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Systematic Data Management for Real-Time Bridge Health Monitoring Using Layered Big Data and Cloud Computing

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ABSTRACT: Current paper presents a layered big data and a real-time decision-making framework for bridge data management as well as health monitoring. There are emergency conditions that prevent timely fixing of bridge's damage. At these situations, road users are the right decision makers who should directly be informed about the bridge condition. Using this framework, sensors embedded on bridges could be designed to send warning messages to Variable Message Signs and cell phones within a defined region. To address difficulties of real time communication with road users and/or experts in central management office, the emerging technology of big data and cloud computing could be utilized.

KEYWORDS: Asset Management; Big Data; Bridge Health Monitoring; Cloud Computing; Variable Message Sign.

1 INTRODUCTION

Transportation facilities constitute one of the most important and vital public assets and account for a major portion of capital expenditure worldwide. These facilities serve to be well constructed, rehabilitated and maintained to support safe movements of people and goods. Efficient and safe transportation is essential to general public to meet higher level of welfare. With the increasing travel demand, it is getting, however, more critical to provide transportation services. Recently, transportation agencies are more interested in applying systematic approaches for proper management of existing assets and at the meantime conducting appropriate planning to cater future needs. This strategic movement is referred to as Transportation Asset Management (TAM), which makes investment decisions to preserve, expand and operate transportation facilities using comprehensive datasets in project and network scales. The overall, long-term objective of the asset management program is to optimize, or fully leverage, the asset portfolio to provide reliable and sustainable assets that fully meet current and known future agency business needs in order to ensure performance and condition standards that comply with all applicable regulations while minimizing the life cycle costs.

A highway system has a number of physical facilities including pavements, bridges, roadside elements and traffic control devices, all of which have their own service characteristics and require specific approaches for maintenance. For instance, bridge management system as a part of TAM, seeks to identify current and future deficiencies in order to assist in making cost-effective decisions. Therefore, it is crucial to have sufficient data to identify the optimum case for bridge repair and rehabilitation over given time periods and available funds. Enhancing user benefits in terms of bridge safety and reliability in operations requires continuous bridge health condition monitoring to ensure preventing catastrophic events.

The current situation and future of surface transportation infrastructure in the United States is at a critical point. Approximately, one-third of bridges in U.S. are approaching to the end of their service life. This may be attributed to increasing travel demand along with constant or even decreased investment in highway infrastructure, especially bridge maintenance.

As was discussed earlier, availability of valid datasets enables decision makers to apply timely bridge maintenance programs and extend its service life to prevent or minimize subsequent additional construction costs and burden on agencies as well as society. Although, there has been significant progress in sensor technologies for collecting structural condition of bridges and conducting timely treatment, however, Bridge Health Monitoring (BHM) still remains a challenge. BHM seeks to determine whether structural condition of bridge performs as expected or there is some kind of deterioration in its behavior. It can greatly enhance the service life of the structure and improve users' satisfaction in general.

With the advancement of data-acquisition and storage programs, faster and easier approaches can be conducted for bridge health monitoring. Application of social media, mobile devices, sensors, video, and imagery technologies are some examples in this regard. This study intends to discuss applying big data and cloud computing for data management pertinent to bridge health monitoring. A new framework for real time BHM will also be proposed.

