STATE OF CALIFORNIA • DEPARTMENT OF TRANSPORTATION

TECHNICAL REPORT DOCUMENTATION PAGE

TR-0003 (REV 04/2024)

1. REPORT NUMBER	2. GOVERNMENT ASSOCIATION NUMBER	3. RECIPIENT'S CATALOG NUMBER
CA24-4193	N/A	N/A

4. TITLE AND SUBTITLE

Balsi Beam Implementation Research

5. REPORT DATE

6-27-2023; Revised 09-06-2024

6. PERFORMING ORGANIZATION CODE

AHMCT Research Center, UC Davis

7. AUTHOR

Bahram Ravani & Saeid Delshad

8. PERFORMING ORGANIZATION REPORT NO.

UCD-ARR-23-06-27-01

9. PERFORMING ORGANIZATION NAME AND ADDRESS

AHMCT Research Center
UCD Dept. of Mechanical & Aerospace Engineering Davis, California 95616-5294

10. WORK UNIT NUMBER

N/A

11. CONTRACT OR GRANT NUMBER

65A0749 Task ID 4193

12. SPONSORING AGENCY AND ADDRESS

California Department of Transportation
P.O. Box 942873, MS #83
Sacramento, CA 94273-0001

13. TYPE OF REPORT AND PERIOD COVERED

Final Report
06-29-2022 to 06-28-2023

14. SPONSORING AGENCY CODE

Caltrans

15. SUPPLEMENTARY NOTES

N/A

16. ABSTRACT

The Balsi Beam system was developed by Caltrans as a Mobile Work Zone Protection System for worker protection. The system is integrated as a self-contained tractor trailer system with telescoping beams which can be deployed to a work zone and adjusted in length without a need for a crane or any other equipment. There are, however, no guidelines for proper and effective utilization of the Balsi Beam system for highway maintenance operations. The Balsi Beam implementation research project has evaluated and identified where and under what conditions to use the Balsi Beam system at highway work zones and thus improve protection of highway workers. The scope of this research did not include evaluating other devices used or considered for worker protection in highway work zones or providing any comparisons of the Balsi Beam system to other devices or systems.

17. KEY WORDS	18. DISTRIBUTION STATEMENT
Work Zone Protection, Mobile Worker Protection, Balsi Beam	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

19. SECURITY CLASSIFICATION *(of this report)*

Unclassified

20. NUMBER OF PAGES	21. COST OF REPORT CHARGED
54	N/A

Reproduction of completed page authorized

DISCLAIMER

The research reported herein was performed by the Advanced Highway Maintenance and Construction Technology (AHMCT) Research Center, within the Department of Mechanical and Aerospace Engineering at the University of California – Davis, for the Division of Research, Innovation and System Information (DRISI) at the California Department of Transportation. AHMCT and DRISI work collaboratively to complete valuable research for the California Department of Transportation.

This document is disseminated in the interest of information exchange. The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California or the Federal Highway Administration. This publication does not constitute a standard, specification, or regulation. This report does not constitute an endorsement by the authors, or the Department, of any product described herein.

The contents of this report do not necessarily reflect the official views or policies of the University of California. This report does not constitute an endorsement by the University of California of any product described herein.

For individuals with sensory disabilities, this document is available in alternate formats. For information, call (916) 654-8899, TTY 711, or write to California Department of Transportation, Division of Research, Innovation and System Information, MS-83, P.O. Box 942873, Sacramento, CA 94273-0001.

Advanced Highway Maintenance and Construction Technology Research Center

Department of Mechanical and Aerospace Engineering
University of California at Davis

Balsi Beam Implementation Research

Authors:
Bahram Ravani, Principal Investigator
Saeid Delshad

Report Number: CA24-4193
AHMCT Research Report: UCD-ARR-23-06-27-01
Final Report of Contract: 65A0749 Task ID 4193

DATE June 27, 2023, Revised 09-06-2024

California Department of Transportation

Division of Research, Innovation and System Information

Executive Summary

Caltrans has designed and developed several Balsi Beam systems to help improve the safety of its workers at certain highway work zones. There are, however, no guidelines for proper and effective utilization of the Balsi Beam system for highway maintenance operations. The aim of the Balsi Beam research implementation project was to identify where and under what conditions to use the Balsi Beam system at highway work zones and thus improve safety of the highway workers. The scope of this research did not include evaluating other devices used or considered for worker protection in highway work zones or providing comparisons of the Balsi Beam system to other devices or systems.

The approach used in this research involved reviewing existing data related to the Balsi Beam system including its published crash performance data and gathering information from Caltrans personnel who have used or evaluated the Balsi beam system in the past to identify the relevant maintenance tasks where the system can potentially be considered to improve safety of the highway workers.

The Balsi Beam system is driven into place at a work zone and as compared to traffic cones; it provides a positive barrier separating the live traffic and the workers. The Balsi Beam system can be used to occupy a lane or a shoulder and due to the fact that its barrier beam can swivel from one side to the other, it can be used to provide protection at either side of a traffic lane. Its utilization does not need any additional equipment, and its length can be adjusted without the need for a crane or other equipment.

The Balsi Beam system does require a TMA (Truck Mounted Attenuator) equipment and a separate shadow truck with a TMA to be used in the rear to provide positive protection from a rear impact. In many short-duration or short-term stationary operations, positive protection in the form of a TMA vehicle is provided in the rear of the operation while the side of the operation which is adjacent to a traffic lane is not positively protected and only traffic cones or similar devices are used to delineate live traffic adjacent to the work zone. In such situations the use of the Balsi Beam system can improve the safety of the highway workers working in the work zone.

In terms of crashworthiness, a review of the published existing crash test data on the Balsi Beam system indicates that only its beam portion has been tested internally by Caltrans using a prior crashworthiness standard, NCHRP 350 [1]. Caltrans crash test report published in 2008 [2] indicates that there were not "any specified testing criteria for this type of barrier. Therefore, the barrier was tested under NCHRP Report 350 test Level 2 for Longitudinal Barriers" and was reported

[2] to be at Test Level 2 (TL-2) which is for impact speeds of 43 MPH (70 KPH) or less. A Caltrans standard specification ([3], section 12-3.23B) indicates that use of impact attenuator vehicles complying with TL-2 test crashworthiness are intended in California for roadways with pre-construction posted speed limits of 45 MPH or less. The Balsi Beam system also has not been tested based on the new crashworthiness evaluation criteria contained in the Manual for Assessing Safety Hardware (MASH) [4]. For temporary barriers, Caltrans has established a timeline for compliance with these newer standards by 2026 [5].

The scope of this research did not include evaluating other devices used or considered for worker protection in highway work zones.

Major Results and Recommendations

In applying the Balsi Beam system at a work zone all national, state, and local safety standards and requirements are recommended to be followed as well as any recommendations from safety engineers and professionals. The Manual on Uniform Traffic Control Devices (MUTCD) [6] in its Part VI standards sets forth the basic principles and standards for temporary traffic control on all US roadways. In maintenance/construction operations when temporary traffic control is used, the Balsi Beam system (when applicable) can improve worker protection in lateral impacts as compared to when cones or similar non-positive methods of protection are used. Below is the list of recommendations for the operation of Balsi Beam system:

- The Balsi Beam system can be most useful for short-duration stationary or short-term stationary work zones of up to 12 hours.
- The system may also be considered, in some cases, for intermittent moving operations (speeds of up to 3 MPH) since the system can be moved slowly when it is fully extended. In such operations, the workers are recommended to wait until Balsi Beam is repositioned, fully stopped, the landing gears are fully extended and engaged, and the brakes are reengaged before resuming work. It is not safe for the workers to continue working while Balsi Beam is moving, the brakes are not engaged, and the landing gears are not extended and engaged.
- The Balsi Beam system is recommended to be used as a work zone protection system for worker protection in a lane closure setting and not as a longitudinal barrier used as a temporary traffic control device.
- The Balsi Beam system is recommended to be operated more on highways (main lines/roads) and not on secondary roads especially when there are only two lanes or there is no shoulder. This is because it is cumbersome to control the traffic on secondary roads without completely blocking it or using some form of directional traffic control such as the use of flag persons.

