Impact of Traffic Management on Construction Work Using Connected Vehicle Systems

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Abstract- *The Rehabilitation and maintenance of heavy and infrastructure projects, the fragmented nature of the construction supply chain, and the uncontrolled arrival of delivery vehicles to work sites can cause major disruptions to local traffic flow and elevate congestion, particularly in urban transportation networks. In construction projects, dealing with traffic and safety issues around a work zone is inevitable and a major concern for both the public and managers of transportation networks. Traditional methods for work zone traffic control focus on guiding and warning drivers through the work zone. Intelligent Transportation Systems (ITS) based methods are more proactive, and can redirect traffic to alternate routes in order to minimize the total travel time of a network. This project investigates the impact of using Connected Vehicle systems in work zones and quantifies the benefits associated with Connected Vehicle systems. In Connected Vehicle systems, data is exchanged wirelessly between nearby vehicles, infrastructures, and mobile devices. This leads to improvements in safety mobility as well as greatly reduces adverse environmental impacts of transportation systems. In this study, a microscopic simulation model is utilized to demonstrate traffic flow in a network and emulate the connected vehicle systems. The outcome of this study shows that connected vehicle systems can significantly assist to improve mobility and reduce traffic congestions associated with work zones.*

Keywords- construction work, vehicle systems, traffic, ITS.

I. INTRODUCTION

1.1 INTRODUCTION

Many highways in India are experiencing an increase in traffic volumes. Simultaneously, there is a huge demand from motorists and travelers to reduce delays. Agencies are seeking innovative approaches to better plan construction projects and thus minimize impacts on road users. A work zone is an area of highway or urban road with heavy building construction, expansion or repair. Work zones can significantly impact both traffic congestion and safety. A traditional way of marking a work zone is through signs, pavement markings, barriers, and construction vehicles. These signs normally continue to the end of the construction zone. Work zones may be implemented for a short or long time, depending on the size of the project. For example, the repair of a part of a highway is generally a short term constructions work and the construction of a new bridge is often a longer term construction project. Given the nature of urban daily life and the scarcity of land, most heavy constructions have to be implemented in conjunction with everyday activities and events. Lane expansion of a highway and the construction of a new condominium in a densely populated area are examples for which construction projects have to be continued in conjunction with existing traffic flow.

The Rehabilitation and maintenance of heavy and infrastructure projects, the fragmented nature of the construction supply chain, and the uncontrolled arrival of delivery vehicles to work sites can cause major disruptions to local traffic flow and elevate congestion, particularly in urban transportation networks. In construction projects, dealing with traffic and safety issues around a work zone is inevitable and a major concern for both the public and managers of transportation networks. Traditional methods for work zone traffic control focus on guiding and warning drivers through the work zone. Intelligent Transportation Systems (ITS) based methods are more proactive, and can redirect traffic to alternate routes in order to minimize the total travel time of a network. This project investigates the impact of using Connected Vehicle systems in work zones and quantifies the benefits associated with Connected Vehicle systems. In Connected Vehicle systems, data is exchanged wirelessly between nearby vehicles, infrastructures, and mobile devices. This leads to improvements in safety mobility as well as greatly reduces adverse environmental impacts of transportation systems. In this study, a microscopic simulation model is utilized to demonstrate traffic flow in a network and emulate the connected vehicle systems. The outcome of this study shows that connected vehicle systems can significantly assist to improve mobility and reduce traffic congestions associated with work zones.

1.2 CONNECTED VEHICLE CONCEPTS

Connected Vehicle is a US Department of Transportation program to develop and deploy a fully connected transportation system which enables data exchange among vehicles, infrastructure and mobile devices in order to improve safety, mobility and adverse environmental impacts of transportation systems. This system is also used by traffic officials to manage traffic, by travelers to set their schedules and by transportation companies to manage their vehicle fleets. The connectivity among vehicles, infrastructure, and mobile devices is achieved through various wireless communications. The data obtained from Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communication in conjunction with in-vehicle equipment which are able to process the data and issue warning and advisory message were perceived to save lives and time as well as environment. Figure 1.2 shows how an "I am here" message can be disseminated by vehicles and be converted into other types of messages for other vehicles using various applications such as collision warning systems to improve safety and mobility. Figures 2 illustrates a safety application of a connected vehicle system In which the blue vehicle receives a warning message in case its driver attempts to an unsafe overtake.