1.1 RELATED WORK

Condition monitoring of bridges have long been practiced. Cheng and Melhem [1] investigated the effectiveness of using fuzzy case-based reasoning model for bridge health monitoring. Their developed model produced reliable results with small errors. Gul et al. [2] proposed a low-cost practical monitoring approach to perform proper lubrication level in an open gear of a movable bridge by using video cameras. They developed two indices for monitoring of the open gear by investigating two different image processing methods. Im et al. [3] conducted a study reviewing GPS application for structural health monitoring. They pointed out that although the application of GPS as a Structural Health Monitoring (SHM) method cannot be applied in all different types of structures, however, it is useful in cable-supported bridges. Kallinikidou et al. [4] carried out a study with concentration on the areas of data management, data quality control, and feature extraction of meaningful parameters to describe the response of large-scale infrastructure systems for SHM. Based on the associated data, appropriate action could be taken for proper treatment on the bridge. Smarsly and Law [5] presented the design and implementation of an agent-based wireless system for SHM which resulted into 95% and 96% reduction in sensor data transmitted and the power consumption, compared to the case when all raw data had to be transmitted to a remote computer for analysis. Kaloop et al. [6] used GPS technology with wavelet principal component analysis and spectrum methods for monitoring of bridge deck deformation and analyzed the behavior and movement of bridge under moving traffic loads. Kurata et al. [7] developed a new wireless internet based SHM system for large-scale civil infrastructure. The proposed method was validated on the New Carquinez (Alfred Zampa Memorial) Bridge in Vallejo, California. Laory et al. [8] presented a novel model-free data-interpretation methodologies that combined moving principal component analysis with each of four regression-analysis methods: i) robust regression analysis; ii) multiple linear analysis; iii) support vector regression; and iv) random forest for damage detection during continuous monitoring of structures. For the combined data-interpretation methods, the best regression analyses were found to be those that are compatible with eigenvector-correlation characteristics. Wijesinghe et al. [9] presented a development work for an in situ sensor which is based on the strain-life fatigue analysis method for the detection of fatigue damage in steel bridge.

1.2 MOTIVATION AND OVERVIEW OF THE CURRENT STUDY

Bridge data collection and storage, as well as making timely decisions in order to deal with damages on bridge's structure and prevent catastrophic events, is still a challenge and requires more advanced approaches. The current study endeavors to incorporate big data and cloud computing technologies with principles of Transportation Asset Management (TAM) strategy to develop new framework for bridge data management, health monitoring, and decision making.

1.3 OUTLINE

The remainder of this paper is organized as follows: Section 2 introduces concept of big data and the way it relates to cloud computing. Application of Global Positioning System (GPS) and Geographic Information Systems (GIS) in transportation field, have also been discussed here. Section 3 upgrades existing commonly used bridge management flowchart and creates a layered big data framework for bridge data management and health monitoring. A real-time decision making framework for bridge health monitoring has also been proposed. Finally, Section 4 presents a study summary and draws conclusions.

2 BIG DATA AND CLOUD COMPUTING

The size of data in different fields including transportation is booming up all around the world. By passing the time, new angles of technology in different fields like computer science, information processing, and transportation have been identified and human beings are getting more and more curious to make interdisciplinary application of emerging technologies. For instance, in order to extract useful information from large unstructured datasets and create harmonized and well organized data, a computational process called data mining was introduced which comprises of data classification, regression, clustering and summarization.

Michael Cox and David Ellsworth introduced the term big data in 1997 to be applied for large volumes of data [10]. The term big data has been recently used in many studies to capture features of huge datasets [11], [12], [13], [14], [15], [16]. As its two words imply by themselves, it is large and unusual size of datasets that cannot be handled efficiently using the conventional and routine manners and tools. Due to its huge size, it requires special way to be processed and get ready for utilization. Two main points which need special attention in dealing with big data for critical decision making are i) physical design and conceptual correlation between various datasets; and ii) maintenance and processing. Main features of big data can be summarized in four-V as volume, velocity, variety, and value. Volume represents big size of datasets; velocity indicates speed of data collection and transferring; variety stands for different data types which involve in collected datasets; and finally value represents the importance of data for utilization.

Big data investments in 2013 shows that 64% of organizations invested or planned to invest in big data technology compared to 58% in 2012 [17]. Big data requires fast analytical processes and algorithms to organize and analyze these massive datasets. They can receive the information from several sources such as social media, mobile devices, sensors, video, and imagery. Collected datasets are usually unstructured that are not easy to be utilized. In order to clean up and create structured datasets, they need to be so called correlated and harmonized.

There are several techniques to address unstructured datasets. MapReduce is a framework for distributed computing to address processing large unstructured data sets. In simple words, MapReduce divides input files into chunks and processes these in different steps. Hadoop is an open source version of MapReduce. Hadoop clusters are useful for processing massive datasets. It has a distributed file system as its data storage layer called Hadoop Distributed File System (HDFS) and HBase distributed database. Hadoop is a Java-based MapReduce application for big data processing. What Hadoop does is mapping a single large workload into smaller sub-workloads. Then merges (reduces) these smaller workloads to get the final result. MapReduce framework can be leveraged to process large datasets using “cloud” resources.