- A TMA (Truck Mounted Attenuator) and a separate truck with a TMA needs to be used in the rear to provide positive protection from a rear impact when using the Balsi Beam system.
- The Balsi beam system is only recommended to be used with both beams on one side providing its maximum height of 36 inches.
- The length of the work area when using the Balsi Beam system is approximately 20 to 30 feet and can be adjusted without the need for a crane or other equipment.
- The average minimum time for the deployment of the Balsi Beam at a site is approximately 15 to 20 minutes.
- The width of the work zone that can be protected by the Balsi Beam system can be 10 to 20 feet wide (using either a lane and a shoulder or 1 to 2 lanes on the left or right side of the road. The system can be set up and used on:
    - Left or right shoulder
    - First lane from the right or left
    - Second lane from the right or left
- When the Balsi Beam is operated in the second lane from the left or right, it can provide two lanes of safe zone with the help of one or more barrier vehicles parked behind and on the first lane from the left or right.
- In general, the Balsi Beam system is more suitable for operations that are limited to a small, fixed location and require at least several hours to be completed.
- The Balsi Beam system is not preferred for operations that are carried out along a lane or shoulder such as litter pickup, patrolling, and landscaping.
- ***The limitations of the Balsi Beam system (discussed in the next section) need to be considered by proper safety professionals for each application.***
- Using the above considerations, the use of the Balsi Beam system can be considered for the following applications (when appropriate in terms of crash performance requirements in the area that is being used):
    - Guardrail Replacements
    - Side and Barrier Wall Repairs
    - Bridge Maintenance including Deck/Joint and Seal Repairs
    - Repair operations including Joint, Median, deck and Spall Repairs
    - Rail operations such as Edge Ground Rail, K rail, and Paint Railing
    - Slab Replacements & Asphalt Fill
    - Sign, Signal, and Lighting Installations/Maintenance
    - Pavement Core Sampling
    - Loop Detector Installations

- Gore Point and End Treatment Repair

- The Balsi Beam system can also be potentially considered for certain maintenance operations such as time-consuming cleaning and inspection works, Pothole Filling, and Culvert Replacement.
- Proper training is needed for the Balsi Beam operators so that they would be knowledgeable on the ideal placement and proper engagement of the unit at a work zone.

Current Limitations of the Balsi Beam System

- The Balsi Beam system cannot completely protect a work zone with large footprints.
- The Balsi Beam system is recommended to be considered (when appropriate) to be used as a work zone protection system for worker protection only in a lane closure setting.
- The Balsi Beam system is not recommended to be moved continuously down the road with workers within its protection area.
- The Balsi Beam system is not recommended to be used on secondary roads especially when there are only two lanes or there is no shoulder without any appropriate directional traffic control such as use of flag persons. It is more intended for operation on highways (main lines/roads).
- The Balsi Beam system by itself does not provide proper crash protection from a rear impact. Therefore, it requires a TMA (Truck Mounted Attenuator) equipment and a shadow truck with a proper size TMA to be used in the rear to provide positive protection from a rear impact when it is being used.
- In terms of satisfying any applicable crash test standards or any crash performance requirements, ***the authors are not traffic engineers and presently are not fully familiar with all federal and state classifications of traffic control devices and worker protection systems in terms of applicability of any crash test standards. The authors care about the safety of highway workers and traveling public, and therefore, defer to and highly recommend consultation with appropriate roadway safety professionals familiar with different state and federal requirements on proper classification of the Balsi Beam system in terms of a traffic control device or a worker protection system and any applicable crash test standards to make sure it is used on roadways with applicable speed limits.***

- A Caltrans published crash test report from 2008 indicates that "there are not any specified testing criteria for this type of barrier. Therefore, the barrier was tested under NCHRP Report 350 test Level 2 for Longitudinal Barriers". This testing by Caltrans which is based on a prior crashworthiness standard NCHRP Report 350 [1] for Longitudinal Barriers has reported the beam portion of the Balsi Beam system to be at Test Level 2. A Test Level 2 rating indicates that the beam portion of the device does provide crash protection (according to the test standard for which it was evaluated) when it is impacted by a vehicle whose impact speed does not exceed 43 MPH (70 KPH). The 2008 Caltrans crash test report recommends that the locations for use of the Balsi Beam "should be evaluated to ensure that the potential for vehicle impacts do not exceed Test Level 2 conditions (i.e. under 70" kph or "43 mph)".
- The data in the 2008 Caltrans test report in terms of barrier deflection showed acceptable barrier deflection of the beam portion of the Balsi Beam system at the Test Level -2 (TL-2) which is only up to impact speeds of 43 MPH (70 kph).
- The applicability of the new crashworthiness evaluation criteria contained in the Manual for Assessing Safety Hardware (MASH) [4] to the beam portion of the Balsi Beam system has not yet been evaluated. The new MASH standards (both TL-2 and TL-3) require the use of larger vehicles, with greater weight and higher center of mass which can result in higher impact forces. Although the height of the Balsi Beam (36 inches) is 4 inches above the height of classical K-rails or Jersey barriers, evaluation of MASH crashworthiness criteria can also provide data on crash performance of the beam portion of the Balsi Beam system with respect to vehicles with greater weight and higher center of mass.

Areas for Consideration for Future Research

- Future research is needed to compare the Balsi Beam unit to other mobile positive barrier systems to develop a relative table for the effectiveness of each system under different conditions.
- The applicability of the new crashworthiness evaluation criteria contained in the Manual for Assessing Safety Hardware (MASH) [4] to even the beam portion of the Balsi Beam system as a work zone protection system for worker protection is an area for consideration for future research. Although the height of the Balsi Beam (36 inches) is 4 inches above the height of classical K-rails or Jersey barriers, evaluation of MASH crashworthiness criteria can also provide data on beam portion of the Balsi Beam's crash

performance with respect to vehicles with greater weight and higher center of mass.

- Since crash testing are usually performed in a limited fashion which would provide only few data points, it would also be useful to also perform physical simulations of crash testing using computational models with dynamic crash modeling programs such as LS-Dyna [7]. In this manner, simulations can be performed for multiple angles of attack from the errant vehicles and impacts at different points on all the critical points of the Balsi Beam system providing a more comprehensive view of its ability to protect workers. Such models are best to be calibrated using crash test data so that they would provide more realistic simulation results. The same type of simulation can also evaluate the level of worker protection of the system with vehicles with higher center of mass.

Table of Contents

List of Figures

List of Tables

List of Acronyms and Abbreviations

Acronym	Definition
AHMCT	Advanced Highway Maintenance and Construction Technology
Caltrans	California Department of Transportation
DOT	Department of Transportation
FHWA	Federal Highway Administration
LON	Length of Need
MASH	Manual for Assessing Safety Hardware
META	Maintenance Equipment Training Academy
NCHRP	National Cooperative Highway Research Program
TL	Test Level
TMA	Truck Mounted Attenuator
TTI	Texas Transportation Institute

Acknowledgments

Authors thank the California Department of Transportation (Caltrans) for their support, in particular Hamid Ikram and Juan Arya from the Division of Research, Innovation and System Information. The contribution of Bob Meline from Caltrans is greatly appreciated for providing more details regarding the crash testing and crashworthiness evaluation of the Balsi Beam. The authors would also like to thank members of the project panel who provided valuable input and advice throughout this project specifically Theresa Drum, Larry Schwartz, Geno Cervantes, Curtis Scribner, John Miller, Steven Smith, Robert Rexin and his crew.

Special thanks to Miguel Medina and his crew who demonstrated the Balsi Beam system and its operation at Caltrans META, which helped us in improving the Balsi Beam guidelines provided in this report.

Chapter 1: Introduction

Problem

Caltrans has designed and developed several Balsi Beam systems to help improve the safety of its workers at certain highway work zones. Although Caltrans has performed field testing of the Balsi Beam system, there are no guidelines for proper and effective utilization of the system at highway work zones. There was a need to develop guidelines and establish procedures for effective utilization of Balsi Beam system in highway maintenance and construction tasks when its use is appropriate. This research was intended to develop guidelines for the effective utilization of Balsi Beam and to make recommendations on the maintenance tasks for which it can be considered based on the experience of highway workers who have used the Balsi Beam system within Caltrans operations.

Objectives

The main goals of this research were to make recommendations and create guidelines for most effective utilization of the Balsi Beam system and discuss under what conditions and where the Balsi beam system can or cannot be used in highway work zones.

Scope

This research was mainly focused on using data related to the use of Balsi Beam system by Caltrans' highway maintenance crews and to develop guidelines and recommendations for its broader use by Caltrans. The scope of this research did not include evaluating other devices used or considered for worker protection in highway work zones or providing any comparisons of the Balsi Beam system to other devices or systems.

Background and Literature

The Balsi Beam system is a positive work zone protection device for worker protection that can be considered for work zone safety to provide some level of protection to workers from errant vehicles. Maintenance operations typically use a shadow vehicle with a Truck Mounted Attenuator (TMA) placed upstream of the maintenance activity. The Balsi Beam system provides additional worker protection from vehicles entering the work area downstream of the shadow vehicle.

Intrusion accidents resulting in injuries to highway workers have been studied in the literature (see, for examples, [8, [9]). The first of these two studies have evaluated some of the characteristics of intrusion accidents and their locations comparing them to other traffic and construction accidents. The second study [9], has evaluated factors that are significant in producing injuries to highway workers. It has been concluded that work zone location, time of day for the maintenance or construction task, and the nature of the task requiring worker activity have the most significant impact in injury risks to highway workers. These studies show that intrusion accidents do occur, and crash protection devices can play a significant role in mitigating injuries to highway workers from intrusion accidents.

The Balsi Beam system was originally designed and patented by Caltrans [10] after a 2001 traffic accident where, two Caltrans workers were hit by an impaired driver in a work zone – Mark Balsi lost a leg and the Balsi Beam is named in his recognition. Since then, Caltrans has designed and developed several Balsi Beam systems to help improve the safety of its workers at certain highway work zones. Several State Departments of Transportations have evaluated and studied mobile barriers for work zone protection (see, for example, [11-13]).

