Technical Report Documentation Page

1. Project No.	2. Government Accession No.	3. Recipient's Catalog No.
SWUTC/09/476660-00016-1		

4. Title and Subtitle	5. Report Date
Pilot Information System for Cross-Border Hazmat Transportation	October 2009
	6. Performing Organization Code
7. Author(s) Rajat Rajbhandari, Ivan Calzada, Barry Thatcher, Michael Noonchester	8. Performing Organization Report No.
9. Performing Organization Name and Address Center for International Intelligent Transportation Research Texas Transportation Institute 4050 Rio Bravo, Suite 151 El Paso, Texas 79902	10. Work Unit No. (TRAIS)
	11. Contract or Grant No. DTRT07-G-0006
12. Sponsoring Agency Name and Address Southwest Region University Transportation Center Texas Transportation Institute Texas A&M University System College Station, Texas 77843-3135	13. Type of Report and Period Covered
	14. Sponsoring Agency Code

15. Supplementary Notes

Supported by a grant from the U.S. Department of Transportation, University Transportation Centers Program

16. Abstract

Under NAFTA requirements, all hazardous materials that are shipped into Mexico or generated during the manufacturing process must be shipped back to its point of origin, typically the United States. Thus, the delivery and return of hazardous materials have created a hazmat transportation corridor. At present, there is no automated, real-time method to track hazardous materials shipments crossing the U.S.-Mexico border. As a result, border agencies (specially the first responders) do not have advanced information about the hazardous materials being transported through border crossings and other locations within their communities. This lack of information hinders first responder's ability to respond to hazardous materials incidences.

The objective of the study was to propose a prototype of an information system by which hazardous materials movement will be relayed and/or shared with local and regional agencies (mainly the first responders) which will assist these agencies to respond to major hazardous materials incidents more efficiently. This prototype information system was designed for first responders as a model for what could be developed for the wide range of stakeholders from all U.S. and Mexican border states. A large part of the initial research was spent in identifying the agencies that played minor and major roles in transportation of hazardous materials across the border. The researchers found that a large number of agencies played various roles in what turned out to be extremely complicated process of hazardous materials transportation and incident response. Finally, based on stakeholder needs, the research proposed logical and physical architecture of a prototype system to monitor movement of hazardous materials in the border area and to provide advanced warning of hazardous materials related incidents to the first responders.

17. Key Words	18. Distribution Statement
Hazardous Materials, Border Crossing, Intelligent Transportation System	No restrictions. This document is available to the public through NTIS: National Technical Information Service 5285 Port Royal Road Springfield, Virginia 22161

19. Security Classif.(of this report)	20. Security Classif.(of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	101	

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

PILOT INFORMATION SYSTEM FOR CROSS-BORDER HAZMAT TRANSPORTATION

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October 2009

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ACKNOWLEDGEMENT

The support for this research was provided by a grant from the U.S. Department of Transportation, University Transportation Centers Program to the Southwest Region University Transportation Center. The Center would also like to acknowledge those who were instrumental in the compiling and presenting of information found in this report.

ABSTRACT

Under the North American Free Trade Agreement requirements, all hazardous materials that is shipped into Mexico or generated during the manufacturing process must be shipped back to its point of origin, typically the United States. Thus, the delivery and return of hazardous materials have created a hazmat transportation corridor.

At present, there is no automated, real-time method to track hazardous materials shipments crossing the U.S.-Mexico border. As a result, border agencies (specially the first responders) do not have advanced information about the hazardous materials being transported through border crossings and other locations within their communities. This lack of information hinders first responder's ability to respond to hazardous materials incidences.

The objective of the study was to propose a prototype of an information system by which hazardous materials movement will be relayed and/or shared with local and regional agencies (mainly the first responders) which will assist these agencies to respond to major hazardous materials incidents more efficiently. This prototype information system was designed for first responders as a model for what could be developed for the wide range of stakeholders from U.S. and Mexico.

A large part of the initial research was spent in identifying the agencies that played minor and major roles in transportation of hazardous materials across the border. The researchers found that a large number of agencies played various roles in what turned out to be extremely complicated process of hazardous materials transportation and incident response.

Finally, based on stakeholder needs, the research proposed logical and physical architecture of a prototype system to monitor movement of hazardous materials in the border area and to provide advanced warning of hazardous materials related incidents to the first responders.

EXECUTIVE SUMMARY

Movement of Hazardous Materials across the U.S.-Mexico Border

The U.S.-Mexico border region experiences a concentrated flow of hazardous materials (referred hereafter as HAZMAT). As of 2002, U.S. exported almost 5000 tons (worth 2.4 billion dollars) of HAZMAT to Mexico. On the Mexican side of El Paso, Texas, 2600 manufacturing plants use and produce an enormous amount of HAZMAT. Under NAFTA requirements, all HAZMAT that is shipped into Mexico or generated during the manufacturing process must be shipped back to its point of origin, typically the United States. Thus, the delivery and return of hazardous materials have created a HAZMAT transportation corridor.

At present, there is no automated and real-time method to track HAZMAT movement on the U.S.-Mexico border. As a result, the first responders do not have advanced information about the HAZMAT being transported through border crossings and other locations within their communities. This lack of information hinders the first responder's ability to respond to HAZMAT incidences, to plan HAZMAT transportation routes, and to develop effective transportation systems. HAZMAT incidents that occur on either the U. S. or Mexican side of the border usually require first responders on both side to coordinate address the situation in a timely manner.

Goals and Objectives of the Research

The objective of the study was to develop a prototype of an information system by which HAZMAT movement will be relayed and/or shared with local and regional agencies (including the first responders) which will assist agencies to respond to major HAZMAT incidents. This prototype information system was designed for first responders as a model for what could be developed for the wide range of stakeholders from U.S. and Mexican border states.

It is hoped that the project will significantly help in creating a bi-national real-time HAZMAT transport monitoring system for first responders (e.g. El Paso Fire Department and Ciudad Juarez fire department). Though this effort was primarily focused on the needs of first responder organizations, it helped identify the flow and information needs of the large number of other border HAZMAT stakeholders. For example, the project also identified the data needs of safety inspection agencies, which include Federal Motor Carrier Safety Administration, Texas and New Mexico Department of Public Safety, U.S. and Mexican regulatory and customs agencies at both sides of the border including the Environmental Protection Agency. This will permit structuring of data transmissions among these various organizations to enhance security issues.

In overall, the project modeled a communications strategy that could be used to monitor and share HAZMAT shipment information to first responders. The project also helped address safety, security, and infrastructure issues involved with the movement of hazardous materials.

Identification of the Stakeholder Needs of the Region

A large part of the initial research was spent in identifying the agencies that played minor and major roles in transportation of HAZMAT across the border. The researchers found that a large number of agencies are engaged in what turned out to be extremely complicated process of HAZMAT transportation and incident response. Researchers identified stakeholders in the border region of El Paso and surrounding cities in U.S. and Mexico. The research team then divided agencies into three different categories based on an individual agency's roles and responsibilities related to HAZMAT. These categories are incident observers, calls and notifications receivers, and incident responders.

The stakeholder agencies in the both sides of the border coordinate at different levels to respond to incidents related to hazardous materials. As a first major task in the research, all stakeholder agencies (that are involved in various capacities regarding transportation of hazardous materials) in the border region were identified, including their roles and responsibilities. Representatives from these agencies were interviewed to identify shortfalls and requirements to respond to HAZMAT incidents. The researchers concentrated in identifying communication needs of first responders in the region. Many agencies also play a dual role in observing and responding to HAZMAT related incidents, such as local police and fire departments, which are first responders in most cases.

Information Needs of Agencies to Respond to HAZMAT Incidents

Based on conversations with the stakeholders, the researchers decided that it would be difficult to propose and develop a prototype that will fulfill the needs of all three categories of stakeholders. The interviews with the stakeholders also revealed that local first responders (in both U.S. and Mexico) do not have any form of advanced information related to HAZMAT crossing the border (and moving through the community) until the incident occurs and are called to respond.

If the first responders (especially fire departments) had advanced information regarding nature and quantify of HAZMAT crossing the border, environmental conditions of HAZMAT (temperature, pressure, and other environmental conditions), geographical position of the truck, then the first responders can undoubtedly reduce response time of incidents and efficiently contain the spill and contamination. It was decided that a conceptual prototype system should be developed to provide the first responders with advanced information of HAZMAT being transported across the border. More specifically the first responders expressed the need for the following type of information to respond to HAZMAT more efficiently:

- Immediate notification when a HAZMAT incident occurs;
- Nature and quantity of HAZMAT material involved in the incident;
- Equipment needed and best strategy to contain the HAZMAT spill;
- Reaction of HAZMAT material with the environment; and
- Contact information of entities that can provide further information of the material that is involved in the incident.

Logical and Physical Architecture of the Prototype System

The prototype information system was divided into four subsystems: Programming Parameters Acquisition and Transmission Subsystem, Trailer Monitoring Subsystem, HAZMAT Incident Notification Subsystem, and HAZMAT Incident Response Subsystem.

Programming Parameters Acquisition and Transmission Subsystem: Using Emergency Response Guidebook 2008 (ERG 2008) and on the e-manifest, this subsystem will obtain detailed information on HAZMAT including threshold values for environmental parameters related to the HAZMAT. These environmental parameters include temperature, pressure, radiation etc. The subsystem will also define cargo's weight, shipment units (boxes and barrels). Based on the origin and destination of the HAZMAT truck the shipper will also pre-define the transportation route and geo-fencing parameters.

Trailer Monitoring Subsystem: This subsystem is responsible for detecting HAZMAT incidents due to harmful change in environmental conditions, leaks, and spills, unwarranted tampering of sealed containers, and diversion from pre-defined routes etc.

HAZMAT Incident Notification Subsystem: This subsystem will distribute the incident message to first responders, proper emergency management center (EMC), HAZMAT carrier, and truck driver.

HAZMAT Incident Response Subsystem: This subsystem will analyze and verify that the incident message corresponds to actual incident. The subsystem will notify the first responders based on the incident notification message and obtain incident response information from the WISER system.

The physical architecture of the prototype is based on the assumption that all the subsystems mentioned earlier can be built and programmed into one or more hardware components (with several devices) that can be retrofitted on the truck or trailer. The researchers have identified existing and known technologies that could be used to build the components of individual subsystems. A combination of technologies, such as global positioning system, radio frequency identification, accelerometer and engine diagnostics, and environmental sensors should be integrated into one device (a central processing unit), which will constantly monitor changes in parameters.

The detection of a HAZMAT incident should initiate the creation of the HAZMAT incident notification message, which could be based on IEEE 1512.3 Standard for Hazardous Material Incident Management Message Sets for Use by Emergency Management Centers. The transmission of the notification message to the emergency management center can be performed by the monitoring subsystem installed in the truck. The emergency management center or the first responder with assistance from the WISER system can develop plans to provide adequate response, containment of spills and leaks, necessary evacuation etc. The EMC dispatcher will be in charge of analyzing the message and inform proper first responders (in both countries and two states) in the case of HAZMAT incident.

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CHAPTER 1. BACKGROUND

1.1 Cross-Border Freight Flow

According to Bureau of Transportation Statistics (BTS), 2008 land port exports value from U.S. to the North American Free Trade Agreement (NAFTA) members was $278 billion dollars. In addition, on 2008 the value of U.S. land port imports from NAFTA members ascended to $275 billion dollars. BTS on its North American Transborder Freight Database classifies all exports and imports in 99 different commodities. Table 1 shows the export and import values of various commodities traded between the U.S. and other NAFTA member countries.

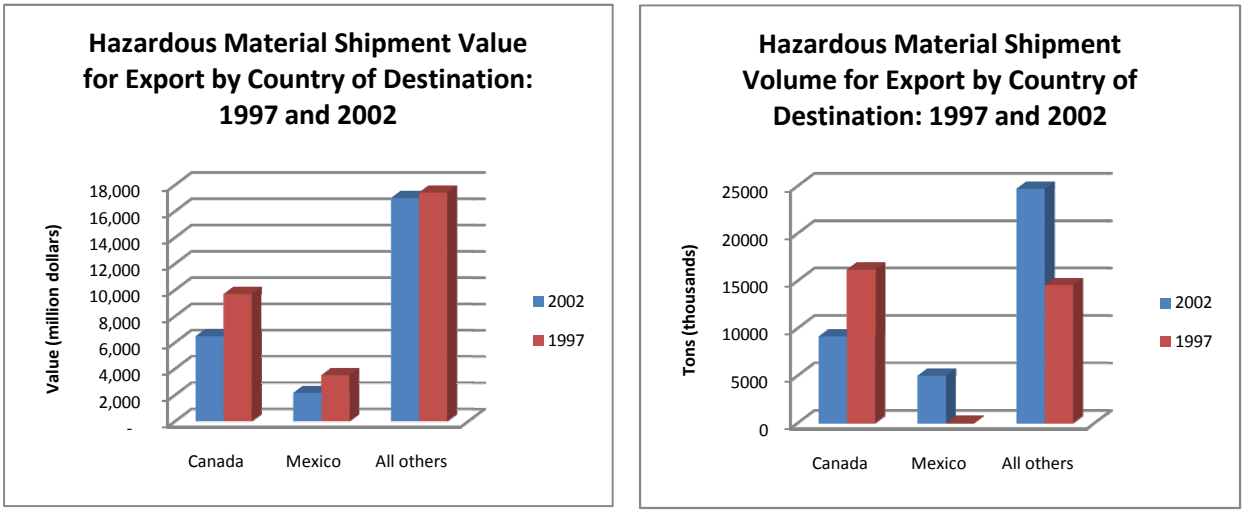
Table 1 Value of Trade between the U.S. and other NAFTA Members in 2008

Exports		Imports	
Commodity Code	Value *	Commodity Code	Value*
87	$ 40,457	85	$ 54,460
84	$ 36,495	84	$ 31,221
85	$ 30,226	87	$ 17,203
39	$ 11,876	98	$ 8,929
90	$ 8,574	39	$ 8,898
48	$ 6,931	90	$ 8,366
73	$ 5,835	94	$ 7,282
94	$ 4,699	48	$ 6,243
27	$ 4,423	71	$ 4,997

*Values in million U.S. dollars
Source: Bureau of Transportation Statistics (1)

1.2 Cross-Border Flow of Hazardous Materials

The U.S.-Mexico border region experiences a concentrated flow of hazardous materials (HAZMAT). On the Mexican side, 2,600 manufacturing plants use and/or produce an enormous amount of HAZMAT. Under NAFTA requirements, all HAZMAT that is shipped into Mexico or generated during the manufacturing process must be shipped back to its point of origin, typically the United States. The U.S. side has concentrated areas of storage and disposal facilities. Thus, the delivery and return of hazardous materials have created a HAZMAT transportation corridor. Figure 1 shows the value and volume of HAZMAT exported to Canada, Mexico and other countries by the U.S.



Source: Bureau of Transportation Statistics (1)

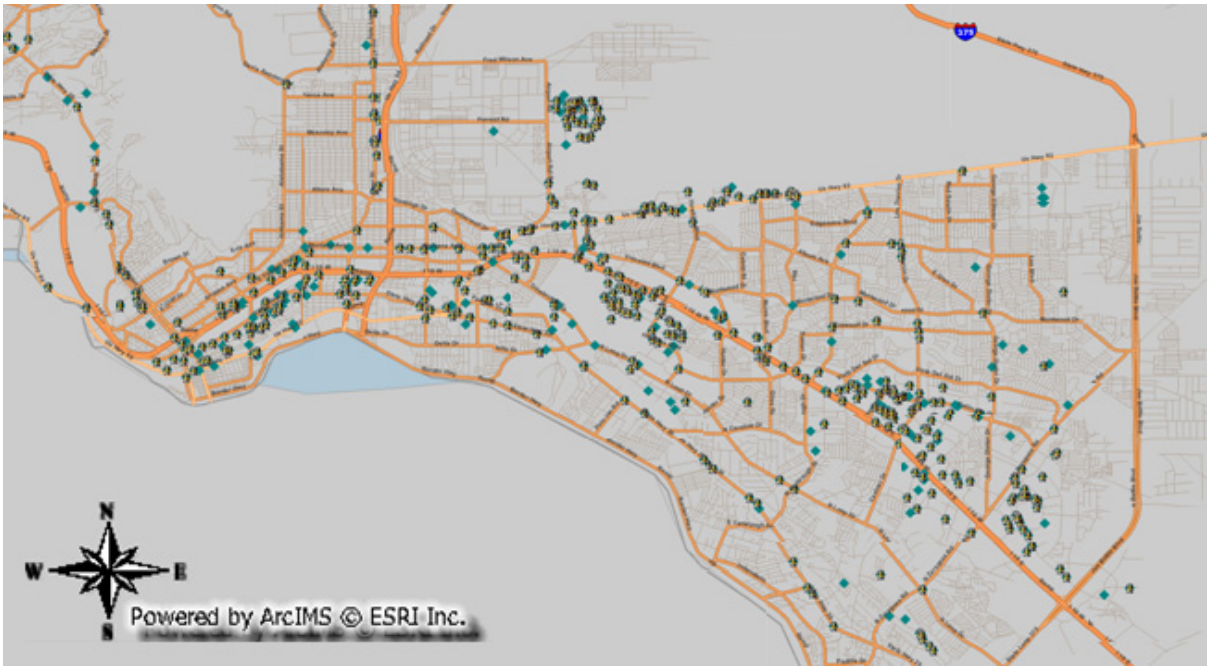
Figure 1 Volume and Dollar Value of HAZMAT Exported by the U.S. in 1997 and 2002.

1.3 Brief Description of Ciudad Juarez, El Paso and Las Cruces Regions

The El Paso region is served by three international ports of entry through which millions of commercial vehicles cross every year (including the ones carrying hazardous materials). These ports of entry not only serve commercial vehicles but also passenger vehicles, buses, and pedestrians. The location of all three land ports of entry (POE) - Paso Del Norte, Bridge of the Americas and Ysleta are shown in Figure 2. In addition, the Santa Teresa POE, which is located in the State of New Mexico, also serves a significant volume of commercial vehicle traffic. Out of all four ports of entry, Paso Del Norte POE is the only one that does not allow commercial vehicle to cross the border. Among rest of the three ports of entry, Ysleta is the only one that allows trailers containing hazardous materials to cross the border.

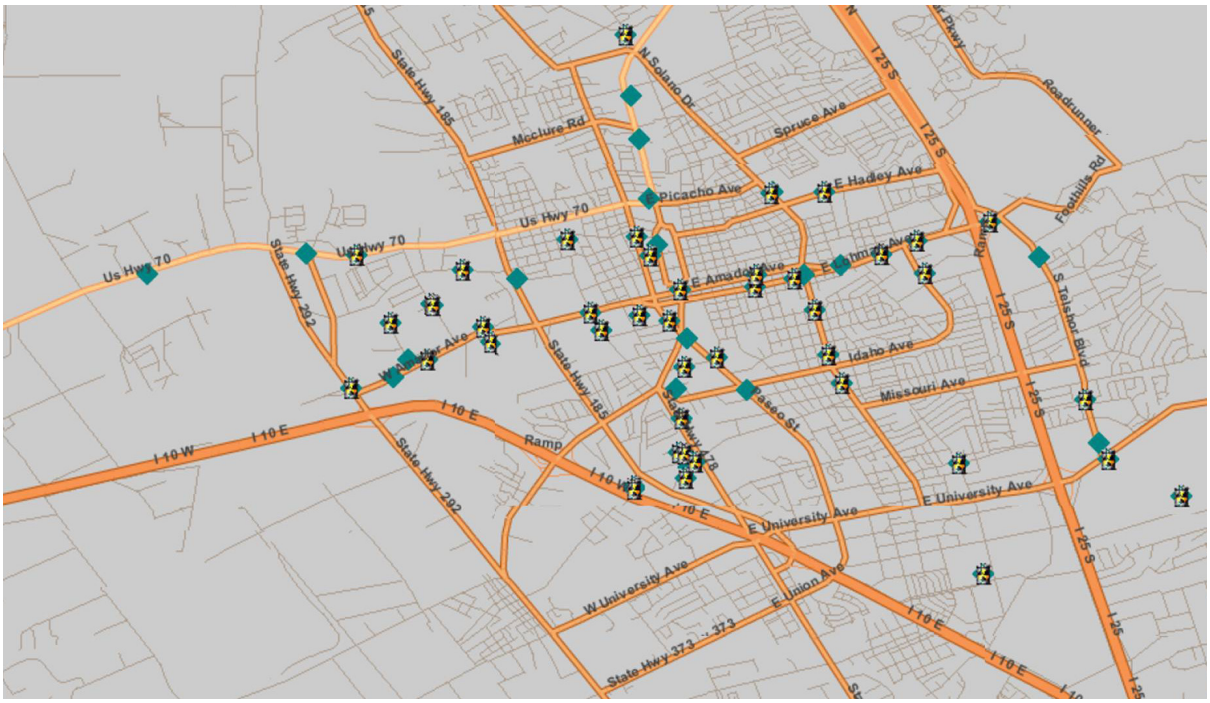
Figure 2 Location of Land Ports of Entry in the El Paso Region.
Source: U.S. Department of Housing and Urban Development.

Figure 4 and Figure 4 show HAZMAT handling and/or generating facilities in the El Paso and Las Cruces area, most of these facilities are located near the U.S.- Mexico border. Las Cruces has fewer facilities than El Paso handling and/or generating HAZMAT compared.



Source: U.S. Department of Housing and Urban Development.

Figure 3 Hazardous Waste Handling and/or Generating Facilities in the El Paso Area

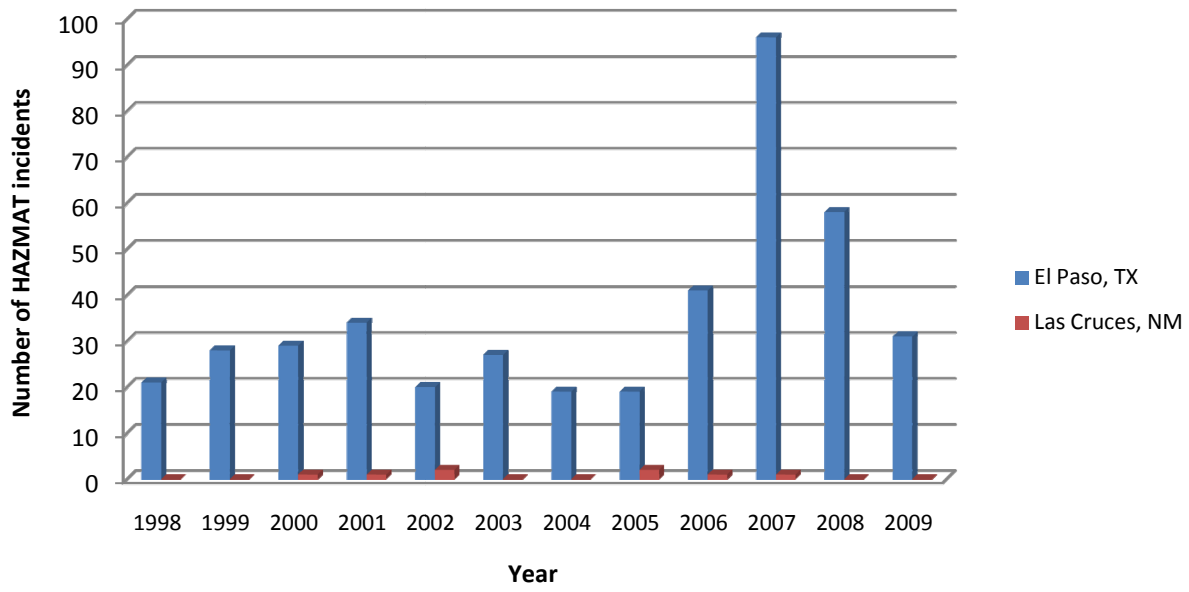


Source: U.S. Department of Housing and Urban Development.

Figure 4 Hazardous Waste Handling and/or Generating Facilities in the Las Cruces Area

1.4 HAZMAT Related Incidents

The U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration (PHMSA) require that every HAZMAT incident be reported to the agency. The information on HAZMAT incidents is available to the public through a website. Figure 5 shows the number of highway related HAZMAT incidents in El Paso and Las Cruces area. The statistics shows that that the number of HAZMAT related incident on highways in much higher in El Paso than in Las Cruces. This is clearly attributed to the large number of HAZMAT crossings through the ports of entry in El Paso area.



Source: Pipeline and Hazardous Material Safety Administration (2)

Figure 5 Number of Highway Related HAZMAT Incidents in El Paso and Las Cruces

Table 2 shows that the State of Texas has one of the highest numbers of highway related HAZMAT incident in the nation. This can again be attributed to the fact that a large number of HAZMAT crosses the U.S.-Mexico border through more than half a dozen ports of entry in the state.

Table 2 Top Five U.S. States with Highest Number of Highway Related HAZMAT Incidents

2007		2008		2009 (Jan-May)	
State	**Incidents**	**State**	**Incidents**	**State**	**Incidents**
California	**1,597**	**California**	**1,379**	**California**	**304**
Utah	**1,411**	**Texas**	**1,306**	**Illinois**	**248**
Oklahoma	**1,228**	**Idaho**	**1,038**	**Texas**	**236**
Illinois	**1,212**	**Ohio**	**1,028**	**Ohio**	**168**
Rhode Island	**1,010**	**Pennsylvania**	**866**	**Pennsylvania**	**166**

Source: Pipeline and Hazardous Material Safety Administration (3) (4) (5)

1.5 Goals and Objectives of the Research

At the present, there is no automated, real-time method to track these shipments anywhere along the U.S.-Mexico border (or the U.S.-Canadian border). As a result, first responders do not have access or knowledge of HAZMAT moving in the area or crossing the border. This lack of information hinders a community's ability to respond to HAZMAT related incidents, alternate routes, and develop effective transportation systems. A major HAZMAT incident on a highway could create a severe traffic congestion lasting several hours in addition to

other human hazards. In addition, HAZMAT incidents that occur on either the U.S. or Mexican side of the border usually require the coordination of first responders on both sides to resolve the incident in an efficient manner. For example, with the sister city agreements between the City of Sunland Park and Ciudad Juarez the fire fighters from both cities physically assist in HAZMAT incidents across the border. Hence, the advanced information of HAZMAT movement (including type, amount, response methods etc.) could position the first responders in preparing resource for responding to HAZMAT incidents well in advance.

The objective of the study was to develop a prototype of an information system by which HAZMAT movement will be relayed and/or shared with local and regional agencies (including the first responders) which will assist agencies to respond to major HAZMAT incidents. This prototype information system was designed for first responders as a model for what could be developed for the wide range of stakeholders from all U.S. and Mexican border states. It is hoped that the project will significantly help in creating a bi-national real-time HAZMAT transport monitoring system for first responders (e.g. El Paso Fire Department and Ciudad Juarez fire department).

1.6 Major Tasks and Research Framework

Based on the stakeholder needs for creating a bi-national real-time HAZMAT transport monitoring system, a great deal of effort was focused on identifying the needs of first responders from both sides of the border. This helped identify the information needs of the first responders and other agencies that play a significant role in HAZMAT. A significant portion of the research was spent in identifying the agencies that play roles (small and big) in transportation of HAZMAT across the border. The researchers identified agencies that are engaged in HAZMAT transportation as well as incident response. Researchers identified stakeholders in the border region of El Paso and surrounding cities in U.S. and Mexico.

