California AHMCT Program
University of California at Davis
California Department of Transportation

CONCEPTS FOR INCIDENT CLEARING SYSTEMS FOR AUTOMATED HIGHWAY SYSTEMS*

Phillip W. Wong
Ken S. Sprott
Bahram Ravani

AHMCT Research Report
UCD-ARR-94-06-14-01

Interim Report of Contract
DTFH61-93-C-00189

June 14, 1994

*This work was supported by Federal Highway Administration (FHWA) Contract Number DTFH61-93-C-00189 and by the California Department of Transportation (CalTrans) Advanced Highway Maintenance and Construction Technology Program at U.C. Davis

Abstract

This report provides design concepts and information for the development of servicing vehicles to clear incidents on Automated Highway Systems (AHS). The design concepts presented in this document are based on information provided from preliminary information and documents on the AHS.

Disclaimer / Disclosure

This work was supported by Federal Highway Administration Contract No. DTFH61-93-C00189 and by the California Department of Transportation (CalTrans) Advanced Highway Maintenance and Construction Technology Program at U.C. Davis.

1.0 Introduction

The field of Automated Highway Systems (AHS) is a very diverse area of research. This report concentrates on one of the more practical aspects of any type of highway system: the means to clear a roadway incident to minimize traffic disruption and maximize roadway throughput. Removing roadway incidents in a timely manner is of prime importance due to increased traffic density on the AHS. In this report, a "roadway incident" is defined as any type of failure in the automobile that causes the automobile to stop responding to commands from the AHS control computer. Examples of faults include electronic faults such as automobile computer controller failure to mechanical failures such as flat tires or malfunctioning engines. Furthermore, any type of vehicle accident is considered a "roadway incident." Since the automobile cannot respond to commands from the central computer, a "servicing vehicle" must be dispatched to retrieve the malfunctioning automobile. Additionally, the servicing vehicle must be able to remove road debris and other obstructions from the roadway in order to maintain traffic flow. This report considers different types of servicing vehicles ranging from manually operated to semi-automatic to fully autonomous. Each of the design concepts are based on preliminary AHS design information available at this time. As more AHS information becomes available, it is expected that the servicing vehicle concepts will become finalized.

2.0 Automated Highway Systems (AHS) Assumptions

Since AHS design information at present in only preliminary, several assumptions have been made regarding AHS capability to facilitate the analysis needed to prepare the design concepts for the Roadway Servicing Vehicle (RSV).

2.1 Incident Reporting Capability

It is assumed that AHS will have the ability to perform lane closure and status reporting under an external controller command. AHS configurations reviewed to date indicate that this capability is considered reasonable and to be a sound assumption about system capability. The status reporting capability of AHS is considered especially important since many of the designs detailed later in this report depend upon status information to locate the incident.

2.2 Isolated Lanes

Due to the autonomous nature of AHS, it is assumed that non-autonomous and autonomous vehicles will not be mixed in the same roadway lane, but be operated on separate special roadway lanes. Some of the design concepts present later assume further isolation and that a barrier or wall is used to physically separate the autonomous/non-autonomous lanes.

2.3 Lane Placement

It is envisioned that the AHS roadway lanes would be retrofitted into today's existing roadways in the same fashion as today's carpool lanes and bus ways. Thus, the AHS lanes would most likely be placed in the number 1 lane position to minimize interference with entrance and exit ramps. AHS vehicles not entering from designated entrance ramps would have to travel through normal lanes before reaching the AHS lane entrance.

2.4 Specially Designed Vehicles

Since the AHS roadway provides enhanced capability, vehicles traveling along the road must be modified to take advantage of the roadway's capability. Specifically, the authors assume that the vehicle's design can be sufficiently modified to allow for a means of efficient removal from an incident. The amount of design modification to the vehicles will depend on the final configuration of the RSV.

3.0 Design Considerations

This RSV system study is based upon several design requirements and constraints.

3.1 Problem Description

The goal of this design report is to develop several types of concepts for systems to remove stalled, disabled, or damaged vehicles from an AHS roadway lane. Additionally, road debris or obstructions should be removable by the system from an AHS roadway lane. The types of systems under consideration are (1) manual, (2) semi-automatic, and (3) fully automatic. To minimize response time, each of the RSVs will operate within a designated service area along a portion of AHS roadway.

3.2 Operational Requirements

The primary operational design requirement for the RSV is the ability to operate and be integrated within the AHS framework. This includes compatibility with computer and data information exchange, as well as general mechanical compatibility with the AHS infrastructure. An example of data compatibility is the ability of the RSV computer system to identify the roadway incident location from the AHS computer status reports. Mechanical compatibility defines design characteristics such that the RSV must stay within AHS' roadway weight limits and overcrossing height limits.

Preliminary AHS reports indicate that different classes of vehicles (i.e., different weights, sizes, etc.) will operate in AHS lanes. Therefore, the design concepts for the RSV must be able to handle the different classes of vehicles. In addition to removing roadway incidents, the RSV must be able to remove and manipulate general road debris that is commonly found on the roadway.

To maintain efficient traffic flow, an incident clearing response time of 15 minutes is used as a design criteria. A fifteen minute response time is used since analysis indicates that this is the best balance between response time and the cost of stationing RSVs along the AHS roadway.

Lastly, in order to minimize the cost of AHS vehicles, a minimum of modifications should be made to the vehicles to accommodate the servicing procedure of the RSV. The locations of existing hard points of the AHS vehicles will be used when ever possible to guide the design of the attachment fixture of the RSV.

3.3 Safety Requirements

For safety reasons, the RSV will operate with the occupants still inside the car. At no time will the vehicle occupants be require to leave the vehicle during the entire servicing procedure. Occupant interaction with the RSV will take place through the vehicle's on-board computer or communication system. Additionally, the RSV must not obstruct or hinder the normal operation of the AHS lane. Thus, once the RSV has serviced the disabled vehicle, the RSV and the disabled vehicle must be able the travel at near normal speeds to the nearest servicing station.