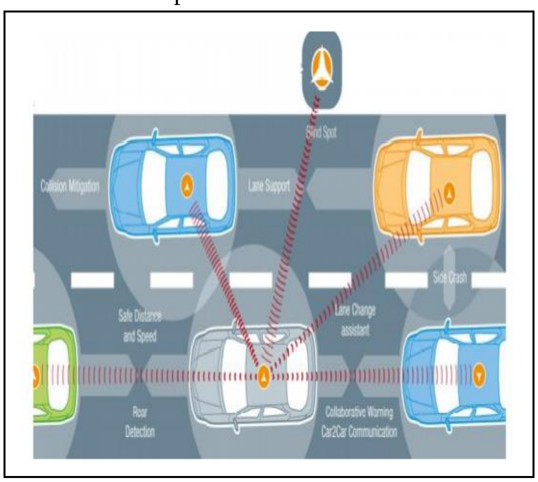

Fig 1: "I am here" message can be disseminated by vehicles

1.3 CURRENT ITS TECHNOLOGY FOR WORK ZONES

ITS technologies can significantly assist in traffic management in and around construction zones by diverting motorists to appropriate alternate routes, reducing traffic congestion, and by improving safety performance for both travelers and workers while reducing delays. Various ITS applications relevant to work zone management have emerged in the market . However when it comes to operation, all these applications are providing motorists advance information about traffic situations ahead, through communication devices, in order to help drivers safely and efficiently navigate through work zones. The most common applications of ITS in work Variable speed limits, andDynamic lane merge systems, zones can be categorized in these 3 groups: Real time information systems. Dynamic lane merging systems create no-passing zones in advance of a work zone to advise drivers to merge early, rather than wait to do so at the taper area. The selection of this strategic point is based solely on traffic conditions in and around the work zone. The system automatically determines a point in which motorists can merge into a single lane, causing minimum impact on the traffic flow. Variable speed limit is applied to manage traffic speeds approaching work zones. According to research, motorists most often ignore static speed limit signs thus the transition from high speed to low speed or even stopped traffic has proven to be very dangerous (in some cases with fatal consequences). In 2002 Michigan Department of Transportation and Michigan State University implemented a Variable Speed Limit (VSL) system in a number of work zones to evaluate the effectiveness of this approach in dealing with work zone traffic management. The results indicated that the system can effectively contribute to reduced travel time and improved road safety. Real-time traveler information system is another application of ITS in work zones. The system will provide accurate and online information using non-intrusive traffic sensors to measure traffic flow, for motorists granting them the option of making informed decisions on their routes, speed, and departure time. By providing this sort of information to travelers, some of the anxiety and impatience caused by the uncertainty of delays can be reduced. Travelers can change their modes of transportation, routes, or times of travel. Managers are also able to instantly and accurately respond to traffic congestions on the network. Informing drivers in advance of a work zone can lead to some opting to take alternate routes or detours, thus reducing the demand for passing through the work zone.

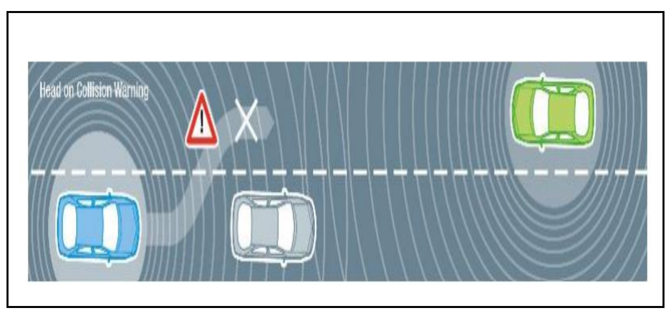

Fig 2: ITS working Variable

1.4 OBJECTIVE

- Support the economic vitality of the metropolitan area, especially by enabling global competitiveness, productivity, and efficiency.