Based on the needs of the first responders and other stakeholders, the project modeled a communications strategy that could be used to monitor and share HAZMAT shipment information to first responders. The project also helped address safety, security, and infrastructure issues involved with the movement of hazardous materials.

CHAPTER 2. IDENTIFICATION OF STAKEHOLDER NEEDS

2.1 Introduction

A large part of the initial research was spent in identifying the agencies that played minor and major roles in transportation of HAZMAT across the border. The researchers found that a large number of agencies are engaged in what turned out to be extremely complicated process of HAZMAT transportation and incident response.

As a first major task in the research, all stakeholder agencies (that are involved in various capacities regarding transportation of hazardous materials) in the border region were identified, including their roles and responsibilities. Representatives from these agencies were interviewed to identify shortfalls and requirements to respond to HAZMAT incidents. The researchers concentrated in identifying communication needs of first responders in the region.

Further sections describe how stakeholders communicate while responding to HAZMAT related incidents, including dispatch/communication centers that receive the HAZMAT calls, and agencies securing hazardous sites, containment of spills etc. This chapter also summarizes the interviews that the research team conducted in order to obtain much of the information related to need for HAZMAT related communication between various stakeholders, primarily first responders. Finally, it summarizes the findings for configuring viable information technology designs for first responders.

2.2 Identification of Stakeholders in the Region

Based on pre-existing knowledge of duties and responsibilities of government agencies in U.S. and Mexico, the research team developed a list of agencies in both countries that are involved with HAZMAT in various capacities. The project monitor also assisted in identifying some of the agencies involved with HAZMAT. The research team then divided agencies into three different categories based on an individual agency's roles and responsibilities related to HAZMAT. These categories are following:

- Incident Observers;
- Calls and Notifications Receivers; and
- Incident Responders.

Many agencies also play a dual role in observing and responding to HAZMAT related incidents, such as local police and fire departments, which are first responders in most cases. In rare situation, local police and fire departments may have to call Environmental Protection Agency's cleanup contractor or special HAZMAT teams.

2.3 Incident Observers

Incident observers include agencies that identify and/or see HAZMAT related incidents and call agencies that has capabilities to send the information about the incident to appropriate agencies for response. Table 3 includes a list of bi-national stakeholder agencies from the U.S.-Mexico border region with roles as HAZMAT incident observers. HAZMAT related incident observers include agencies that do not have adequate capabilities to respond to the incident and hence require the assistance of another agency. For example, Customs and Border Protection (CBP) has a significant amount of responsibilities in responding to HAZMAT spills inside the port compound and have basic level of training, but limited amount of equipment and infrastructure to respond to a spill or incident. Because of this, CBP will immediately notify the appropriate HAZMAT response team in the City of El Paso or appropriate county.

Table 3 List of Stakeholder Agencies with Roles as HAZMAT Incident Observers

Stakeholder Name	Country - State - City
General Public	U.S. and Mexico
Customs and Border Protection	U.S.
New Mexico State Police	U.S. – State of New Mexico
Texas State Police	U.S. – State of Texas
El Paso County Sheriff	U.S. – State of Texas
Dona Ana County Sheriff	U.S. – State of New Mexico
City of El Paso Fire Department	U.S. – State of Texas – City of El Paso
City of Las Cruces Fire Department	U.S. – State of Texas – City of Las Cruces
City of Sunland Park Fire Department	U.S. – State of Texas – City of Sunland Park
Ciudad Juarez Fire Stations	Mexico – State of Chihuahua – Ciudad Juarez
Civil Protection	Mexico
New Mexico Department of Public Safety	U.S. – State of New Mexico
Texas Department of Public Safety	U.S. – State of Texas
Texas Commission on Environmental Quality (TCEQ)	U.S. – State of Texas
City of El Paso Department of Environment	U.S. – State of Texas – City of El Paso
Procuraduria Federal de Proteccion al Medio Ambiente (PROFEPA)	Mexico
Secretaria de Medio Ambiente y Recursos Naturales (SEMARNAT)	Mexico
HAZMAT Carriers	U.S. and Mexico

2.3.1 General Public

Anybody in the border area can call the appropriate emergency call center such as 911, Sheriff, or city or state police departments to notify appropriate officials of a incidence. They have no responsibility or obligation for communicating HAZMAT incidences and, therefore, little need of additional HAZMAT information. The stakeholders range from community leaders,

transportation planners, and non-governmental agencies that serve as watchdogs for HAZMAT flow in the border area.

Perhaps the cross border HAZMAT information could be made available to appropriate groups other than first responders and government agencies directly involved in HAZMAT transportation. This information should be developed and sectioned in a secure environment depending on who operates the system and who needs the HAZMAT information. For example, university and researchers would need access to one kind of information while community planners and leaders will need access to another kind. In addition, perhaps the information could be summarized according to predetermined fields and sent or made accessible to these stakeholders.

2.3.2 Customs and Border Protection

Customs and Border Protection Agency has specific responsibilities for inspecting HAZMAT as it enters the United States from Mexico. Currently, the Zaragoza port of entry is the designated HAZMAT port of entry for the El Paso/Ciudad Juárez region. At this specific port, as in all HAZMAT ports along the border, Customs and Border Protection is authorized and responsible for cleaning up and reporting HAZMAT incidents in the legally defined port area.

In other words, CBP has to act much like a fire department because it has to respond to the incidents and much like state police or sheriff because they have reporting responsibilities as well. This dual responsibility makes for a specific HAZMAT vulnerability because CBP has a significant amount of responsibilities in the complex port movement, and they receive basic levels of training, but they have limited amount of response equipment and infrastructure and a limited amount of space and other resources to respond to a spill or incident. Because of this, they will immediately notify the appropriate HAZMAT response team in the city of El Paso or appropriate county or city HAZMAT response teams.

The CBP personnel associated with HAZMAT inspection and response at the Zaragoza POE would greatly welcome additional information from the HAZMAT carrier and parent chemical company (1). Currently, CBP receives HAZMAT information via the current trucking manifest system, in both electronic and hardcopy form. The manifest information describes the kind and amount of hazardous materials being transported.

The CBP could benefit from additional information such as that provided by the Emergency Response Guide (6). This could include information about the hazardous material such as its interactions with common environments, level and kind of risk for handlers and surrounding environment, safe handling, approved containers, general containment methods, and contact information for either the Environmental Protection Agency (EPA) or the parent chemical company that could provide additional instructions.

2.3.3 New Mexico State Police

The New Mexico State Police has a unique responsibility of being the top organization in charge of a HAZMAT incident response. However, this is mostly a pro-forma responsibility

because the agency has neither proper training nor equipment to manage a HAZMAT incident (2). While the agency is required to be at the site of incident, in practice the agency immediately turns over the HAZMAT containment responsibility to first responders from the appropriate fire department. The agency, however, remains at the scene to ensure that all appropriate organizations are notified, and maintain the safety of non-responders or outsiders around the incident site.

The New Mexico State Police also assures that responders receive necessary law enforcement support to manage HAZMAT incidents effectively. Further, New Mexico State police has its own call center and data systems through which data files can be transmitted. This cell phone information could be sent from the mobile data vehicle computers or emergency call centers in El Paso and Las Cruces.

2.3.4 Texas State Police

The Texas State Police does not have similar ambiguous responsibilities as the New Mexico State Police. The Texas State Police do not have to respond to HAZMAT incidents, but the agency can be called on to maintain security at the scene of an incident and surrounding area. Relevant information about the HAZMAT spill could easily be sent to their mobile vehicle data systems, which could enhance their ability to secure the scene.

2.3.5 El Paso and Dona Ana County Sheriff

The sheriff's departments of El Paso and Dona Ana County have no specific HAZMAT responsibilities other than notifying appropriate authorities of incidents and maintaining security at the scene of an incident and surrounding area. Relevant information about the HAZMAT spill could easily be sent to their mobile vehicle data systems, which could enhance their ability to secure the scene.

2.3.6 Fire Stations from Cities of El Paso, Las Cruces, and Sunland Park

Local fire stations are the default first responders for HAZMAT incidents. Hence, these agencies are under the same obligation as private citizens, police departments, or other governmental authority to report HAZMAT incident using the appropriate communication channel, such as the call center, mobile vehicle data terminals, cell phones, radios, or e-mails.

2.3.7 Fire Stations from Ciudad Juárez and Civil Protection

Much like the United States, the first responders for HAZMAT incidents in Mexico rests primarily with the local fire stations, under the direction of Civil Protection. The fire stations communicate the HAZMAT information to the emergency call center. When the incident happens in Ciudad Juarez, the fire department's on-scene coordinator has the responsibility to contact the Civil Protection and aware him about the situation. Civil Protection will then evaluate the situation and contact the proper authorities. If the incident puts at risk the border infrastructure, Civil Protection has the responsibility to call fire departments from the City of El Paso and Sunland Park and aware them of the incident.

2.3.8 New Mexico and Texas Department of Public Safety

These two state entities have the responsibility to inspect vehicles, trailers, and drivers for compliance with HAZMAT laws and regulations. However, these agencies are not authorized or equipped to respond to HAZMAT incidents. These agencies are responsible, like many other government agencies, to report the HAZMAT spill to the appropriate authorities.

2.3.9 Texas Commission on Environmental Quality and City of El Paso Department of Environment

These agencies have jurisdictions over the long-term vulnerability and impact of a HAZMAT spill on the environment, whether in county or city areas. Thus, these agencies will respond immediately to a HAZMAT incident to see if immediate action is required to reduce long-term impact of the incident on the environment. However, these agencies coordinate with the Environmental Protection Agency, the parent chemical company, and others to make sure that the final cleanup was done according to the best practices for maintaining environmental health of the area.

2.3.10 Procuraduria Federal de Proteccion al Medio Ambiente and Secretaria de Medio Ambiente y Recursos Naturales

Procuraduria Federal de Proteccion al Medio Ambiente in Mexico is in charge of checking that maquiladoras (factories) comply HAZMAT shipment and disposal. In addition, in case of an HAZMAT incident, PROFEPA needs to notify Secretaria de Medio Ambiente y Recursos Naturales of the nature of the incident. PROFEPA is only in charge of notifying the SEMARNAT about the HAZMAT incident and cannot take any legal actions against maquiladoras. SEMARNAT is the only agency which as legal authority to take actions against private entities for violations regarding hazardous materials.

2.3.11 HAZMAT Carriers

HAZMAT carriers have direct responsibilities for ensuring the safety of the hazardous cargo being transported. The carriers are also liable for incidents caused due to negligent packaging or transportation of hazardous cargo. The truck drivers are required by both Mexican and U.S. laws to be trained to respond to basic HAZMAT incidents. The drivers are required to know the specific contents and corresponding HAZMAT risks and basic containment procedures of the cargo. The drivers are required to call the EPA's HAZMAT hotline immediately to notify and receive basic instructions for dealing with the incident. In addition, the HAZMAT carrier is responsible for contacting local first responders in case of an incident. In addition, the carrier has to report the incident to appropriate U.S. federal authorities, including the Federal Motor Carrier Safety Administration (FMCSA) and the Pipeline and Hazardous Material Safety Administration (PHMSA).

In many cases, the truck drivers are not completely aware of the hazardous material being transported or the nature of the material. Few trucking companies receive HAZMAT information via the current trucking manifest system, in both electronic and hardcopy form. The manifest

information describes the kind and amount of hazardous materials being transported. However, the drivers sometimes neither receive the proper information nor believe the correctness of the information. These truck drivers are trained in Mexican HAZMAT compliance, but because of NAFTA, are allowed to carry HAZMAT in U.S. border regions without a U.S. driver's license. Likewise, U.S. drivers can enter Mexico with hazardous cargo without a Mexican driver's license. These truck drivers, both U.S. and Mexico, may be trained in basic HAZMAT response and are possibly familiar with *the Emergency Response Guide.*

The truck drivers noted that it would be beneficial to obtain real-time information about the HAZMAT cargo that is being transported. The information could include real-time measurement of interaction of HAZMAT with the current environment, level and kind of risk for handlers, safe handling, approved containers, general containment methods, and contact information for EPA, FMSCA, or the parent chemical company that could give instructions that is more specific to handling an incident.

The research team interviewed six HAZMAT truck drivers from STIL (Servicios de Transporte Internacional y Local) concerning their information needs for carrying HAZMAT on U.S. roads and across the border. All STIL personnel have authorized cell phone systems through which PDF or other kinds of data files can be transmitted. This cell phone information could be sent from the mobile data vehicle computers or emergency call centers in El Paso and Las Cruces.

2.4 Sister City Agreements

Along the U.S.-Mexico border areas, many cities have signed sister city agreements. Many of these agreements were inspired by the U.S. and Mexico Border 2012 program. However, due to liability issues associated with the risk of responding to a HAZMAT incident in other side of the border, fire departments in the U.S. side are not allowed to cross into Mexico and directly respond to HAZMAT incidents. For example, one of the most important liability issues is disability insurance. Insurance companies in the U.S. will neither recognize nor pay disability to U.S. fire station personnel if they are injured when responding to an incident in Mexico.

This dilemma might be changing soon because authorities are trying to mandate disability coverage regardless of where the accident or the disability occurred. However, no authority will risk predicting the outcome. In spite of these hurdles, cities of El Paso and Sunland Park in the U.S. side maintain close relationship with colleagues from Ciudad Juarez and provide frequent training in HAZMAT response. There is existing information sharing agreements some of which are formalized and some are informal. For example, the El Paso fire department has close ties with counterparts in Ciudad Juarez and communicates with fire stations from the other side of the border via telephone calls in case of HAZMAT incident.

2.5 Calls and Notifications Receivers

Calls and Notification Receivers include agencies that have capabilities to connect to a Public Safety Answering Point (PSAP) and are trained and certified to route HAZMAT related incident call to local emergency medical, fire, and law enforcement agencies. Table 4 includes a

list of bi-national stakeholder agencies from the U.S.-Mexico border region with roles as HAZMAT incident related calls and notifications receivers. These call receivers also include offices of emergency management that have the capabilities to manage emergency response and to undertake pre-emptive identification and prioritization of potential threats due to HAZMAT spill. For example, the EPA has a toll-free call center for carriers to register their HAZMAT incidents as soon as possible. The call center will help with basic containment and security issues and also notify other related authorities of the HAZMAT incident.

Table 4 List of Stakeholder Agencies with Roles as HAZMAT Calls and Notifications Receivers

Stakeholder Name	Country - State - City
Dona Ana County Office of Emergency Management	U.S. – State of New Mexico
Mesilla Valley Regional Dispatch Authority (MVRDA)	U.S. – State of New Mexico
El Paso County Office of Emergency Management	U.S. – State of Texas
Mobile Data Vehicle Transmission	U.S. – State of Texas and State of New Mexico
Environmental Protection Agency Call Center	U.S.
U.S. Department of Transportation (Pipeline and Hazardous Material Safety Administration)	U.S.
Centro de Emergencia y Respuesta Inmediata (CERI)	Mexico-State of Chihuahua- Ciudad Juarez

2.5.1 Dona Ana County Office of Emergency Management

The Dona Ana County Office of Emergency Management operates the regional Emergency Operations Center (EOC). This is achieved through a cooperative agreement with all the governments within the County. The purpose of the center is to manage emergency response and to undertake pre-emptive identification and prioritization of potential threats and to assist in pre-planning emergency responses in an all hazards approach. The center disseminates information and provides training to various emergency-response agencies. The office supervises and oversees mitigation and planning of HAZMAT incidents.

2.5.2 Mesilla Valley Regional Dispatch Authority

The State of New Mexico has designated Mesilla Valley Regional Dispatch Authority as the designated Public Safety Answering Point for Dona Ana County. Dialing 911 quickly connects to a PSAP dispatcher trained and certified to route calls to local emergency medical, fire, and law enforcement agencies. The MVRDA provides dispatching and coordination of response to the emergency services of Dona Ana County, the City of Las Cruces, the Towns of Hatch and Mesilla, and City of Sunland Park. The MVRDA was created in 1989 through a Joint Powers Agreement between the City of Las Cruces and Doña Ana County, becoming the first consolidated dispatch center in the State of New Mexico. In 2007, the Center received 426,369 telephone calls resulting in 313,943 incidents dispatched.

2.5.3 El Paso County Office of Emergency Management

The El Paso County Office of Emergency Management is responsible for development and implementation of plans for the protection of the community and for minimizing the effects of a natural or manmade disaster. The agency is further responsible for designing and directing local emergency exercises, coordinating the activities of local agencies and resources during disaster, coordinating requests for assistance and providing information to the state and federal agencies during disaster operations. The agency also coordinates with other city and county departments regarding responsibilities during a disaster, and compiling and submitting all reports required by the state and federal agencies. This agency is also responsible to respond to hazardous materials incidents.

The call center at the agency can receive notifications of HAZMAT incidents through the normal 911 calls, e-mails, mobile phones, and through designated radio transmissions from city, county, state, and/or federal authorities. The call center is the default channel for receiving a notification of a HAZMAT incident and relaying that information to the appropriate first responders as well as other authorities responsible for cleanup and long-term environmental issues. With the multitude of responsibilities of the call center, the personnel in the center are usually only trained and equipped to relay the basic information about the HAZMAT incident, and not about how to contain or clean up the spill.

2.5.4 Mobile Data Vehicle Transmission

The States of New Mexico and Texas Police, sheriff's departments of El Paso and Dona Ana Counties, and the Police Departments of El Paso, Las Cruces, and Sunland Park have various technologies for storing and transmitting information from their police vehicles to emergency call centers and other HAZMAT related authorities. Thus, these mobile vehicles could access the HAZMAT information through a variety of formats and could relay or retransmit that information to a great variety of HAZMAT authorities.

2.5.5 Environmental Protection Agency Call Center

The Environmental Protection Agency has a toll-free call center for carriers to register HAZMAT related incidents as soon as possible. The call center will help with basic containment and security issues, and it will notify other related authorities of the incident. The call center probably duplicates mechanisms for notifying appropriate authorities, but it is also a federal registry of HAZMAT related incidents, and will notify the appropriate EPA contractor that is specially trained to respond and contain specific HAZMAT incidents. EPA has contractors that specialize in cleaning and managing incidents that are beyond capability of local fire departments.

2.5.6 Centro de Emergencia y Respuesta Inmediata

This center is in charge of dispatching police, medical and fire fighters unit in the City of Ciudad Juarez, Mexico. Anyone can call this number to notify regarding all kinds of incidents

including HAZMAT incidents. Dispatchers have basic training in HAZMAT incidents. Their main objective is to obtain the name, address phone number an nature of the emergency. Based on the information and address first responders will be dispatched to the location of the incident. The agency uses the same technology as the one used by the 911 system in the U.S.. The only difference is that beside the basic communication with field units, the agency can identify the location of nearest field unit using GPS devices. In addition, all emergency units are equipped with basic radio systems.

2.6 Incident Responders

Incident responders include agencies that have adequate training and equipment to contain most HAZMAT related incidents. Table 5 includes a list of bi-national stakeholder agencies from the U.S.-Mexico border region with roles as HAZMAT incident responders. These agencies include local fire departments to contain the hazardous spill and local law enforcement agencies to secure the area of the incident. Local fire departments are also capable of cleaning up most general HAZMAT spills, while leaving more complicated, toxic, or unusual spills to more specialized teams that are brought in specific to the nature of the spill. These specialized response teams mostly include EPA and cleanup contractors. In some cases, manufacturer of the HAZMAT might also be called to identify the content of the spill. The carrier (primarily the truck driver) has the immediate responsibility of ensuring safety and securing the HAZMAT scene.

Table 5 List of Stakeholder Agencies with Roles as HAZMAT Incident Responders

Stakeholder Name	Country - State - City
City of El Paso Fire Department	U.S. – State of Texas – City of El Paso
City of Las Cruces Fire Department	U.S. – State of Texas – City of Las Cruces
City of Sunland Park Fire Department	U.S. – State of Texas – City of Sunland Park
Ciudad Juarez Fire Stations	Mexico – State of Chihuahua – Ciudad Juarez
Civil Protection	Mexico
New Mexico State Police HAZMAT Unit	U.S. – State of New Mexico
City of El Paso Police Department	U.S. – State of Texas – City of El Paso
Texas Commission on Environmental Quality Emergency Response Coordinator for El Paso Region	U.S. – State of Texas
Environmental Protection Agency and HAZMAT Cleanup Contractor	U.S.
Federal Motor Carrier Safety Administration (FMCSA)	U.S.
Manufacturer of HAZMAT	U.S. and Mexico
Shipper and Carrier of HAZMAT	U.S. and Mexico

2.6.1 Fire Stations from Cities of El Paso, Las Cruces, and Sunland Park

The local fire stations are the default first responders and are trained and equipped to contain most HAZMAT related incidents. These agencies are capable of cleaning most

HAZMAT spills, while leaving more complicated, toxic, or unusual spills to teams that are more specialized. The City of El Paso and the County of El Paso have their respective HAZMAT jurisdictions according to city and county line designations, although they can call other departments from other jurisdictions for support.

The City of Sunland Park's fire station has the jurisdiction for Southern Doña Ana County to respond to HAZMAT related incidents and is equipped with the latest training and equipment. The fire station routinely coordinates with the first responders and hazardous materials workers in Ciudad Juárez. The City of Sunland Park also has a sister city agreement with Ciudad Juárez and is more apt to cross over into Ciudad Juárez.

The fire station personnel at cities of El Paso, Sunland Park, and Las Cruces would greatly welcome additional information from the HAZMAT carrier and parent chemical company. Currently, fire station personnel receive only the HAZMAT information that is given to them from the emergency call center or from other state or federal authorities, who most of the time, do not know or have access to additional information. Not surprisingly, this information is sketchy, lacking critical details about the type and amount of chemicals being carried on the truck. The fire station personnel have been well trained in the use of the *Emergency Response Guide* (6), which was collaboratively produced by the U.S. department of transportation, Transport Canada, and the Secretariat of Communication and Transportation of Mexico. An English version of this guide is available as a software download that can be installed on the laptops of response personnel.

However, if information specifically relevant to the type and amount of HAZMAT carried on this trailer were available immediately, the fire station personnel could save valuable time usually spent on looking up this information. The additional information could include the exact nature of the hazardous material and its interactions with common environments, its a level and kind of risk for handlers and surrounding environment, safe handling, approved containers, general containment methods, and contact information for either the EPA, FMSCA, or the parent chemical company that could give more specific instructions.

This information could be sent in a portable document format (PDF) file, for example, through the fire station's current e-mail system. Further, personnel at all three fire stations have authorized cell phone systems through which PDF or other kinds of data files can be transmitted. This cell phone information could be sent from the mobile data terminals, vehicle computers or emergency call centers in El Paso and Las Cruces.

2.6.2 Fire Stations from Ciudad Juárez and Civil Protection

In cases of a HAZMAT incident Ciudad Juarez Fire Department has the responsibility to attend and mitigate the incident. In order to mitigate the incident the fire Department does have some equipment to control moderate HAZMAT spills. In case that the incident exceeds the Fire Department equipment capabilities, the on-scene coordinator (typically a firefighter) has the responsibility to contact Civil Protection. Civil Protection has the responsibility to send qualified personnel to the scene to evaluate the incident and contact the appropriate authorities. The Director of Ciudad Juarez Civil Protection has the responsibility to contact El Paso and Sunland

Fire Department and alert them if the HAZMAT incident has a potential risk to cross to El Paso or Sunland Park area.

Ciudad Juarez Fire Department does not count with other technology besides radio system. While attending to a HAZMAT incident, the only resource available to fire fighters from the department is the "Guia de Respuesta en Caso de Emergencia" (Spanish translation of the Emergency Response Guide)."

2.6.3 New Mexico State Police HAZMAT Unit

The New Mexico State police have direct authority over a HAZMAT incident and cleanup. However, in practice, they relegate the cleanup and containment to the appropriate HAZMAT team, whether this is the first responders from the fire station, the EPA contractor responsible for ultimate cleanup, or any other authorized HAZMAT responder. As mentioned earlier, the New Mexico State police HAZMAT unit could be a central mechanism for receiving and retransmitting critical HAZMAT information through its mobile data vehicle terminals, radio system, and e-mail and Internet capabilities.

2.6.4 City of El Paso Police Department

The City of El Paso's Police Department has a representative from the U.S. Department of the Homeland Security, who is responsible for the city's response to HAZMAT incidents. The El Paso Police Department receives incident notification through the 911 Communication Center. Police officers from the City of El Paso are dispatched to HAZMAT incidents much like the New Mexico State Police and control the incident and render support to fire department personnel.

Police officers from the department are given basic training on HAZMAT incidents, and each has an *Emergency Response Guide* (6). However, the agency indicated that the guide is often hard for the personnel to use. Hence, the department would like the HAMZAT related information sent to the officers via laptops or mobile data terminals that are in every police vehicle. In addition to information related to HAZMAT, information about appropriate personal protection gear/equipment and standoff zones and clear or evacuation were also desired. This would assist local police personnel in performing their primary support role more efficiently during HAZMAT incidents. Comprehensive information on the hazardous materials was not as important. It was also suggested that along with the HAZMAT information, data sent to the police personnel should include a page reference into the *ERG* for the specific hazardous material/chemical involved in the incident or a summary of the materials.

2.6.5 Texas Commission on Environmental Quality - Emergency Response Coordinator for El Paso Region

The Texas Commission on Environmental Quality (TCEQ) has an immediate and real time responsibility to assess the impact of the HAZMAT incidents for the State of Texas. They are empowered to assess the impact of the incident on the environment, water system, underground water, air quality and other contamination sources. They are called at all hours of

the day/night to respond to an incident. They are alerted of incidents through the 911 Command Center, the Fire Department ER, Regional EOC or from even truck drivers directly. The Emergency Response Coordinator, Jose Ojeda, has in his office all the necessary communications equipment and a terminal to receive information about an incident.

The Emergency Response Office coordinates closely with the City of Sunland Park in NM but have to coordinate with anyone in Las Cruces or from Dona Ana County. Personnel from his office will go into NM to respond if necessary. In January, they had a joint exercise with the City of Sunland Park Fire Department and have another coming. He indicated that the State of New Mexico has a "Civil Support Team" stationed in Albuquerque that can be and is dispatched to the area in the event of a HAZMAT incident. The responsibilities of the Civil Support Team appear to be primarily clean-up. Texas also has such a Civil Support Team.

2.6.6 Environmental Protection Agency and Cleanup Contractor

The Environmental Protection Agency is obligated and authorized to contract with special contractor who can be sent to a HAZMAT incidence to contain and clean up the spill. The contractor is responsible to the EPA for its work. The EPA manages this cleanup through its call center. This call center will also work with the HAZMAT carrier and the parent company of the hazardous material itself to ensure safe and proper containment and cleanup of the spill. Many private companies involved in hazardous materials are keenly prepared to manage an incident and fly a team to the site.