3.4 Operational Scenarios

3.4.1 RSV stationed in roadway median at specific intervals

Once the AHS computer system has located an incident, the AHS central computer will dispatch the RSV from its designated base station (Figure 3.4.1). The RSV will travel to the incident site and service the roadway incident (Figure 3.4.2). The method of vehicle service will depend on the design of the RSV. For example, some design concepts involve lifting the entire vehicle onto the RSV, other involve just towing the disabled vehicle. The RSV and disabled vehicle will travel together as a unit to the nearest designated service area (Figure 3.4.3). Once there, the occupants may disembark from their vehicle and contact the proper agencies to repair their vehicle (Figure 3.4.4).

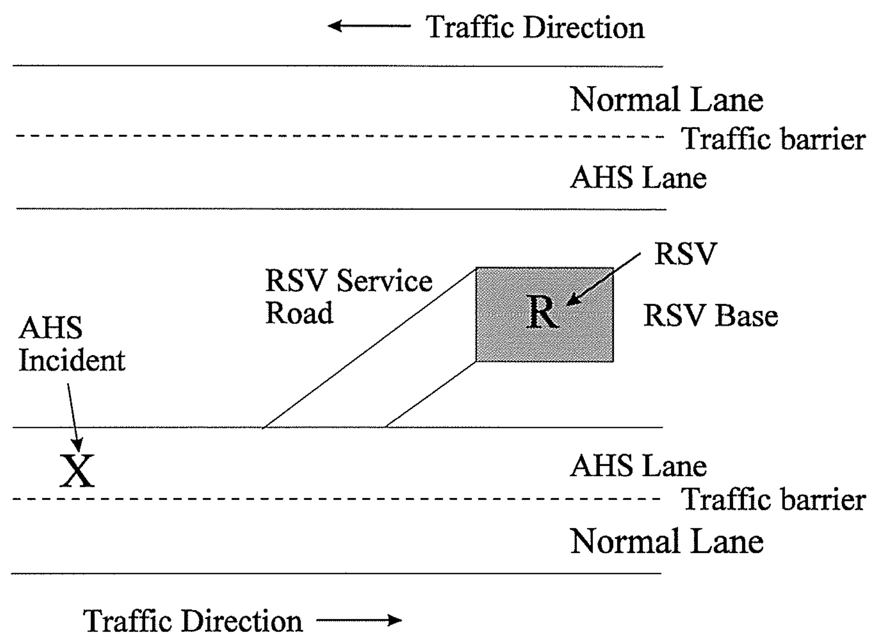

Figure 3.4.1: AHS central computer detects roadway incident

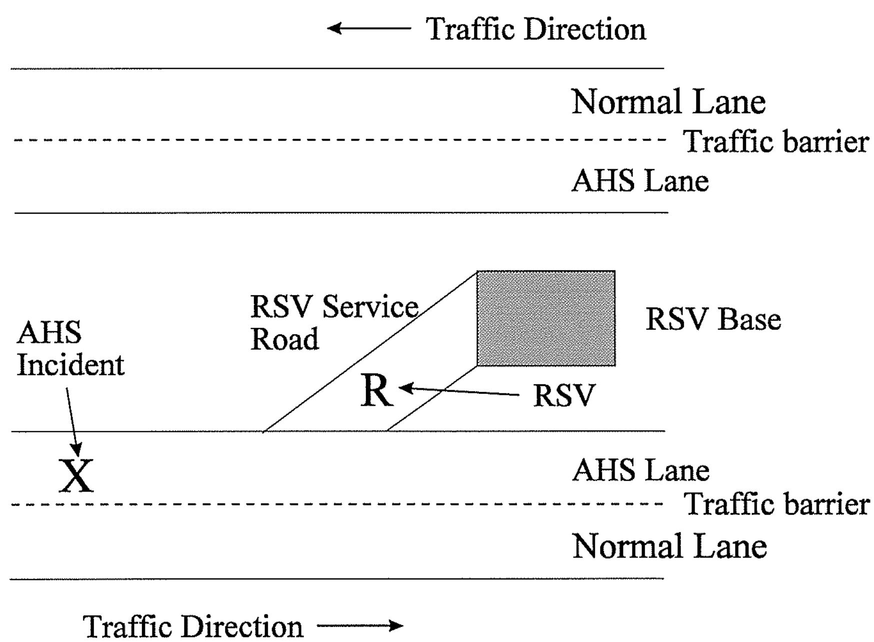

Figure 3.4.2: RSV traveling to incident site

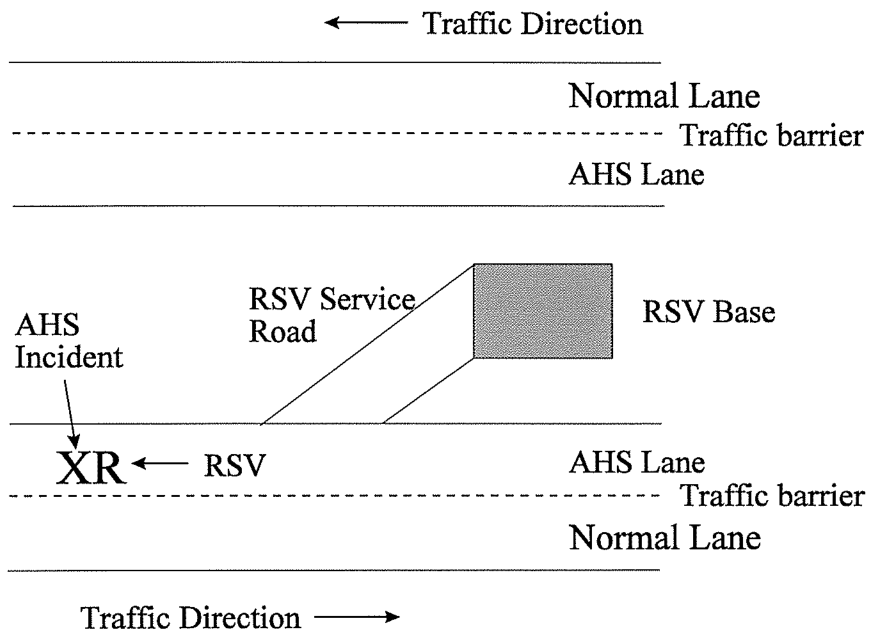

Figure 3.4.3: RSV servicing disabled vehicle

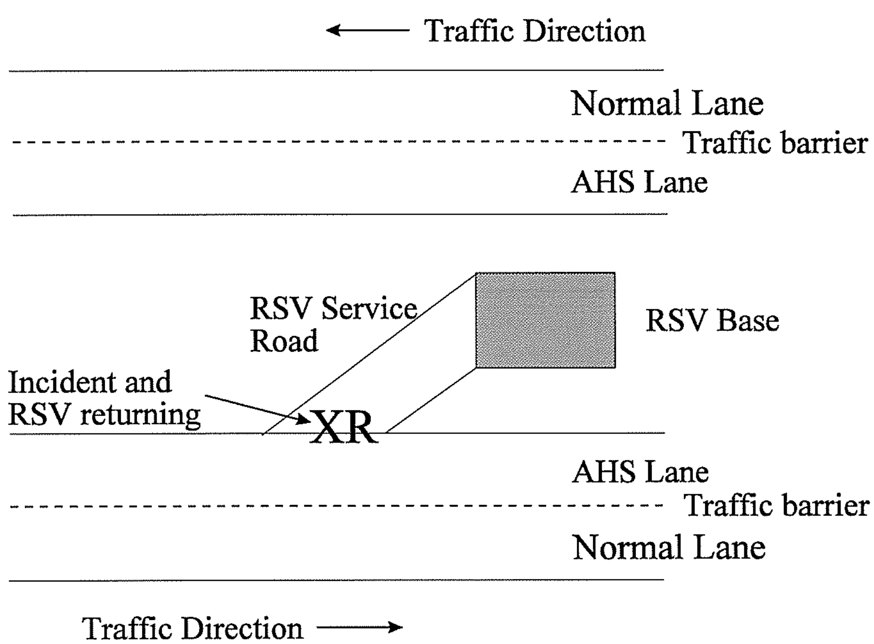

Figure 3.4.4: RSV and vehicle returning to service area

3.4.2 Roving RSV scenario

In this operational scenario, the RSV would patrol a stretch of designated AHS roadway. The RSV would constantly circulate along the roadway looking for incidents to service. When the RSV either contacts a roadway incident or is notified of one by the AHS central computer, the RSV would service the disabled vehicle and remove it to a service area. The RSV would then return to its patrol area and continue operating.

3.4.3 RSV as part of the infrastructure