Some of the functional requirements and potential applications areas for highly mobile barrier systems has also been studied [14-15] as well as a cost benefit analysis of such systems [16]

Research Methodology

AHMCT research team evaluated previous studies, published documents, and the functional design of the Balsi Beam and developed a proper specification of its operational envelop and discussed available published data on its crash performance. Such information is important since it will guide its potential uses in maintenance and construction operations. The results were reviewed by the project panel and then the researchers worked with the project panel to identify different maintenance functions and situations where the Balsi Beam system can benefit highway workers. These maintenance functions were mapped into the operational envelope of the Balsi Beam system to determine where it can best be used. The results provided a set of recommendations that can be considered by Caltrans to update their maintenance manual. All the results and recommendations are based on the data and information obtained from Caltrans personnel and their field operational crew who have had some experience with the Balsi Beam system as well as other relevant publications outlined in the section on background and the literature. The specific tasks for this research project were as follows:

Task 1. Manage Project

Task 2. Develop the Functional and Operational Envelop for the Balsi Beam

Task 3. Identify and classify Relevant Maintenance Situations

Task 4. Map results of Tasks 2 and 3 and develop recommendations.

Task 5. Develop Final Report.

Overview of Research Results and Benefits

The key deliverables of this project include:

- **Develop the functional and operational envelop for the Balsi Beam:** AHMCT reviewed some of the existing data, documents and information related to Balsi Beam and developed a proper specification of its functional and operational envelop. This information is needed to properly understand the performance of the Balsi Beam system to assess its use in different applications.
- **Identify and classify relevant maintenance situations:** The Balsi Beam system has a specific length and width, and it is integrated as a tractor-trailer system. It has the benefit of being able to be deployed very fast at any location without the need for a crane or other equipment for its deployment. The work zone location should be consistent with its length such that it would allow the tractor-trailer vehicle to properly access and be contained in the location. AHMCT researchers consulted with Caltrans field personnel and evaluated different categories of maintenance sites and functions where the Balsi Beam system can best be utilized to improve worker safety. The types or category of maintenance functions where the Balsi Beam system is best suited for implementation are then identified for consideration assuming that the system can satisfy crash performance requirements for the site under consideration.
- **Map results of previous tasks and synthesize the results to develop recommendations:** This task involved synthesizing the results of Tasks 2 and 3 matching site and maintenance type categories with Balsi Beam technical specifications. The final result is a set of recommendations on maintenance functions and categories where the Balsi Beam can provide the best benefit and can be considered for implementation for worker protection.

Chapter 2:
Develop the Functional and Operational Envelop for the Balsi Beam System

The functional and operational envelope of the Balsi Beam system was developed through consultation with Caltrans field personnel including bridge crews, inspection of a Balsi Beam system, and requesting and receiving measurements of the system from a Caltrans bridge maintenance crew.

The Balsi Beam system is made of two barrier strong steel beams (the beam portion) connected to a front and rear deck housing customized equipment and is configured as a tractor-trailer system (Figure 2.1). The carrier trailer is attached to the front deck through a 5th wheel slide. The beams can be extended or retracted, and the 5th wheel can slide forward (for deployment) and backward (for stowage). Different sections of Balsi Beam do not separate/detach from each other.

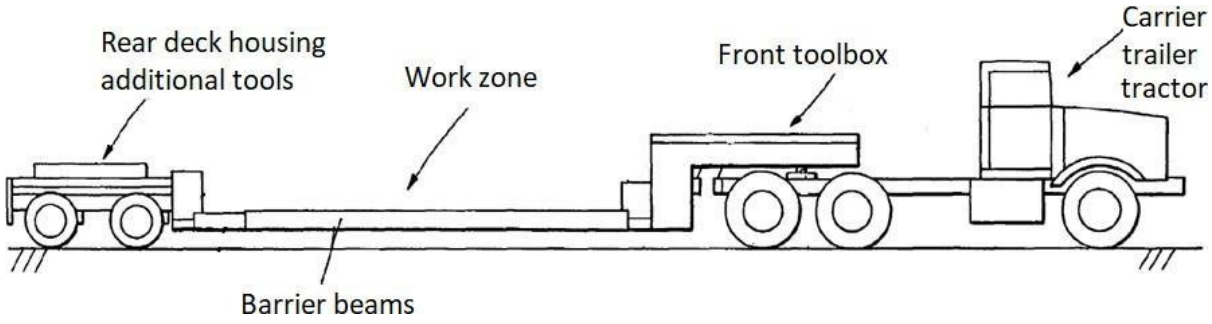

Figure 2.1: The configuration of the Balsi Beam System.

The basic physical envelope and functional specifications of the Balsi Beam system are summarized in table 2.1. The Balsi Beam system weighs around 20,000 lbs. and its overall length with its carrier trailer can vary between 40-50 feet (depending on the extension of barrier beams). There are two telescoping expandable steel barrier beams that rotate to provide a stackable two beam protection barrier on either side of the trailer. The telescoping action allows adjusting the length of the worker protection area without the need for a crane or other equipment. The two decks (one in front and one in the back) provide space for carrying certain equipment and tools needed for some of the maintenance operations. Examples of a set of equipment and tools that can be carried on the decks of a Balsi Beam system are provided in chapter 3.

Figure 3.1 shows examples of some of the common equipment which can be carried on the rear deck of the Balsi beam system such as air compressors, welders, generators, and certain materials.

Table 2.1: Physical envelope and specifications of the Balsi Beam system.

Category	Attribute	Specification (ft.)
Space	Balsi Beam length (with carrier tractor)	50’
	Balsi Beam width	10'
	Balsi Beam Height from Ground	3’
	Retracted beams length	18'
	Extended beams length	30'
	Barrier height (both beams on one side)	3'
	Rear deck dimensions	9' × 8'
	Front deck dimensions	7.5' × 8'
	Maximum work zone dimensions within one lane	8' × 30'

Barrier height when both beams are on one side is 3 feet high and when one beam is on each side is about 2 feet off the ground. Balsi Beam is rarely operated with one beam on each side as it is not considered safe to operate it in the middle lane and have traffic passing by both sides. The height of three feet when both beams on one side is 4 inches above the height of classical K-rails or Jersey Barriers. The average minimum deployment time for the Balsi Beam is approximately 15 to 20 minutes and can be as short as 10 minutes.

Balsi Beam system as a vehicle is not considered an oversized vehicle and can move at highway speeds without requiring any permits.

The operational envelop of the Balsi Beam system can vary depending on the retraction and extension of the barrier beams and can be as short as 18 feet (when retracted) and as long as 30 feet when extended. Hence, the work area length of Balsi Beam is 18-30 feet. Adjustment of the length of the beam does not

require the use of a crane or any other equipment. The safe work zone that can be provided by Balsi Beam system has a width of 10-20 feet depending on if it is used on the road and the shoulder or when it is used on 1 or 2 lanes on the left or right side of the road. The Balsi Beam system can be set up and used on

i. left or right shoulder,
ii. first lane from the left or right, or
iii. the second lane from the left or right.

An example set up of the Balsi beam system in one lane used by Caltrans in the past is depicted in Figure 2.2. As can be seen in this figure, a TMA is used to provide protection from rear impacts and cones are used alongside of the beams to improve noticeability of the operation for the live traffic.

When the Balsi Beam system is operated in the second lane from the left or right, it can provide two lanes of safe zone with the help of one or more barrier vehicles parked behind and on the first lane from the left or right as depicted in Figure 2.3. As can be seen in Figure 2.3, one or several barrier vehicles, which are 10 to 15 feet long, are set behind the Balsi Beam system without any gaps, to cover the first lane. Furthermore, traffic cones are placed on the side, behind and in front of Balsi Beam system for as many as required to set the perimeter.