- To identified and consequently controlled improving the overall traffic efficiency and providing a smooth traffic flow.
- To reduce traffic with Connected Vehicle Urban Traffic Management (CVUTM) to create a smart road traffic ecosystem.

II. LITERATURE REVIEW

FengxiangQiao (2017)Intelligenty Work Zone System and Connected Vehicle Technologies to Reduce Crashes in Roadway Construction Area

Even though a lot of countermeasures have been implemented in construction area (or called work zone), there are still many crashes in work zone reported in the United States. Angle and rear-end crashes account for about 35 % in total in work zones, the major causes of which are drivers' failure to follow the speed limits and traffic controls on lane merging. Another cause is the presence of large trucks that obstruct the sight of other vehicles in the relatively narrow construction zone areas, which could lead to multi-vehicle collisions. Conventional work zone warning technologies are mostly well defined in the Manual of Uniform Traffic Control Device (MUTCD), and include: A. Flagging, B. Traffic signs, C. Pilot car, D. Arrow panels with portable message signs, E. Channelizing devices / barricades, and F. Lighting. Recently, the Intelligent Work Zone (IWZ) systems are developed combining the functions of a. detection, b. system monitoring, c. system communication, d. system analysis, b. data management, and c. dynamic information, which is able to predict and provide motorists with real-time information (travel time, delay or speed) on a freeway work zone, so as to better inform motorists on all useful information. The connected vehicle (CV) technologies are developed to enable vehicles to communicate with each other and with the roadside infrastructure. The measures of effectiveness of the work zone warning system include the measurement of relevant operational factors, and the reduction in the occurrences of negative effects. It is recommended deploying and testing all possible intelligent technologies, especially the CV technologies for even smarter control of traffic movement in roadway work zone areas.

III. METHODOLOGY

THEORETICAL CONTAIN - CONNECTED VEHICLES

3.1 INTRODUCTION

The term connected vehicles refers to applications, services, and technologies that connect a vehicle to its surroundings. A connected vehicle includes the different communication devices (embedded or portable) present in the vehicle, that enable in-car connectivity with other devices present in the vehicle and/or enable connection of the vehicle to external devices, networks, applications, and services. Applications include everything from traffic safety and efficiency, infotainment, parking assistance, roadside assistance, remote diagnostics, and telematics to autonomous self-driving vehicles and global positioning systems (GPS). Typically, vehicles that include interactive advanced driver-assistance systems (ADASs) and cooperative intelligent transport systems (C-ITS) can be regarded as connected. Connected-vehicle safety applications are designed to increase situation awareness and mitigate traffic accidents through vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications. ADAS technology can be based on vision/camera systems, sensor technology, vehicle data networks, V2V, or V2I systems. Features may include adaptive cruise control, automate braking, incorporate GPS and traffic warnings, connect to smart phones, alert the driver to hazards, and keep the driver aware of what is in the blind spot. V2V communication technology could mitigate traffic collisions and improve traffic congestion by exchanging basic safety information such as location, speed, and direction between vehicles within range of each other. It can supplement active safety features, such as forward collision warning and blind-spot detection. Connected vehicles technologies are also expected to be a fundamental component of automated driving as they will allow the exchange of sensor and awareness data among vehicles, cooperative localization and map updating, as well as facilitate cooperative maneuvers between automated vehicles.