In this operational scenario, the RSV would be built in as part of the infrastructure of the AHS. For example, the RSV could be contained within the roadway barrier and activated when needed. This design would insure high availability of the RSV and allow the road to be cleared very quickly.

4.0 Design Concepts

4.1 Manual Roadway Service Vehicle

This concept is the most primitive of systems considered in this report. The manual RSVs would be operated part-time by human attendants and be little more than present day tow trucks modified to use the AHS system (Figure 4.1.1). Attachment systems would consist of either the sling and hook system or the wheel lift systems in use today. The system's main advantage is that little new technology, other than AHS equipment, would have to be developed to make it operational. Indeed, the AHS vehicles would not need to incorporate interfaces and structural modifications to accommodate the RSV.

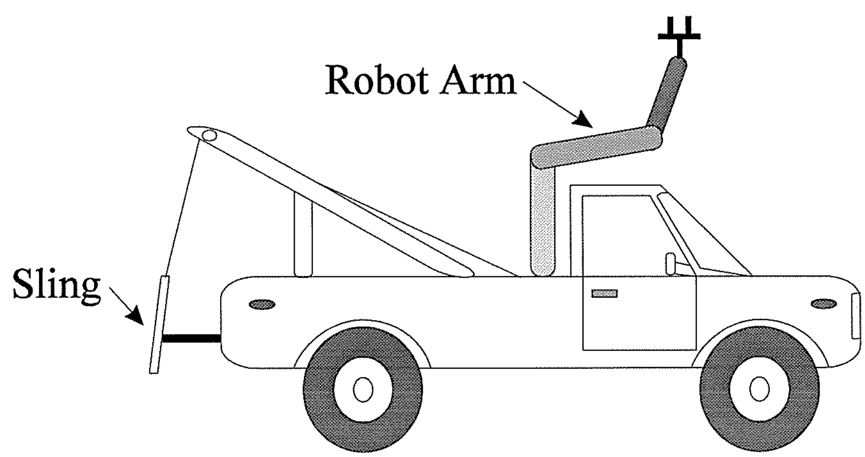

Figure 4.1.1: Tow Truck with servicing arm

4.2 Movable Barrier RSV

Initial deployment plans of AHS indicate that Jersey-type barriers will be used for AHS lane isolation. By incorporating a lifting mechanism into the barriers, roadway incidents can be cleared almost immediately. Once the AHS central computer detects an incident, the barrier closest to the incident would deploy. Lifting forks would move underneath the disabled vehicle (Figure 4.2.1) and lift it off the ground (Figure 4.2.2). Wheels would then deploy from beneath the barrier (Figure 4.2.3) and then move the disabled vehicle/barrier unit from the AHS lane to the shoulder (Figure 4.2.4).