2.6.7 Federal Motor Carrier Safety Administration

The Federal Motor Carrier Safety Administration is responsible for licensing and regulating the movement of HAZMAT in the United States and in the U.S.-Mexico border zones. This responsibility includes inspecting the HAZMAT transportation unit, including the trailer, tractor, packaging materials, and packing configuration. In addition, HAZMAT incidents must be reported to FMCSA and the U.S. Department of Transportation's Pipeline and Hazardous Materials Safety Administration. FMCSA and PHMSA provide guidance and answers to critical questions with regard to hazardous materials spills. More information can be found at the following website: www.fmcsa.dot.gov/safety-security/HAZMAT/spills.htm. These two agencies, however, have limited if no responsibility for the actual cleanup.

2.6.8 Manufacturer of HAZMAT

The chemical, biological, or industrial company that manufactured the hazardous material that was spilled is responsible for providing containment and cleanup information for that specific material. Often, the chemical company will send or make available appropriate representatives to assist, manage, or undertake the containment and cleanup. It might be important to create some kind of communication link between apparent chemical company and the corresponding HAZMAT responders.

2.6.9 Shipper and Carrier of HAZMAT

The HAZMAT carrier has both immediate and long-term responsibility for ensuring the safe movement of hazardous materials. The truck driver has the immediate responsibility of ensuring his safety and securing, if possible, the immediate HAZMAT scene. The transportation company is responsible for training its hazardous materials drivers in basic HAZMAT identification, secure shipment, and basic safe handling of hazardous materials.

With some less risky hazardous materials, the truck driver might be capable of containing and responding to the HAZMAT spill, even though the driver is obligated to call appropriate authorities who have the ultimate responsibility in deciding who needs to respond to the incidence. As mentioned earlier, many HAZMAT transportation companies are well equipped in terms of data communication and could benefit from the additional HAZMAT information that could be made available in addition to many of the other stakeholders.

2.7 Summary of Findings

2.7.1 System

The optimal communication system would describe the hazardous material, amount, and information about the specific load and how it is packaged. Several systems exist, *Emergency Response Guide* (ERG) and the Wireless Information System for Emergency Responders (WISER), to provide detailed information about the hazardous materials that could be involved in the incident. Both the ERG and WISER are comfortable and familiar information formats for response personnel.

The message or communication sent to the personnel involved in the incident should contain the actual type and amount of hazardous materials matched to the appropriate response guide from these two previously mentioned sources. Information on potential issues resulting from several different kinds of materials being involved in the same incident need also to be communicated as soon as available. Responders need to be warned about perimeter and plum issues as early as possible. Real-time information on weather issues that could impact plume need to be communicated with other HAZMAT information.

Communications formats need to be developed from priorities provided by first responders. Ease of information access is critical. Safety alerts needs to be provided in a dramatic and easily understood manner. Information formats need to be tested with first responders. For regional communication, consideration needs to be given to the provision of this information in Spanish.

2.7.2 Technologies

Information can be sent to first responders via a wide range of technologies, including cell phone, e-mail, voice radio systems, and mobile data terminals. The Union Pacific Railroad has developed custom cell phones that can take quality video and broadcast this to a headquarter location. Mobile data terminals and cameras are standard in most police cars and can be a means of receiving and sending information on a HAZMAT incident.

Current communications technologies can permit the broadcast and reception of audio, video, e-mail, data transference, teleconference, and can be connected real-time to a significant variety of roadside transmitters and sensors. The capabilities of these technologies should be reviewed with first responders and prioritized in a budgetary context.

2.7.3 Interoperability

Interoperability has become a widely held goal for law enforcement and first responder agencies in the post-911 environment. The interoperable communication of information/data on a HAZMAT incident needs to be an understood goal. This could be potentially challenging goal in this region given the two state governments, the U.S. federal government, and the governments in Mexico.

2.7.4 Network

The communications system to support technologies to be utilized by first responders can be wireless, wire, or fiber optics. Most likely, some combination of these communication system technologies will optimize the responder's performance in a HAZMAT incident. Fiber optics is viewed by most as the technology that should form the backbone of the communications network. This technology would provide the speed and security necessary to support a first responder system. Ultimately, the first responder will want wireless devices at his/her person while responding to an incident.

Three of the four El Paso POEs are connected to a regional "fiber ring." This fiber capacity will optimize communications for these POEs. The Ysleta POE and the Santa Teresa POE are not connected into a fiber system. Ysleta is the current entry/exit point for hazardous materials in this region and the Santa Teresa POE is scheduled to become the HAZMAT port for the region. Efforts need to be coordinated to bring these two points into a fiber ring. Fiber optics does extend into Mexico and could become a significant means of HAZMAT incident communications.

2.7.5 Organization

In both New Mexico and Texas, first responder organizations are comfortable with information being cleared through a centralized dispatch center. In Texas, this is referred to as the 'command center.' In New Mexico, this is referred to as MVRDA. The use of such centers will act to control the flow of information and coordinate the response support from the various agencies that could potentially be involved in an incident.

At some point an emergency operations center can be brought into play depending on the extent or severity of the incident. The organizational command of an incident response varies by state. In New Mexico, the State Police are in charge of HAZMAT incidents. In Texas, the El Paso Fire Department is in charge of the incident.

Organizational anomalies do exist. TCEQ staff is empowered to take command of an incident. It is more likely that this would happen in El Paso County where there is only a

volunteer fire department. At the international ports of entry, CBP is organizationally responsible for all that transpires. However, they do defer to the local first responders in the context of a HAZMAT incident.

At times, formal organizational chains are not strictly followed. Sometimes trucking companies notify TCEQ staff directly of an incident. At incidents in New Mexico, the State Police turn over most responsibility for an incident to the local fire department's response unit. Despite organizationally assigned chains, most local responders appear to have worked out a very cooperative management situation during incidents and no problems were noted relative to hegemony.

Most interviewees agreed that information flow should be centralized through these existing command centers. Several times, however, interviewees noted that information could or should be simultaneously sent to first responder organizations and the command centers. Further discussions with first responder organizations on this issue appear appropriate.

The role to be played in HAZMAT incident response by the "fusion centers" being created in states needs to be defined. These centers are still in their infancy and appear to have a primary role in responding to potential terrorism actions.

2.7.6 Costs

There is a wide variety of technology, referred to by some interviewees as "gadgetry," that could significantly improve the flow and display of information to the HAZMAT incident first responder. Much of this technology was enticing to those interviewed. However, the capital costs of much of this equipment were prohibitive to many of the local first responders. Mobile data terminals and in-vehicle dashboard mounted cameras are now standardized technologies for law enforcement agencies in the region. The utilization of this technology to improve HAZMAT incident communication may minimize new capital costs for law enforcement agencies. The cell-phone camera technology developed for Union Pacific Railroad employees was of interest to some agencies. However, the costs could prove prohibitive to local governments.

Creating the fiber communications backbone for a wireless system is a critical investment that might have to be considered prior to attempting to address the communication and technology system. Maintenance costs need also to be addressed in considering technologies. Finding the most cost-appropriate technology, ongoing maintenance costs factored, is an important issues when attempting to design the optimal communications system for local HAZMAT incident response agencies.

2.7.7 Training

Training on equipment and systems developed/selected for the region is critical and should be integrated into the frequent training available to first responders, including regularly scheduled laptop exercises. The nature of hazardous materials has resulted in a significant amount of ongoing training. Ongoing training was viewed as critical to the effective use of the

communications system. The existing training programs should be tapped for training on new communication systems and technologies. Interviewees noted that training, and field training in particular, was one of the major factors in the successful introduction of technologies.

2.7.8 Legal Constraints/Security

Some of the technologies that provide a potential benefit to law enforcement agencies have significant legal issues revolving around potential invasiveness. The technologies that potentially could improve the communications needed for HAZMAT response, including cameras, do not appear to be constrained by such legal issues. However, interviewees were uniform in their view that information being communicated about a HAZMAT incident needs to be secure. CBP has traditionally viewed hazardous materials manifest information as needing to be secure; this security requirement appears to results from the potential terrorist hijacking of hazardous materials.

Balanced against this security requirement is the need for potential first responders to have maximum information about materials involved in an incident. First responder agencies did not necessarily see the need for advance information on regular hazardous materials shipments across the border. However, the first responders want maximum real-time information on shipments involved in an incident. The security requirements of CBP and shipping agencies (trucking firms and maquilas) need careful consideration in system design.

First responder agencies did see the need for securing the information being communicated during an incident. It was perceived that uncontrolled information could create issues and even panic in the public that could hamper response efforts. Indications are that wireless technology can now be made secure. Security needs to be a priority for HAZMAT incident communications.

2.7.9 Conclusion

The stakeholder agencies in the both sides of the border coordinate at different levels to respond to incidents related to hazardous materials. As a first major task in the research, all stakeholder agencies (that are involved in various capacities regarding transportation of hazardous materials) in the border region were identified, including their roles and responsibilities, as illustrated in Figure 6. Representatives from these agencies were interviewed to identify shortfalls and requirements to respond to HAZMAT incidents. The researchers concentrated in identifying communication needs of first responders in the region. Many agencies also play a dual role in observing and responding to HAZMAT related incidents, such as local police and fire departments, which are first responders in most cases. In rare situation, local police and fire departments may have to call Environmental Protection Agency's cleanup contractor or special HAZMAT teams.

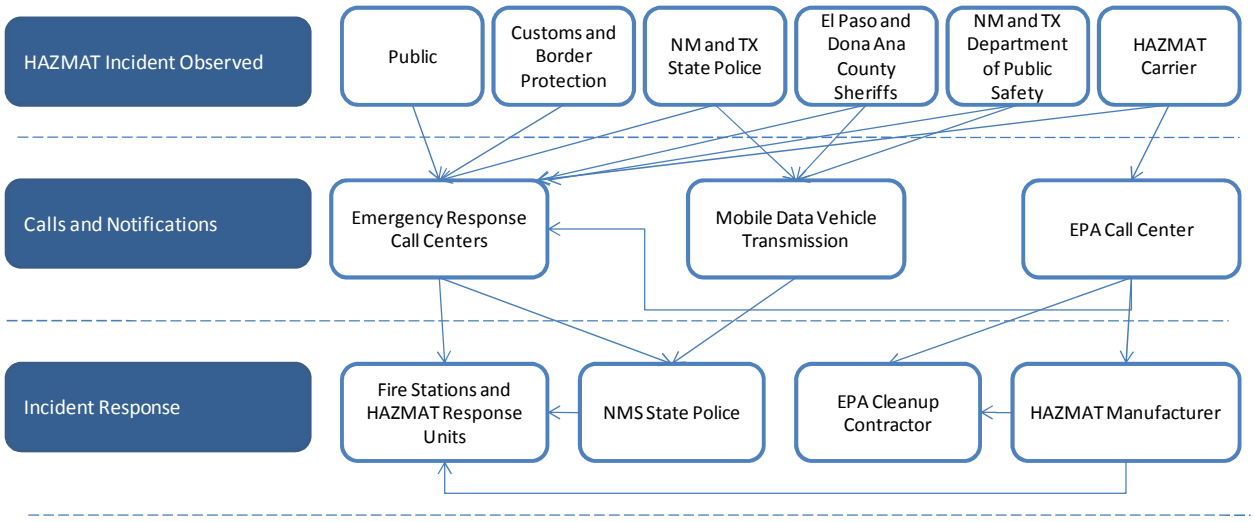


Figure 6 Illustration of Complex Interaction between Agencies While Responding to HAZMAT incidents.

In conclusion, the most helpful communication system would describe the hazardous material, amount, and response information about the specific load. Both the *Emergency Response Guide* and the Wireless Information System for Emergency Responders have all the response materials information architecture that response personnel are used to. Thus, the message or communication sent to the appropriate response personnel would contain the actual material and amount of hazardous materials matched to the appropriate response guide from these two important sources. As mentioned, the message can be sent via cell phone, e-mail, or through the appropriate emergency response centers.

More research probably needs to be carried out to assess the actual usefulness of WISER because none of the emergency response personnel in this area had mentioned using it. Perhaps it is too new, having only been released in the last few years, or it is not user friendly.

CHAPTER 3. HIGH LEVEL SYSTEM FRAMEWORK AND SYSTEM ARCHITECTURE

3.1 Applicable Intelligent Transportation System Architectures

Based on conversations with the stakeholders, the researchers decided that it would be difficult to propose and develop a prototype that will fulfill the needs of all three categories of stakeholders. The interviews with the stakeholders also revealed that local first responders (in both U.S. and Mexico) do not have any form of advanced information related to HAZMAT crossing the border (and moving through the community) until the incident occurs and are called to respond.

The Border Information Flow Architecture (BIFA) was created to facilitate agencies in the U.S.-Canada border to develop interoperable and formal programs to respond to not only HAZMAT incidents but also other major incidents that might affect the cross-border flow of traffic (7). However, no such information architecture exists for U.S.-Mexico border. For the purposes of this research, BIFA was referred to identify market packages relevant to cross-border communication. These market packages could be adapted to U.S.-Mexico border. On the other hand, the El Paso's regional ITS architecture were referred to identify market packages and services that could be potentially be used by agencies in both sides of the border to monitor hazardous materials cargo and respond to HAZMAT incidents.

3.2 Mapping Stakeholder Requirements to BIFA and National ITS Architecture

Under NAFTA requirements, all HAZMAT excess to the manufacturing process or the resultant waste from the manufacturing process must be returned to its point of origin, typically the United States. If the HAZMAT was generated in a Factory in Ciudad Juarez, the HAZMAT needs to be shipped in trailers, cross the border and arrive to point of origin where the HAZMAT was originated. When the trailer is in transit to the HAZMAT point of origin, incidents such as spills and traffic accidents may occurs, requiring immediate action from first responders. It has been identified that stakeholders need the following type of information to plan a HAZMAT response more efficiently:

- Immediate notification when a HAZMAT incident is occurs.
- Nature and quantity of HAZMAT material involved in the incident.
- Equipment needed and best strategy to contain the HAZMAT incident.
- Reaction of HAZMAT material with the environment.
- Contact information of entities that can provide further information of the material that is involved in the incident.

The proposed information system will provide immediate notification of HAZMAT incidents to first responders, which will include HAZMAT description, amount, and information about the specific load will be relayed and shared in real-time with first responders, to minimize the response time when major HAZMAT incident occur in the El Paso-Sunland Park-Ciudad Juarez area.

The Border Information Flow Architecture and the El Paso's Regional ITS Architecture (8) includes information flows between the agencies for various user services and market packages, including HAZMAT. As described in Section 4.1, even though BIFA supports ITS architecture for border regions in U.S. and Canada, information such as relevant user services and market packages related to HAZMAT can be easily applied to the U.S.-Mexico border regions. In addition, El Paso's Regional ITS Architecture also provides appropriate user services and functional requirements relevant to HAZMAT related incident response.

However, these user services and market packages are primarily related to responding to HAZMAT incidents and do not include real-time HAZMAT monitoring and pro-active intervention of threats due to possible spills and leaks. For example, CBP inspectors are not aware if a container carrying HAZMAT is entering the facility with possible leaks, which could pose a significant threat to CBP personnel inside the compound. Similarly, first responders (especially fire departments) are also completely unaware of HAZMAT movements and crossings in the city until an incident occurs when their response is required. BIFA and El Paso's Regional ITS architecture does not include these types of pro-active monitoring user services and market packages that could raise the effectiveness level of HAZMAT response.

3.3 Border Information Flow Architecture

The Transportation Border Working Group, a bi-national group that works to enhance coordination and planning between the United States and Canada, identified collaboration on the implementation of border technology as one of its key priorities. To advance this priority, the U.S. Department of Transportation, the Federal Highway Administration (FHWA), and Transport Canada, in partnership with state and provincial transportation organizations, regional planning organizations, and other federal agencies, initiated the development of a Border Information Flow Architecture (7).

The architecture was designed as a tool that can be used by agencies (in both U.S. and Canada) that operate at or near to border to guide the planning, development, and implementation of ITS and other technology. Lack of coordination and collaboration among these various agencies often results in the deployment of technology that is not interoperable, redundant or is an impediment to efficient operations. The architecture seeks to address these problems and intends to aid agencies in planning and implementing interoperable technologies at the U.S-Canada border. It is important to mention that even thought the BIFA was primarily developed for U.S.-Canada border; there are user services and market packages that can be adapted to U.S.-Mexico border.

Table 6 describes user services and functions in BIFA related to HAZMAT information and communication needs between agencies and first responders. In the absence of an ITS architecture for U.S.-Mexico border, user services and functions in BIFA can be used to design high-level architecture for the HAZMAT information system for the border region.

Table 6 List of Market Packages in BIFA Related to HAZMAT Management

Market Package	Description	Elements	Related Market Packages
CVO10-Dangerous Goods Planning and Incident Response - Canada Market Package	This market package for Canadian Dangerous Goods teams integrates incident management capabilities with commercial vehicle tracking to assure effective treatment of dangerous goods material and incidents. Dangerous goods tracking is performed by the Fleet and Freight Management Subsystem. The Emergency Management subsystem is notified by the Commercial Vehicle if an incident occurs and coordinates the response.	- Canadian Public Safety Dispatch - Commercial Vehicles Fleet Management Systems - Provincial Emergency Preparedness Centre - RCMP Emergency Services	(U.S.) CVO10: HAZMAT Management (Can) CVO10: Hazardous Material Planning and Incident Response
CVO10-HAZMAT Management - U.S. Market Package	This market package for U.S. HAZMAT teams integrates incident management capabilities with commercial vehicle tracking to assure effective treatment of HAZMAT material and incidents. HAZMAT tracking is performed by the Fleet and Freight Management Subsystem.	- Commercial Vehicles Fleet Management Systems - State Level Public Safety Dispatch - U.S. Emergency Operations Center - U.S. Local Public Safety Dispatch Centers	(U.S.) CVO10: HAZMAT Management (Can) CVO10: Hazardous Material Planning and Incident Response
CVO11-Roadside Dangerous Goods - Canada Field to Center Market Package	This market package instance for Field systems in Canada provides the capability to detect and classify security sensitive Dangerous Goods on commercial vehicles using roadside sensing and imaging technology. Credentials information can be accessed to verify if the commercial driver, vehicle and carrier are permitted to transport the identified Dangerous Goods. If the credentials analysis and sensed Dangerous Goods information do not agree, the vehicle can be signaled to pull in, and if required, an alarm can be sent to Emergency Management to request they monitor, traffic stop or disable the vehicle.	- Canadian Automated Roadside Inspection and Enforcement Systems - Canadian Public Safety Dispatch - Carrier Data Exchange System - Commercial Vehicles	(U.S.) CVO11: Roadside HAZMAT Security Detection and Mitigation
CVO11-Roadside HAZMAT - U.S. Field to Center Market Package	This market package for U.S. Field systems provides the capability to detect and classify security sensitive HAZMAT on commercial vehicles using roadside sensing and imaging technology. Credentials information can be accessed to verify if the commercial driver, vehicle and carrier are permitted to transport the identified HAZMAT. If the credentials analysis and sensed HAZMAT information do not agree, the vehicle can be signaled to pull in, and if required, an alarm can be sent to Emergency Management to request they monitor, traffic stop or disable the vehicle.	- Commercial Vehicles - State CVIEW System - State Level Public Safety Dispatch - U.S. Automated Roadside Inspection and Enforcement Systems	(U.S.) CVO11: Roadside HAZMAT Security Detection and Mitigation

RCMP = Royal Canadian Mounted Police, Source: Border Information Flow Architecture (7)

One of the unique features of BIFA is demonstrating the need for coordination between local agencies in U.S. and Canada while responding to emergencies at the border. Even though BIFA does not clarify if such emergencies include HAMZAT, however it is expected to include such incidents. In terms of coordinating emergency response, BIFA includes interoperability of communication between two countries for dispatchers to share information and messages while responding to emergency. Table 7 includes a list of market packages in BIFA related to emergency response management between local, state, and federal agencies in both countries.

Table 7 List of Market Packages in BIFA Related to Emergency Response Management and Coordination between U.S. and Canada

Market Package	Description	Elements	Related Market Packages
EM1- Emergency Response Management - Canadian Public Safety Market Package	This market package for Canadian Public Safety Agencies provides basic public safety call-taking and dispatch services. It includes emergency vehicle equipment, equipment used to receive and route emergency calls, and wireless communications that enable safe and rapid deployment of appropriate resources to an emergency. Coordination between Emergency Management Subsystems supports emergency notification between agencies. Wide area wireless communications between the Emergency Management Subsystem and an Emergency Vehicle supports dispatch and provision of information to responding personnel.	- Canadian Public Safety Dispatch - Other Regional Public Safety Comm. and Dispatch Centers - RCMP Emergency Services - State Level Public Safety Dispatch - U.S. Local Public Safety Dispatch Centers	(U.S.) EM01: Emergency Call-Taking and Dispatch (Can) EM1: Emergency Response Management
EM1-Emergency Call-Taking and Dispatch - U.S. Public Safety Market Package	Same as above, except this market package is for the U.S. local public safety agencies.	- Same as above	Same as above

Source: Border Information Flow Architecture (7)

Figure 7 illustrates the flow of information between local, state, and federal agencies in U.S. and Canada to manage emergency response at the border. A much more efficient, formalized and, interoperable communication can be contemplated between agencies in the U.S. and Mexico, to replace existing method of sharing information through cell phones. A formalized connection between the two countries at the border would open-up a much broader data-exchange capabilities to respond to incidents related to hazardous material crossing the border.

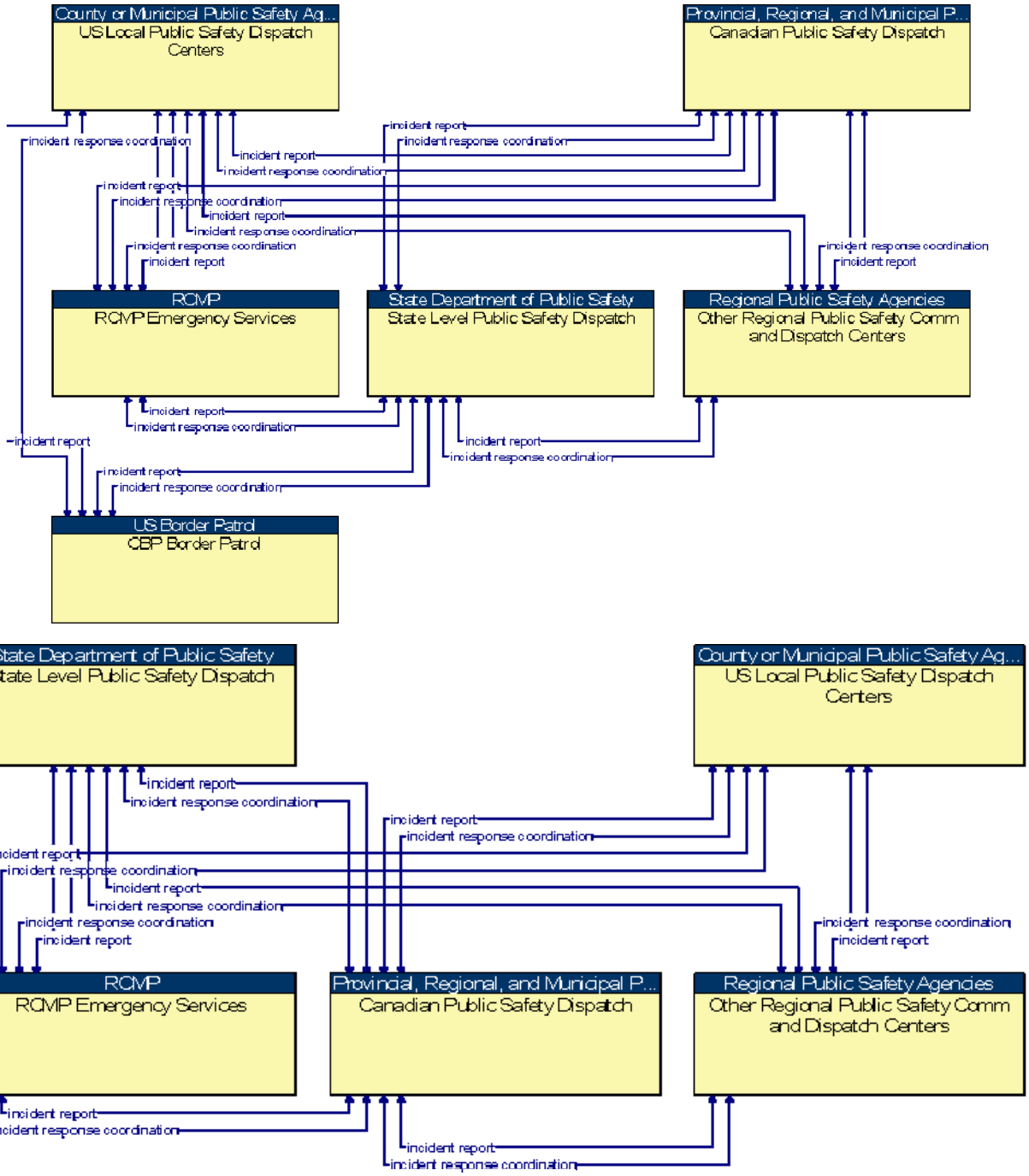


Figure 7 Market Package Diagram – Emergency Call Taking and Dispatch between U.S. and Canadian Agencies

RCMP = Royal Canadian Mounted Police
Source: Border Information Flow Architecture (7)

3.4 El Paso Regional ITS Architecture

The El Paso's regional ITS architecture includes several market packages to share transportation information (mostly archived data) between local agencies in the U.S. and agencies in Mexico (9). However, sharing information and coordinating emergency response is not one of them, in contrast to market packages mentioned in the BIFA architecture. The El Paso regional ITS architecture includes a market package ("CV010-HAZMAT Management") related to management of incidents related to hazardous material in the El Paso area, which is illustrated in Figure 8. The City of El Paso's communication center plays a vital role in dispatching incident related information from commercial vehicles to fire department and other state agencies. As shown in the figure below, there are no formalized information sharing mechanisms between first responders in El Paso and Ciudad Juarez (Mexico).