Fig 3: Connected Vehicles System

3.2 HOW CONNECTED VEHICLES WILL IMPROVE SAFETY

Connected vehicle safety applications will enable drivers to have 360-degree awareness of hazards and situations they cannot even see. Through in-car warnings, drivers will be alerted to imminent crash situations, such as merging trucks, cars in the driver's blind side, or when a vehicle ahead brakes suddenly. By communicating with roadside infrastructure, drivers will be alerted when they are entering a school zone, if workers are on the roadside, and if an upcoming traffic light is about to change. Pivotal work is being conducted to guarantee that these driver warnings will not be a distraction and that people will only be made aware when they are approaching danger. The connected vehicle system will be similar in many ways to other wireless networks and will create a dynamic transportation network based on an open platform to allow for new and creative applications. Open standards allow anyone to develop new products and applications that will work in this space.

3.3 TRAFFIC EFFICIENCY

Navigation, online route planning, street view. New generation navigation systems can allow users to plan a route at home and send it to the car, to see photographs and recommendations about nearby places, and to take advantage of real time information to obtain optimal routes. Real time information about fuel prices (i.e. spotting the cheapest gas station in the surroundings) and maps of the available parking spots can be provided as well. Navigation information can be also presented on a contact analog head-up display, thus presenting augmented reality information in the driver's principal sight and therefore avoiding distracting her from driving.

Traffic, weather and road condition monitoring. Viewing the vehicle as a component in a bigger system, traffic congestion management becomes a fundamental feature for connected cars: vehicle-to-infrastructure communication can be exploited to gather information (anonimously announced by every vehicle on the road) about position, speed, and points of origin and destination of cars, and to send them to other applications in order to prevent road congestions. Vehicles can work as moving sensors of road and weather conditions, and communicate the information gathered to others, directly or with the intermediation of the infrastructure. The use of information of multiple sensors moving in the same area guarantees the quality of the data provided to other cars. Such services lie under the name of Advanced Traveler Information and Advanced Traffic Management Systems. Autonomous stations on the edge of the road are able to provide information that, combined with the data gathered by on-vehicle sensors, can enable a reliable detection of critical situations on the road. For instance, blocked cars can inform road-sideunits about the situation. Figure 5 shows how a connection with road-side units can be used to communicate the presence of a road blockage (which may be caused by construction sites, objects on the road, adverse weather conditions, or car accidents) to approaching vehicles, by means of the activation of warning lights.

3.4 CURRENT ITS TECHNOLOGY FOR WORK ZONES

- ITS technologies can significantly assist in traffic management in and around construction zones by diverting motorists to appropriate alternate routes, reducing traffic congestion, and by improving safety performance for both travelers and workers while reducing delays.
- Various ITS applications relevant to work zone management have emerged in the market . However when it comes to operation, all these applications are providing motorists advance information about traffic situations ahead, through communication devices, in order to help drivers safely and efficiently navigate through work zones. The most common applications of ITS in work zones can be categorized in these 3 groups:
  - Dynamic lane merge systems,
  - Variable speed limits, and
  - Real time information systems.

IV. PROPOSED METHOD

- This study evaluates potential benefits of connected vehicle systems as innovative tools to address capacity reductions caused by construction zones. Network travel time and average vehicle speeds were used as Key Performance Indexes (KPI) to assess the performance measures of connected vehicles system.
- In order to quantify potential benefits of a connected vehicle system, the KPIs associated with a network with a construction zone in which vehicles were not equipped with connected vehicle and a network with a construction zone in which a portion of vehicles were equipped with connected vehicle enabled vehicles were compared. For simplification purposes the former is referred to as Case 1 and the latter is referred to as Case 2. In Case 2, the market penetration of connected vehicle enabled vehicles was assumed as a variable ranging from 10% to 50% to study the impact of this variable.
- A microscopic traffic simulation model, PARAMICS, was used to measure the impact of implementing the

connected vehicle system. Microscopic traffic models provide more accurate information about drivers' reaction on different conditions like queue length, lane closure, travel time etc. To model a connected vehicle system in PARAMICS, it was assumed that the connected vehicle enabled vehicles switch their route to the shortest path between their origin and destination. This path is likely a route that does not pass through the construction zone.