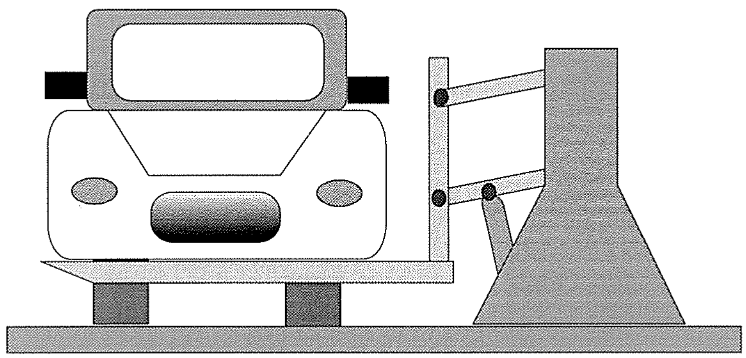

Figure 4.2.1: Deployment of movable barrier RSV

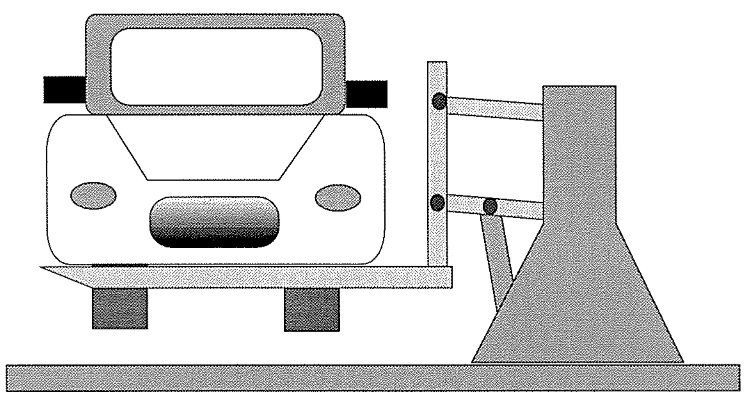

Figure 4.2.2: Lifting the vehicle

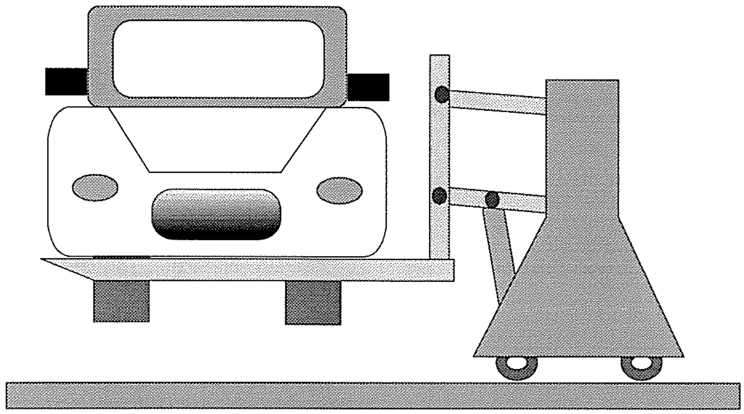

Figure 4.2.3: Wheel deployment

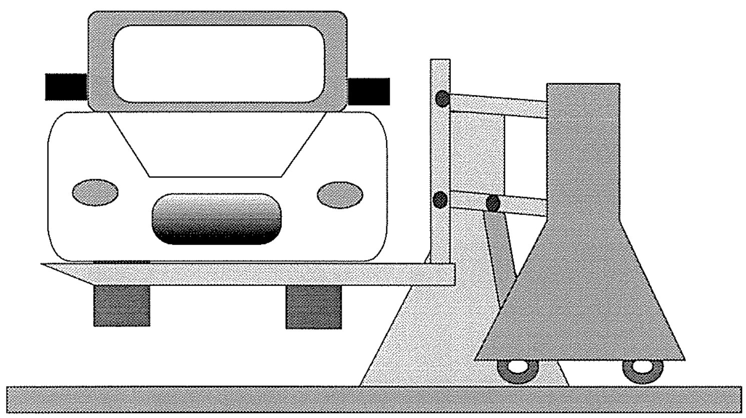

Figure 4.2.4: Clearing the roadway incident

4.3 Over Barrier Lift System RSV (OBLS RSV)

Since the AHS roadway is envisioned to be constructed in the same way as today's carpool and bus lanes, instead of having RSV service islands at intervals along the AHS roadway, the "over barrier lift system" (OBLS) RSV would be able to enter and exit the roadway using normal entrances and exits. The OBLS RSV would drive in the normal lanes and then pull up beside the AHS incident (Figure 4.3.1). Next, the OBLS RSV deploys its lift system. (Figure 4.3.2 and 4.3.3). The OBLS RSV then lifts the disabled vehicle over the isolation barrier (Figure 4.3.4 and Figure 4.3.5) and carries the vehicle to the nearest designated service area (Figure 4.3.6).

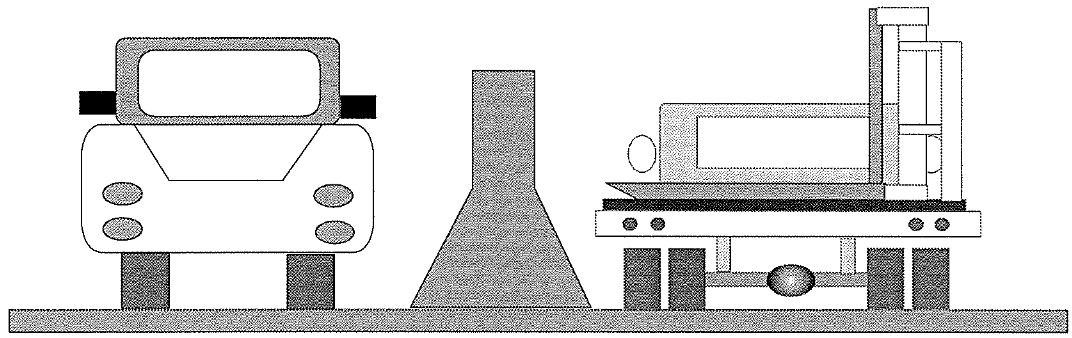

Figure 4.3.1: OBLS RSV pulling alongside

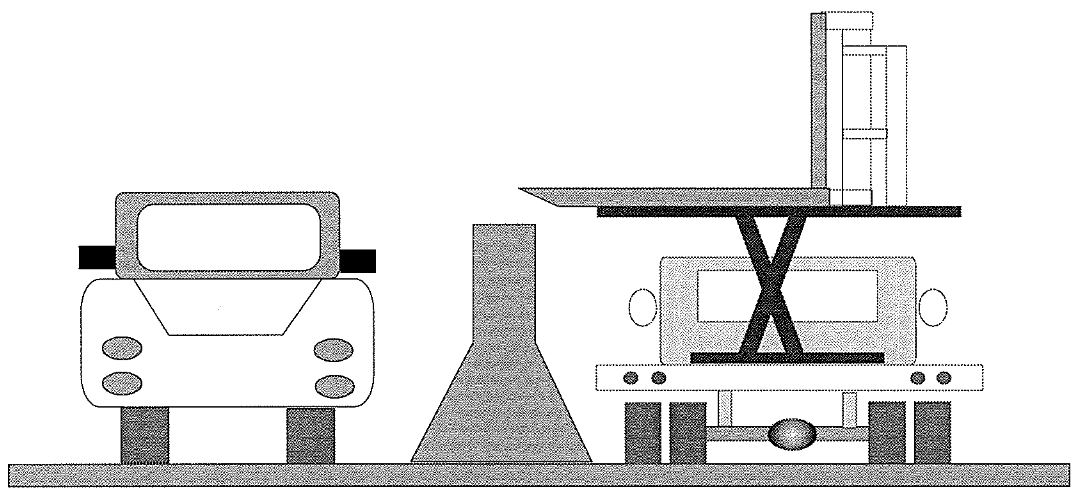

Figure 4.3.2: Lift deployment (Step 1)