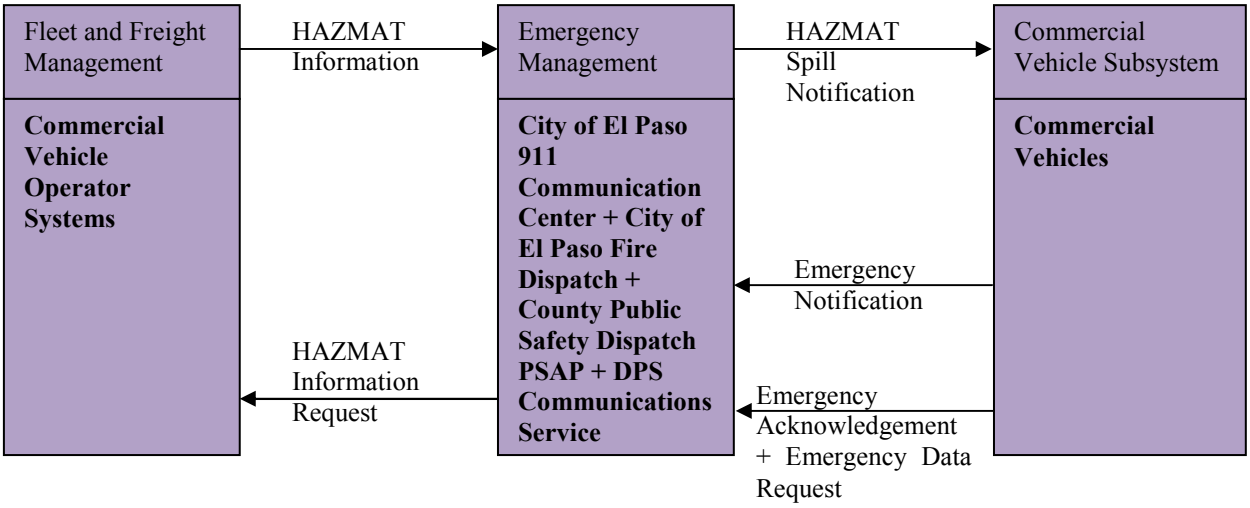


Figure 8 HAZMAT Response and Management Related Market Package in the El Paso's Regional ITS Architecture

DPS = Texas State Department of Public Safety
PSAP = Public Safety Answering Point
Source: El Paso Regional ITS Architecture (9)

For incidents (which includes HAZMAT related incidents) inside the CBP's jurisdiction, the City of El Paso's local fire department and medical services can respond when requested by the CBP. Figure 9 shows a market package in the El Paso's regional ITS architecture that includes flow of incident information between CBP and local first responders.

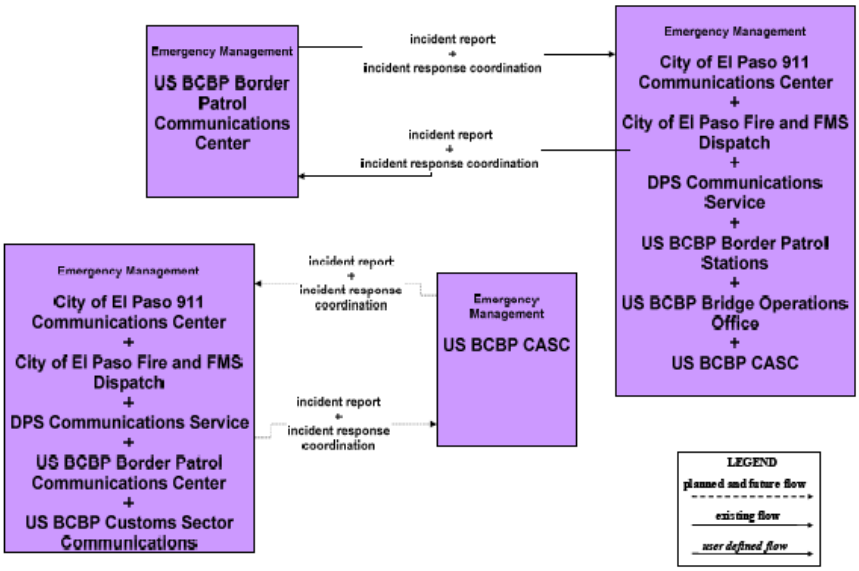


Figure 9 Market Package Diagram – Emergency Response by the U.S. CBP in the El Paso Region

FMS = Fire Medical Service
U.S. BCBP = United States Bureau of Customs and Border Protection
CASC = Customs Area Security Center
Source: El Paso Regional ITS Architecture (9)

3.5 National ITS Architecture

User services and market packages (and equipment packages) in both architectures are primarily related to responding to HAZMAT incidents and do not include real-time monitoring, relaying advanced HAZMAT related information, and pro-active intervention of threats due to possible spills and leaks. The National ITS architecture provides several equipment packages for real-time and on-board monitoring of cargo, which can be adapted to monitoring of HAZMAT. Table 8 includes a list of equipment packages that pertain to real-time monitoring of cargo and HAZMAT and provide freight security in addition to response and management of HAZMAT related incidents.

Table 8 HAZMAT Management Related Market Packages in the National ITS Architecture

CV010 HAZMAT Management Market Package	Description
On-Board Cargo Monitoring	This on-board equipment package monitors the location and status of the commercial vehicle and its cargo. It sends the collected data to appropriate centers and roadside facilities, including emergency management in the case of HAZMAT incidents. Depending on the nature of the cargo, this equipment package may include sensors that measure temperature, pressure, load leveling, acceleration, and other attributes of the cargo.
Commercial Vehicle and Freight Security	This equipment package provides for the security of the commercial vehicle and the freight that it carries by detecting breaches such as seals or locks being broken into by unauthorized personnel and/or any other unauthorized tampering. In addition, this equipment package monitors the commercial vehicle driver and compares it with the planned driver for the vehicle. In a similar manner, the driver and vehicle that have been assigned to move freight are monitored and compared with the planned assignment for that freight. In all cases, any deviations to the planned assignments and any breach or tamper events are reported to the Emergency Management Subsystem.
Fleet HAZMAT Management	This equipment package manages hazardous materials shipments. In the event of an incident, it notifies the Emergency Management Subsystem, providing information on the nature of the cargo and the vehicle equipment.

3.5.1 The Hazardous Materials Security and Incident Response User Service

The Hazardous Materials Security and Incident Response User Service provide emergency personnel at the scene of hazardous materials incident immediate information on the types and quantities of hazardous materials present in order to facilitate a quick and appropriate response. The service includes tracking of security sensitive hazardous materials shipments, notification of security sensitive HAZMAT unauthorized activity, notification of unauthorized security sensitive HAZMAT driver, and roadside security sensitive HAZMAT monitoring.

3.5.2 On-board Safety and Security Monitoring User Service

The On-board Safety and Security Monitoring user service non-intrusively monitors the driver, vehicle, and cargo and notifies the driver, carrier, and, possibly, enforcement personnel if an unsafe situation arise during operation of the vehicle. Such an unsafe situation might involve the status of driver fatigue, vehicle systems, or cargo shift. This user service also assures freight container, trailer, and commercial vehicle integrity by monitoring on-board sensors for a breach or tamper event and monitoring assignment integrity between the vehicle, the driver or custodian, and the freight container.

3.5.3 Emergency Notification and Personal Security User Service

The Emergency Notification and Personal Security user service provides the ability for travelers to notify appropriate emergency response personnel regarding the need for assistance due to emergency or non-emergency situations. The notification can be initiated manually by the traveler, or it could be provided from a vehicle automatically on the occurrence of a crash. The service also provides for monitoring, threat alerts, and automated security system support in secure areas. Secure areas encompass physical areas related to travel including remote areas and critical transportation infrastructure. In addition, the service provides wide area alert to notify the traveling public in emergencies such as child abductions, severe weather watches, and warnings, natural and human-caused disasters, military operations, and civil emergencies where lives and/or property are at stake. Finally, the service prevents public distribution of traveler information that may influence individual privacy or public safety.

3.5.4 Functional Requirements of the National ITS User Service Requirements

Functional requirements define and specify WHAT a system must do, use formal "shall" language and specify a function in terms that the stakeholders, particularly the system implementers, will understand. In the National ITS Architecture, functional requirements have been defined for each user service. Individual requirements are assigned User Service Requirement Number (USRN). Table 9 through Table 12 includes pertinent user service requirements along with the URSN for each requirement. In the logical architecture of the proposed system, requirements fulfilled by individual subsystems are mapped with the corresponding requirements stated in the National ITS Architecture.

Table 9 User Service Requirements for On-Board Safety and Security Monitoring

USRN	Description
4.3.0	ITS shall include an On-Board Safety and Security Monitoring (OBSSM) function, that provides monitoring and warnings of safety and security problems. For safety related issues, the primary importance is to inform the driver, as soon as possible, of any problem that has been detected. Of secondary importance is notifying the carrier of detected safety problems. Last in importance is the notification of appropriate enforcement agencies. For security related issues, the commercial vehicle driver and authorized freight data users are informed of any problems related to freight container, trailer or commercial vehicle integrity. For commercial vehicle driver/commercial vehicle/freight container or trailer assignment mismatches, authorized freight data users are informed of a potential problem.
4.3.2	OBSSM shall include a Vehicle System (VS) that is a part of each vehicle.
4.3.2.2	The VS shall provide the capability to alert the vehicle driver whenever there is a critical safety problem or potential emergency.
4.3.2.4	The VS shall include a Vehicle Integrity (VI) function.
4.3.2.4.1	The VI shall monitor on-board sensors to detect a breach or tamper event.
4.3.2.4.2	The VI shall provide the capability to collect and process vehicle integrity information.
4.3.2.4.3	The VI shall provide integrity event information to the driver and carrier's dispatch function.
4.3.2.5	The VS shall include a Vehicle Asset Management (VAM) function.
4.3.2.5.1	VAM shall provide the capability to monitor and track the location and movement of commercial vehicles by authorized users.
4.3.3	OBSSM shall include a Freight Security Management (FSM) function
4.3.3.1	FSM shall include a Freight container or trailer Integrity (FI) function
4.3.3.1.1	FI shall monitor freight container or trailer data to detect a breach or tamper event.
4.3.3.1.2	FI shall provide the capability to process freight container or trailer integrity data.
4.3.3.1.3	FI shall support the transmission of freight integrity data to freight data users.
4.3.3.2	FSM shall include a commercial vehicle driver/commercial vehicle/freight container or trailer Assignment Integrity (AI) function.
4.3.3.2.2	AI shall include the capability to store the driver/commercial vehicle/freight container or trailer assignment information.
4.3.3.2.3	AI shall include the capability to monitor the identity of the driver.
4.3.3.2.4	AI shall include the capability to monitor the identity of the commercial vehicle.
4.3.3.2.5	AI shall include the capability to monitor the identity of the freight container or trailer.
4.3.3.2.6	AI shall provide the capability to correlate the identity of the driver, commercial vehicle and freight container or trailer with the planned assignment.
4.3.3.2.7	AI shall alert authorized freight data users when a driver/commercial vehicle/freight container or trailer mismatch has been detected and verified.

Adopted from the National ITS Architecture (1)

Table 10 User Service Requirements for Hazardous Material Security and Incident Response

USRN	Description
4.5.0	ITS shall include a Hazardous Materials (HAZMAT) Security and Incident Response (HSIR) service.
4.5.1	HSIR shall include a HAZMAT Incident Notification (HIN) function.
4.5.1.1	HIN shall include the capability to provide enforcement and HAZMAT response teams with timely and accurate information on cargo contents when the vehicle is involved in an incident.
4.5.1.2	HIN shall be capable of providing the following Information :
4.5.1.2(a)	Time of incident.
4.5.1.2(b)	Location of the incident.
4.5.1.2(c)	The material(s) involved.
4.5.2	HSIR shall provide an Operation Focal Point (OFP) for initiating appropriate responses.
4.5.2.1	OFP shall be capable of being implemented as either a centralized dispatch or several de-centralized dispatch units or vehicles.
4.5.2.2	OFP shall provide the capability for existing dispatch centers to receive the calls, determine response requirements, and route distress calls to predesignated responding agencies.
4.5.2.3	OFP shall provide the capability for operators to coordinate with other agencies and response services to include, but not be limited to, the following:
4.5.2.3(a)	State and/or local transportation officials.
4.5.2.3(b)	Police departments
4.5.2.3(c)	Highway patrol.
4.5.2.3(e)	Emergency medical services.
4.5.2.3(f)	Environmental protection agencies (e.g. EPA, TCEQ)
4.5.2.3(g)	HAZMAT teams.
4.5.3	HSIR shall include a Communications (COMM) function.
4.5.3.1	COMM shall provide the capability for distress signals to be sent to a focal point.
4.5.3.2	COMM shall provide the capability for relay of distress information to response units in real-time.
4.5.3.3	COMM shall provide the capability for data to be sent from any location covering all areas of the contiguous United States.
4.5.3.4	COMM shall provide the capability for linkages/interfaces with various existing networks
4.5.3.5	COMM shall provide the capability for the motorist to travel from region to region without performing manual adjustment of equipment.
4.5.4	HSIR shall include a HAZMAT Security (HS) function.
4.5.4.1	HS shall include a security sensitive HAZMAT shipment tracking function (HSTF).
4.5.4.1.3	HSTF shall identify when the security sensitive HAZMAT shipment has deviated from the planned route.
4.5.4.1.4	HSTF shall have the capability of identifying sensitive (or geo-fenced) geographic areas.

4.5.4.1.5	HSTF shall identify when the security sensitive HAZMAT shipment has entered a sensitive geographic area.
4.5.4.1.6	HSTF shall include the capability to notify public safety agencies, including those having jurisdiction over the location, when a significant security sensitive HAZMAT route deviation has been detected and verified

Adopted from the National ITS Architecture (1)

Table 11 User Service Requirements for Emergency Notification and Personal Security

USRN	Description
5.1.3	ENPS shall include a Remote Security and Emergency Monitoring (RSEM) function to create an environment of safety in secure areas.
5.1.3.2	RSEM shall include a Surveillance and Sensors (SS) function.
5.1.3.2.1	SS shall provide surveillance and sensor technology and the data processing required to alert operators and appropriate agencies of potential incidents and threats at the Secure Areas.
5.1.3.2.1.2	SS shall provide sensors that may include, but are not limited to acoustic, environmental threat (such as nuclear, biological, chemical, and explosives), infrastructure condition and integrity, motion and object sensors.
5.1.3.2.1.3	SS shall provide data processing based on surveillance and sensor inputs to determine when an anomaly or suspicious activity (vehicle or human) has been detected in the Secure Area and alert the operators, travelers, appropriate agencies and organizations of a security threat.
5.1.3.2.3	SS shall allow operators to verify an alarm.

Adopted from the National ITS Architecture (1)

Table 12 Process Specifications and User Requirement Numbers from the National ITS Architecture

	Process Specification	USRN
2.1.2	Provide Commercial Vehicle Fleet Manager Interface	*4.3.0, 4.3.2, 4.3.2.4, 4.3.2.4.3*
2.1.3	Provide Fleet Manager Commercial Vehicle Communications	4.3.0 , 4.3.2 , 4.3.2.5.1
2.1.5	Manage Driver Instruction Store	4.3.0 , 4.3.3 , 4.3.3.2
2.1.6	Manage Commercial Vehicle Incidents	4.3.0 , 4.3.2 , 4.3.2.4 , 4.3.2.4.3 , 4.3.3 , 4.3.3.2 , 4.3.3.2.7
2.4.2	Collect On-board Commercial Vehicle Sensor Data	4.3.0 , 4.3.2 , 4.3.2.4 , 4.3.2.4.2 , 4.3.3 , 4.3.3.2 , 4.3.3.2.4 , 4.3.3.2.5

2.4.3	Analyze Commercial Vehicle On-board Data	4.3.0 , 4.3.2 , 4.3.2.2 , 4.3.2.4 , 4.3.2.4.1 , 4.3.2.4.2
2.4.4	Provide Commercial Vehicle Driver Interface	4.3.0 , 4.3.2 , 4.3.2.4 , 4.3.2.4.3
2.4.5	Communicate Commercial Vehicle On-board Data to Vehicle Manager	4.3.0 , 4.3.2 , 4.3.2.2
2.4.6	Provide Commercial Vehicle On-board Data Store Interface	4.3.0 , 4.3.2 , 4.3.2.2
2.4.7	Manage CV On-board Data	4.3.0 , 4.3.2 , 4.3.2.4.2 , 4.3.3 , 4.3.3.2 , 4.3.3.2.4 , 4.3.3.2.5
2.4.9	Authenticate Commercial Vehicle Driver	4.3.0 , 4.3.3 , 4.3.3.2 , 4.3.3.2.3
2.7.1	Manage Freight Incidents	4.3.0 , 4.3.3 , 4.3.3.1 , 4.3.3.1.1 , 4.3.3.1.3
2.7.5	Process Freight Integrity Data	4.3.0 , 4.3.3 , 4.3.3.1 , 4.3.3.1.2
2.7.6	Provide Freight Manager Interface	4.3.0 , 4.3.3 , 4.3.3.1 , 4.3.3.1.3
2.7.7	Provide Shipper Booking Interface	4.3.0 , 4.3.3 , 4.3.3.2
5.1.1.2	Identify Commercial Vehicle Emergencies	4.3.0 , 4.3.3 , 4.3.3.2 , 4.3.3.2.7
10	Satisfy Implementation Requirements	4.5.0 , 4.5.3 , 4.5.3.5
2.1.1.3	Provide Commercial Fleet Static Route	4.5.0 , 4.5.4 , 4.5.4.1 , 4.5.4.1.4
2.1.1.4	Provide HAZMAT Incident Support	4.5.0 , 4.5.1 , 4.5.1.2 , 4.5.1.2(c) , 4.5.2 , 4.5.2.3
2.1.1.5	Manage Commercial Vehicle Fleet Map Data	4.5.0 , 4.5.4 , 4.5.4.1 , 4.5.4.1.4
2.1.1.6	Monitor Commercial Vehicle Route	4.5.0 , 4.5.4 , 4.5.4.1 , 4.5.4.1.3 , 4.5.4.1.5
5.1.1.1	Coordinate Emergency Inputs	4.5.0 , 4.5.1 , 4.5.1.1 , 4.5.1.2 , 4.5.1.2(a) , 4.5.1.2(b) , 4.5.1.2(c) , 4.5.3 , 4.5.3.1 , 4.5.4 , 4.5.4.1
5.1.1.3	Collect Incident And Event Data	4.5.0 , 4.5.3 , 4.5.3.1
5.1.2	Determine Coordinated Response Plan	4.5.0 , 4.5.4
5.1.4	Manage Emergency Response	4.5.0 , 4.5.2 , 4.5.2.1 , 4.5.2.2 , 4.5.2.3 , 4.5.2.3(a) , 4.5.2.3(b) , 4.5.2.3(c) , 4.5.2.3(e) , 4.5.2.3(f) , 4.5.2.3(g) , 4.5.3 , 4.5.3.3 , 4.5.3.4 , 4.5.4
5.3.2	Dispatch Vehicle	4.5.0 , 4.5.3 , 4.5.3.2
5.3.7	Provide Emergency Vehicle Route	4.5.0 , 4.5.3 , 4.5.3.2

1.1.4.2	Provide Traffic Operations Personnel Traffic Data Interface	5.1.3
1.3.4.2	Provide Traffic Operations Personnel Incident Data Interface	5.1.3
5.1.1.4.4	Disseminate Threat Info	5.1.3 , 5.1.3.2 , 5.1.3.2.1 , 5.1.3.2.1.3
5.1.1.4.6	Provide Operator Interface for Security	5.1.3 , 5.1.3.2 , 5.1.3.2.1 , 5.1.3.2.1.3

Adopted from the National ITS Architecture (1)

3.6 Applicable ITS Standards

ITS standards describe interconnection and information exchange between ITS systems, products, and components. ITS standards establish communication rules for how ITS devices can perform, how they can connect, and how they can exchange data (7). The use of standards gives transportation agencies confidence that components from different manufacturers will work together, without removing the incentive for designers and manufacturers to compete to provide products that are more efficient or offer more features. ITS standards are

- Voluntary and are not mandated by law.
- Consensus-based, which means the standard has attained general agreement by interested parties and agencies.
- Open, which means these standards are not proprietary.

BIFA also suggests a standards-based approach to integrating systems between U.S. and Mexico. Such integration will facilitate the exchange of transportation-related data in the near-term and more easily accommodate future equipment replacement, system upgrades, and system expansion (7). Table 13 includes a list of ITS standards that are applicable to cross-border HAZMAT monitoring and communications. For a complete list of ITS standards, readers should refer to the U.S. DOT ITS JPO's Standards website (10).

Table 13 List of ITS Standards Applicable to Cross-Border HAZMAT Monitoring and Communications

SDO	Document ID	Type	Title
AASHTO	NTCIP 1201	Message/Data	Global Objects Definitions
	NTCIP 1407	Message/Data	NTCIP Control Center Objects
	NTCIP C2C	Communication Protocol	NTCIP Center-to-Center Standards Group
IEEE	IEEE IM	Message/Data	Incident Management Standards Group
	IEEE Std 1455-1999	Message/Data	Standard for Message Sets for Vehicle/Roadside Communication
	IEEE 1512.3	*Message/Data*	*Standards for Hazardous Material Incident Management Sets for Use by Emergency Management Centers*
	IEEE 1512-2000	Message/Data	Standard for Common Incident Management Sets for Use by Emergency Management Centers
ITE	ITE TM 1.03	Message/Data	Standard for Functional Level Traffic Management Data Dictionary (TMDD)
	ITE TM 2.01	Message/Data	Message Sets for External Traffic Management Center Communication

Note: AASHTO = American Association of State Highway and Transportation Officials, IDE = NTCIP = National Transportation Communications for ITS Protocol, IEEE = Institute of Electrical and Electronic Engineers, ITE = Institute of Transportation Engineers, TMDD = Traffic Management Data Dictionary, SDO = Standards Definition Organization

Among all ITS standards in the Table 13, the standard IEEE *1512.3* is the one that deals primarily with the communication of vital data about cargo and contents of vehicles and buildings involved in transportation-related events (11). It is a companion volume to the base standard, IEEE STD 1512-2000, IEEE Standard for Common Incident Management Message Sets for Use by Emergency Management Centers. The goal of this standard is to support the communication necessary to take the real-world cargo/content information available to personnel supervising the emergency, and use off-site databases to make further information available to that person for efficient management of the emergency. This requires messages that support communication of information that is available to and from off-site databases to accomplish two decision-support functions, which are as following:

- To retrieve further information about what the cargo and/or contents are, based on what are often quite partial cues available on site. That information is available in off-site databases managed by shippers, carriers and Fleet and Freight Management centers; and

- To retrieve information about the characteristics of the cargo and/or contents that is important for incident management, such as toxicity, flammability, danger of explosion, size of a potential toxic plume, environmental damage; recommended set-back distances and evacuation areas.

CHAPTER 4. AVAILABLE TECHNOLOGY

A comprehensive literature review was performed to identify available tools and technologies that could be integrated into the prototype information system. The literature review identified several existing tools used by first responders. The following sections describe the technologies that are readily available and could be employed in the design of the prototype. Most technologies and applications that are mentioned are specifically targeted for first responders.

All the tools and applications mentioned below have capabilities to provide the first responders proper response information about hazardous material and calculations on potential damage concerning the spill. However, during the researcher's conversations with fire departments (usually the early first responders) in the El Paso-Ciudad Juarez region, the Emergency Response Guide was the only tool that was in use. It is assumed that the prototype information system will interact with one or more of these tools and/or applications to determine HAZMAT related parameters, including type of material, proper containment, and response.

4.1 CAMEO®, ALOHA® and MARPLOT®

Computer Aided Management of Emergency Operations (CAMEO®), Areal Locations of Hazardous Atmospheres (ALOHA®) and Mapping Application for Response, Planning and Local Operational Task (MARPLOT®) were developed by the NOAA (National Oceanic and Atmospheric Administration) and U.S. EPA (Environmental Protection Agency). All modules interact to provide first responders proper response information about hazardous material and calculations on potential damage concerning the spill (12), (13), (14). These calculations are displayed in a map. Each of the modules previously mentioned have a specific function. Table 14 provides a description on functionality of the modules.

Table 14 Brief Descriptions of Functions of CAMEO®, ALOHA® and MARPLOT®

Module	Function
CAMEO®	Contains a Chemical Library with approximately 6,000 chemicals. The library also includes 10,000 chemicals synonyms and identification number for faster identification during an incident. Includes a RIDS (Response Information Data Sheets) which includes physical properties, health hazards, information about air and water hazards, and recommendations for firefighting, first aid, and spill response. Provides a Reactivity Worksheet where chemicals can be virtually mixed. This worksheet determines the hazards that could arise if the chemicals are mixed during the incident.
ALOHA®	Calculates the toxicity, flammability, thermal radiation, and overpressure from hazardous materials involved in an incident. These calculations are based on the weather conditions that are input by the user.
MARPLOT®	Is a general-purpose mapping application. The data calculated from ALOHA® is displayed in a map using this application.

The typical usage of CAMEO by first responders during HAZMAT incidents is shown in Figure 10. First, the chemical that is involved in the incident has to be identified. After the name of the chemical has been entered in the CAMEO, the location where the incident is taking place has to be indicated to enable MARPLOT features. In order to enable ALOHA module, certain weather conditions such as; wind speed, ground roughness, cloud cover and air temperature need to be input by first responders. Finally, ALOHA outputs the calculations using MARPLOT module. Figure 11 shows the output that the first responder obtain.

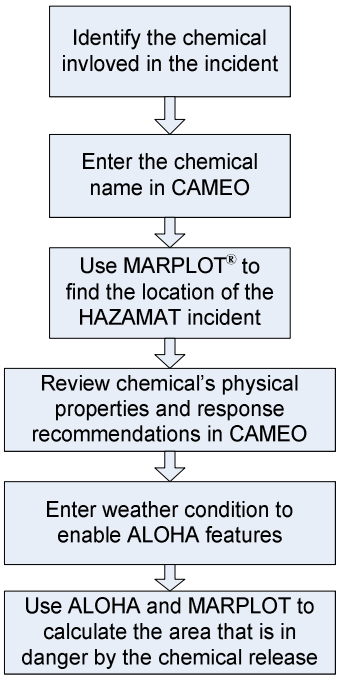


Figure 10 Application of CAMEO®, ALOHA® and MARPLOT® During HAZMAT Incidents

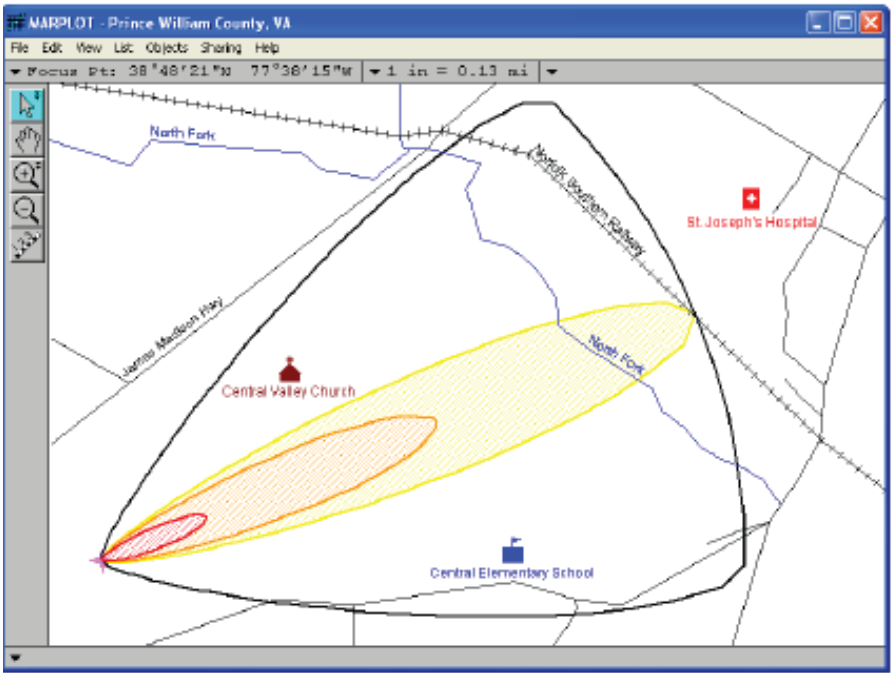


Figure 11 Output of ALOHA Visualized in MARPLOT

4.2 Emergency Response Guidebook 2008

The Emergency Response Guidebook was developed by the U.S. Department of Transportation, Transport Canada and Secretariat of Communications and Transportation of Mexico (6). The purpose of this guidebook is to provide First Responder critical information to control HAZMAT incidents. ERG provides different ways of HAZMAT identification such as Material Name, UN number, placard and transportation container. Once the material has been identified, the proper way to respond to the HAZMAT incident can be obtained. The ERG guidebook also provides the distances to determine the hot, mild, and cold zones. The Emergency Response Guide published in 2004 was available only as hardcopy. ERG 2008 however is also available as a software application and can be installed in Pocket PCs and PC. This software helps first responders by allowing them to focus on the response rather than in properly identifying the page in the ERG guidebook.