- To account for attributes of connected vehicles, artificial zones were added to the model to emulate drivers taking alternate routes to avoid stocking in traffic jam associated with construction zone. These zones do not exist in real-world situations and only attract vehicles. Artificial zones are indicated in Figure 3 by circles. It is assumed that connected vehicle are informed about the construction zone ahead of time and minimize their own travel time by taking alternate routes to avoid the construction zone. In this model connected vehicles are assumed to be able to update their route information through devices which are installed onboard. The dynamic feedback function of PARAMICS, allows them to get information about traffic ahead of time and change their route cost table and select the shortest path recommended to them by their devices.

V. CONNECTED VEHICLE DATA ASSESSMENT

This section presents an assessment of the data that are currently available and are expected to be available from vehicles

5.1CONNECTED VEHICLE DATA ELEMENTS

The connected vehicle (CV) message types and components are specified in the Society of Automotive Engineers (SAE) J2735 standards (SAE International, 2016). The latest standards are the fifth edition.The J2735 standards specify a number of message types. The basic safety message (BSM) is one of these message types that will be used for vehicle-to-vehicle communication. The BSM contains vehicle safety-related information broadcasted to surrounding vehicles, but can also be sent and/or captured by the infrastructure. The BSM, as defined in the J2735 standards, consists of two parts. Part 1 is sent in every BSM message broadcasted 10 times per second and will be mandated to be broadcasted by the NHTSA ruling. It contains core data elements, including vehicle position, heading, speed, acceleration, steering wheel angle, and vehicle size. BSM Part 2 consists of a large set of optional elements such as precipitation, air temperature, wiper status, light status, road coefficient of friction, Antilock Brake System (ABS) activation, Traction Control System (TCS) activation, and vehicle type. BSM Part 2 elements are sent based on criteria that are not specified in the J2735 standards. However, not all of these parameters are currently available from vehicles, as described later in this section, and they will not be mandated by the USDOT.

Figure 5.1 shows the message format of the BSM (Hong at al., 2014). Table 2-1 shows the potentially useful data elements of the BSM Part 1 and BSM Part 2. A preliminary assessment of the use of BSM messages to support Dynamic Mobility Applications (DMA) found that BSM Part 1 is useful for a limited subset of mobility applications, but is not solely sufficient for most applications. pointed out that simple probe data, such as vehicle location, speed and heading, can be useful for very important applications like traffic monitoring, Advanced Traveler Information Systems (ATIS), traffic signal timing analyses, and for planning purposes.

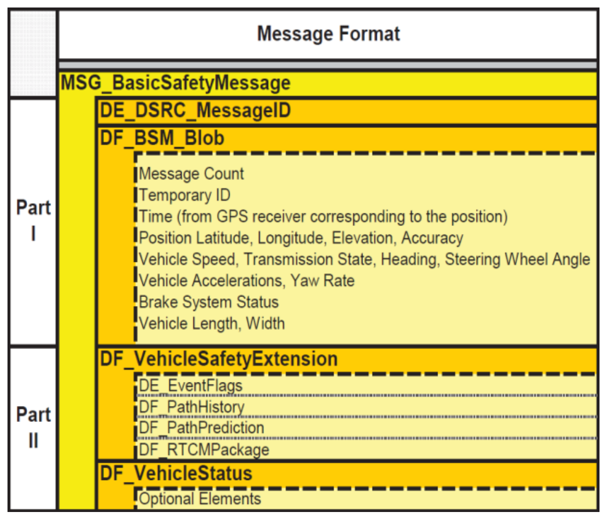

Fig 4: The Format of Basic Safety Messages

Table 1: Potentially Useful BSM Parameters

Data	# Applications	BSMPart 1	BSMPart 2	ExchangeType
Vehicle mass	4		□	Periodic
Vehicle placardedas HAZMAT carrier	1		□	Periodic
Vehicle size	6	□		Periodic
Vehicle type(fleet vehicles)	6		□	Periodic
Wiperstatus	9		□	Periodic
Wipercharged	9		□	Event driven