Cloud computing has emerged as a subject of interest for researchers and practitioners. It has received lots of applications along with lower IT costs, which turns into significant efficiency level [18]. A general and simple definition of cloud computing is remote control or software virtualization [19]. Cloud has five main layers as follows [20]: Layer 1) Cloud Application: provides interface and access-management tools for specific application services to the cloud end users. This model is referred to as Software as a Service (SaaS). Layer 2) Cloud Software Environment: providers of the Cloud software environments assist users as well as developers of cloud applications in terms of programming language level. This services are called as Platform as a Service (PaaS). Layer 3) Cloud Software Infrastructure: this part provides essential resources to other higher layers. These services can be categorized as: Infrastructure as a Service (IaaS) for end users, Data Storage as a Service (DaaS) which allows users to store their data at remote disks and access them anytime as they want, and Communication as a Service (CaaS) which provides communication possibilities in different aspects. Layer 4) Software Kernel: this layer provides the core management points for taking care of software. Layer 5) Hardware and Firmware: end users, those who directly interact with the cloud, require a lot of IT subleasing Hardware as a Service (HaaS).

Cloud computing gives the opportunity to users to access computing infrastructures and software resources as different parts of a network. A cloud service can determine a very good quality of any transportation assets’ location from a raw data using Geographical Positioning System (GPS) [21]. It can also provide strong fitness and an opportunity for Geographic Information Systems (GIS) in creating multiple layers of traffic and transportation assets’ data [22].

2.1 GLOBAL POSITIONING SYSTEM (GPS)

There are a number of satellite-based positioning systems like GPS and GSM in use. GPS is a navigational system that is based on satellite and was initially started by the US department in Defense in 1973. Soviet Union developed the Global

Navigation Satellite System (GLONASS) which is currently running by the Russian Government. European Union built the Galileo system which is expected to be completed in 2014. At the meantime, Chinese government is also planning to fully develop BeiDou (COMPASS) Navigation Satellite System by 2020 [23].

GPS technology has recently received more attention in transportation studies. Venter and Joubert [24] described the use of GPS data to analyze the travel behavior and fuel consumption patterns of motorists in Gauteng Province, South Africa. Hongxia et al. [25] analyzed collected individual travel data from GPS to investigate travel behavior and develop models for urban traffic planning. Huang et al. [26] proposed an approach for estimating travel time along roadways using collected data from GPS. Zhao et al. [27] developed a methodology for identifying and ranking the road bottlenecks using data from GPS mounted on trucks.

There are three main components in GPS including: i) Satellite Vehicles or the Space Segment; ii) Control Segment; and iii) User Segment. As the name of Satellite Vehicles implies, they are satellites in space. In order to monitor and control the satellites, Control Segment can be used which is a network of ground-based facilities and is composed of a master control station, an alternate master control system, 12 command and control antennas, and 16 monitoring sites. The User Segment is the receiver equipment and uses the signals from Satellite Vehicles to arrive at a location [23].

GPS can significantly help to find out the desired location. However, it cannot assist in finding other attributes of that specific location. As Abler [28] noted, “GPS equipment will tell me where I am with great precision. But knowing precisely where I am may not be very helpful. Location, no matter how precisely specified, is sterile in and of itself. Context determines whether knowledge of location is invaluable. Contextual knowledge immensely enriches the value of locational information”. To address this issue, providing that all required data are collected, GIS is the right tool for storing and mapping all attributes of associated link or node within a transportation network.

2.2 Geographic Information Systems (GIS)

GIS based analysis enables decision makers to organize available datasets and apply proper management procedure on them. By utilizing the advanced information technology in transportation field, it is possible to determine the relationship among road network, vehicles, traffic stream, environment, and other attributes in order to get closer familiarity with desired locations and make the right decision.

More than half a century ago, in 1963, Tomlinson proposed the Canadian GIS based technology for data management and mapping of information [29]. Since then, it has vastly been used in academia and industry for digitizing and analyzing the corresponding data. GIS creates dynamic and somehow smart maps which embeds several attributes of a specific node or link into a readable box. Having all these detailed information at the same time, enable experts to get full view of different locations simultaneously.