4.3 Wireless Information System for Emergency Responders

Wireless Information System for Emergency Responders (WISER) is a system designed to assist fire departments while responding and containing the hazardous material during incidents. WISER is an application that has been developed by the National Library of Medicine (15). It combines the information from different databases such as POISINDEX® System, Chemical Hazards Response Information System (CHRIS), Fire Protection Guide to Hazardous Materials, National Institute for Occupational Safety and Health (NIOSH) pocket guide to Chemical Hazards, Integrated Risk Information System (IRIS), Emergency Response

Guidebook, American Conference of Governmental Industrial Hygienist (ACGIH) Guidelines for the Selection of Chemical Protective Clothing.

WISER provides a wide range of information on hazardous substances, including substance identification support, physical characteristics, human health information, and containment and suppression advice. To aid in decision-making, users can specify the role that is being currently performed at the scene of an incident, and WISER organizes the critical information in a sequence most relevant to the first responder on the scene. The application is available in English and can be downloaded and stored in a laptop. WISER also supports PC- and PDA-based browsers. The web version of the application is also available. Surprisingly, none of the emergency response personnel interviewed during this research including the fire departments in El Paso, Las Cruces, and Sunland Park was aware of the WISER application.

This application is tailored to three categories of first responders, which are basic first responders, HAZMAT specialists, and Emergency Medical Services (EMS) personnel. Some of the features of WISER are the following:

Material identification based on:
- Material Properties
- Symptoms

Categories such as:
- DOT (Department of transportation) Hazard classification
- WMDs (Weapons of Mass Destruction)
- NFPA (National Fire Protection Association) 704 placard
- Transportation placard or container

Electronic versions of Guidebooks such as:
- Emergency Response Guidebook 2008
- WMD Response Guidebook

Triage Procedures:
- START Adults Triage Algorithm
- JumpSTART Pediatric Triage Algorithm

Radiological Tools
- Dose Estimators
- Radiation Unit Converter

Mapping of Protective Distances based on:
- Hazardous Material
- Spill size
- Time of Day
- Wind direction

Reference Material such as:

Emergency contacts
Initial Dose activities
Manual for First Responders
Radiological Terrorism – Emergency Management Pocket Guide for Clinicians

If the location of the spills is known and a connection to internet is available, then WISER can interface with Microsoft® Visual Earth and produce a map with the recommended protective distances. The location of the spill can also be input as street address or latitude/longitude. Figure 12 shows WISER mapping feature displaying protective area for a gasoline related spill.

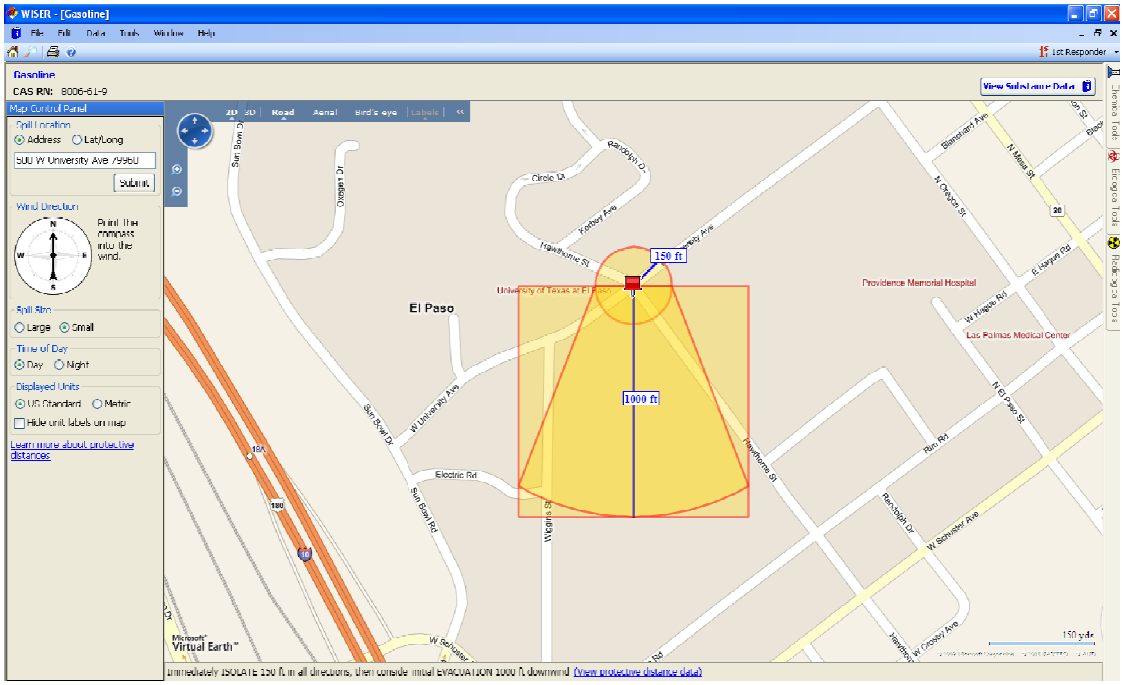


Figure 12 Distance Mapping Feature Provided by the WISER

4.4 TeleGeoMonitoring

TeleGeoMonitoring (TGM) is a discipline that combines the use of different technologies such as Geographical Information Systems (GIS), exchange of information between multiple field devices/sensors/systems, real-time decision support system (16). It is important to notice that the definition of Real Time Decission can vary based on applications. Some applications will consider a Real Time Decission if the time delay is in the miliseconds range. Other applications will still consider a Real Time Decission if the time delay is greater than a minute.

TGM can be classified based on the architecture of the system. The three type of architectures for TGM are centralized, co-operative and federated. Figure 13 Centralized Architecture (16)shows a centralized architecture, in which the data from fixed sensors or mobile sensors installed in vehicles are sent to a control center. The control center processes the data and sends replies to the sensors if necessary. In this type of architecture only the control center knows the status of all the sensors invloved in the system.

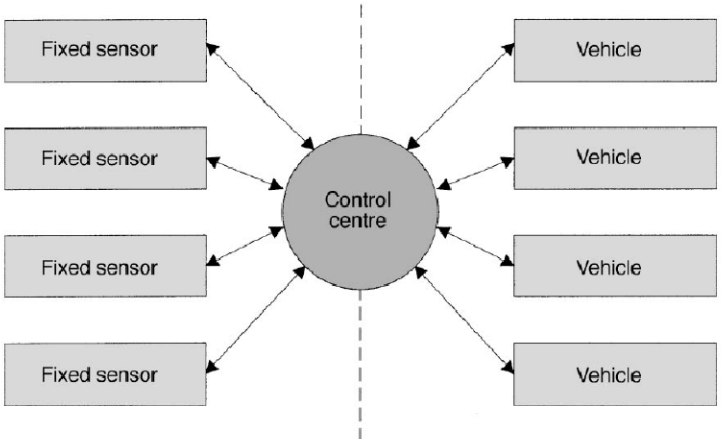


Figure 13 Centralized Architecture (16)

In a co-operative architecture, all entities (sensors, mobile devices etc) involved in the system can share and receive information from each other, as illustrated in Figure 14. Consequently, all entities are aware of the status of the rest of the entities. The network infrastructure for this architecture is more complex compared with a centralize architecture, but in case a failure, the overall system will not shut down completely.

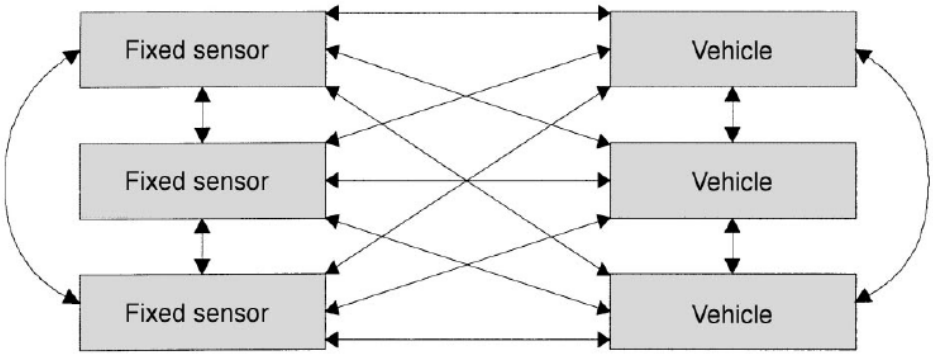


Figure 14 Co-operative Architecture (16)

In a federated architecture, a single entity could be connected to more than one TGM systems. A diagram showing federated architecture is shown in **Error! Reference source not found.**. In this case, TGM system A can be centralized architecture and TGM systems B and C a co-operative systems.

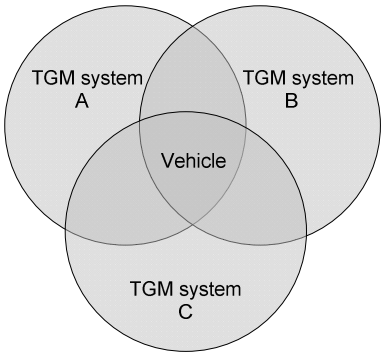


Figure 15 Federated Architecture (16)

4.5 RFID Technology

Radio Identification (RFID) technology is divided in two main categories: passive and active (17). Active devices require an external power source, either a powered infrastructure or an external battery. Passive devices do need power to operate, but obtain power using either magnetic induction or electromagnetic wave capture.

The RFID systems are made up of two main components: the reader and tags. The reader is in charge of interrogating the tags. Typically, tags will only contain a unique binary identifier. Depending on the model of the tag it will have Read only or Read and Write capabilities. In a passive system, the tag will only transmit identification number whenever they are interrogated by the reader. The reading distances of the tags will depend on the technology being implemented by the manufacturer. If using near-field RFID the read distances are in the range of 10 cm-30 cm at most. Far-field technologies will have accurate reading distances of 3 meters (18). Active RFID tags provide a reading distance of 100 meters or more. These reading distances can be achieve since active tags will use their internal battery to transmit their serial number with greater power than passive tags. Active tags continuously transmit its serial number even when their serial number is not required.

RFID tags work over different frequency spectrum. The frequency of operation for active and passive tags are different. Table 15 shows the typical operational frequencies of RFID tag and power characteristics.

Table 15 Classification of RFID by Operational Frequency

Frequency	Passive	Active
125 kHz	Yes	
134 kHz	Yes	
13.56 MHz	Yes	
865 MHz	Yes	
900 MHz	Yes	
433 MHz		Yes
2.45 GHz		Yes

Source: Introduction to RFID technology (18)

4.6 Internet Protocol Interoperability and Collaboration System

Cisco® IP Interoperability and Collaboration System (Cisco IPICS) Server is used to create virtual talk groups (VTGs) to facilitate Push-to-Talk (PTT) communications between different types of technologies of land mobile radios with users of personal computers, landline phones, cellular phones, and Cisco Unified Internet Protocol phones (18).

The Cisco IPICS Server is a security-enhanced, Linux-based platform installed on select Cisco 7800 Series Media Convergence Servers, a family of proven and reliable hardware platforms that can be deployed in mobile command units or in headquarters, branch offices, or operations centers.

Cisco IPICS uses internet protocol standards and network infrastructure for its operation. Personnel at operation centers can interact with the system via the Cisco IPICS Administration Consoles. This console is a Web Base Graphical User Interface (GUI) that allows the user to manage the resources efficiently and provide fast interoperable connections. Figure 16 shows the network capabilities of Cisco IPICS.

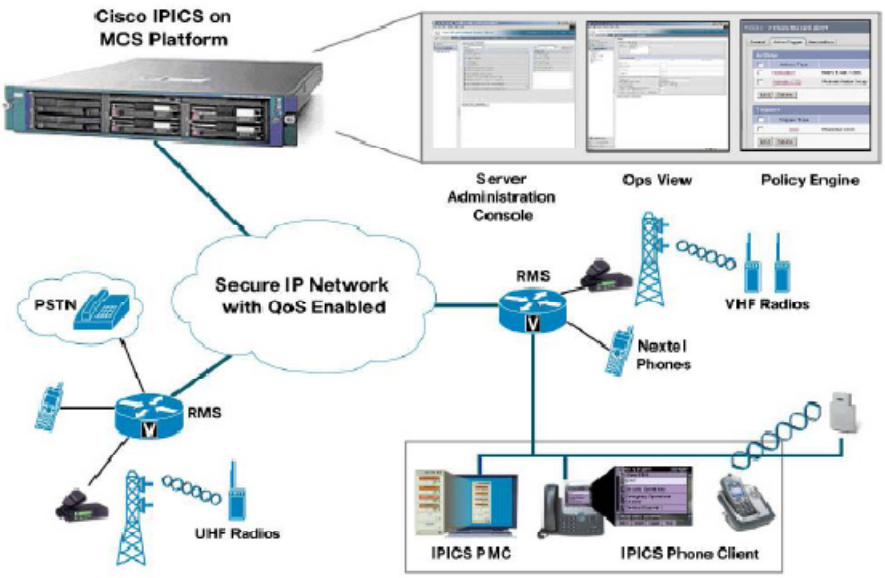


Figure 16 Cisco IPICS Network Capabilities (Cisco Systems Inc., 2008)

CHAPTER 5. PROTOTYPE SYSTEM

5.1 Background

Current practices for cross-border hazardous materials and emergency response related to HAZMAT incidents where analyzed to develop the prototype information system. The analysis showed that carriers in Ciudad Juarez need to send an electronic version of the truck manifest (usually called e-Manifest), through the Automated Commercial Environment (ACE) portal from the Customs and Border Protection, at least 24 hours before attempting to clear Ysleta Port of Entry facilities.

The e-manifest contains information regarding; truck, trailer's cargo, and truck driver information. When a carrier is transporting HAZMAT, besides the e-manifest sent to CBP, the truck driver must have a hard copy of the truck manifest in the trailer at all times. The reason for having a hard copy of the manifest is that in case of a HAZMAT incident, the truck driver is able to inform first responders the type of materials that are present in the cargo area.

As mentioned in Chapter 2 by the Fire Departments in El Paso, Ciudad Juarez and Sunland Park, the actual problem with HAZMAT incidents is that they don't have any information about the material or materials present in the incident until they arrive to the site of the incident. Another need identified was that they are still using a hard copy of the Emergency Response Guidebook when attending HAZMAT incident, even though a free downloadable version of ERG is available at the Pipeline and Hazardous Materials Safety Administration. The electronic version of the ERG can be installed on PC, laptop and some smart phones. Another available software tool for HAZMAT emergency responders is the Wireless Information System for Emergency Responders, an overview of the tool is presented in chapter 3.

In the United States as well as in Mexico, emergency management centers can be contacted by dialing a dedicated telephone number. The emergency number in the United States is 911 and in Mexico 066. During the last years, EMCs have been enhanced their systems. As an example, most of the 911 EMC in the United State have been upgraded to comply with Enhanced 911 (E 9-1-1) specifications. These capabilities include the possibility to determine the location of a caller using the voice over internet protocol (VoIP) and wireless technology within a range of less than 125m.

The next enhancement to the emergency management center in the United States will be the Next Generation 911 (NG 9-1-1) system, which will support data transfer and multimedia transmissions. EMCs in Mexico do not have data transfers or multimedia transmission either, but they have been upgrading their systems by installing surveillance technology, which suggest that they keep enhancing their EMCs.

The design of the information system is based on the research of actual technologies and emerging technology, IEEE 1512.3Standard for Hazardous Material Incident Management Message Sets, stakeholder needs analysis and National ITS functional requirements. The description of the system is described using two types of architectures; logical and physical. The architectures are described at a high level and low level. The logical architecture is presented

using Unified Modeling Language (UML) diagrams and the physical architecture uses network based diagrams.

5.2 Objectives and Scope of the System

The main goal of the system is to determine if an incident has occurred during HAZMAT transportation. If an incident is detected, proper regional emergency management center, (either in the U.S. or Mexico) will be contacted by the HAZMAT carrier through a data transfer communication device installed in the cargo area. In addition, crucial incident information will be relayed to first responders by the EMC to facilitate the incident mitigation. Moreover, the information system integrates software tools to help first responders manage the HAZMAT incident in an effective manner.

5.3 Assumptions and Constraints

The proposed system design assumes the following:

- The carrier has access to HAZMAT routes and HAZMAT information databases;
- The EMCs has the capability to receive data transfers (e.g. e-mails and text messages); and,
- The EMCs will have access to WISER software tool.

The system's main constraint is the inability to validate the identity of the truck driver appointed in the e-manifest.

5.4 Logical and Physical Architecture

The logical architecture of the system is presented using a block diagram and UML diagrams, which are used to visualize complex systems using standardized diagrams (e.g., Use Case diagrams, Activity diagrams, Class Diagrams, etc). For the purposes of this project and due to time constraints, only Use Case and Activity Diagrams where utilized to describe the logical architecture of the information system.

A Use Case diagram shows the interaction between systems and users, system boundaries and the processes that are involved in the system. This type of diagram also allows indicating the interaction between processes. The limitation with Use Case diagram is that it is not possible to determine how each process is being carried out. However, this limitation is solved by integrating Activity diagrams to the logical architecture of the system. The main objective of Activity diagrams is to show the steps needed to carry out a process. In order to describe each step accurately, additional Activity diagrams are presented.

In addition to the Use Case and Activity diagrams, results to be achieved by an individual component of the system was mapped to the National ITS User Service Requirement Number, which are listed in Chapter 4. The high level description of the physical architecture includes networking based diagrams that show the data flow between subsystems and the type of equipment that are needed for the development of the information system. At the low-level

description, the best location for the installation for each sensor and interfaces for data transfers are specified.

5.5 Logical Architecture of the System

5.5.1 High-Level Architecture

The prototype information system was divided into four subsystems: Programming Parameters Acquisition and Transmission Subsystem, Trailer Monitoring Subsystem, HAZMAT Incident Notification Subsystem, and HAZMAT Incident Response Subsystem. In order to provide a better understanding each subsystem was divided into different components. The block diagram in Figure 17 shows the high-level logical architecture of the prototype information system. It also shows the data flow between subsystems and components. Finally, for each component contains a brief description of their task.

The initialization of the systems occurs after the truck manifest data is submitted at the ACE portal, therefore creating an e-manifest of the truck. The creation of e-manifest enables HAZMAT carriers to create an electronic version and hard copy of the truck manifest. The electronic version of the e-manifest should be loaded to a programming parameter definition program. The program, based on the data from the e-manifest, will obtain the maximum allowed sensor's thresholds for HAZMAT transportation, HAZMAT transportation route, and geo-fence parameters. These parameters are the programming parameters required to configure the Trailer Monitoring Subsystem.

After the programming parameters have been acquired, a transmission file will be created. The transmission file consists of the programming parameters and an electronic copy of the e-manifest. The transference of the transmission file from the Programming Parameters Acquisition and Transmission Subsystem to the Trailer Monitoring Subsystem needs to be carried over a secure wired communication link, to avoid unauthorized users intercept the data. After the communication link has been established and secured, the transference of the file to the Trailer Monitoring Subsystem should initiate.

The Trailer Monitoring Subsystem should be responsible for monitoring the trailer cargo area during transportation for any HAZMAT incidents such as; HAZMAT spills, fire in the cargo area, trailer rollover or crash, missing HAZMAT, and trailer going off route. The programming parameters will be used to set the maximum allowed environmental conditions inside the trailer cargo area and set the geo-fence. The Trailer Monitoring Subsystem should poll sensor's readings constantly and based on the readings determine if a HAZMAT incident has occurred.

The detection of a HAZMAT incident should trigger the creation of the HAZMAT incident notification message by the Trailer Monitoring Subsystem. The notification message should be transferred to the HAZMAT Incident Notification Subsystem. This subsystem will be in charge of distributing the HAZMAT incident notification message to the proper EMC, HAZMAT carrier, and the truck driver. The HAZMAT Incident Response Subsystem should be initialized once the proper EMC receives the HAZMAT incident notification message.

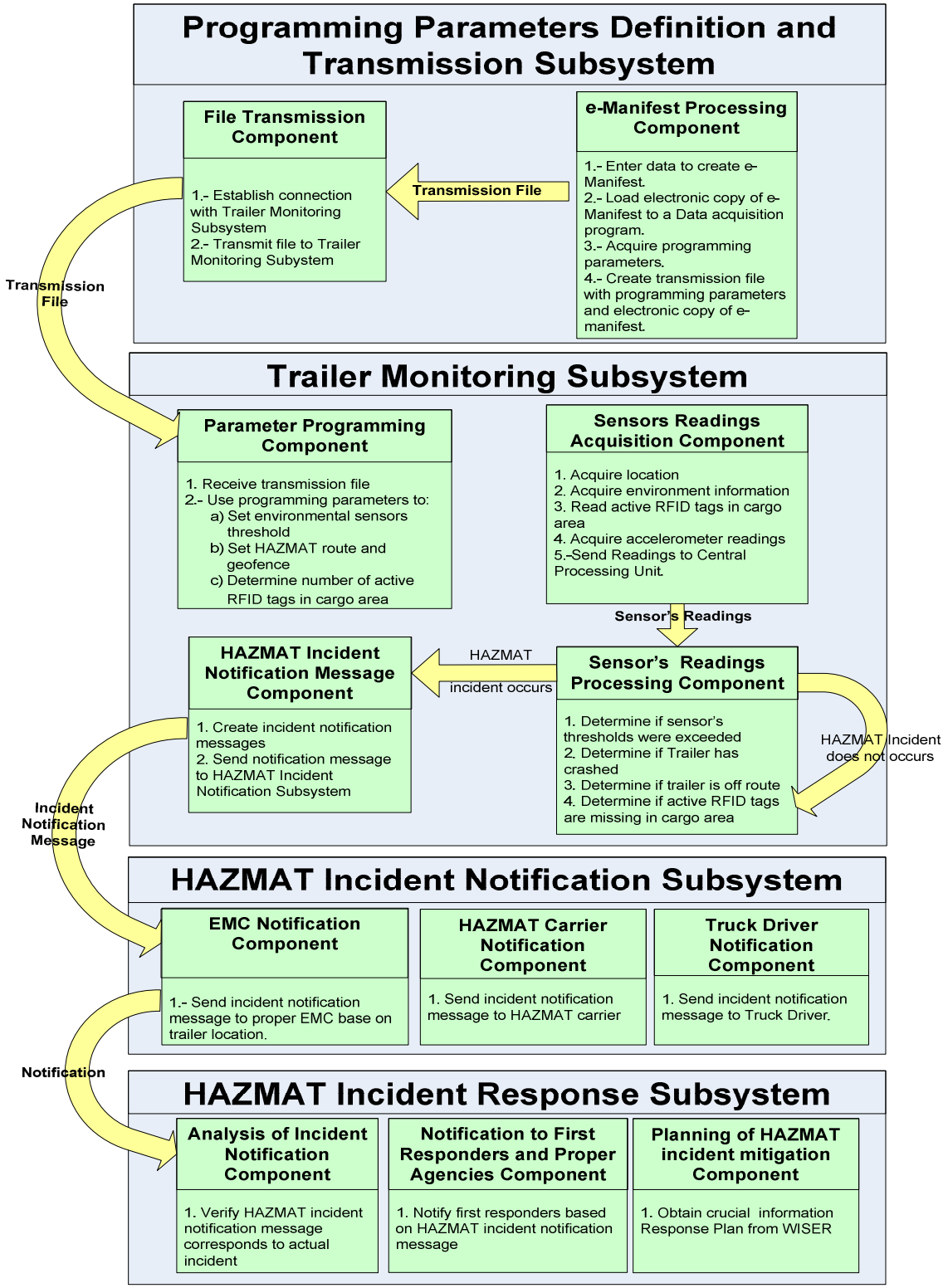


Figure 17 High-Level Architecture of Prototype Information System for Cross-Border HAZMAT Transportation

At the emergency management center, the dispatcher or the recipient of the incident notification message should verify that the message correspond to an actual HAZMAT incident (e.g. the sensor's thresholds have been exceeded or the truck has exceed the geo-fence). After verification, first responders will be dispatched to the scene of the HAZMAT incident. The dispatcher shall have the option of sending the on-scene commander detailed information regarding the HAZMAT involved in the incident using WISER software tool. The dispatcher should also have the capability to connect different first responder's communication devices to provide faster and more efficient communication between agencies and first responders.

5.5.2 Programming Parameters Definition and Transmission Subsystem

At least 24 hours before a trailer attempts to cross at the land port of entry, the carrier has to submit trailer, cargo, and driver information at the ACE portal to create the truck's e-manifest. The Programming Parameters Acquisition and Transmission Subsystem use this HAZMAT transportation requirement as its starting point. Another requirement for HAZMAT transportation is to have a hard copy of the truck manifest in the truck's cabin at all times. Therefore, once the e-manifest has been submitted, the HAZMAT carrier needs to create an electronic version and a hard copy of the manifest. The hard copy should be place inside the truck's cabin and the electronic version should be loaded to the programming parameter definition program.

The programming parameters definition program should obtain information regarding the HAZMAT present in the cargo area. The required information to be determined from the e-manifest is:

- Name of all HAZMAT to be transported;
- Number of barrels, card boxes and pallets present in the cargo area;
- Origin and destination of HAZMAT truck; and,
- Information regarding trailer (e.g. make, model, color, etc.) and truck driver.

