for the deployment of the MBT-1 to work zones is very critical. As already mentioned, the MBT-1 must be assembled at a yard site before deployment to the field since it cannot be readily and safely converted from either a left or right side barrier to the other side at the roadway job site. It was identified that the best application of the device is on straight sections of roadway without a need to use ramps, clover leafs, or intersections. In New Jersey, the geometry of the roadway systems would require that the MBT-1 be setup at a yard for deployment to roadways of geometry as those found on tolls or Interstate roads.

There are positive and encouraging developments by the implementation of MBT-1 on pilot projects. There are three State's Department of Transportation; including Colorado,

New Jersey, and Texas that have purchased and are testing the MBT-1. The researchers were notified by the manufacturer that other State's DOTs are considering purchasing the MBT-1.

The statistics are clear that there is a mandate for this type of safety precaution for road workers; it is just a matter of having the adequate resources and applications for this vehicle, which has become the secondary issue for this research (refer to Figure A5). The deciding factor is that lives must be protected at all cost. It is estimated that a lost life can cost the state and municipalities millions of taxpayer's dollars, not to mention the invaluable loss of a family member.

In order to perform a comprehensive assessment and demonstrate the effectiveness of the MBT-1, further evaluation and testing beyond the limited testing which occurred during this study on various work activities and work sites must be performed on the system. Therefore the researchers recommend the undertaking of further studies nationwide for evaluating this system and understanding its safety potential as well as which work zone types would fully benefit from a barrier such as the MBT-1.

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Texas Transportation Institute (2004), *Development of Functional Requirements for a Highly-Mobile Barrier System to Protect Highway Workers: Final Report*. FHWA, U.S. Department of Transportation, Washington D.C., June 2004.