Thill [30] introduced the concept of GIS transportation and emphasized on primary requirements to apply this technology in transportation domain. Shaw and Xin [31] presented a temporal GIS design for analyzing the interaction between land use and transportation. Loo [32] used crash, road network and district board databases in GIS to validate crash locations. Juan and Feng [33] proposed a component-oriented GIS based framework for traffic management. Kuo et al. [34] utilized ArcGIS for geocoding of the crime and crash data as well as defining the hotspots and organizing the best patrol routes within a network. Miller [35] discussed the role of GIS and social medial for cultivating transportation systems. Richardson [22] addressed impacts of real-time space-time functions on GIScience and how more progress can be made in this field. Tao [29] reviewed advancements of GIS for city management in terms of facilitating urban modeling and decision-making.

GIS plays an important role in organization, harmonization and analyzing of temporal-spatial data and also improves energy efficiency and the need for man power in data storage and retrieval. It is a very useful cartographic tool for the computerized storage as well as graphic display of multiple layers of locational data and associated information. Considering the fast development of urbanized and surrounding areas, it would have been complicated to create non-digitized maps for planning and management purposes. In compare to non-computer-based maps, GIS has greatly improved the efficiency of making and updating maps. It has brought many advantages for decision-makers as well as general public to investigate various alternatives to end up with clear understanding and right decision for implementation.

3 Layered Big Data Framework for Bridge Data Management and Health Monitoring

Figure 1 illustrates detailed procedure for bridge data management and health monitoring using concepts of big data and cloud computing. It incorporates the big data application and cloud computing with transportation asset management fundamentals. There are two phases involved in this framework, phase 1 is “cloud” based while the second phase is “decision” based. First phase is comprised of three layers including data collection, data transfer, and data storage as well as visualization. These three layers could get benefit of cloud computing technology and handle the processing of datasets using cloud resources. In the second phase, which is mainly coming from asset management strategy, experts and decision makers viewpoints are closely embedded into the framework. This phase has also three different layers as i) Data evaluation; ii) Projects prioritization; and iii) Projects implementation.