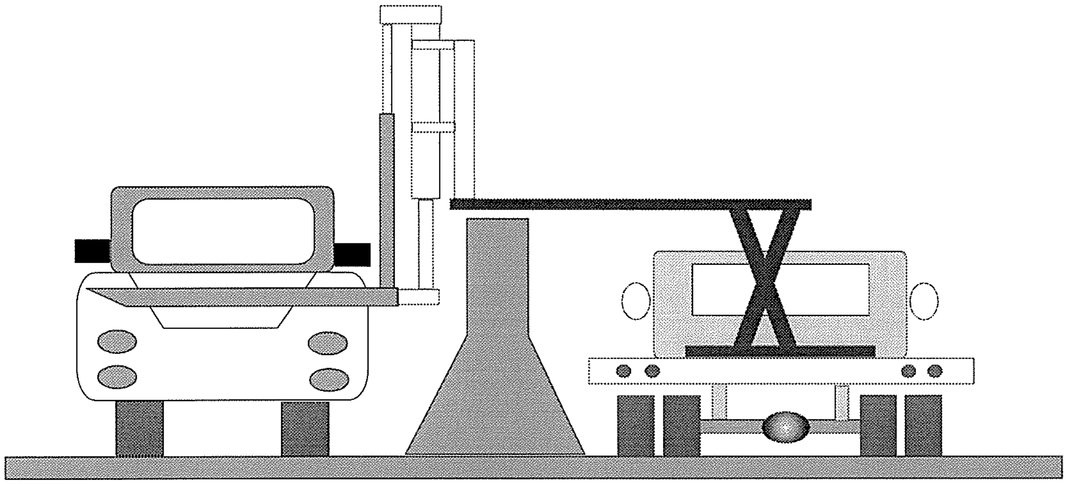

Figure 4.3.3: Left deployment (Step 2)