9. APPENDIX

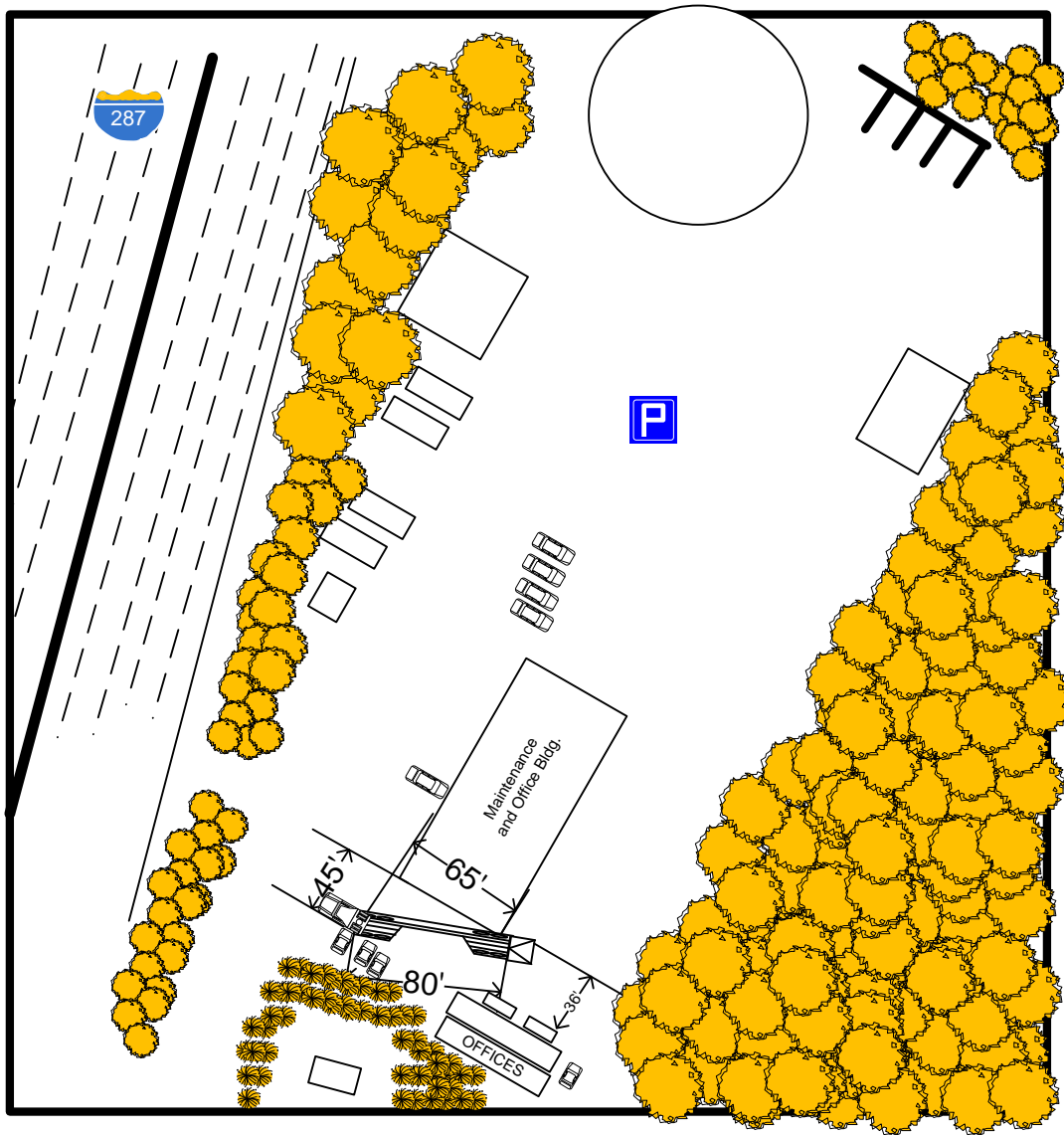


Figure A1. A Layout of the Hanover Maintenance Yard (Space Requirements)

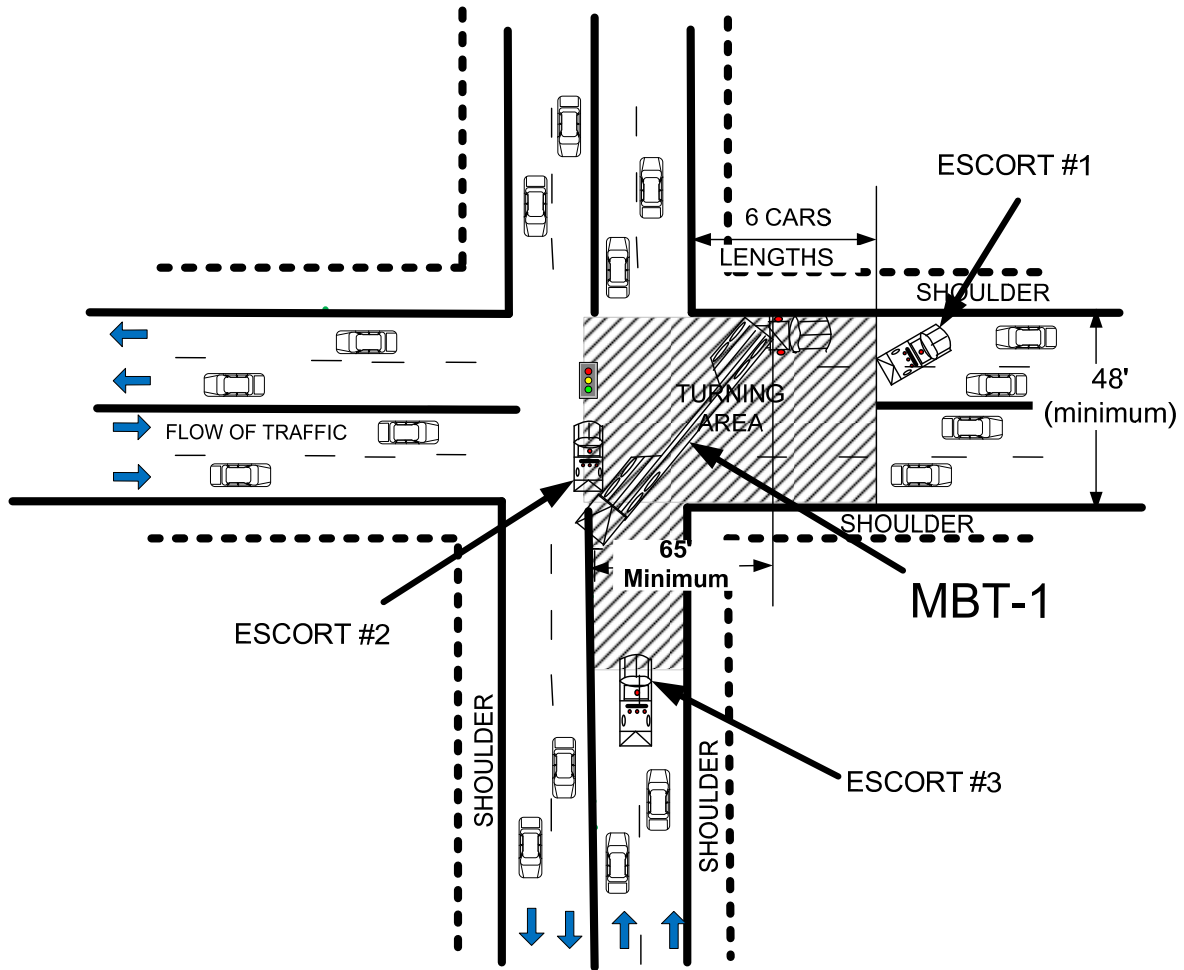


Figure A2. Depicts the setup for a two section MBT-1 90 degree turn using three escort vehicles (Turning Radius is approximately 49 feet)