Once the necessary information has been acquired from the e-manifest, the program will access the HAZMAT information and HAZMAT routes databases. This step will allow the program to determine the maximum allowed environmental conditions inside the cargo area, HAZMAT route and geo-fence parameters that will be used to configure the Trailer Monitoring Subsystem. The acquisition of the programming parameters should enable the creation of a text file containing the configuration data. The final step should be the creation of a transmission file. The transmission file will contain the text file and the electronic version of the e-manifest. This transmission file should be send to the Trailer Monitoring Subsystem through a secure wired communication link. Figure 18 and Figure 19 show the Use Case diagram and the Activity diagram for the Programming Parameter Definition and Transmission Subsystem

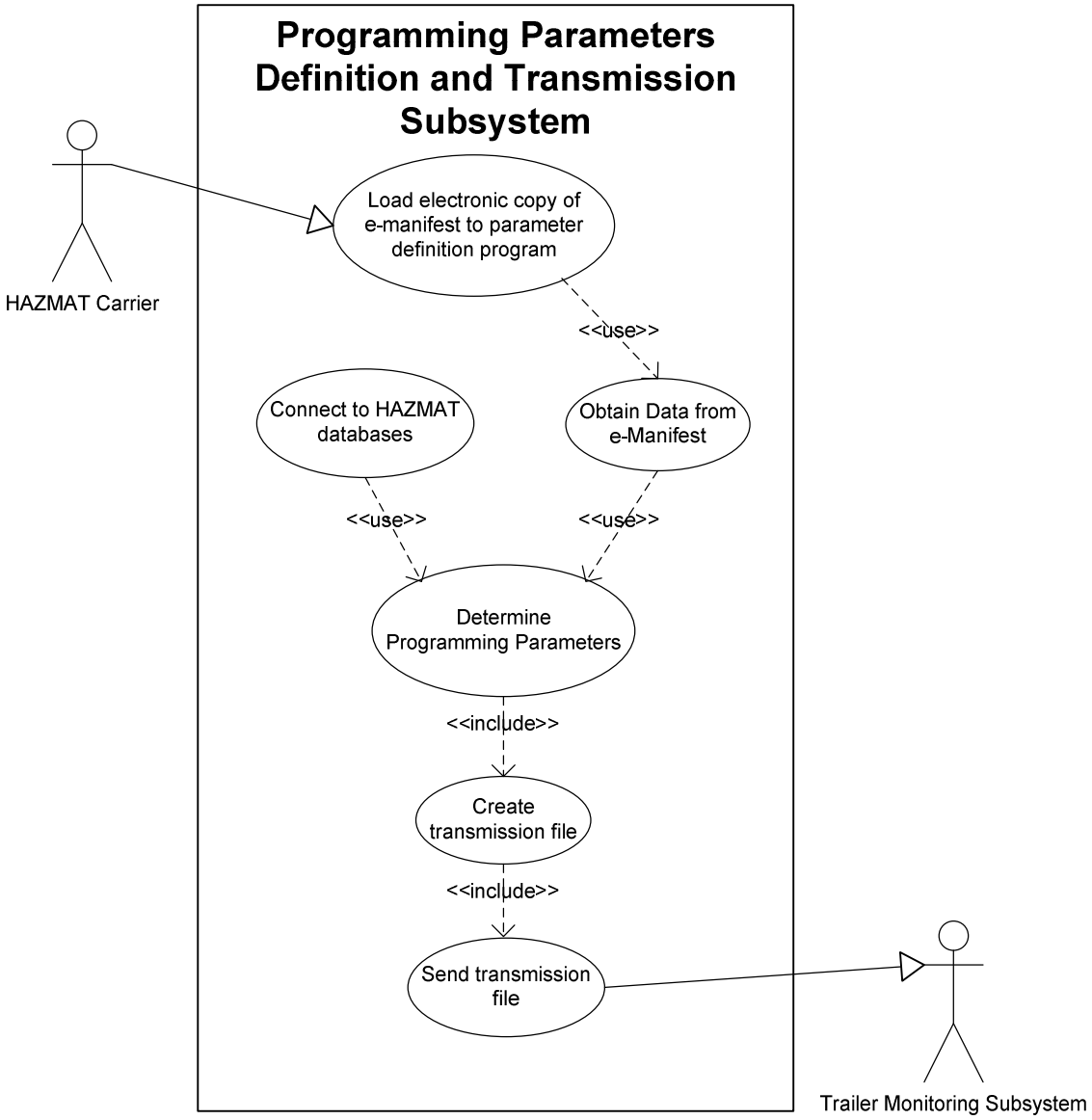


Figure 18 Use Case for Programming Parameters Definition and Transmission Subsystem

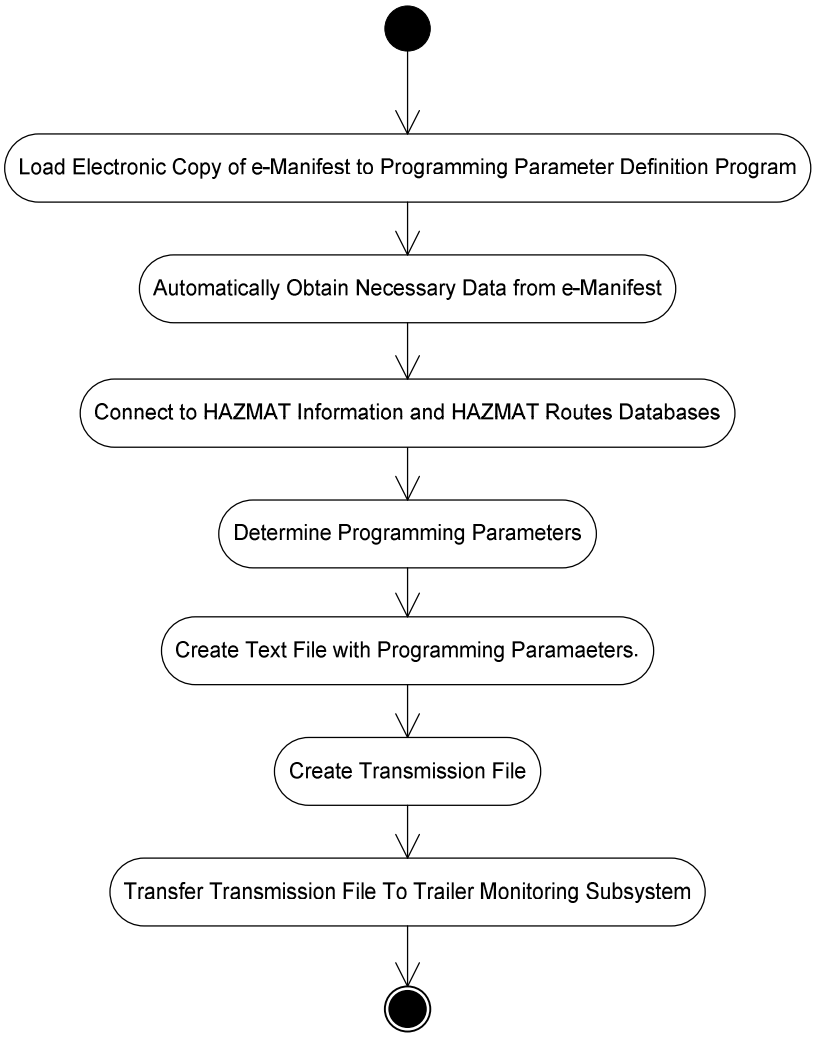


Figure 19 Activity Diagram for Programming Parameters Definition and Transmission Subsystem

Load Electronic Copy of e-Manifest to Programming Parameter Definition Program

The programming parameters definition program should be able to read the electronic version of the e-Manifest. The HAZMAT carrier should load the e-manifest to the programming parameters definition program. Currently, the e-manifest file is in a Portable Document File format. Therefore, program should be able to acquire information from a PDF.

National ITS USRN satisfied: 4.3.3.2.2

Automatically Obtain Necessary Data from e-Manifest

The e-Manifest Processing Component will read the e-Manifest, extract data, and store the necessary pertinent information (e.g. information on truck drivers, content of the shipment),

as illustrated in Figure 20. The Trailer Monitoring Subsystem will be monitoring the presence of HAZMAT barrels and card boxes in the trailer cargo section using RFID technology. Therefore, the quantity of Active RFID tag in the trailer needs to be determined based on the information in the e-manifest.

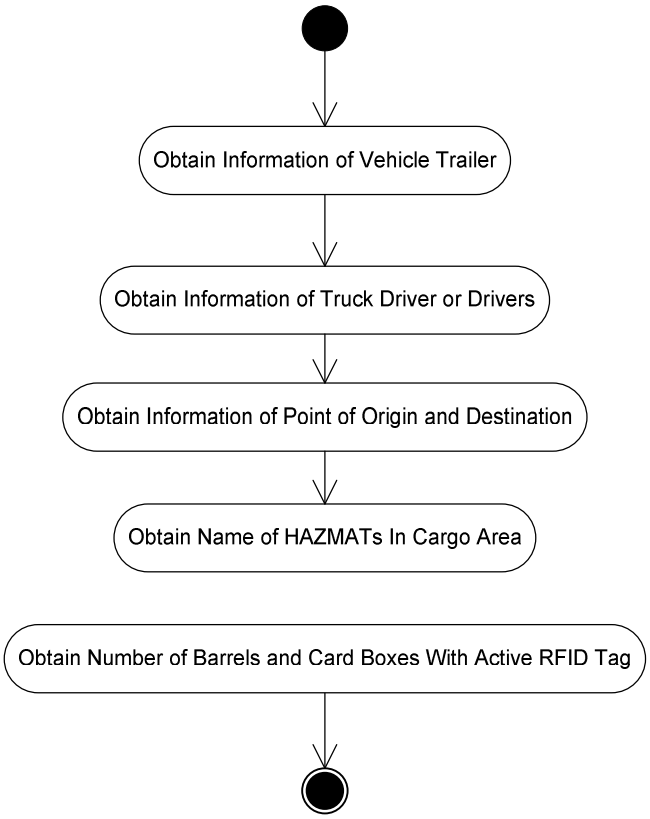


Figure 20 Activity Diagram for Automatically Obtain Necessary Data from e-Manifest

Connect to HAZMAT Information and HAZMAT Routes Databases

The Programming Parameter Definition subsystem will have access to two databases, which will reside at the HAZMAT carrier facilities. The HAZMAT information database will be the provide data related to the maximum allowed environmental conditions inside the trucks cargo area. This database can be the one provided when installing the electronic version of the Emergency Response Guidebook. The HAZMAT route database will provide the best routes available for HAZMAT transportation, based on the point origin of the HAZMAT truck and in the destination.

Determine Monitoring Parameters

Based on the information acquired from the databases the thresholds values for the sensors will be determined. In the case, that two or more HAZMAT is being transported, and then it has to be analyzed which material is more susceptible to any environmental change. Based on that analysis the maximum sensor's threshold will be determined. As shown in Figure 21, in case that a HAZMAT was not found in the HAZMAT information database the HAZMAT carrier will have to input the thresholds manually.

The final step before the creation of the text file with the programming parameters is to determine the route for HAZMAT transportation. The program will be able to determine the best route for HAZMAT transportation. Based on the HAZMAT route a geo-fence will be created around route. The geo-fence will allow the driver to deviate from the original route in case of an accident, but will send an alarm if the trailer goes off the geo-fence. Therefore, also based on the HAZMAT route there will be determined where the truck can be parked for long periods (e.g. land ports of entry, rest areas, etc). The complete process for determining the route, geo-fence and long-period parking location is shown in Figure 21.

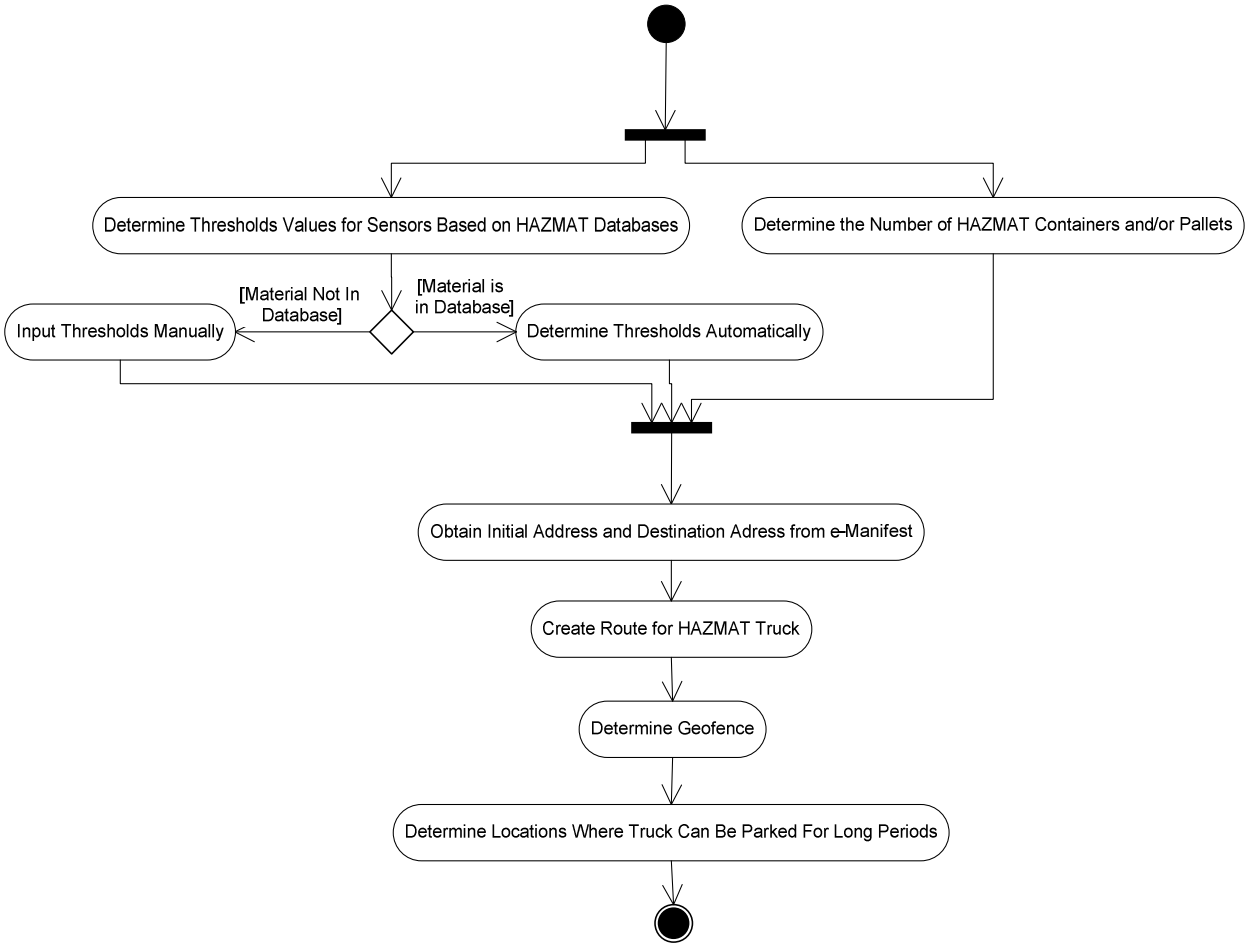


Figure 21 Activity Diagram for Determine Monitoring Parameters

Create Text File with Programming Parameters

All the programming parameters need to be included in a text file that will be send to the Trailer Monitoring Subsystem. These programming parameter include:

- Maximum allowed environmental sensor's thresholds;
- HAZMAT route;
- Geo-fence; and
- Location where trailer can be parked for long periods.

Create Transmission File

The transmission file consists of the text file with the programming parameters and a PDF that contains a copy of the e-manifest.

National ITS USRN satisfied: 4.3.3.2.2

Transfer Transmission File to Trailer Monitoring System

The transmission file needs to be transfer over a secure communication link, to avoid unauthorized users obtaining information of the HAZMAT shipment.

National ITS USRN satisfied: 4.3.3.2.2

5.5.3 Trailer Monitoring Subsystem

The Trailer Monitoring Subsystem will receive the transmission file from the Programming Parameters Definition and Transmission Subsystem. These programming parameters will allow the subsystem to set the thresholds of the environmental sensor, set the HAZMAT route, and geo-fence, and specify the number of active RFID tags present in the cargo area. The main objective of the Trailer Monitoring Subsystem is to be able to detect the following HAZMAT incidents:

- Detect if the HAZMAT truck is off route;
- Detect if a HAZMAT spills is occurring;
- Detect if the cargo area has the appropriate environmental condition for HAZMAT transportation;
- Detect if a fire is present in the cargo area;
- Detect if HAZMAT is been remove from the cargo area; and
- Detect if HAZMAT truck has crashed or roll over.

In case that any of the previously mentioned incident is detected, the Trailer Monitoring Subsystem should create a HAZMAT incident notification message and send it to the HAZMAT Incident Notification Subsystem. The incident notification message will be created following the IEEE 1512.3 Standard for Hazardous Material Incident Management Message Sets for Use by Emergency Management Centers. The Use Case for the Trailer Monitoring Subsystem is shown in Figure 22.

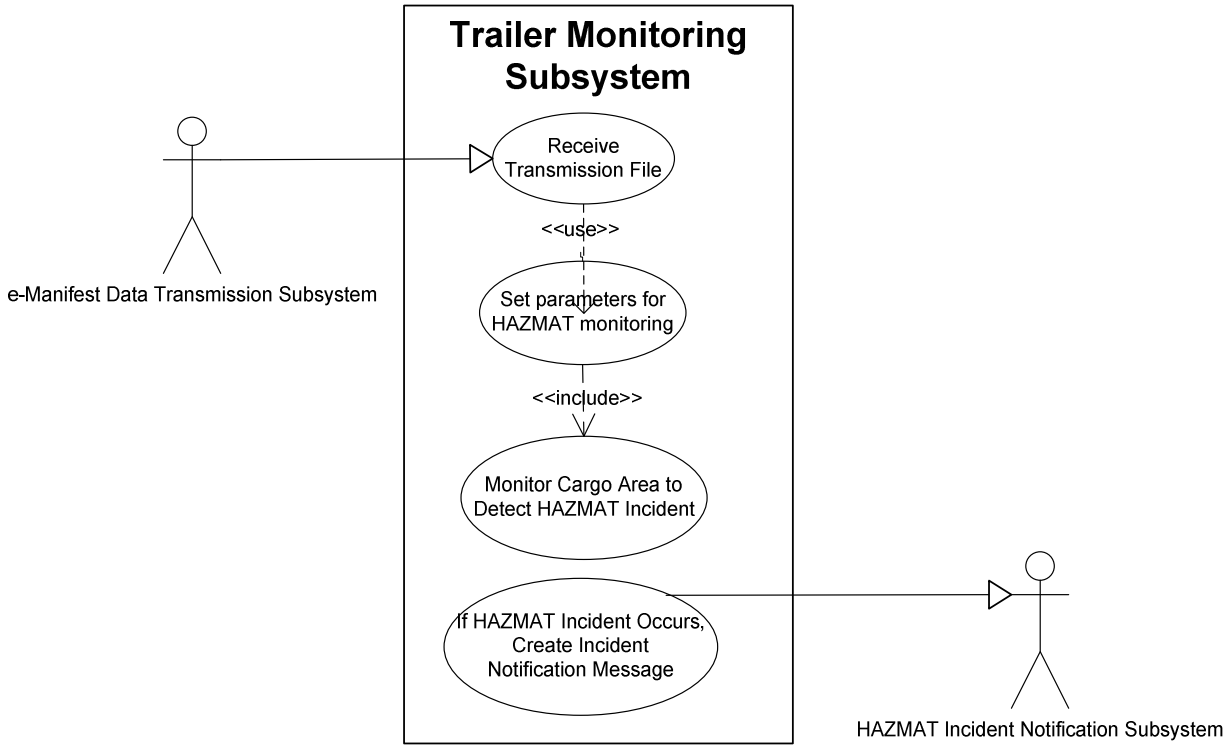


Figure 22 Use Case for Trailer Monitoring Subsystem

The Trailer Monitoring Subsystem will remain in monitoring state until an incident is detected or the HAZMAT truck arrives safely to its destination. Figure 23, shows the activities that needs to carried out in order to set thresholds, detect HAZMAT incidents and create HAZMAT incident notification message.

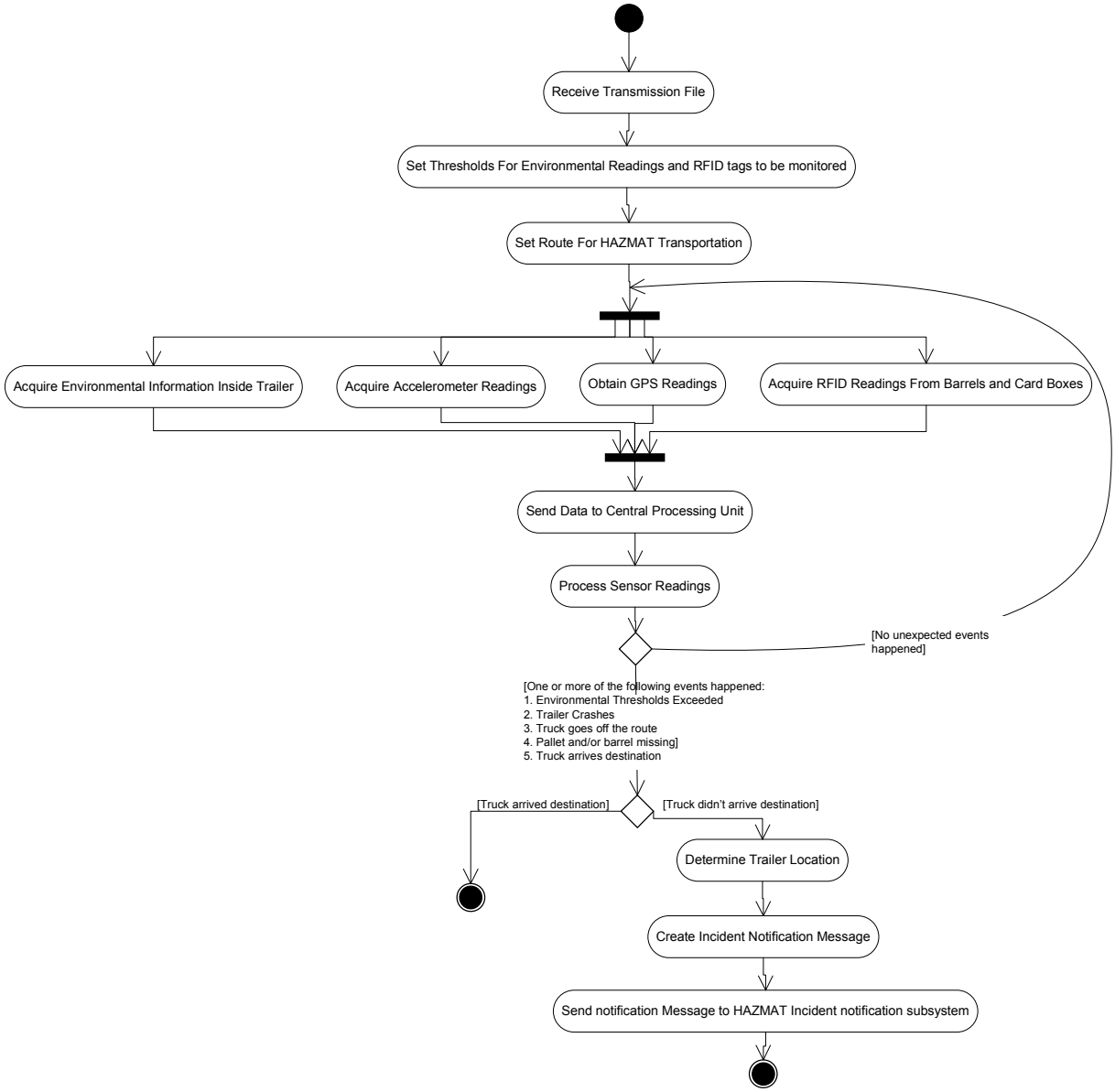


Figure 23 Activity Diagram for Trailer Monitoring Subsystem

Receive Transmission File

The reception of the e-Manifest Data will be carried out as shown in Figure 24.

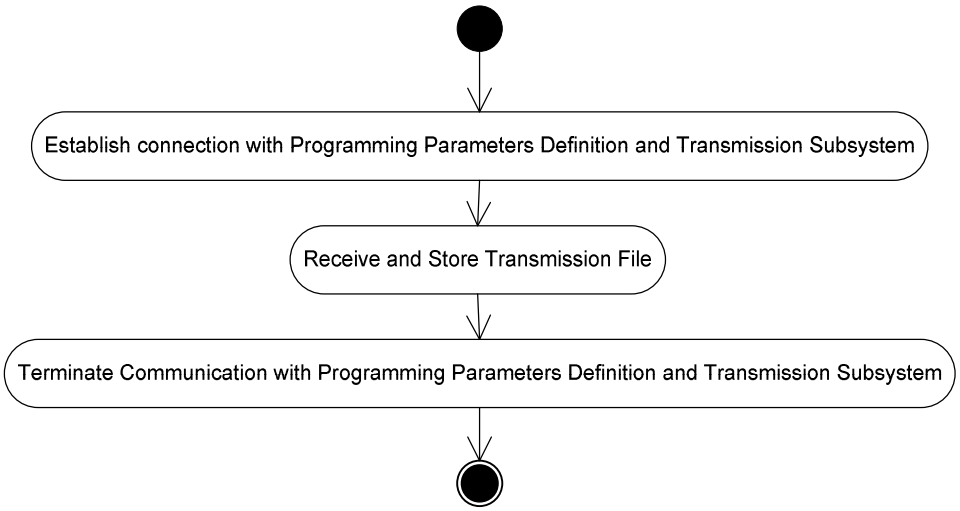


Figure 24 Activity Diagram for Receive Transmission File

Set Thresholds for Environmental Readings and RFID tags to be monitored

The thresholds for the sensors will be based on the text file containing the programming parameters in the transmission file. The sensors that will be programmed are temperature, radiation, humidity, and pressure sensors. The number of active RFID tags in the cargo area, also need to be programmed.

National ITS USRN satisfied: 4.3.2.4.1

Set Route for HAZMAT Transportation

The geo-fence parameters will be sent to the GPS system to monitor if the truck is on route. The locations where the truck can be parked for long period will also be programmed with the parameters contained in the transmission file.

National ITS USRN satisfied: 4.3.2.5.1

Acquire Environmental Information inside Trailer

This process involves obtaining reading from each sensor and sending the reading to the Central Processing unit for further analysis. The order in which each sensor reading will be acquired is shown in Figure 25.

National ITS USRN satisfied: 4.3.3, 4.5.4, 5.1.3.2.1.2,

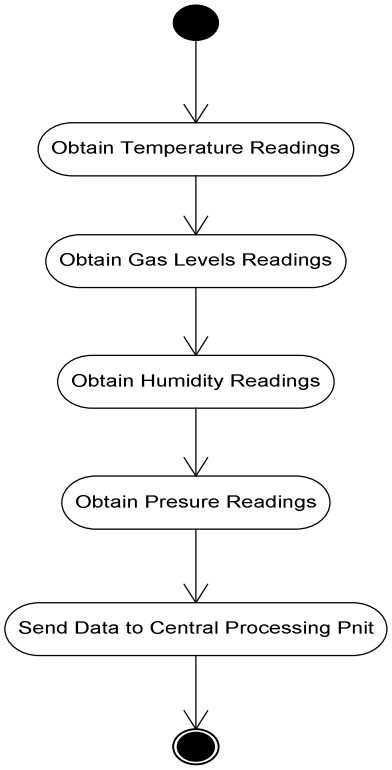


Figure 25 Activity Diagram for Acquire Environmental Information inside Trailer

Acquire Accelerometer Readings

The accelerometer reading will be use to determine if the truck has been involved in a crash or if a rollover has occurred. The reading will be send to the Central Processing unit to be processed. The two measurement provided by the accelerometer are tilt reading and acceleration, these reading will be obtained in the sequence shown in Figure 26.