Table 2: Messages and Communication Modes

	V2V	V2I	I2V
Basic SafetyMessagePart1	□	□	
Basic SafetyMessagePart2	□	□	
Emergency Vehicle Alert	□		
Common Safety Request	□		
Probe Vehicle Data		□	
Signal Request Message		□	
Road side Alert			□
Traveler Information			□
MAP Data			□

5.2 CASE STUDY NETWORK

- In order to evaluate potential benefits of the Connected Vehicle system in work zones, a case study area in the Amaravati City. The selected work zone (Figure 3) was located on the Kondeshwarphata. The construction zone is shown in Figure 4.
- Data in Table 1 are the total travel between zones for the peak hour. To estimate the O-D matrix (Table 1) a gravity model was used. In the gravity model, square of free flow travel time between each origin and destination was used as the impedance function. Equation 1 shows the gravity model:
- $T_{ij}=O_iD_jf_{ij} / \sum O_if_{ij}$ (1)

Where,

T_{ij}: represent number of trips between zone i and j,
O_i: Trip production of zone i,
D_j: Trip attraction of zone j, and f_{ij}: Impedance functions.

It should be noted that the traffic simulation model was not calibrated in this study. The main reason is that Case 2 scenarios were compared with Case 1 and any calibration process will not have any effect on the results.

Fig5: PARAMICS network kondeshwar phata

Fig 6: Construction Zone Kondeshwar Phata

Table 3: Origin-Destination Matrix (OD)–Vehicle/Hour

ODZones	2	1	4	7	8	9	3	Total
2	-	505	572	111	875	111	17	**2200**
1	505	-	260	50	398	50	8	**1271**
4	572	260	-	57	451	57	9	**1405**
7	111	50	57	-	87	11	2	**219**
8	875	398	451	87	-	87	13	**1911**
9	111	50	57	11	87	-	2	**219**
3	17	8	9	2	13	2	-	**51**
Total	**2200**	**1271**	**1405**	**219**	**1911**	**219**	**51**	**9810**

5.2.1Results

The following 5 scenarios were run using the simulation model described earlier: Table 2 shows the results of the simulation model for various scenarios including:

- Network without the construction zone and without connected vehicle capabilities which is referred to as Existing Network,
- Network with the construction zone and without connected vehicle capabilities which is referred to as Existing Network with Construction Zone,
- Network with the construction zone and assuming that 10% of vehicles are Connected Vehicle enabled which is referred to as 10% Connected Vehicle,
- Network with the construction zone and assuming that 20% of vehicles are Connected Vehicle enabled which is referred to as 20% Connected Vehicle, and
- Network with the construction zone and assuming that 50% of vehicles are Connected Vehicle enabled which is referred to as 50% Connected Vehicle.

VI. CONCLUSION

- With the increased need to rehabilitate and execute heavy construction projects and industries in MIDC of Amaravati, implementing major changes in normal traffic conditions is inevitable.

- Lane closures are one of the most common modifications which, without proper management, could impose adverse impacts on mobility and safety within the construction zone.
- A microscopic traffic simulation is utilized in this paper to study the impact of deploying connected vehicle in and around work zone.
- The aim was to examine and compare the impact of connected vehicles on the mobility of different scenarios. T
- he scenarios include lane closure with an ordinary traffic management and the same situation with different market penetration of connected vehicle enabled vehicles in the network (10% to 50% utilization through the network).
- Comparing the results clearly shows that connected vehicle system can contribute to mitigating congestion and improving mobility in and around work zones.
- Providing real time information data along with accurate alternate route information in advance of a work zone can result in better route selection and as a result, improved safety and mobility

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