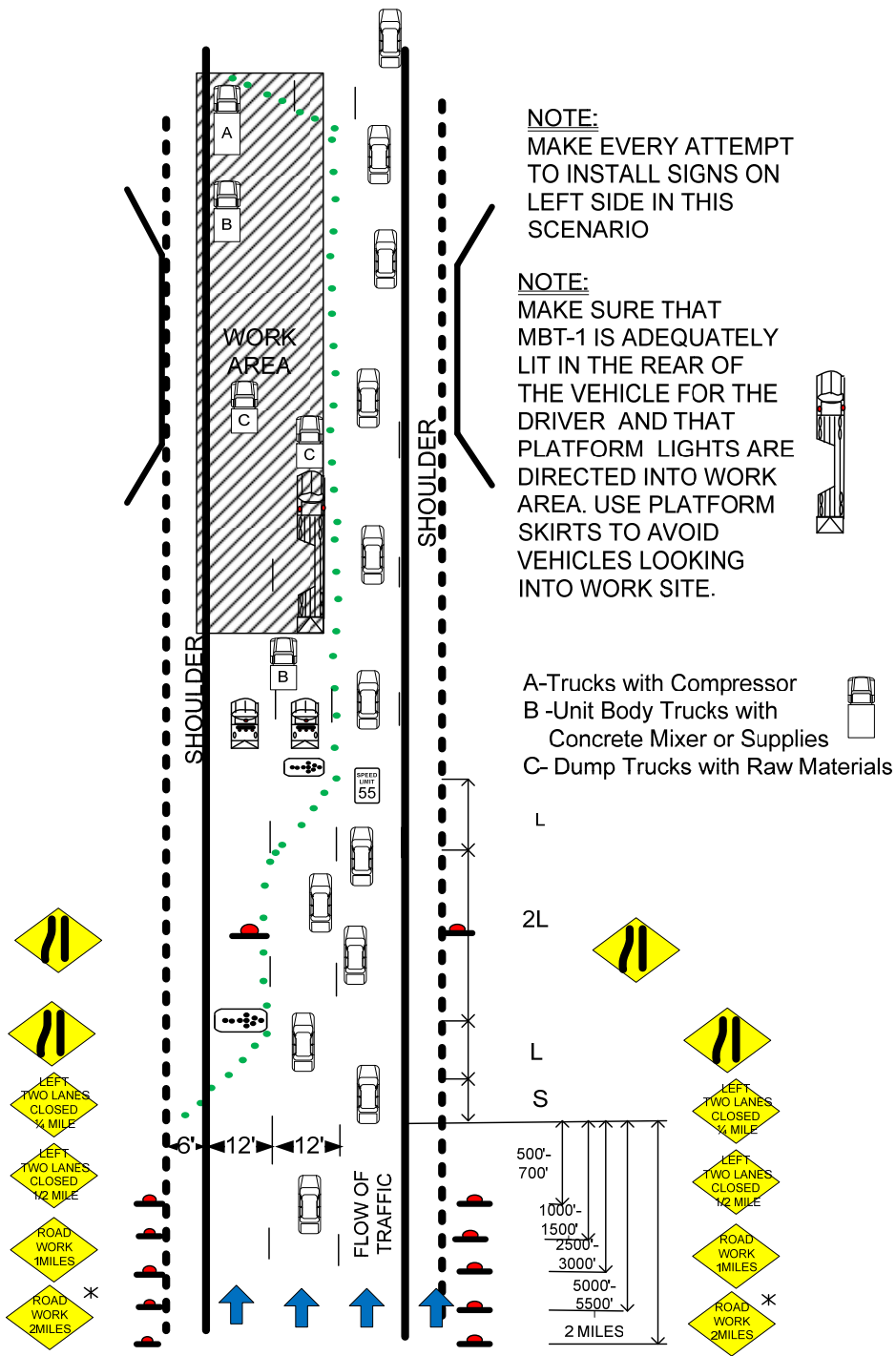


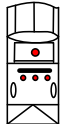
Figure A3. Traffic Safety Set Up Configuration for the Saddle River Project (Case Study on Route 17 off of Allendale Road, Saddle River, NJ.)