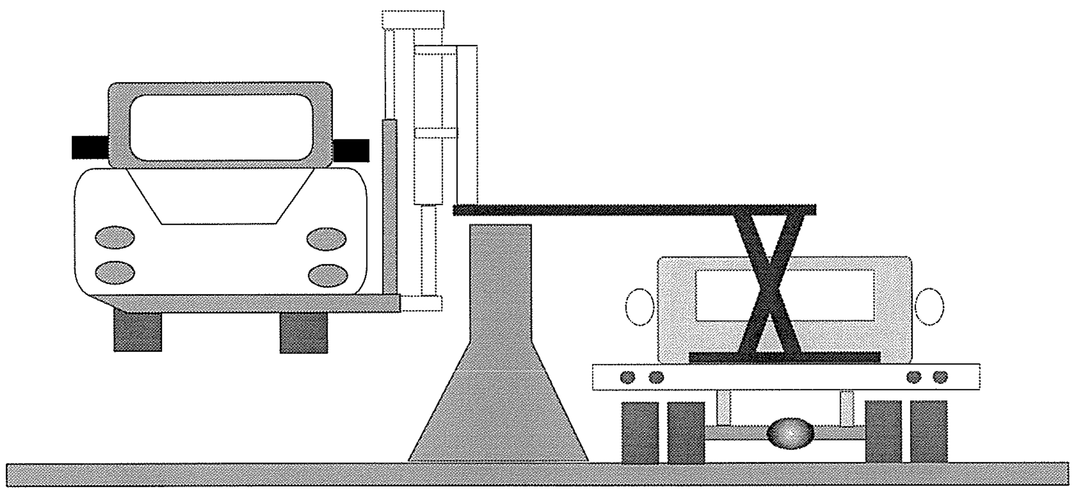

Figure 4.3.4: Lifting the vehicle over the barrier

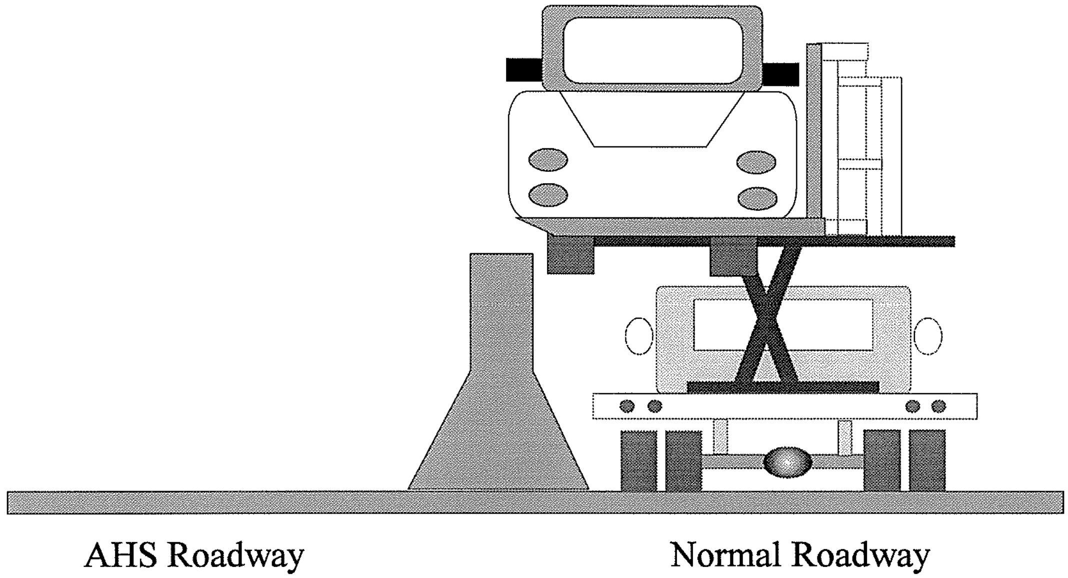

Figure 4.3.5: Lowering the vehicle

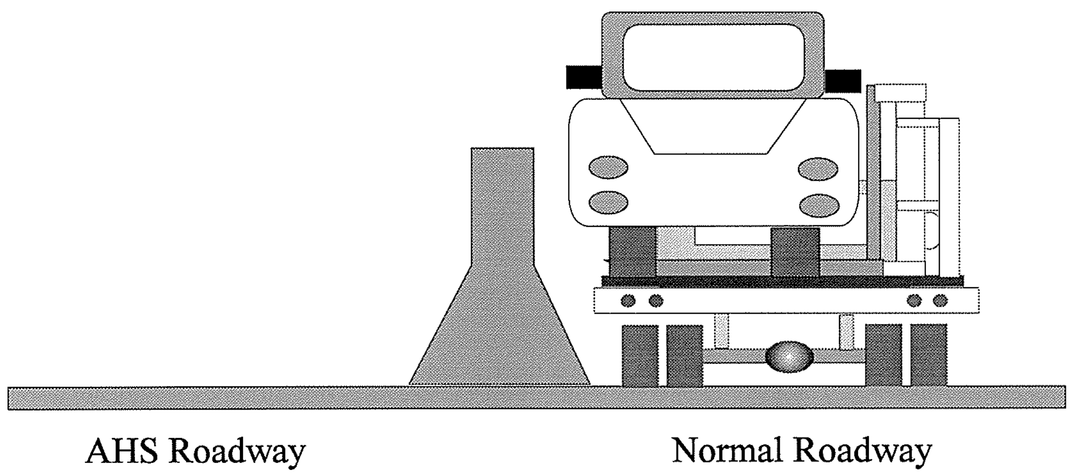

Figure 4.3.6: Removing the vehicle

4.4 Flatbed RSV

The flatbed roadway service vehicle consists of an automated flatbed servicing vehicle. Its operational scenario would be the same as described in Section 3.4.1. The servicing vehicle has a small robotic grasping arm that translates along the length of the flatbed. When the arm reaches the bottom, the RSV's computer commands the arm to grasp a fixture on the underside of the disabled vehicle (Figure 4.4.1). Once the vehicle is grasped, the arm translates back, pulling the disabled vehicle up the RSV's ramp. When the top is reached, the ramp lowers (Figure 4.4.2) and the RSV returns with the disabled vehicle to the servicing area.

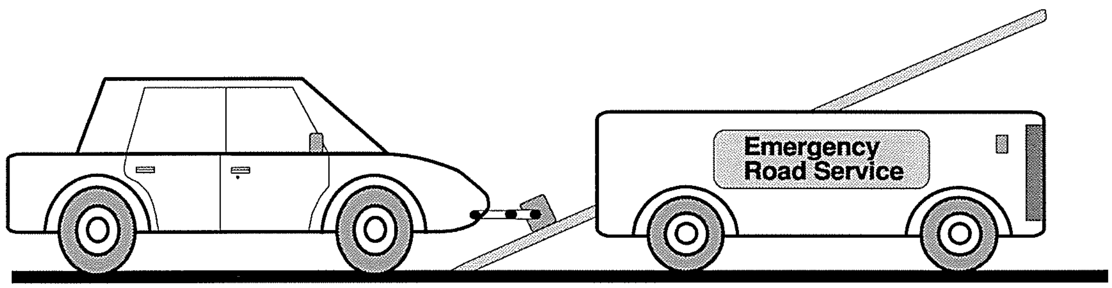

Figure 4.4.1: Initial loading configuration

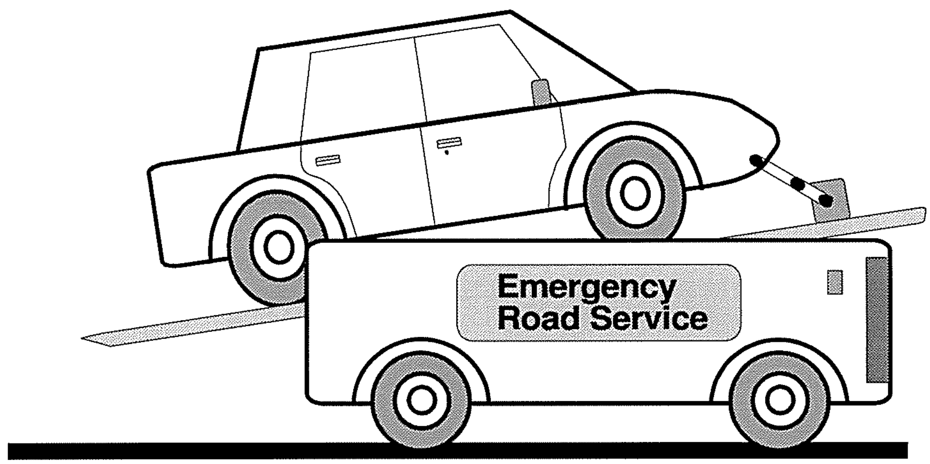

Figure 4.4.2: Final loading configuration

4.5 Barrier Mounted RSV

Since the AHS roadway lane may be separated by Jersey-type barrier, uninterrupted access to the AHS roadway may be gained by using the Barrier Mounted RSV (BM RSV). The BM RSV is designed to ride on top of the Jersey barrier to the AHS roadway incident. Once it arrives at the site, a stowable arm is deployed (Figure 4.5.1 and Figure 4.5.2). At the end of the arm, a grasping fixture would then attach to a mating fixture on the underside of the disabled vehicle. The BM RSV would then pull the disabled vehicle at reduced speed to the nearest service area.