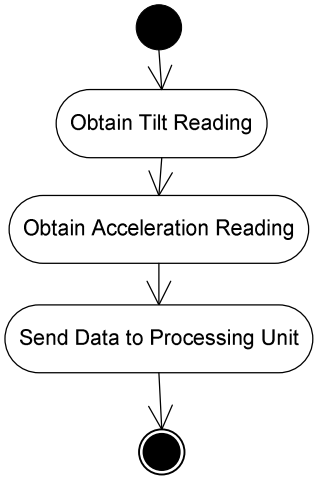


Figure 26 Activity Diagram for Acquire Accelerometer Readings

Obtain GPS Readings

The GPS will verify that the trailer has not gone off route based on the geo-fence parameters. The readings only readings that will be obtained by the GPS are longitude and latitude. The reading will be obtained in the sequence shown in Figure 27.

National ITS USRN satisfied: 4.3.2.5.1, 4.5.4.1.3.

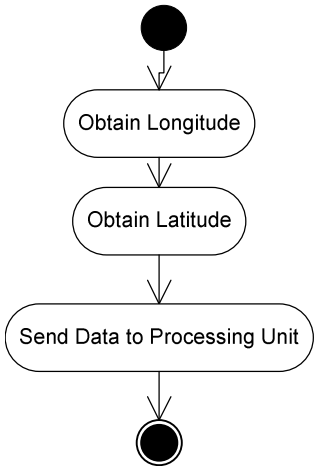


Figure 27 Activity Diagram for Obtain GPS Readings

Acquire RFID Readings from Barrels and Card Boxes

The RFID reading will be utilized to verified that the barrels and card boxes containing HAZMAT has not been extracted from the cargo area. Since the RFID reader are able to pick up any RFID signal that operate in the same frequency, the data needs to be filtered before sending it to the central processing unit. The process is shown in Figure 28.

National ITS USRN satisfied: 4.3.3.1.1, 4.3.3.1.2

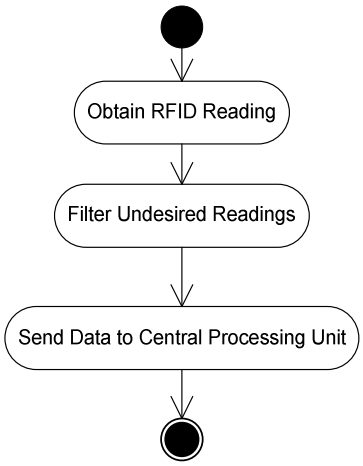


Figure 28 Activity Diagram for Acquire RFID Readings from Barrels and Card Boxes

Send Data to Central Processing Unit

The sensor data acquisition rate will depend on the type of power supply for the Trailer Monitoring Subsystem. If the power supply for the system is provided by the truck then the rate will be as fast as the central processing unit can receive readings, without compromising the sensors readings. In case that the Trailer Monitoring Subsystem is running on battery based power supply the data acquisition rate will need to be determined to maximize the battery charge and still provide reliable monitoring capabilities.

Process Sensors Readings

The processing unit will be in charge of determining the following conditions:

- Environmental sensor readings have not gone over sensor's thresholds;
- Trailer has been in a crash or rollover accident;
- Trailer has gone off route;
- Barrel or card box is missing in cargo area; and,
- Truck has arrived to destination.

The process to determine if any of the previously mentioned conditions have occurred is shown in Figure 29. The Sensor's Readings Processing Component will continue in monitoring state until one or more the previous mentioned conditions occur. The only condition that will turn off the Trailer Monitoring Subsystem is if the truck arrives to its destination. If other condition has been detected then the Trailer Monitoring Subsystem will send a HAZMAT incident notification message to the HAZMAT Incident Notification Subsystem.

National ITS USRN satisfied: 4.5.4.1.1, 4.5.4.1.5, 4.5.4.1.6, 5.1.3, 5.1.3.2, 5.1.3.2.1, 5.13.2.1.3

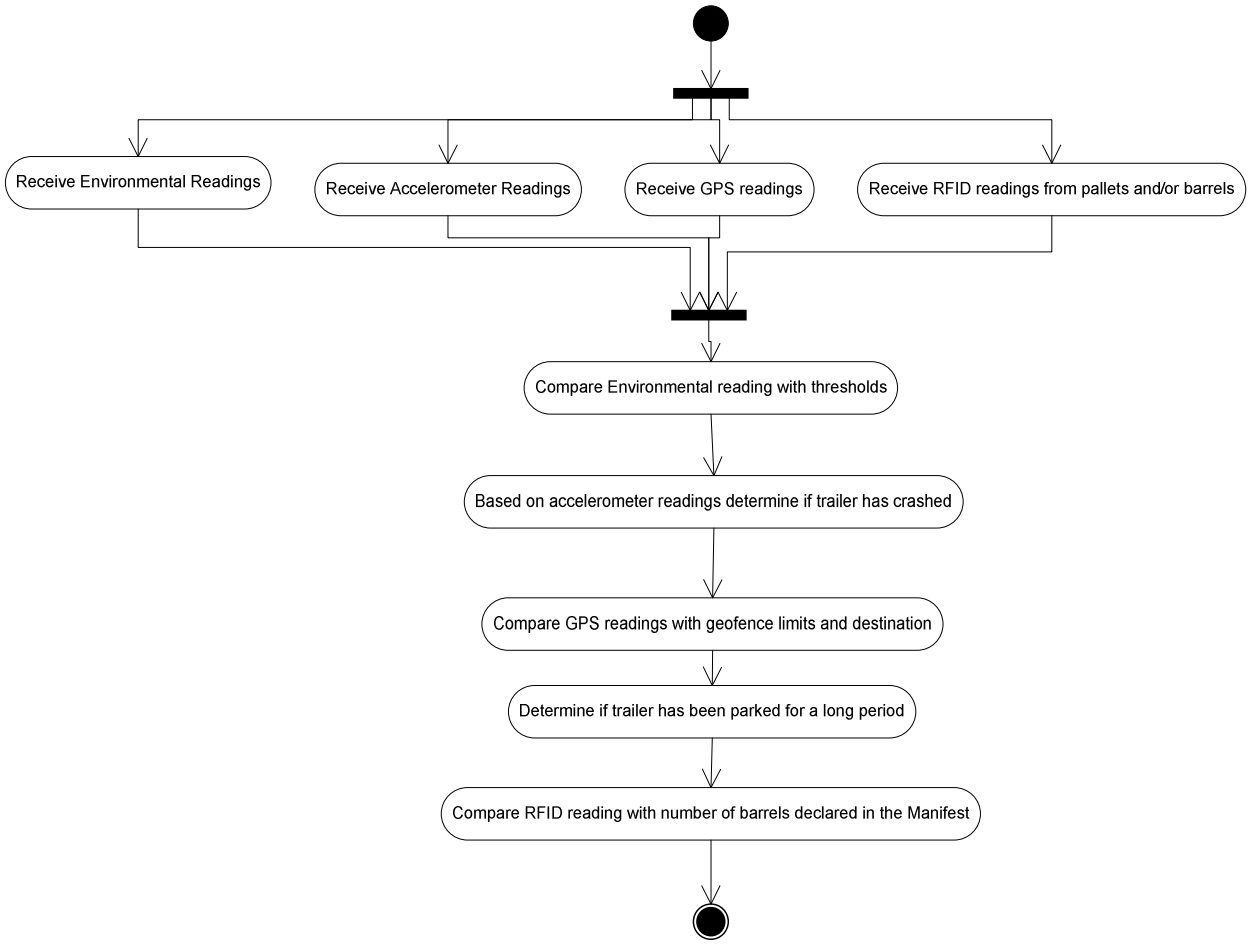


Figure 29 Activity Diagram for Process Sensors Readings

Determine Trailer Location

Depending on the trailer location, different emergency management centers need to be contacted, therefore, the Trailer Monitoring Subsystem needs to determine if the trailer is within the U.S. or Mexican boundaries. Figure 30 shows the information needed to contact the proper EMC.

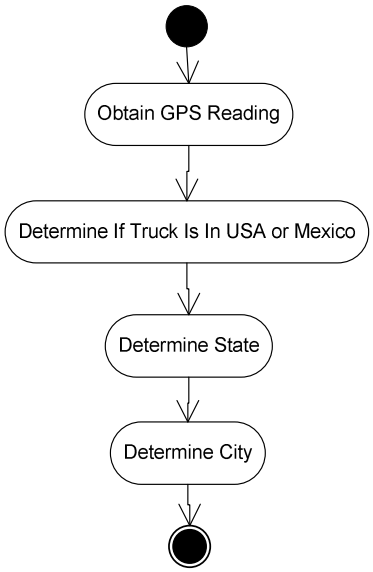


Figure 30 Activity Diagram for Determine Trailer Location

It is important to determine the city because in actuality the EMC (911 in the U.S. or 060 in Mexico) first task of the dispatcher, when contacting them through wireless technology, is to verify that the call has been routed to the proper EMC. In case that there was an error, the call will be transferred to the proper EMC. This problem will be fixed when NG 911 is implemented since the location of wireless communication devices will require to provide accurate GPS readings (Research and Innovative Technology Administration 2005).

Create Incident Notification Message

The creation of the Incident Notification message was designed using the IEEE 1512.3 standard. The process to create the message is shown in Figure 31. This message will be transmitted as a PDF file to the HAZMAT Incident Notification Subsystem. The Incident Notification Message needs to be created in both languages since truck drivers that cross the trailers to the United States not always speak English. Therefore, depending on the trailer's location the message will be transmitted in different language. The notification process is explained in detail in the Incident Notification Subsystem.

National ITS USRN satisfied: 4.5.1.2, 4.5.1.2(a), 4.5.1.2(b), 4.5.1.2(c)

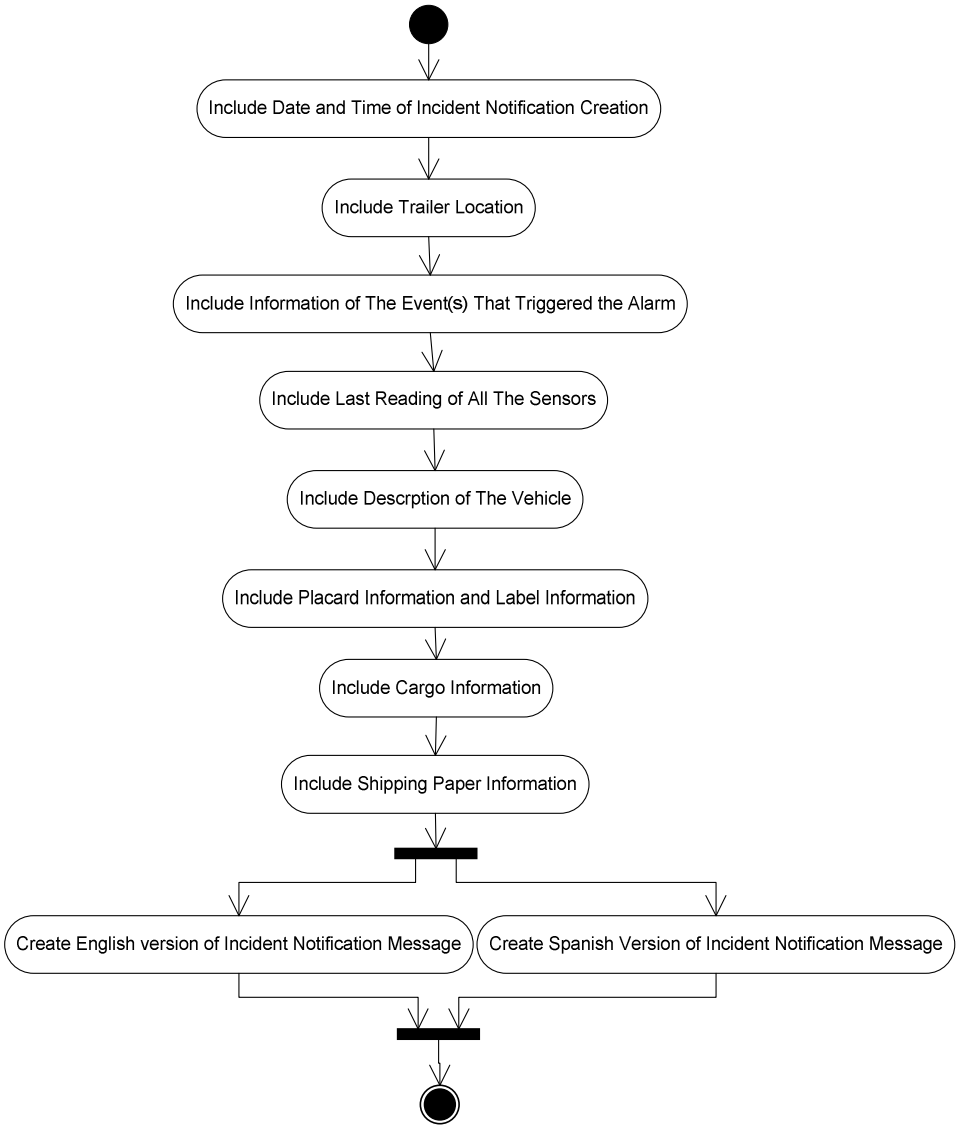


Figure 31 Activity Diagram for Create Incident Notification Message

Send notification Message to HAZMAT Incident Notification Subsystem

Both versions of the Incident Notification Message will be sent to HAZMAT Incident Notification Subsystem for proper distribution.

5.5.4 HAZMAT Incident Notification Subsystem

After the incident notification message has been created by the Trailer System, the HAZMAT Incident Notification System will be in charge of delivering the message to the HAZMAT Carrier, truck driver, and Emergency Management Center, as shown in Figure 32. The transference of the incident notifications will be implemented using wireless technology (e.g. GPRS or 3G).

As identified in Chapter 1, HAZMAT carriers and truck drivers have capabilities of receiving notification, through their cellular phones in PDF. In case of the EMC in United States boundaries, the HAZMAT Incident Notification Subsystem will take advantage of the features of NG 9-1-1, described in Chapter 3. The Notification Subsystem will take advantage of the data transfer capabilities on NG 9-1-1.

Mexican Emergency Management Centers have a system comparable to the Basic 9-1-1 system. They are able to receive phone calls and they will dispatch Emergency Response Units using a Radio Operating System. In order for Mexican Emergency Management Centers to receive HAZMAT Incident Notification Messages they will need to upgrade their system with similar capabilities of NG 9-1-1 in order for them to receive data transfers from the HAZMAT Incident Notification System.

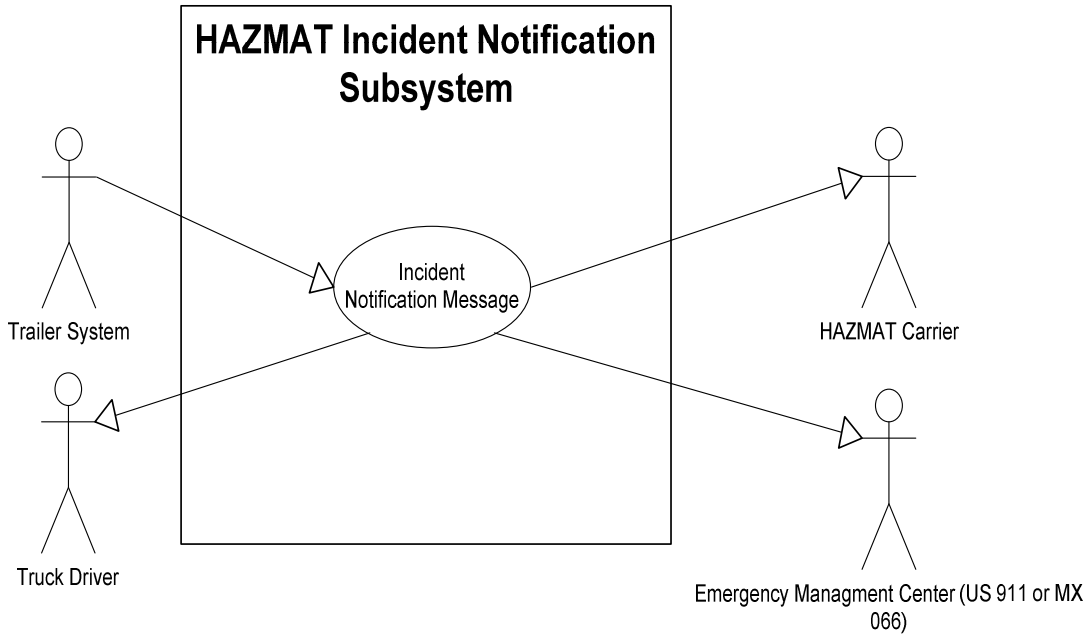


Figure 32 Use Case for HAZMAT Incident Notification Subsystem

The HAZMAT incident notification message will be delivered in different language depending on the location of the trailer. The language selection for the incident notification message can be observed in Figure 33. The HAZMAT carrier will have the option of determining the preferred language to receive incident notification message. In the case of the

EMC and truck driver, the selection of the language for the notification selection will be based on the location of the trailer. Truck driver that cross the border with HAZMAT are required to speak English.

National ITS USRN satisfied: 4.3.0, 4.3.2, 4.3.2.2, 4.3.2.4.3, 4.3.3.1.3, 4.3.3.2.7, 4.5.0, 4.5.1, 4.5.1.1, 4.5.4.1.6,5.1.3.2.1, 5.1.3.2.3), 4.5.2.1, 4.5.2.2, 4.5.2.3, 4.5.2.3(a), 4.5.2.3(b), 4.5.2.3(c), 4.5.2.3(d), 4.5.2.3(e), 4.5.2.3(f), 4.5.2.3(g), 4.5.3, 4.5.3.1, 4.5.3.2, 4.5.3.3, 4.5.3.3

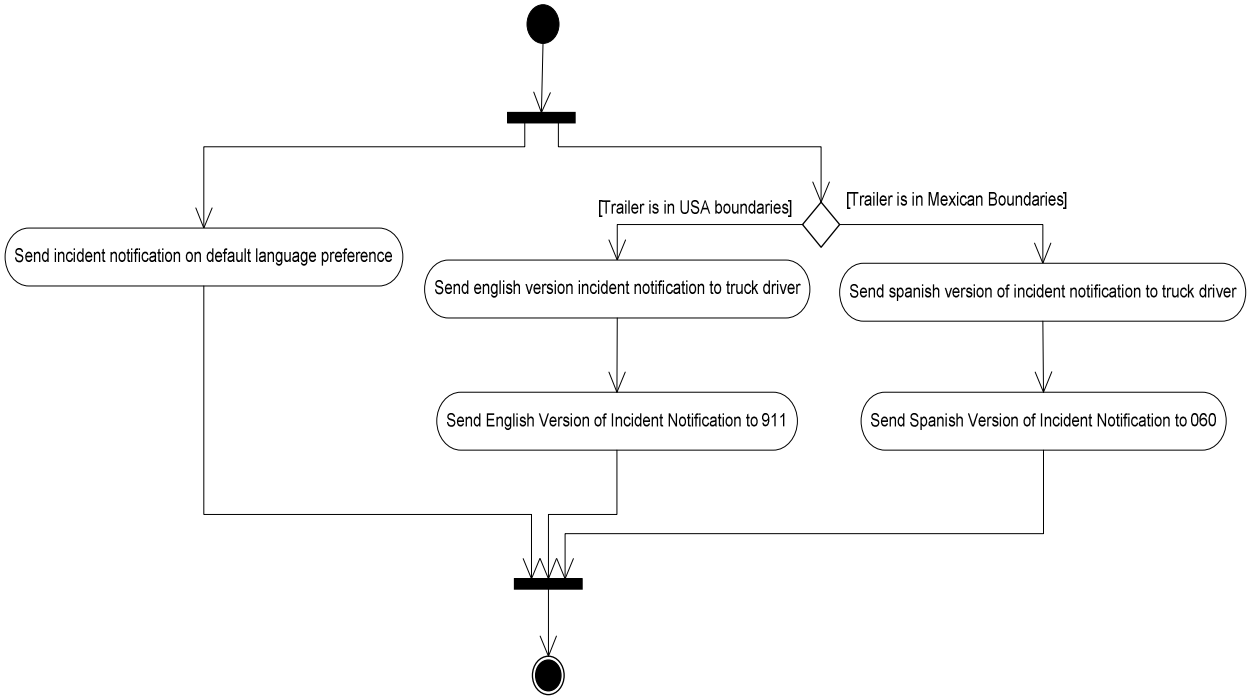


Figure 33 Activity Diagram for HAZMAT Incident Notification Subsystem

5.5.5 HAZMAT Incident Response Subsystem

Once the EMC receives the notification, a dispatcher needs to corroborate that a HAZMAT incident is in progress. The process will include the analysis of the sensors installed in the trailer and verification of the HAZMAT incident (e.g. calling the truck driver to ensure the notification received is an emergency). When a HAZMAT incident has been positively identified, then the established regional standards to respond a HAZAMAT incident need to be initialized.

The HAZMAT Incident Response Subsystem gives the advantage to First Responders of obtaining information about HAZMAT present in the trailer as soon as they receive the notification from the Emergency Management Center. All the information about the HAZMAT will be specified in the HAZMAT Incident Notification Message. Furthermore, the HAZMAT Incident Response System incorporates to the planning of HAZMAT incident mitigation process the utilization of WISER software tool. The integration of WISER to the planning process is explained in detail on the Activity Diagram in Figure 34.

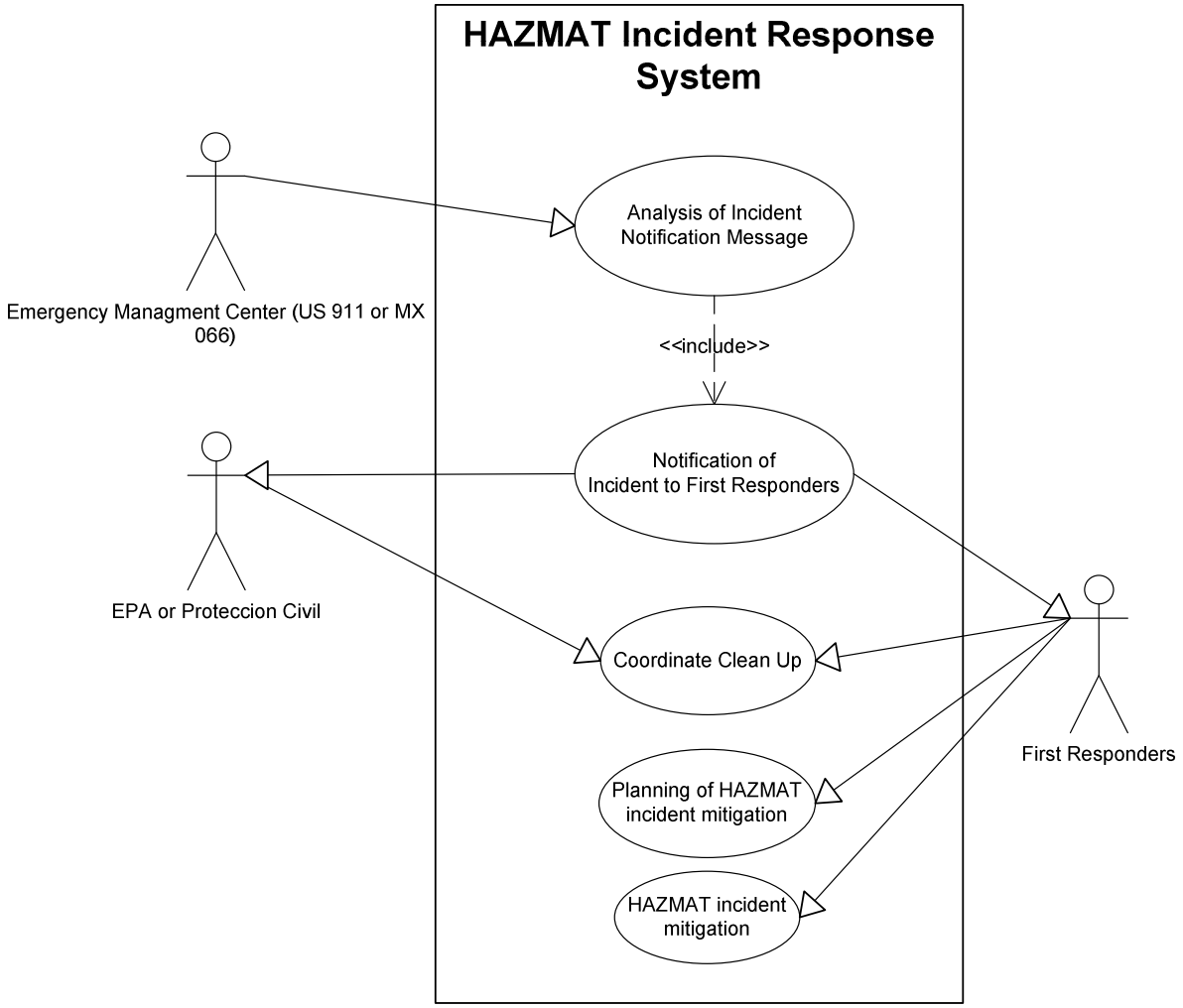


Figure 34 Use Case for HAZMAT Incident Response Subsystem

Analysis of Incident Notification Message

The analysis of the Incident Notification Message will be carried out by an EMC dispatcher. The analysis will include:

- Verify that the call was route to proper EMC based on the city that was identified in the HAZMAT Incident Notification Message;
- Verify that sensors readings correspond to a HAZMAT incident;
- Identify First Responders that need to be present based on type of incident; and,
- If possible, contact truck driver.

National ITS USRN satisfied: 5.1.3.2.3

Notification of Incident to First Responders

Based on the analysis of the EMC dispatcher, different first responders need to be notified. For example, if the incident notification message is with respect a truck going off route, then the Police Department need to contacted first. The dispatcher will need to follow the EMC notification process for each possible scenario.

National ITS USRN satisfied: 4.3.0

Coordinate Clean Up

In case that a HAZMAT has occurred then environmental agencies (i.e. EPA in the U.S. or Proteccion Civil in Mexico) need to coordinate the clean up phase with the Fire Department HAZMAT team. Fire Departments, most of the times, will have the necessary equipment for the clean up phase. Nevertheless, environmental agencies need to be informed of the incident.

Planning of HAZMAT incident mitigation

If the incident involves a spill from HAZMAT, the incident mitigation plan phase will take advantage of WISER software. In order to provide a mitigation plan the steps in Figure 35need to be followed. All the data that needs to be input will be obtained from the incident notification message.