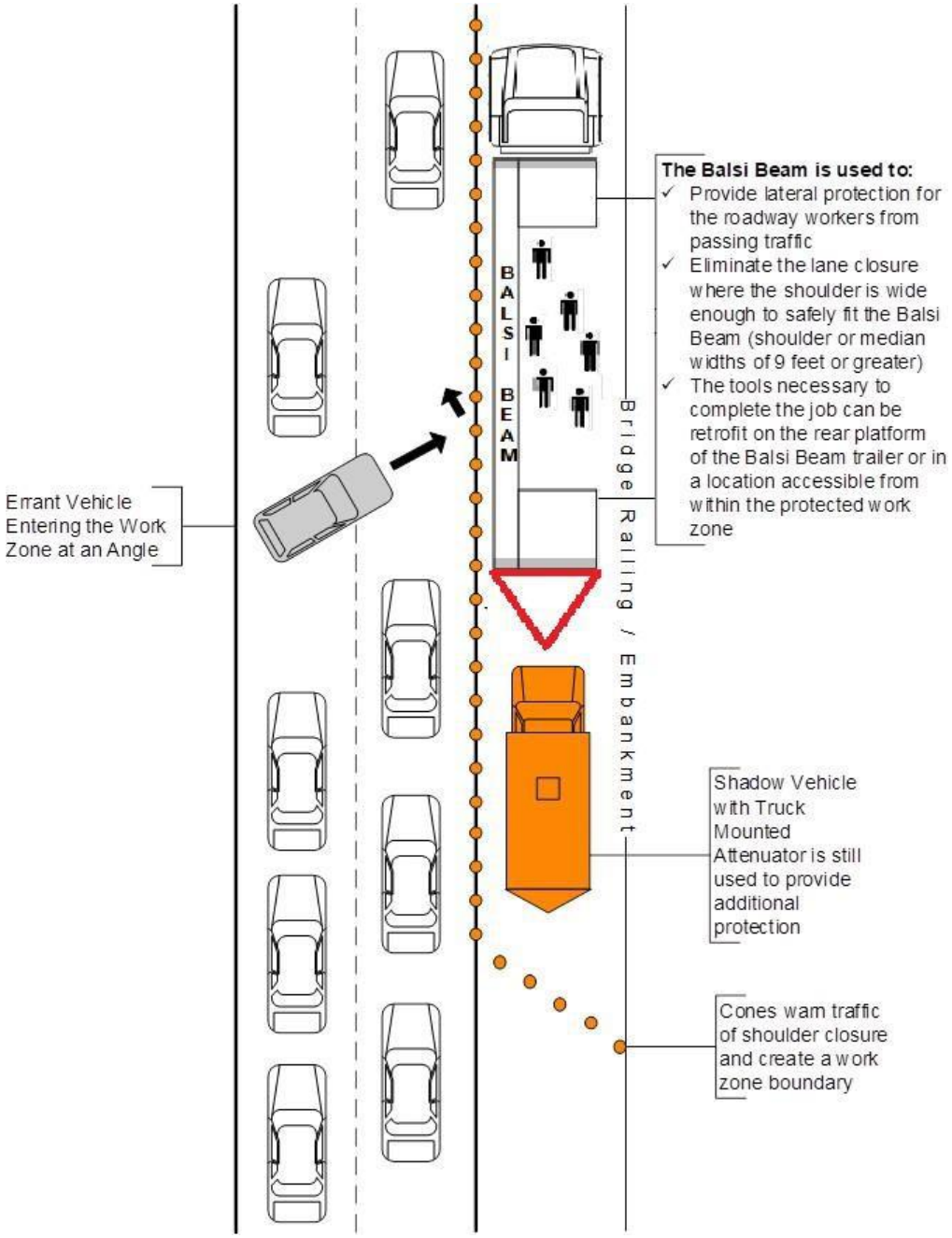

Figure 2.2: Example deployment configuration & operational envelop of the Balsi Beam system when closing one lane on the right.

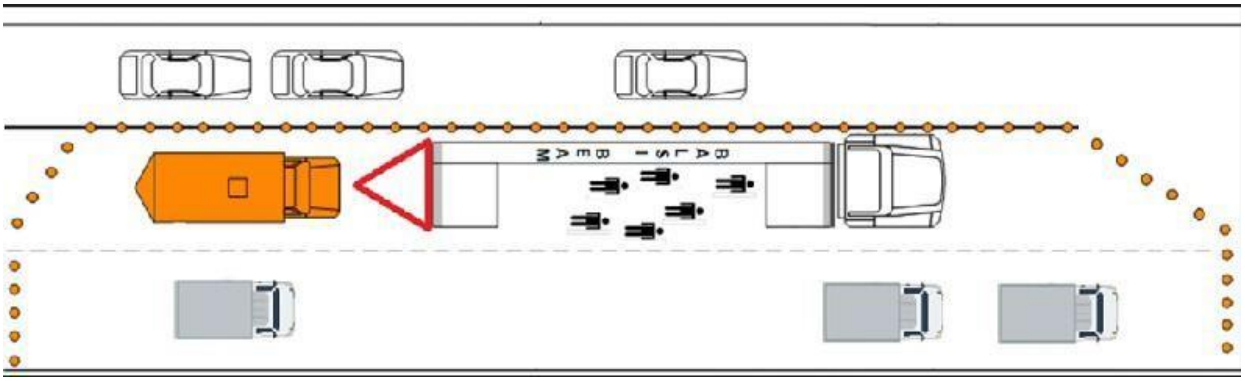

Figure 2.3: Balsi Beam second lane operation in conjunction with a barrier vehicle.

Based on the experience of the Caltrans crew, for operations that are limited to the shoulder, lane closure is typically not required when using the Balsi Beam system. Additionally, the beams do not need to be retracted for dismounting and moving the Balsi Beam in and out of a work zone.

The Balsi Beam system is often operated in highways (main lines/roads) and not on secondary roads especially when there are only two lanes or there is no shoulder. This is because it is cumbersome to control the traffic on secondary roads without completely blocking it.

Crash Test Data and Results

In terms of crash testing requirements, in the context of investigating the feasibility of developing a highly mobile lateral worker protection system, a 2004 draft report from Texas Transportation Institute (TTI) prepared for FHWA [14] has considered the category of Longitudinal Barriers in the NCHRP Report 350 for such barriers. The present authors were not able to obtain a copy of the actual final report and only the draft final report was available to them [14]. This report states that "actual testing of the highly-mobile work zone barrier shall be in compliance with NCHRP Report 350" "or the current equivalent of that document".

The published Caltrans crash test report for the Balsi Beam system from 2008 [2] indicates that "there are not any specified testing criteria for this type of barrier". Therefore, only the beam portion of the barrier was tested by Caltrans, at the time, under NCHRP Report 350 test Level 2 for Longitudinal Barriers. Caltrans reported that test results for the Balsi beam system met the Report 350 Test Level 2 (TL-2) [2] criteria for the Longitudinal Barrier with acceptable barrier deflection. Two tests were performed, one with impact severity of 66 KJ from a 2000 Kg truck and the second with impact severity of approximately 22 KJ from a sedan car crash. Test Level 2 is for when the barrier is impacted by a vehicle whose impact speed does not exceed 43 MPH (70 KPH). The 2008 Caltrans crash test report, under its

recommendation section, indicates that the locations for use of the Blasi Beam "should be evaluated to ensure that the potential for vehicle impacts do not exceed Test Level 2 conditions (i.e. under 70" kph or "43 mph)".

A Caltrans standard specification (section 12-3.23B [3]) indicates that use of impact attenuator vehicles complying with TL-2 test crashworthiness are intended in California for roadways with pre-construction posted speed limits of 45 MPH or less.

It should also be pointed out that there are more recent testing standards under the new crashworthiness evaluation criteria for Longitudinal Barriers contained in the Manual for Assessing Safety Hardware (MASH) [4]. The new testing standards use vehicles with higher weights and higher center of mass. Testing the beam portion of the Balsi Beam system under these standards can evaluate the performance or potential limitations of the beam portion of the Balsi Beam system as a Longitudinal Barrier beyond its existing test data. Caltrans has established a timeline for compliance with these newer standards for temporary barriers by 2026 [5].

Chapter 3:
Identify and Classify Relevant Maintenance Situations

In identifying and classifying maintenance situations where Balsi Beam can or cannot be utilized the following issues were considered:

- a frequent set of maintenance tasks,
- space and timing requirements for the operations,
- work site access requirements,
- equipment needed for the maintenance task and equipment carrying capacity of the Balsi Beam Truck/Trailer system.

Tasks Description

The maintenance tasks considered are summarized in Table 3.1

Table 3.1: Highway maintenance tasks description.

Maintenance Activity	Description
Asphalt Milling	Asphalt milling involves grinding asphalt up to the edge of a travel lane for removal and replacement. A large milling machine moves at 3 mph and takes one full lane. Work rules allow using only 2' from next lane before the work zone must be expanded to two lanes.
Asphalt Overlay	Overlays involve paving asphalt up to the edge of a travel lane. The operation travels at about five mph. Large equipment and multiple work crews are required, and access to an entire travel lane is needed. Work rules allow using only 2' from next lane before the work zone must be expanded to two lanes.
Bridge Maintenance	Many bridge maintenance tasks require short-term stationary work zones that last more than one hour, and they can include a variety of activities. Examples are partial bridge deck replacement and concrete spall repair. (Spalls are chips

	of material that have broken apart from a larger solid body.) Bridge maintenance work generally occurs near the edge of a roadway or on a shoulder, and all equipment usually fits within a one lane area taken with a barrier.
Culvert / Drain Work	Culvert and drain work usually involve using large trucks to clean out drains, with the work occurring in front of the trucks. Extensive culvert and drain work can involve workers on the ground for several hours.
Guardrail Repair	Guardrail repair includes the removal and installation of rail posts, as well as the repair of end treatments on guardrails that have been damaged. Guardrail can require work zones that last more than one hour, but in urban areas guardrail repair is performed mostly from within large vehicles that can repair or replace large sections in less than one hour. Equipment can fit within a one lane area.
Landscape Work	Landscape work and litter pickup both generally take place away from the roadway, and the large distance between the workers and traveling vehicles increases safety and reduces the level of need for work zone protection. It can be difficult to set up the barriers on the shoulder or off the roadway with landscape or litter pickup crews that may not be trained to do so.
Lighting Installation/ Maintenance	Lighting installation and maintenance refers mostly to work on streetlights, and this is a short-duration activity, meaning it lasts less than one hour.
Litter Pickup	Litter activities include picking up roadside litter bags filled by Corrections workers and clearing litter from under guardrails. These are highly mobile operations. Both tasks can now be performed by vehicles.
Pavement Core Sampling	Pavement core sampling involves using a core sampling truck, which can fit within narrow confines. It is a short-duration task.
Pavement Striping	Pavement striping consists of painting the roadway lines between lanes. This is done using large trucks, which keep workers inside vehicles instead of walking on the roadway. This reduces the level of need for protection.