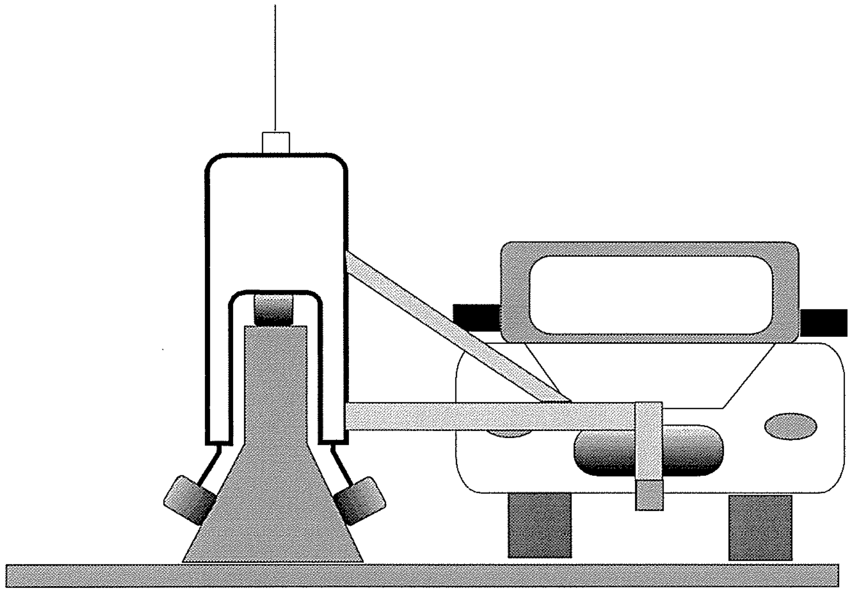

Figure 4.5.1: Front view of BM RSV

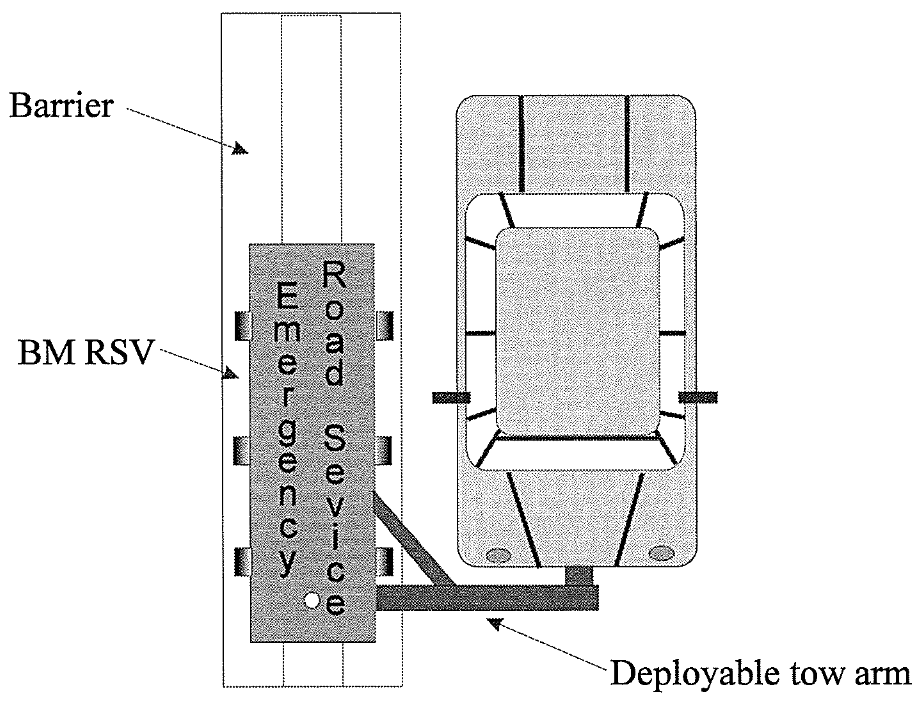

Figure 4.5.2: Top view of BM RSV

4.6 Movable Barrier with Lift Truck

This design concept blends features from the Over Barrier Lift System RSV (section 4.3) and the Movable Barrier RSV (section 4.2). In this concept, the Lift Truck pulls alongside the incident in an adjacent lane (Figure 4.6.1). The Lift Truck attaches a power source to the barrier adjacent to the disabled vehicle. The power source actuates the wheels contained in the barrier (Figure 4.6.2 and 4.6.3). The wheels allow the barrier to be easily moved, thus gaining direct access to the vehicle (Figure 4.6.4). The Lift Truck positions itself to deploy its lifting system, lifts the vehicle from the AHS lane and places it on the truck bed (Figure 4.6.5). The barrier is then replaced and the two vehicles proceed to the nearest service area.

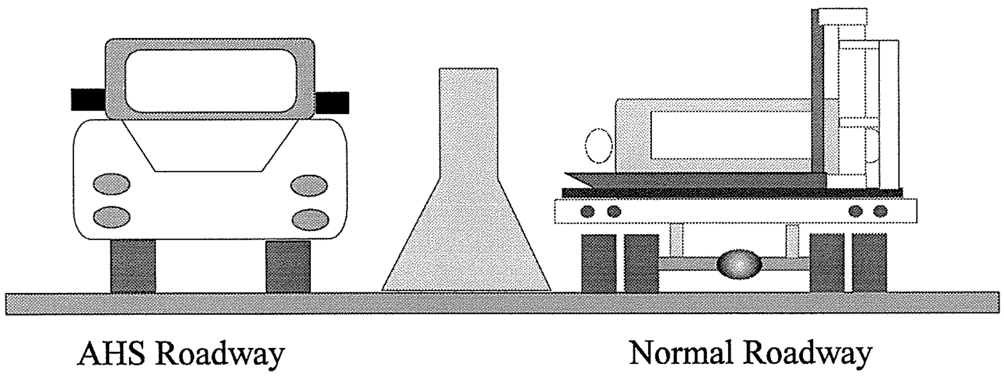

Figure 4.6.1: Lift Truck pulling alongside

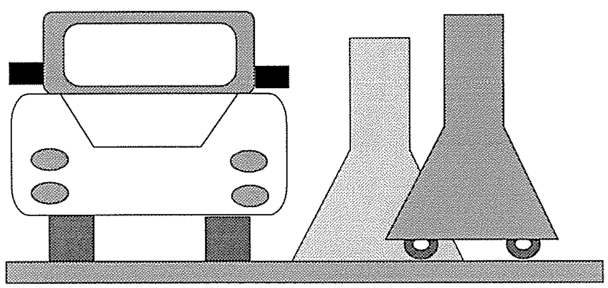

Figure 4.6.2: Barrier wheels deployed (truck not shown)