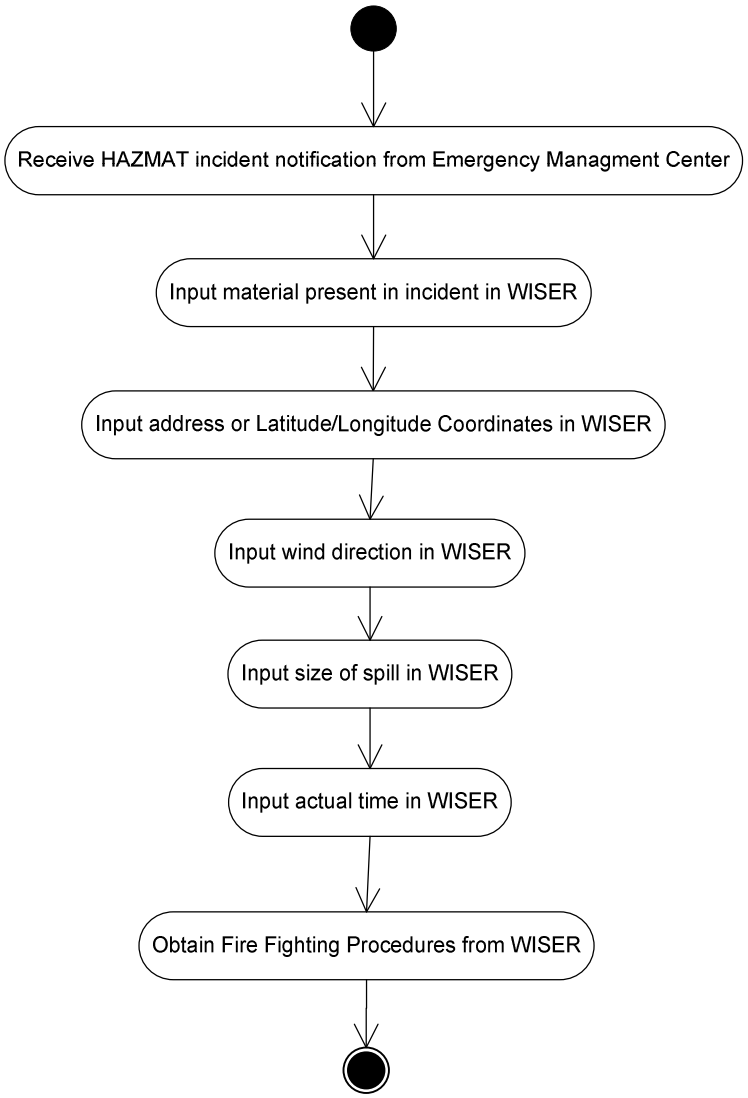


Figure 35 Activity Diagram for Planning of HAZMAT Incident Mitigation

HAZMAT Incident Mitigation

Based on the incident mitigation plan output from WISER the Incident Commander (IC) can determine the best approach to mitigate the incident. It is important to note that WISER will be use as a support tool for the mitigation phase. The Incident Commander's mitigation plan can differ from the one proposed by WISER.

National ITS USRN satisfied: 4.5.2

5.6 Physical Architecture of the System

5.6.1 High-Level Architecture

The system will be initiated by creating the e-Manifest at the HAZMAT carrier location. Once the e-Manifest has been created, an electronic copy of the manifest needs to be created. The electronic copy will then be input to a programming parameters definition program that will acquire the necessary information from the e-manifest to set the maximum allowed environmental conditions and the optimal HAZMAT route for the HAZMAT transportation accessing proper databases as can be observed in Figure 36.

After the parameters and route are obtained, the program will create a text file, which will include the sensor's parameters and route. In addition, a file containing an electronic copy of the e-manifest should be transmitted to the Trailer Monitoring Subsystem. In order to prevent unauthorized users intercept the transmission file. Once the transmission file is created, the transference should be carried over a wired secure communication link.

The sensor's parameters and route received in the text file should be implemented to configure the Trailer Monitoring Subsystem. The transmission file shall be stored in flash memory (or any other type of non-volatile memory) in order to prevent data loss from power failure. After the Trailer Monitoring Subsystem is configured, the subsystem will be continuously polling information from the sensors to verify if any of the sensor's reading corresponds to a HAZMAT incident.

In case that a HAZMAT incident is detected, then a HAZMAT incident notification message shall be created as specified in Section 5.5.3, in PDF format. The notification message will be transmitted through the internet using the 3G network capability on the cellular phone, installed in the monitoring subsystem. The EMC, HAZMAT carrier, and HAZMAT truck driver will receive the PDF file with the HAZMAT incident notification message. The EMC dispatcher will be in charge of analyzing the message and inform proper first responders in case that the notification corresponds to a real HAZMAT incident. If multiple first responders are needed at the scene the EMC dispatcher will have the capability to connect them using the Cisco IPICS server independently of which communication system they are currently using. Besides a detailed HAZMAT Incident Response plan can be obtained accessing WISER database and can be transmitted to First Responders. The complete physical architecture of the system can be observed in Figure 36.

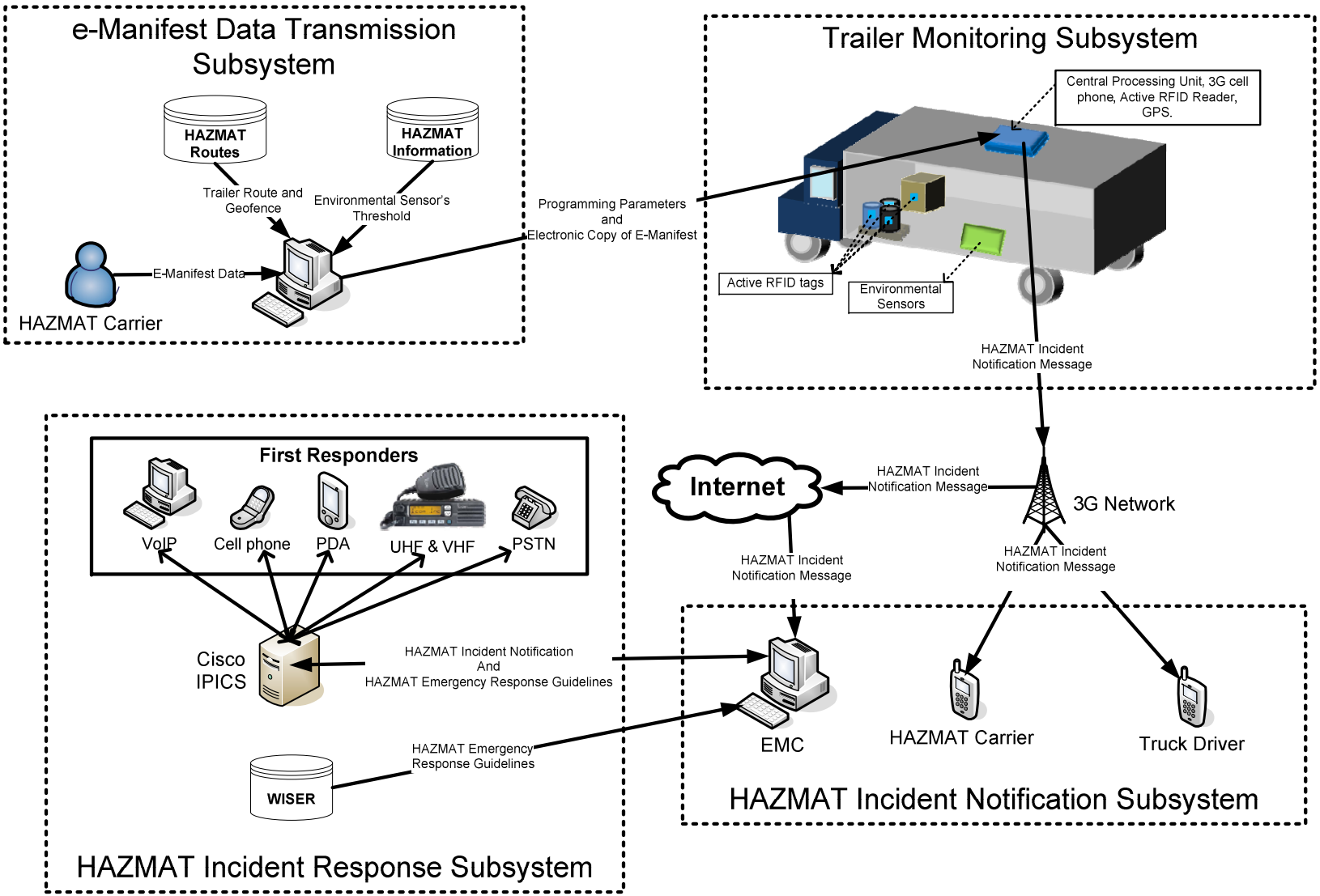


Figure 36 High-Level Physical Architecture for Pilot Information System for Cross-border HAZMAT transportation

5.6.2 Programming Parameters Definition and Transmission Subsystem

The HAZMAT carrier will input the necessary data in the ACE portal, to create the e-Manifest as it is the current practice when shipping HAZMAT across U.S.-Mexican border. Since it is required that every HAZMAT truck have a hard copy of the manifest in the truck at all times, the additional step required is for the HAZMAT carrier to create a PDF file of the truck's manifest. The PDF file will be input to a programming parameters definition program which will use the HAZMAT route and HAZMAT information database to obtain the sensor's, HAZMAT Route and geo-fence parameters as well as the quantity of RFID tags that are present in the truck's cargo area.

Once all the data is acquire, two files will be included in the transmission. The first file will be a text file with all the programming parameters for the Trailer Monitoring Subsystem. The second file will be the PDF file of the trucks manifest. Since the transmission will contain an exact copy of the truck manifest, the files needs to be encrypted to avoid unauthorized user acquiring the data. In addition, an identification method should be implemented in order to prevent external user being able to program the Trailer Monitoring Subsystem

The transference of the transmission files between the HAZMAT carrier and the Trailer Monitoring Subsystem shall be done at the HAZMAT carrier facilities. This file transfer will be possible since the central processing unit installed in the HAZMAT truck will be dismountable. The central processing unit will have a cat5 terminal connection.

The physical architecture of the e-Manifest Data Acquisition and Transmission Subsystem consist of a PC with connection to the Internet and access to the HAZMAT routes and HAZMAT information databases, as shown in the upper left corner in Figure 37.

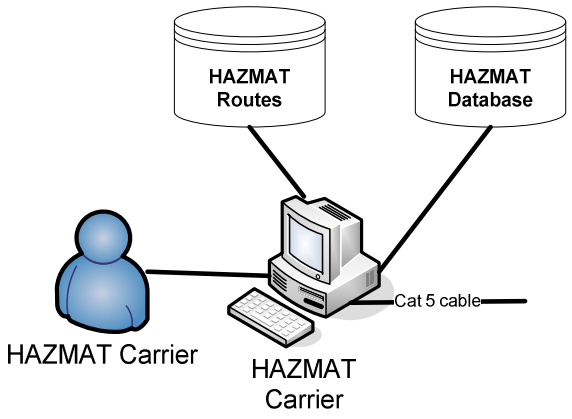


Figure 37 Low-level Physical Architecture For Programming Parameters Definition and Transmission Subsystem

5.6.3 Trailer Monitoring Subsystem

The central processing unit will receive the transmission file at the HAZMAT carrier. After the programming parameters are set on the monitoring subsystem, the central processing unit will be installed on the top of the HAZMAT truck. The central processing unit will have direct connection to the GPS, 3G-enabled mobile phone, RFID reader, and environmental sensors. The reason the central processing unit has to be mounted shall be mounted on top of the truck is to provide a clear view to sky and get accurate GPS readings. The information from the sensors will be polled and used to determining if a HAZMAT incident has occurred.

The physical architecture of the Trailer Monitoring Subsystem is shown in Figure 38. On the top of the trailer the central processing unit, cellular phone, GPS, and RFID reader will be mounted. The system shall be connected to a constant 12V power supply of the trailer. The subsystem should also include a back-up battery in order to provide monitoring capabilities even if the main power supply of the trailer is disconnected. The battery should be installed inside the sensing box to provide additional protection.

The temperature, humidity, pressure, and radiation sensors shall be place in the inside of the trailer's cargo place to provide accurate readings. The temperature, humidity, and pressure sensor should be place in the middle of the cargo section to provide accurate measurements. The radiation sensor should be place on a high place, since gases tend to ascend. Finally, the accelerometer can be place on any place in the cargo area, as long as the accelerometer's orientation is conserved.

Every barrel and cardboard box should contain Active RFID tag, as shown in Figure 40. If the tags are placed only on the pallets, then the detection of a barrel or card box removal will not be possible. Since the tags implemented are Active RFID technology and the distance between the tags and the reader is considered to be a short-range one. The tags can be placed inside the card boxes or the barrels can be stacked one over the other and there should not be significant signal fading. To minimize reading errors the Active RFID reader antenna should be placed inside the trailer.

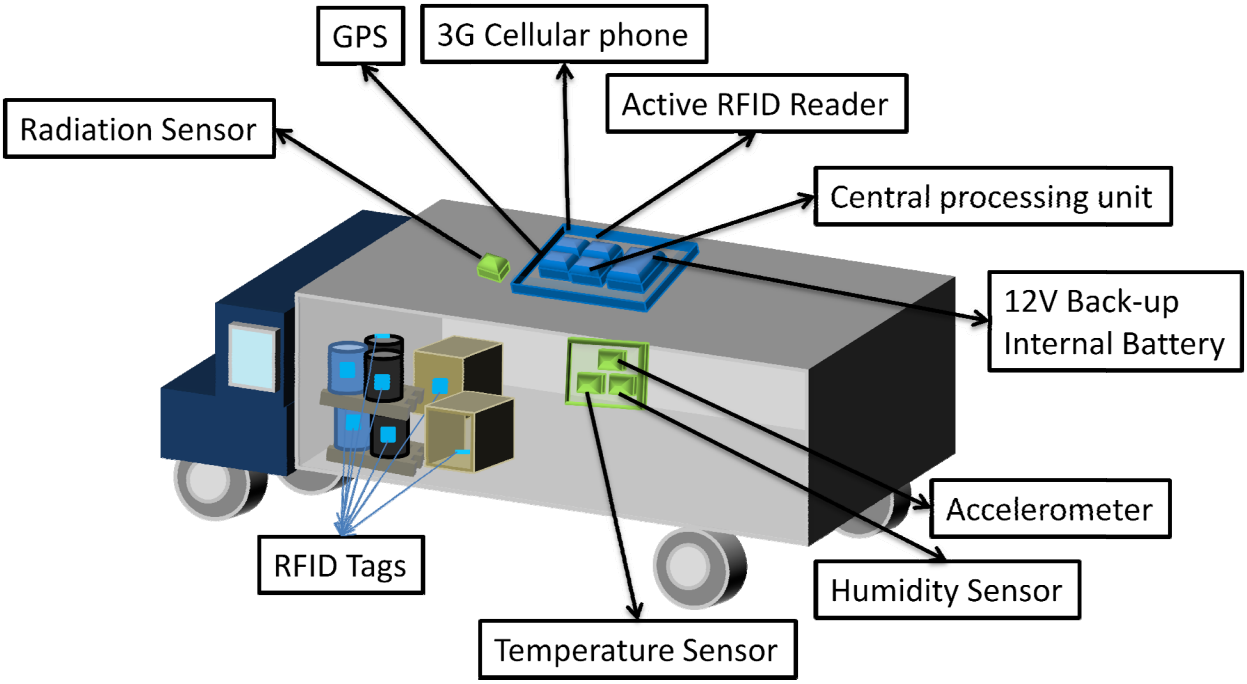


Figure 38 Low-Level Physical Architecture for Trailer Monitoring Subsystem

5.6.4 HAZMAT Incident Notification Subsystem

The physical architecture of the HAZMAT Incident Notification Subsystem consists of two PDA or smart phones and a PC with connection to the internet. The PDA and smart phones, or both should be capable of receiving PDF files. The HAZMAT incident notification message created by the Trailer Monitoring Subsystem should be in PDF format and will contain the information described in Section 5.3.3 of the creation of the HAZMAT Incident Notification Message.

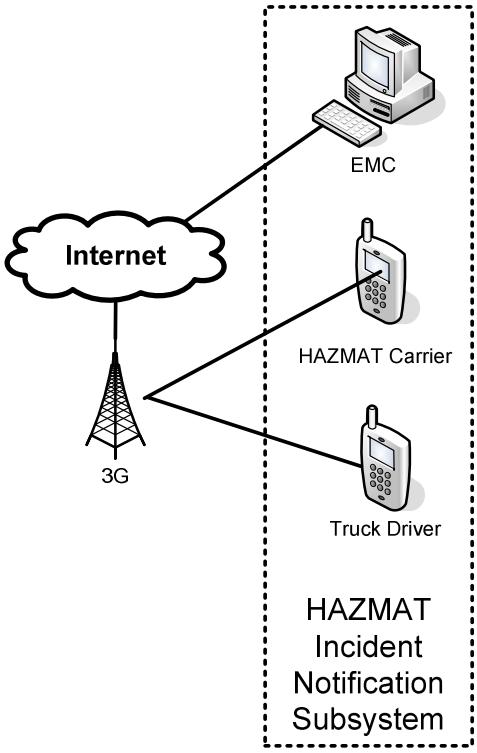


Figure 39 Low-Level Physical Architecture for HAZMAT Incident Notification Subsystem

5.6.5 HAZMAT Incident Response Subsystem

The physical architecture of the HAZMAT Incident Response Subsystem describes the interaction of WISER software and Cisco IPICS server. The initialization of the subsystem starts when the EMC dispatcher receives a HAZMAT Incident notification message. After corroborating that the message corresponds to a HAZMAT incident, the EMC dispatcher through the Cisco IPICS server has the option to notify first responders about the HAZMAT involve in the incident. The EMC dispatcher will have the capacity to communicate with different communications systems such as UHF, VHF, cellular phone, PSTN (Public Switch Telephone Network) and VoIP.

In case first responders need further information about the HAZMAT involved in the accident, the EMC dispatcher can obtain information using WISER software tool. The EMC dispatcher will then be able to send the information to the first responders through Cisco IPICS.

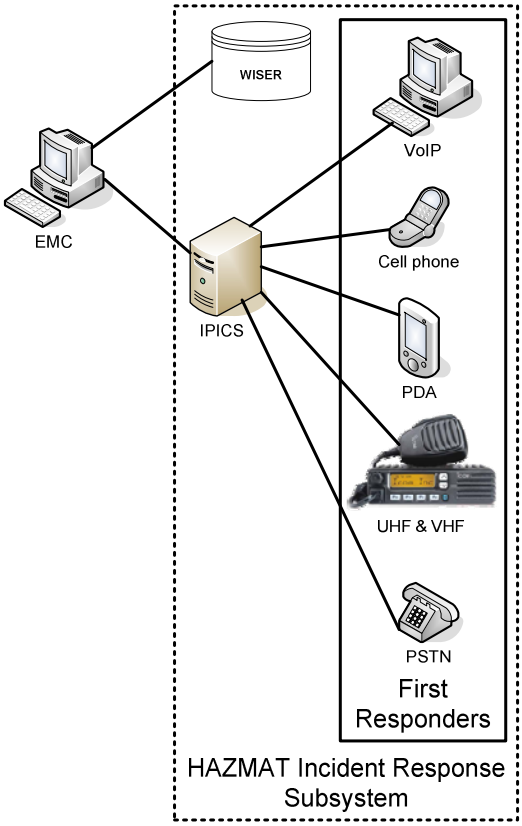


Figure 40 Low-Level Physical Architecture for HAZMAT Incident Response Subsystem

CHAPTER 6. PHYSICAL REQUIREMENTS TO DESIGN AND IMPLEMENT THE SYSTEM

The following chapter identifies the design, implementation, and maintenance requirements for the pilot of the information system described in Chapter 5. The design requirements will identify software or hardware that needs to be developed. The implementation requirements will describe the software and hardware minimum requirements for the system Commercial off-the-shelf (COTS) components. With respect to maintenance requirements, it shall include software upgrades and hardware routine maintenance procedures that will ensure proper operation of the system.

6.1 Design Requirements

In order to implement the system and due to the lack COTS software or hardware for the specific applications, the design of several system components need to consider. Software component design should require the integration of well-known computational methods as well as personal computational method to carry out specific tasks needed to implement the information system. Hardware component design should include the integration of COTS components that will enable data transfer between subsystems and components. Based on the system description in Chapter 5, two components need to be design; programming parameters definition program and monitoring box.

6.1.1 Programming Parameters Definition

The programming parameters definition should be able to carry out the following tasks:

- Provide a graphical user interface (GUI) to upload an e-manifest in PDF,
- Ability read and store data from the e-Manifest,
- Connect to the Hazardous Substances Data Bank from the National Library of Medicine,
- Based on the information from the Hazardous Substances Data Bank and the cargo information from the e-manifest obtain and store optimal environmental conditions for HAZMAT transportation,
- Connect to the Federal Motor Carrier Safety Administration National Hazardous Materials Route Registry, obtain and store the route for HAZMAT transportation based on the point of origin and destination,
- Create a text file with the programming parameters,
- Support data transmission over Ethernet Port using IEEE 802.3 standard.

6.1.2 Monitoring box

The monitoring box should be able to carry out the following tasks:

- Receive the transmission file using RJ45 interface and IEEE 802.3 standard.
- Use transmission file to set sensors thresholds, and HAZMAT transportation routes.
- Obtain sensors reading using serial communication (i.e. RS232, RS422 or RS485) and compare them with sensor's thresholds.
- Create HAZMAT incident report, as described in Chapter 5, in two languages; English and Spanish.
- Distribute the incident report via TCP/IP using 3G network.

In order to detect HAZMAT incidents, the COTS components must meet the minimum requirements described in Table 16.

Table 16 Minimum Specification Requirements for COTS Components in Monitoring Box

Temperature Sensor	
Temperature Range	-40 ±125°C (-40 ±257°F)
Accuracy	±0.5^{o}C @ 25 ^{o}C
Humidity Sensor	
Humidity Range	0-100%
Humidity Resolution	0.03% Relative Humidity
Absolute RH accuracy	±3.5% Relative Humidity
Pressure Sensor	
Barometric Pressure Range	300-1100 mbar
Barometric Pressure Resolution	0.01 mbar
Accuracy	±1.5 mbar @ 25°C
Accelerometer	
Acceleration Range	±4 g
Zero g bias level:	2.0 mg/^{o}C from 25°C
Number of axis	2 (Horizontal, Vertical)
Global Positioning System	
Tracking channels	16
Position Accuracy	10 meters

Antenna support	Active
3G Cellular Modem	
Cellular Network	GSM or CDMA
Toxic Gas Sensor	
Target Gas	• Ammonia (NH_3) • Carbon Monoxide (CO) • Chlorine (Cl_2) • Hydrogen Sulfide (H_2S) • Phosphine (PH_3) • Sulphur Dioxide (SO_2)
Active RFID Reader	
Tx Frequency	433 MHz
Modulation	Amplitude-Shift Keying (ASK)
Typical Transmission Range	Up to 60 meters
Active RFID Tags	
Rx Frequency	433 MHz
Sensitivity	-100 dBm
Demodulation	ASK

Note: g = g-force, GSM = Global System for Mobile Communication, CDMA = Code Division Multiple Access,

6.2 System Implementation and Maintenance

This section focuses on the minimum hardware and software requirements needed to implement and maintain the pilot of information system. The maintenance of the subsystems will focus on keeping software up to date and provide preventive maintenance to avoid high cost reparations.

6.2.1 Programming Parameters Definition and Transmission Subsystem

The minimum hardware and software requirements for this subsystem should be according to the subsystem requirements of the programming parameters definition software. According to the specifications in Chapter 5, the program should obtain all necessary data from the e-manifest. Therefore, the maintenance of the program will include:

- Track modifications in the e-manifest format created by ACE portal.
- Update program data acquisition method in case e-manifest format is modified

The transmission of data between this subsystem and the trailer monitoring subsystem will be carried out through RJ-45 interface. This type of interface requires a CAT-5 cable with RJ-45 terminals. This cable and cable terminals should be checked daily to ensure that the cable is in operational condition.

6.2.2 Trailer Monitoring and HAZMAT Incident Notification Subsystem

The hardware and software requirements for the Trailer Monitoring Subsystem should also be defined in the subsystem requirement document based on the final design of monitoring box. The maintenance procedures for the monitoring subsystem shall include:

- Periodic sensor calibration and verification.
- Update firmware as required.
- Verify interface terminals.
- Check back-up battery charge of monitoring box and active RFID tag internal battery.
- Verify GPS accuracy according to design requirements.

6.2.3 HAZMAT Incident Response Subsystem

The HAZMAT incident response implementation shall be based on the NG 9-1-1 system requirements once the architecture of the system is completely defined. The pilot of the information system is based on the upgrade of the EMC to NG 9-1-1 capabilities of data transfer. It is important to mention that that when the EMC are migrating form E 9-1-1 system to NG 9-1-1 IPICS system requirement need to be considered.

Table 17 includes a list of minimum hardware requirements for IPICS deployment based on the number of active channels.

Table 17 IPICS Minimum Hardware Requirements based on Active Channels

Number of channels	PMC Minimum Hardware Requirements
Up to 4 active channels	• 800 MHz Pentium III class, including Mobile Pentium • 512 MB RAM • 1GB free space • Network interface card
Up to 6 active channels	• 1.5 GHz Pentium IV class, including Mobile Pentium • 512 MB RAM • 1GB free space • Network interface card
Up to 36 active channels	• 3.2 GHz Pentium IV class, including Mobile Pentium • 2 GB RAM • 1GB free space • Network interface card

CHAPTER 7. CONCLUSION

The objective of the study was to propose a prototype of an information system by which hazardous materials movement will be relayed and/or shared with local and regional agencies (mainly the first responders) which will assist these agencies to respond to major hazardous materials incidents more efficiently. This prototype information system was designed for first responders as a model for what could be developed for the wide range of stakeholders from U.S. and Mexico.

A large part of the initial research was spent in identifying the agencies that played minor and major roles in transportation of hazardous materials across the border. The researchers found that a large number of agencies played various roles in what turned out to be extremely complicated process of hazardous materials transportation and incident response. Finally, based on stakeholder needs, the research proposed logical and physical architecture of a prototype system to monitor movement of hazardous materials in the border area and to provide advanced warning of hazardous materials related incidents to the first responders.

The researchers believe that the physical components for a prototype system could be assembled and the system can be deployed successfully using existing technology. However, determining cost of developing a prototype was beyond the scope of the research and should be considered while developing one. One of the drawbacks of the design is that the system relies on cellular data communication to relay information to emergency management centers. However, wireless signals may not be available at all locations. Hence, responding to incidents at remote locations with weak or no wireless signal would be an issue. On the other hand, damage from such incidents at these remote locations is minimal compared to urban and densely populated areas, where strength of wireless signals is adequate.

The prototype system if implemented will undoubtedly provide necessary tools for first responders to identify HAZMAT moving through the border region and the necessary information to respond to incidents more effectively. The system cannot replace the bureaucratic and administrative process of responding to HAZMAT incidents knowing that there is a myriad of agencies involved with HAZMAT information, especially in border regions. However, the system will facilitate the key agencies, such as first responders, to respond to HAZMAT incidents efficiently.

In addition, crucial to successful implementation of such a system is to have necessary buy-ins from all the stakeholder agencies. For example, the e-manifest information is sent to the CBP and EPA by the shipper prior to crossing the border. It is not clear if both agencies would be willing to reveal the HAZMAT related information to a local agency, such as fire departments and local emergency management centers. Currently, the local first responder find out about the HAZMAT only after an incident occurs and are called in to provide response.

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