Pothole Patching	Work for pothole patching generally lasts approximately five minutes at each site. A pothole patching machine is being evaluated that would keep workers off the roadway.
Raised Pavement Marker Installation/ Removal	Similar to pavement striping, raised pavement marker installation and removal work occurs between lanes.
Sealcoat Overlay	A sealcoat overlay involves spraying oil from a large dispensing truck to the top of the pavement.
Sign Installation/ Maintenance	Sign installation and maintenance takes less than one hour at each location.
Snow and Ice Control	Snow and ice control includes plowing snow and spreading sand or salt on the roadway. These activities usually involve using a snowplow or another large truck on the roadway, taking up travel lane space.
Storm Maintenance	Storm maintenance generally consists of traveling to different locations to check for storm damage and then performing an inspection.
Traffic Control (i.e., flagging)	Traffic control includes delineating work zones, flagging traffic, and managing contra-flows.
Traffic Signal Installation/ Maintenance	Traffic signal installation and maintenance, specifically installing traffic loops in the ground, usually takes less than one hour at each location.
Bridge deck/joint repair	Repairing the engineered space between segments of a bridge allowing for horizontal and vertical movement.

In addition to the maintenance tasks discussed in table 3.1, the following tasks were also considered:

- Side and Barrier Wall Repairs
- Slab Replacements
- Loop Detector Installations

- Gore Point and End Treatment Repairs

Space, Timing, Site, and Equipment Requirements

The Balsi Beam system helps create a relatively small, closed space (10' by 18 to 30') to be used as a fixed work zone with positive protection. The system must be securely fixed and stabilized in a location to provide a safe zone which takes time to engage. The crew who are operating the Balsi Beam need to make sure that there is enough time allocated for deployment and stowage of Balsi Beam. These time requirements are summarized in table 3.2.

Table 3.2: Deployment and Stowage Time for Balsi Beam Usage.

Category	Nature of Deployment	Minimum Duration	Recommendation
Time	Deployment/beam extension time	5 minutes	Allow up to 15 to 20 minutes (Follow steps below).
	Stowage/beam stowage time	5 minutes	Allow up to 15 to 20 minutes (Follow steps below).

The minimum time durations listed in Table 3.2 are stated to make sure that the duration of the task is not too short or too long for Balsi Beam to be used. Table A.3 of the appendix summarizes these requirements.

To that end, Balsi Beam is more suitable for operations that are limited to a small, fixed location and require at least several hours to be completed such as:

- Operations within bridges such as seal repair, etc.
- Repair operations such as joint repair, median repair, deck repair, wall repair, spall repair, signal/lighting mounting
- Rail operations such as roadway edge work, guardrail, K rail, paint railing
- Time consuming cleaning and inspection works, pothole filling, culvert replacement.

The Balsi Beam system is not preferred for operations that are carried out along a lane or shoulder such as litter pickup, patrolling, and landscaping. A full list of operations/tasks for which Balsi Beam can be useful or not suitable for can be found in Table A.5 of Appendix A.

The crew can attach/mount various equipment in the rear deck of the Balsi Beam system as depicted in Figure 3.1. The example equipment depicted in Figure 3.1 include:

a. Welder/generator (which needs refueling regularly)
b. Air compressor
c. Various size jackhammers and electric powered tools
d. Painting material and sprays
e. Additional lights for working at night.

The front deck is slightly smaller in size but can still house the same equipment and material if secured in place properly. Overall, these two decks make carrying and accessing the most useful equipment for maintenance functions very easy.

Figure 3.1: Example equipment mounted and carried on the rear deck of the Balsi Beam system.

Chapter 4:
Research Results & Recommendations

In applying the Balsi Beam system at a work zone all national, state, and local safety standards and requirements are recommended to be followed as well as any recommendations from safety engineers and professionals. The Manual on Uniform Traffic Control Devices (MUTCD) [6] in its Part VI standards sets forth the basic principles and standards for temporary traffic control on all US roadways. In maintenance/construction operations when temporary traffic control is used, the Balsi Beam system (**when applicable**) can improve worker protection in lateral impacts as compared to when cones or similar non-positive methods of protection are used.

Main Recommendations

- The Balsi Beam system can be most useful for short-duration stationary or short-term stationary work zones of up to 12 hours.
- The system may also be considered, in some cases, for intermittent moving operations (speeds of up to 3 MPH) since the system can be moved slowly when it is fully extended. In such operations, the workers are recommended to wait until Balsi Beam is repositioned, fully stopped, the landing gears are fully extended and engaged, and the brakes are reengaged before resuming work. It is not safe for the workers to continue working while Balsi Beam is moving, the brakes are not engaged, and the landing gears are not extended and engaged.
- The Balsi Beam system is recommended to be used as a work zone protection system for worker protection in a lane closure setting and not as a longitudinal barrier used as a temporary traffic control device.
- The Balsi Beam system is recommended to be operated on highways (main lines/roads) and not on secondary roads especially when there are only two lanes or there is no shoulder. This is because it is cumbersome to control the traffic on secondary roads without completely blocking it or using some form of directional traffic control such as the use of flag persons.
- A TMA (Truck Mounted Attenuator) and a separate truck with a TMA needs to be used in the rear to provide positive protection from a rear impact when using the Balsi Beam system.
- The Balsi beam system is only recommended to be used with both beams on one side providing its maximum height of 36 inches.

- The length of the work area when using the Balsi Beam system is approximately 20 to 30 feet and can be adjusted without the need for a crane or other equipment.
- The average minimum time for the deployment of the Balsi Beam at a site is approximately 15 to 20 minutes.
- The width of the work zone that can be protected by the Balsi Beam system can be 10 to 20 feet wide (using either a lane and a shoulder or 1 to 2 lanes on the left or right side of the road. The system can be set up and used on:
    - Left or right shoulder
    - First lane from the right or left
    - Second lane from the right or left
- When the Balsi Beam is operated in the second lane from the left or right, it can provide two lanes of safe zone with the help of one or more barrier vehicles parked behind and on the first lane from the left or right.
- In general, the Balsi Beam system is more suitable for operations that are limited to a small, fixed location and require at least several hours to be completed.
- The Balsi Beam system is not preferred for operations that are carried out along a lane or shoulder such as litter pickup, patrolling, and landscaping.
- ***The limitations of the Balsi Beam system (discussed in the next section) need to be considered by proper safety professionals for each application.***
- Using the above considerations, the use of the Balsi Beam system can be considered for the following applications (when appropriate in terms of crash performance requirements in the area that is being used):
    - Guardrail Replacements
    - Side and Barrier Wall Repairs
    - Bridge Maintenance including Deck/Joint and Seal Repairs
    - Repair operations including Joint, Median, deck and Spall Repairs
    - Rail operations such as Edge Ground Rail, K rail, and Paint Railing
    - Slab Replacements & Asphalt Fill
    - Sign, Signal, and Lighting Installations/Maintenance
    - Pavement Core Sampling
    - Loop Detector Installations
    - Gore Point and End Treatment Repair

- The Balsi Beam system can also be potentially considered for certain maintenance operations such as time-consuming cleaning and inspection works, Pothole Filling, and Culvert Replacement.
- Proper training is needed for the Balsi Beam operators so that they would be knowledgeable on the ideal placement and proper engagement of the unit at a work zone.