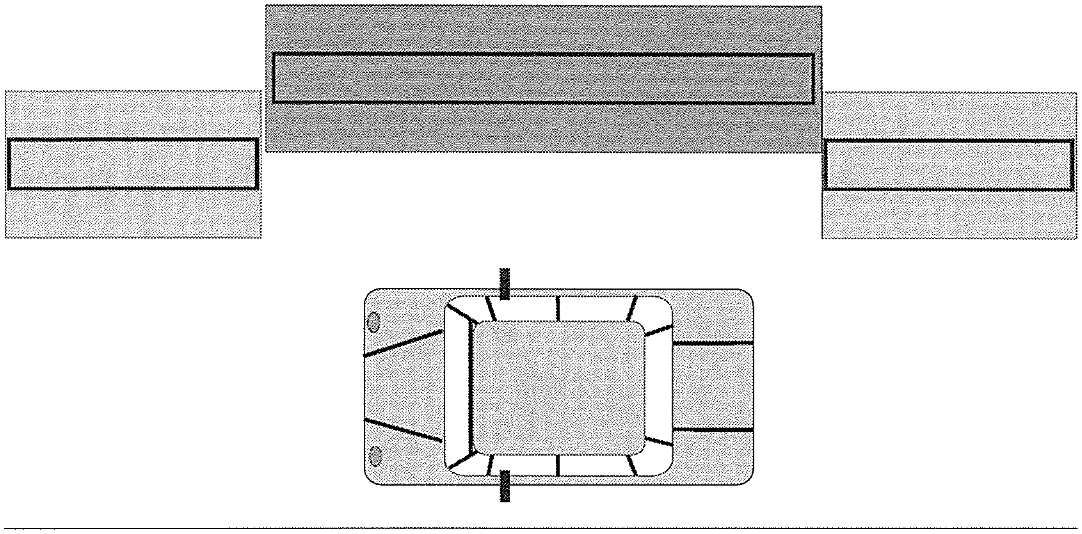

Figure 4.6.3: Barrier moving (Top view)

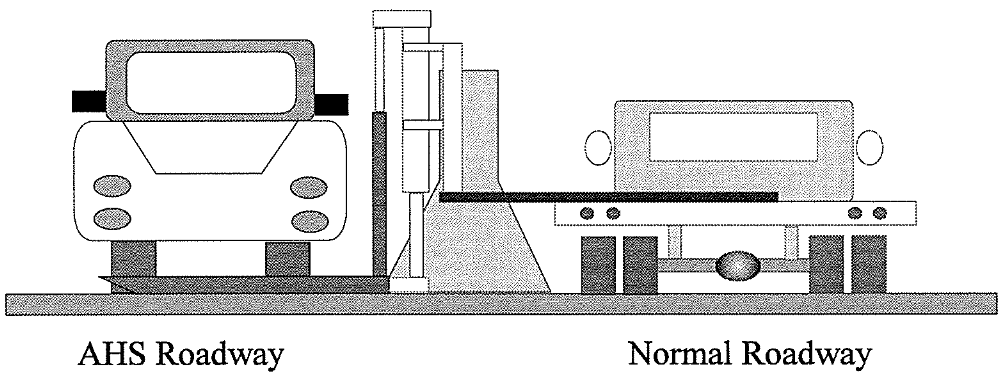

Figure 4.6.4: Lift system deploying

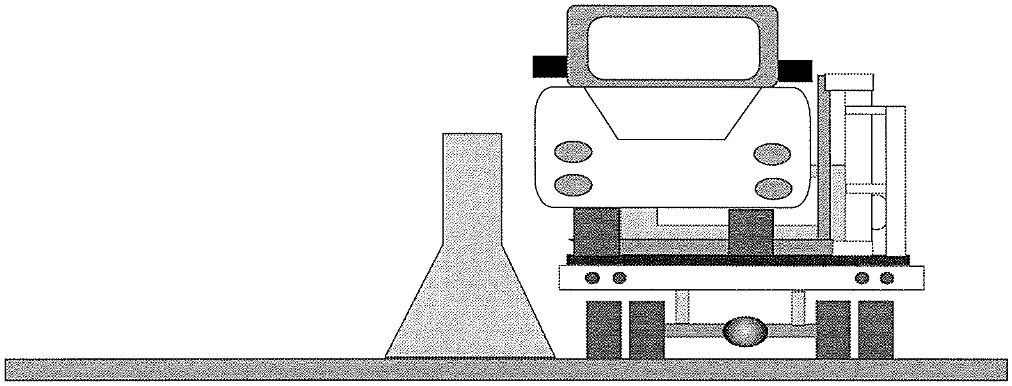

Figure 4.6.5: Vehicle is removed and lane cleared

5.0 Analysis

Of the designs described in Section 4.0, the Manual Roadway Service Vehicle (Section 4.1) and the Movable Barrier with Lift Truck RSV (Section 4.6) appear the be the most technologically and economically feasible. The Manual Roadway Service Vehicle requires the least roadway infrastructure modification. Also, it requires the least technology development since most of the technology is readily adaptable from existing technology. Although the Movable Barrier with Lift Truck RSV requires new technology to be developed for the barrier, the barrier technology and innovation would be useful not only for the AHS program, but for conventional roadway technology as well. The Lift Truck would be an adaptation of existing technology. Both of these conceptual system would not require any modifications to be made to the vehicles and would be adaptable to conventional vehicles as well. A major drawback of both of these systems, however, is that they would not be the most efficient system in clearing the AHS roadway since they would not be totally integrated into the AHS system. These systems also would not be totally automatic and require drivers/attendants to perform their duties.

The Movable Barrier RSV (Section 4.2) and the Over Barrier Lift System RSV (Section 4.3) represent the next most feasible systems to be implemented. Each represent extensive modifications to existing systems and infrastructure. The Movable Barrier RSV would involve total modification of a barrier. Power, propulsion and lifting systems would need to be developed and integrated in the barrier. This integration process presents technological hurdles such as efficient packaging of the mechanical systems and the development of powerful and compact power sources. For the Over Barrier Lift System RSV, the lift system would be the most technologically challenging problem. This problem, however, could be reduced in scope if the vehicles could be modified to include a lifting point on the top of the car, for example.

Finally, the Flatbed RSV (Section 4.4) and the Barrier Mounted RSV (Section 4.5) represent the most technologically challenging. Both would require advances in control systems necessary to drive either on the barrier or on the road to locate an incident and service it automatically. Additionally, both systems would need modifications to the AHS central computer to incorporate automatic incident clearing abilities. These systems would require modifications to the vehicle to include a mount point as well as to the vehicle's control system. Finally, infrastructure would need to be created to service and house the RSVs.