LEGEND


 Core/Drum


 Sign

 Work Vehicle

 Truck with
attached
attenuator
(TMA)


 Mobile Barrier Trailer
MBT-1 with attenuator and
arrow board attached

 Use this sign in addition to
the 1 MILE sign when the
speed limit is 65 mph

 Use only if highway is
undivided

 Arrow Panel

 Variable
Message
Sign (VMS)

 Stop/Slow
Safety sign
paddle

W Width of
Closed Road

L Taper Length

S Shoulder Taper

Figure A4. Legend - Traffic Safety Set Up Configuration

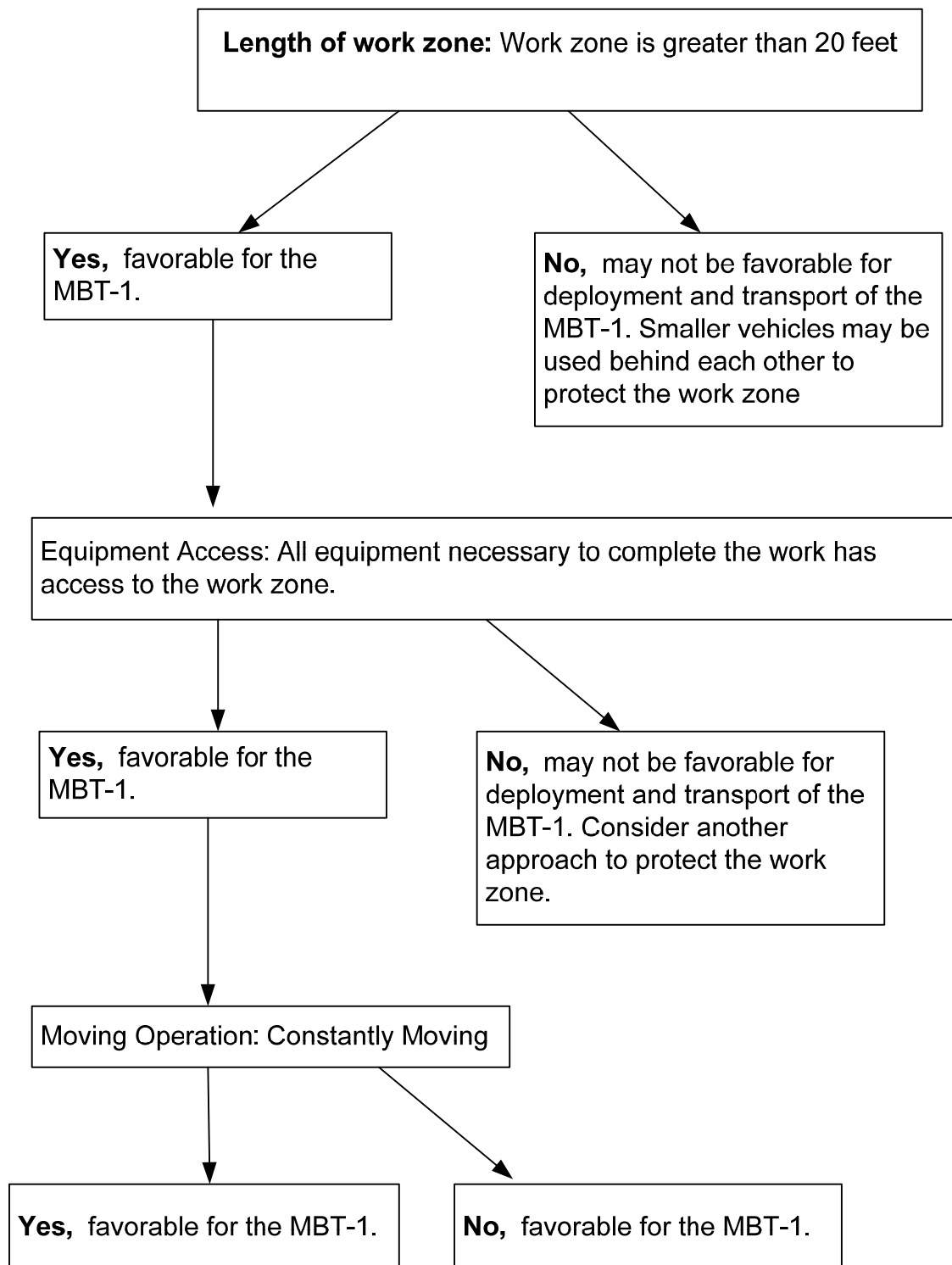


Figure A5. Assessment as to when MBT-1 should be deployed based on the Assessment developed for the Balsi Beam (Ravani, 2006)