Current Limitations of the Balsi Beam System

- The Balsi Beam system cannot completely protect a work zone with large footprints.
- The Balsi Beam system is recommended to be considered (when appropriate) to be used as a work zone protection system for worker protection only in a lane closure setting.
- The Balsi Beam system is not recommended to be moved continuously down the road with workers within its protection area.
- The Balsi Beam system is not recommended to be used on secondary roads especially when there are only two lanes or there is no shoulder without any appropriate directional traffic control such as use of flag persons. It is more intended for operation on highways (main lines/roads).
- The Balsi Beam system by itself does not provide proper crash protection from a rear impact. Therefore, it requires a TMA (Truck Mounted Attenuator) equipment and a shadow truck with a proper size TMA to be used in the rear to provide positive protection from a rear impact when it is being used.
- In terms of satisfying any applicable crash test standards or any crash performance requirements, ***the authors are not traffic engineers and presently are not fully familiar with all federal and state classifications of traffic control devices and worker protection systems in terms of applicability of any crash test standards. The authors care about the safety of highway workers and traveling public, and therefore, defer to and highly recommend consultation with appropriate roadway safety professionals familiar with different state and federal requirements on proper classification of the Balsi Beam system in terms of a traffic control device or a worker protection system and any applicable crash test standards to make sure it is used on roadways with applicable speed limits.***
- A Caltrans published crash test report from 2008 indicates that "there are not any specified testing criteria for this type of barrier. Therefore, the barrier was tested under NCHRP Report 350 test Level 2 for Longitudinal Barriers". This testing by Caltrans based on a prior crashworthiness standard NCHRP

Report 350 [1] for Longitudinal Barriers has reported the beam portion of the Balsi Beam system to be at Test Level 2. A Test Level 2 rating indicates that the beam portion of the device does provide crash protection (according to the test standard for which it was evaluated) when it is impacted by a vehicle whose impact speed does not exceed 43 MPH (70 KPH). The 2008 Caltrans crash test report recommends that the locations for use of the Blasi Beam "should be evaluated to ensure that the potential for vehicle impacts do not exceed Test Level 2 conditions (i.e. under 70" kph or "43 mph)".

- The data in the 2008 Caltrans test report in terms of barrier deflection showed acceptable barrier deflection of the beam portion of the Balsi Beam system at the Test Level -2 (TL-2) which is only up to impact speeds of 43 MPH (70 kph).
- The applicability of the new crashworthiness evaluation criteria contained in the Manual for Assessing Safety Hardware (MASH) [4] to the beam portion of the Balsi Beam system has not yet been evaluated. The new MASH standards (both TL-2 and TL-3) require the use of larger vehicles, with greater weight and higher center of mass which can result in higher impact forces. Although the height of the Balsi Beam (36 inches) is 4 inches above the height of classical K-rails or Jersey barriers, evaluation of MASH crashworthiness criteria can also provide data on crash performance of the beam portion of the Balsi Beam system with respect to vehicles with greater weight and higher center of mass.

Example of Past Uses of the Balsi Beam System in California

This section provides a summary description with photos of example situations where the Balsi Beam system has been used in the past in California by Caltrans. All data and pictures in this section have been provided by different Caltrans personnel, districts, and divisions.

Bridge Deck Repairs

Bridge deck maintenance operations have benefited from the use of the Balsi Beam system. Figure 4.1 depicts one such operation showcasing the Balsi Beam being used by the Kearny Mesa Bridge Maintenance Crew (courtesy of District 11 [17]). The Balsi Beam system is being operated in the second lane. A truck carrying additional material and equipment is parked in front as a barrier vehicle.

Figure 4.1: Balsi Beam provides cover for operating on the second lane (courtesy of District 11).

On bridges the crew does not have access to any escape routes in hazardous situations except for running towards the edge of the bridge which can be unsafe due to the bridge height. When using the Balsi Beam system, the bridge repair crew can tether or connect their harnesses to the beams as a tie off point to get additional safety and support.

Another example of bridge deck repair is bridge deck concrete pour as depicted in Figure 4.2. In this application the Balsi Beam system was first removed to move the cargo truck to pour the concrete.

Figure 4.2: Concrete Pour on a bridge deck (Courtesy of District 11).

Median Repair

Examples provided in the four photographs in Figure 4.3 all show the use of the Balsi Beam system in the same median repair operations on a slightly curved section of the highway. Note that equipment and material needed for the repair was on a vehicle on the opposite side of the barrier in a lane closure in the opposite direction.

Figure 4.3: Median repair on a curved section of a highway (Courtesy of District 5).

Guardrail Repair

The Balsi Beam system has been effectively used for guardrail repairs as depicted in Figures 4.4 and 4.5.

Figure 4.4: Guardrail repair (courtesy of District 11).

Figure 4.5: Guardrail repair (courtesy of district 5).

Highway Sign Repair

The Balsi Beam system has also been used for maintenance functions related to highway signs as depicted in Figure 4.6. In this application, Balsi Beam is deployed in the first lane under a bridge. TMA truck is positioned behind the Balsi Beam system and Traffic cones are used to set the perimeter.

Figure 4.6: Highway sign maintenance & installation (courtesy of district 7).

Stationary Roadway Deck Repairs

The Balsi Beam system can also be used for certain roadway deck repairs as depicted in Figure 4.7.

Figure 4.7: Roadway deck repair during nighttime and day time (courtesy of district 11).

Chapter 5:
Conclusions and Future Research

The Balsi Beam system has been developed by Caltrans as a mobile work zone protection system for worker protection. Several units of the system have been developed by Caltrans and some have been used effectively by some of the maintenance crews in different districts. This research project has used the experience base of these Caltrans maintenance crews and other Caltrans personnel to identify maintenance functions and the types of work zones where the Balsi Beam system can be considered to improve the safety of highway workers. It is hoped that some of the findings in this research can be used to update the Caltrans maintenance manual so that there will be a reference for when and how to consider using the Balsi Beam system to improve the safety of highway workers and traveling public.

In terms of areas for future research, one area for near term consideration is a design review of how to improve the storage capacity and packaging of the auxiliary equipment carried on the two decks of the Balsi Beam trailer. The Balsi Beam system with its two decks in the front and back can potentially be customized to have additional storage boxes. Proper packaging and routing of hoses and wires can also reduce exposure of the crew to live traffic. For example, the connections for the air hoses for using a compressor can be routed through the interior of the trailer instead of the side of the Balsi Beam. The existing location on the side of the beams in some of the units can force the maintenance crew to stand near live traffic to attach the lines. Proper packaging can therefore improve the safety of the workers.

Other areas of future research related to the Balsi Beam system includes:

- Future research is needed to compare the Balsi Beam unit to other mobile positive barrier systems to develop a relative table for the effectiveness of each system under different conditions.
- The applicability of the new crashworthiness evaluation criteria contained in the Manual for Assessing Safety Hardware (MASH) [4] to the Balsi Beam system as a work zone protection system for worker protection is an area for consideration for future research. Although the height of the Balsi Beam (36 inches) is 4 inches above the height of classical K-rails or Jersey barriers, evaluation of MASH crashworthiness criteria can also provide data on Balsi Beam's crash performance with respect to vehicles with greater weight and higher center of mass.
- Since crash testing are usually performed in a limited fashion which would provide only few data points, it would also be useful to perform physical

simulations of crash testing using computational models with dynamic crash modeling programs such as LS-Dyna [7]. In this manner, simulations can be performed for multiple angles of attack from the errant vehicles and impacts at different points on all the critical points of the Balsi Beam system providing a more comprehensive view of its ability to protect workers. Such models are best to be calibrated using crash test data so that they would provide more realistic simulation results. The same type of simulation can also evaluate the level of worker protection of the system with vehicles with higher center of mass.

References

[1] H. E. Ross JR., D. L. Sicking, R. A. Zimmer, and J. D. Michi, "Recommended Procedures for the Safety Performance Evaluation of Highway Features: Report 350." TRB's National Cooperative Highway Research Program (NCHRP) - Transportation Research Board National Research Council - National Academy Press, Washington DC, 1993.
[2] R. Meline, J. Jewell, and C. Caldwell, "Crashworthiness Testing of a Portable Maintenance Work-Zone Barrier." Caltrans, Division of Research and Innovation, Office of Safety Innovation and Cooperative Research - Roadside Safety Research Group, 2008.
[3] "Standard Specifications." California State Department of Transportation, 2018.
[4] *Manual for Assessing Safety Hardware*, Second edition. 2016. [Online]. Available: https://highways.dot.gov/safety/rwd/reduce-crash-severity/aashto-guidance.
[5] S. Takigawa and C. Binns, "MASH Compliance Plan and Policy, Memorandum." Caltrans, Nov. 2019. [Online]. Available: https://dot.ca.gov/-/media/dot-media/programs/safety-programs/documents/mash/mash-compliance-memo-111219.pdf
[6] "Manual on Uniform Traffic Control Devices for Streets and Highways." U.S. Department of Transportation - FHWA. [Online]. Available: https://mutcd.fhwa.dot.gov/
[7] D. Souza, "ANSYS LS-DYNA User's Guide." 2013. [Online]. Available: https://lsdyna.ansys.com/
[8] J. E. Bryden, L. B. Andrew, and J. S. Fortuniewicz, "Intrusion Accidents on Highway Construction Projects," *Transp. Res. Rec. J. Transp. Res. Board*, vol. 1715, no. 1, 2000.
[9] J. M. Wong, M. C. Arico, and B. Ravani, "Factors Influencing Severity to Highway Workers in Work Zone Intrusion Accidents," *Traffic Inj. Prev.*, vol. 12, no. 1, pp. 31–38, 2011.
[10] C. Schiefferly, A. Wheeler, and J. Matsuo, "Mobile Work Zone Protection Device," US 7.410,321 B1, 2008 [Online]. Available: https://patents.google.com/patent/US7410321
[11] J. A. Gambatese, and N. Tymvios, "Evaluation of A Mobile Work Zone Barrier System, Final Report, Oregan Department of Transportation, and Federal Highway Administration, SPR 746, August 2013.
[12] S. D. Schrock, E. J. Fitzsimmons, Ming-Heng Wang, and Y. Bai, "Proposed Positive Protection Guidance for Kansas: Synthesis of Work Zone Positive Protection Devices and State of Practice, University of Kansas and Kansas Department of Transportation Report K-Trans: KU-10-3, Feb. 2013.
[13] "Guidelines for the Use of Positive Protection in Work Zones", Colorado Department of Transportation, January 2010.

[14] Development of Functional Requirements for Highly-Mobile Barrier System to Protect Highway Workers: Final Report Draft, July 2004; available at: https://workzonesafety.org/publication/development-of-functional-requirements-for-a-highly-mobile-barrier-system-to-protect-highway-workers-final-report/.
[15] G. L. Ullman, M. D. Finley, and D. C. Anderson, " Functional Requirements for Highly portable Positive Protection Technologies in Work Zones," in CD-Rom Proceedings of 86th Annual Meeting of Transportation Research Board, Washington D.C. January 21-25, 2007.
[16] G. L. Ullman, V. Iragavarapu, and S. Sun, "Work Zone Positive Protection Guidelines", Texas Transportation Institute Report No. 0-6163-1, Published May 2011, 120 p.
[17] District 11 Bridge crew, "Balsi Beam Kearny Mesa Bridge Maintenance Crew (Review and Recommendations of a Balsi Beam Unit)." San Diego District 11 shop, 2017.

Appendix A:
Balsi Beam Usage Guidelines

Physical Attributes and Space Requirements

Balsi Beam is made of two barrier strong steel beams connected to a front and rear deck housing integrated in the form of a tractor-trailer system (Figure A.1). The carrier trailer is attached to the front deck through its 5th wheel slide. The beams can be extended or retracted, and the 5th wheel can slide forward (for deployment) and backward (for stowage). Different sections of Balsi Beam do not separate/detach from each other.

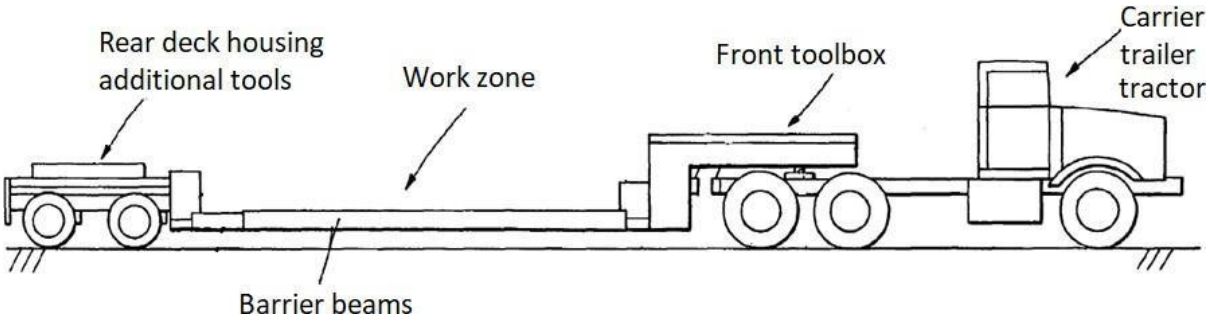

Figure A.1: Balsi Beam Physical Schematics

There are two decks in the front and back of the trailer portion that can be used to store and carry equipment and tools. The physical specifications of the Balsi Beam are summarized in Table A.1.

The physical specifications of the Balsi Beam system as depicted in Table A.1 provides constraints on the types of work zones where the system can be most useful as follows:

1. Balsi Beam work zone (with extended beams) is 8' wide and 30' long. If operated in the second lane or next to the shoulder, workers can use additional barrier trucks to have a safe work zone as wide as two lanes.
2. In a work zone the Balsi Beam system requires a minimum space along the lane, enough to do the operation safely. The system is 50' long with its carrier trailer and is often operated with an attenuator truck parked behind it and trucks carrying material in front of it. Therefore, it is not typically recommended to be used close to intersections or at the entrance of exits or next to sharp turns.
3. Balsi Beam is mostly used in highways with multiple lanes. In secondary roads with fewer lanes Balsi Beam is used either in the shoulder or median

lanes where at least one lane from each side of the road can be left open for the traffic to pass by.

Balsi Beam can be used in the shoulder, the first or the second lane from the left or right side of the road. Depending on where Balsi Beam is operated the rest of the equipment is set up for safe operation and material access. The following images are two examples of how Balsi Beam can be used to provide a safe work zone.

Table A.1: Physical specifications of the Balsi Beam.

Category	Attribute	Specification (ft.)
Space	Balsi Beam length (with carrier tractor)	50'
	Balsi Beam width	10'
	Balsi Beam Height from Ground	3'
	Retracted beams length	18'
	Extended beams length	30'
	Barrier height (both beams on one side)	3'
	Rear deck dimensions	9' × 8'
	Front deck dimensions	7.5' × 8'
	Maximum work zone dimensions within one lane	8' × 30'

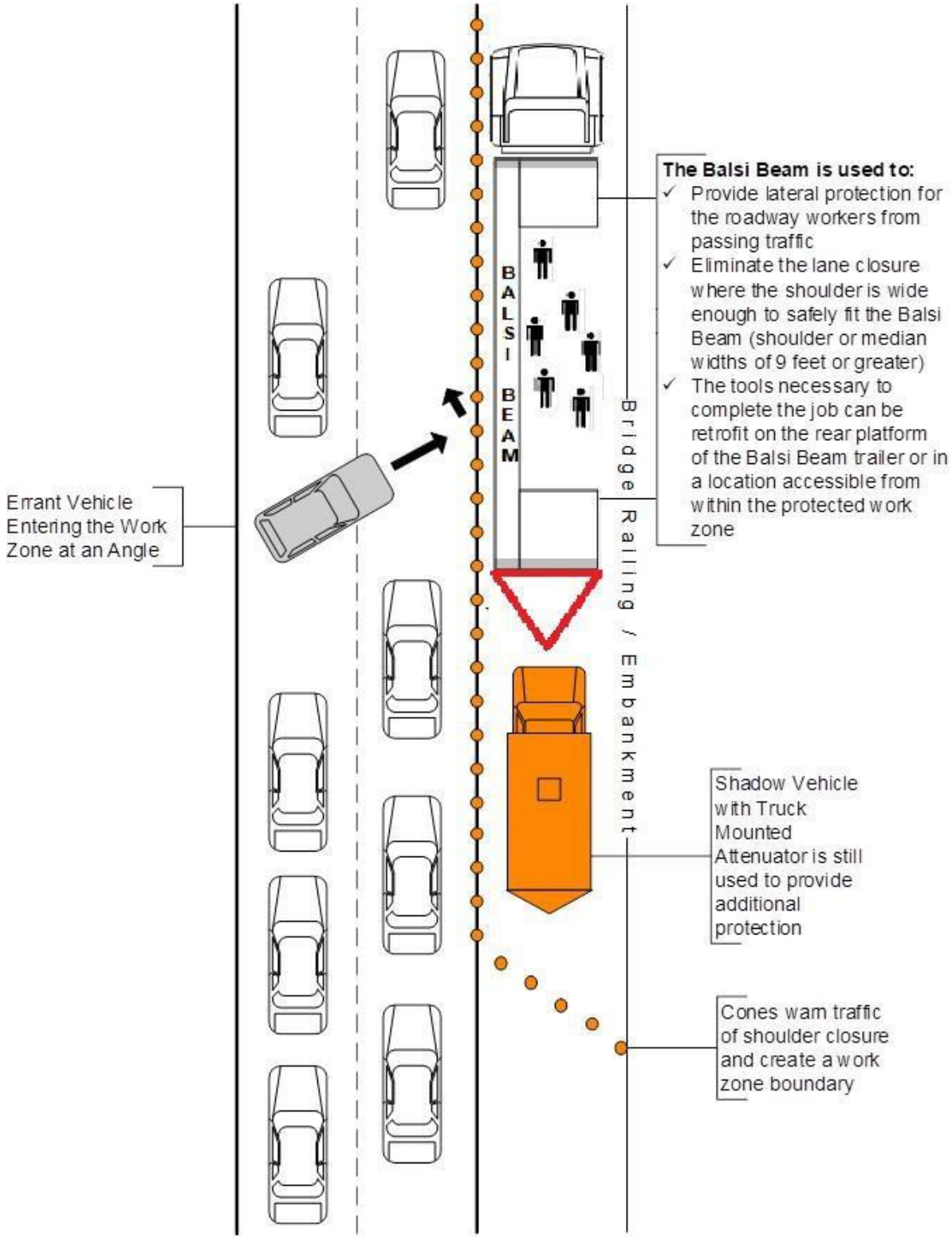

Figure A.2: Balsi Beam used in the first lane or the shoulder of the road. Balsi Beam protects the crew by having two steel beams set between the traffic passing by and the work zone. TMA is parked behind the Balsi Beam for additional protection.

Figure A.3: Balsi Beam used in the second lane of the road. When used in the second lane, the first lane must be protected with an additional barricade truck. The first lane and second lane can be used to set up trucks carrying equipment/material. (Balsi Beam Kearny Mesa Bridge Maintenance Crew)

Balsi Beam Mobility

Balsi Beam is not considered a continuously moving barrier as it cannot move at the same time as workers do the operation.

1. The Balsi Beam system is not suitable for operations where workers have to constantly move along a lane or switch between lanes.
2. Balsi Beam system can only be operated while stationary with the brakes engaged. The system may also be considered, in some cases, for intermittent moving operations (speeds of up to 3 MPH) since the system can be moved slowly when it is fully extended. In such operations, the workers are recommended to wait until Balsi Beam is repositioned, fully stopped, and the brakes are reengaged before resuming work. It is not safe for the workers to continue working while Balsi Beam is moving.
3. In intermittent tasks, the Balsi Beam system can be considered to be used if there are enough time in between intermittent tasks for disengaging and reengaging the brakes.

Below are the mobility specifications for Balsi Beam:

Table A.2: Balsi Beam Mobility Features.

Category	Operation	Nature of Mobility
Mobility	Transport to work area	Move at normal highway speed
	Use in stationary operation	Operate with extended/retracted beams with brakes engaged (avoid constantly moving along the lane)
	Use in Semi-stationary (intermittent) operation	Disengage and reengage the brakes to slightly move Balsi Beam forward.

Balsi Beam Deployment Time Requirements

The crew operating Balsi Beam have to make sure there is enough time allocated for deployment and stowage of Balsi Beam. They need to make sure that the duration of the task is not too short or too long for Balsi Beam to be used. Table A.3 summaries these requirements.

Balsi Beam deployment and stowage can be controlled using a remote controller (that needs battery replacement periodically) and the panel inside the trailer truck as depicted in Figure A.4. Additionally, there is a backup console stacked under the front toolbox deck.

Table A.3: Deployment time requirements of Balsi Beam.

Category	Nature of Deployment	Minimum Duration	Recommendation
Time	Deployment/beam extension time	5 minutes	Allow up to 15 to 20 minutes (Follow steps below).
	Stowage/beam stowage time	5 minutes	Allow up to 15 to 20 minutes (Follow steps below).
	Operation time (with a single crew)	No requirement	Not shorter than 1 hour, often not longer than a day or night.

Figure A.4: Balsi Beam inside and remote-control consoles used to deploy/stow.

Balsi Beam Deployment/Beams Extension Steps

1. Follow all lane closure guidelines.
2. When Balsi Beam in place, depress clutch and engage **PTO**.
3. Turn **Hydraulic Trailer Power** switch on.
4. Turn **Trailer Air** switch on.
5. Select **TMA** on **Trailer Control Wand**.
6. Apply **Trailer Emergency** brakes.
7. Release **Parking Brake**.
8. Make sure that **Hydraulics** are working. (Lower and Raise landing gear to confirm hydraulics are working.)
9. Unlock **5th Wheel Slide**.
10. Back up tractor until **5th Wheel Slide** is full forward. (Tractor rear cross member will fully contact 'V' socket on trailer gooseneck.)
11. Lock **5th Wheel Slide**.
12. Unlock **Extension Lock** switch.
13. Pull tractor straight-ahead **slowly** to extend beam.
14. Lock **Extension Lock** switch.
15. Apply **Parking Brake** and **Tractor Park** brake.
16. Switch **Transport Lock** to unlock position.
17. Lower **Landing Gear** until lights on front of gooseneck indicate **Unlocked** transport locks.
18. Turn on laser and adjust landing gear until laser hits target. (Reflective tape)
19. **Select** beam required (A or B) and rotate.
20. **Raise Landing Gear** until they just come off the ground by 2-3 inches.

For intermittent operations where small movement of Balsi Beam is allowed periodically, follow these additional steps (note that worker protection is not provided until the system is stopped, brakes are re-engaged, and the landing gears are lowered and locked):

a. Lock **Transport Locks**.

b. Make sure **Landing Gear** is all the way up and the light on gooseneck is **Off**.

c. Release all brakes.

d. Travel at **5 MPH Maximum** moving Balsi Beam straight forward without steering left or right.

Balsi Beam Stowage/Beams Retraction Steps

1. Start tractor following standard procedures.
2. Verify **PTO** engaged and **Hydraulic Trailer Power** switch **On**.
3. Unlock **Transport Locks**. (Check both lights on front of gooseneck.)

For stowage from a semi-stationary operation:

   a. Switch **Transport Locks** to unlock.

   b. Lower **Landing Gear** until lights on front of gooseneck indicate **Unlocked Transport Locks**.

4. Verify **Beam Select** switch is correct.
5. **Rotate** upper beam back to transport position (with one beam on each side).
6. Lock **Transport Lock** switch. (Verify locked position with both lights on gooseneck. If transport locks do not lock, adjust landing gear to align laser on target.)
7. Unlock **Extension Lock** switch.
8. Raise **Landing Gear** until landing gear down lamp on controller gooseneck is **Off** and unlock extension lock switch.
9. Verify **Trailer Emergency Brake** applied.
10. Release **Parking Brake** and **Tractor Park Brake**.
11. Back tractor **straight** and **slow** to retract beam.
12. Lock **Extension Lock** switch.
13. Back the tractor up slowly sliding beam against stops to **Insure Lock Set**.
14. Unlock **5th Wheel Slide**.
15. Pull tractor ahead to locate **5th Wheel Slide** for towing.
16. Lock **5th Wheel Slide**.
17. Select and raise TMA on trailer control wand (by setting up/down switch to up).
18. Turn off **PTO**, **Hydraulic Trailer**, and **Trailer Air** switches.
19. Release **Trailer Emergency** brakes.
20. Pull ahead and verify that extension locks are engaged.

21. Select TMA on the trailer control wand (to preserve batteries from going dead.)
22. Follow guidelines for re-entering traffic.

Requirements for Equipment and Material Deployment in a Balsi Beam Work Zone

The Balsi Beam system has two decks (in front and back of the beams) that can be used to carry a variety of equipment. Depending on the task, other equipment and machinery maybe required to be carried on other trucks and then carried in and out of the work zone. Table A.4 includes some recommendations regarding material and equipment that are brought to the work zone when using the Balsi beam.

Table A.4: Equipment/material deployment in a Balsi Beam work zone.

Category	Recommendation
Material	Most materials are okay to be used inside Balsi Beam work zone if they are not hard to move inside the work zone.
Tools Equipment	Use the two decks in the front and back of the Balsi Beam system to carry needed tools when they can fit in such spaces. Leave space behind/next to Balsi Beam for additional tools or trucks carrying equipment but make sure to provide positive protection to block potential intrusions. In operations such as paving which requires large and heavy equipment that cannot be lifted from the ground, Balsi Beam cannot be used in a manner that would block movement of such equipment.

Examples of Equipment Carried on the decks of the Balsi Beam

Examples of equipment and small machinery or tools that can fit on Balsi Beam decks include:

f. Welder/generator (which needs refueling regularly)
g. Air compressor

h. Various size jackhammers and electrical powered tools

i. Painting material and sprays

j. Additional lights for working at night.

Balsi Beam Application and Usefulness

Examples of some of the highway maintenance operations where the use of the Balsi Beam system may or may not be considered are provided in Table A.5. Check mark in the last column of table A.5 would indicate potential usefulness of the Balsi Beam system for the operation shown in the corresponding cell in the first column.

The Balsi Beam system is typically not intended for fully mobile operations where it needs to constantly move or travel along the road. Ideally, Balsi Beam is used for stationary (several hours in one location) or semi-stationary intermittent tasks (where Balsi Beam is slightly moved forward at very low speed intermittently every hour or so).

Table A.5: Balsi Beam requirement checkpoints for highway maintenance tasks.

Maintenance Activity	Work Duration	Time	Space	Mobility	Equipment Material	Useful?
Asphalt Milling	Mobile				X	
Asphalt Overlay	Mobile				X	
Bridge Maintenance	Stationary	X	X	X	X	X
Culvert/Drain Work	Stationary	X		X	X	
Guardrail Repair	Stationary	X	X	X	X	X
Landscape Work	Stationary	X		X	X	
Lighting Installation/ Maintenance	Stationary	X	X	X	X	X
Litter Pickup	Mobile				X	

Pavement Core Sampling	Stationary	X	X	X	X	X
Pavement Striping	Semi-stationary	X	X	X	X	X
Pothole Patching	Stationary	X	X	X	X	X
Raised Pavement Marker Installation/Removal	Mobile		X		X	
Sealcoat Overlay	Mobile				X	
Sign Installation/ Maintenance	Semi-stationary	X	X	X	X	X
Snow and Ice Control	Mobile			X	X	
Storm Maintenance	Mobile		X	X	X	
Traffic Control (i.e., flagging)	Stationary	X		X	X	
Traffic Signal Installation/Maintenance	Semi-stationary	X	X	X	X	X
Bridge deck/joint repair	Stationary	X	X	X	X	X