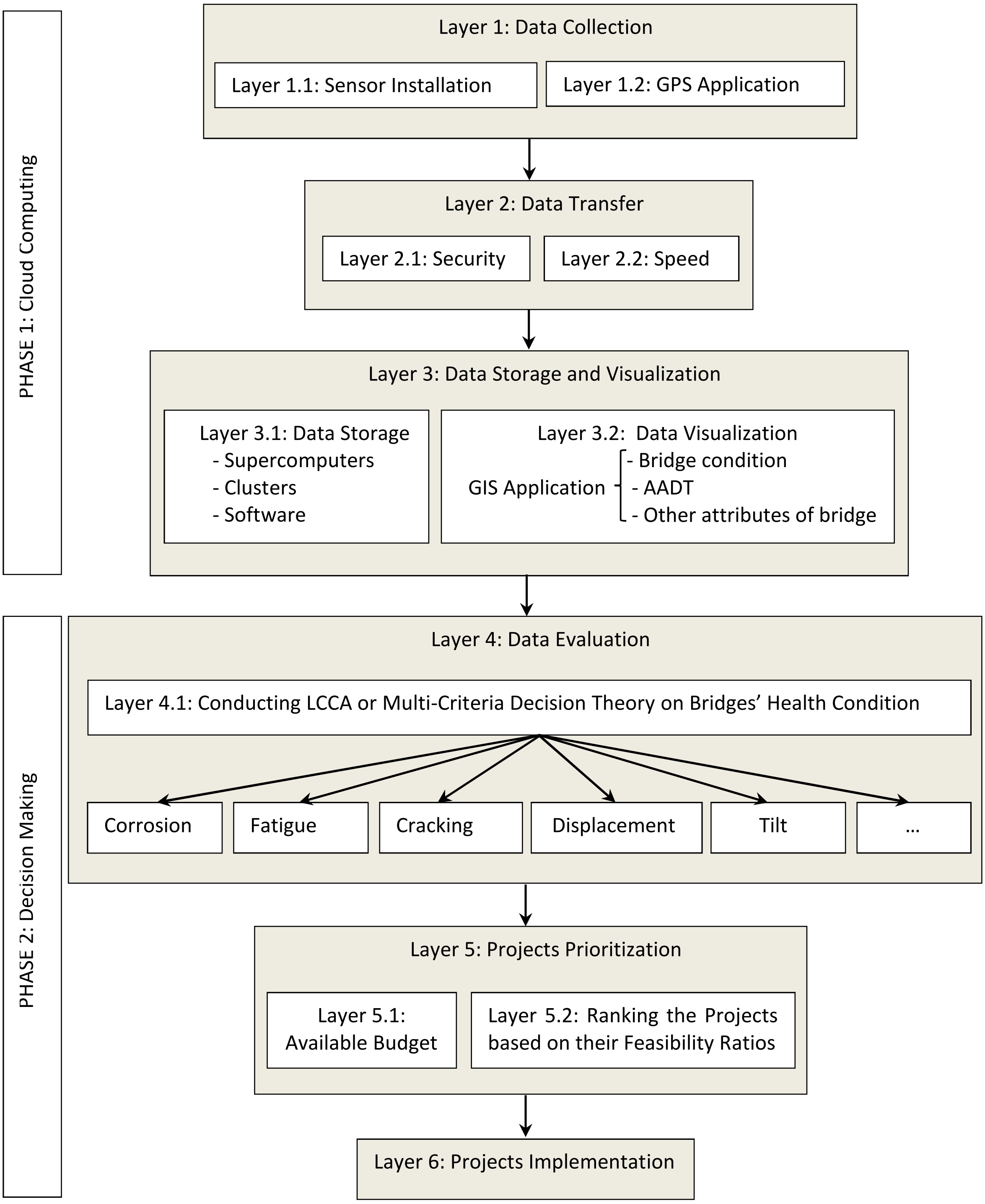

Fig. 1. Layered Big Data Framework for Bridge Data Management and Health Monitoring

Layer 1: Data Collection. In order to collect associated data of bridges' health condition, appropriate sensor types could be installed on desired locations. The sensors, by nature, capture structural condition of bridge and send the information to monitor center via GPS facilities.

Layer 2: Data Transfer. Information security is one of the main issues involved in today's data transferring. Despite proposed secure algorithms by computer science experts, it is also important to consider speed of data transfer from sensor/GPS to storage places. A trade-off analysis needs to be performed between security and speed in order to have an efficient data transfer.

Layer 3: Data Storage and Visualization. It is a struggling point to see how received data could be stored before utilization. In order to address this issue, supercomputers and clusters which are able to store huge datasets, can be used. In pursuant of having all information available, it is worthwhile to create visualized system of data and make organized layers out of them. As was discussed earlier, GIS which has extensively been used in transportation field, is a proper choice for handling this issue. Geo-coding of unstructured data and creating multiple visualized layers in GIS will assist to get easier access to corresponding datasets along with exact location of a bridge and all its attributes including health condition and etc. As such, the unstructured data can somehow be converted to organized and structured information.

Layer 4: Data Evaluation. In order to make the most appropriate decision in regard of bridges' health condition, it is essential to get the viewpoints of experts to see which deterioration type needs to be fixed first to end up with overall network-wide benefits. The overall benefits of the investment option can be determined on the basis of multiple benefit items as captured by changes in related performance measure values. Of the individual benefits items, some of them including reduction in i) construction; ii) deck rehabilitation; iii) superstructure replacement; and iv) maintenance costs and decrease in vehicle operating costs resulted from the investment could be estimated in dollar values. Two general approaches can be used to combine the individual benefit items measured in non-commensurable units into the total benefits measured in a commensurable unit. One approach is to convert the non-dollar valued benefit items into dollar values. The present worth or equivalent uniform annualized dollar values of total benefits in facility service life-cycle are then computed using the life-cycle cost analysis (LCCA) approach. The other approach is to convert non-commensurable benefit items into none-dollar scaling values using the multi-criteria decision theory. Analytical Hierarchy Process (AHP) is a multi-criteria decision approach which could be used for assigning different weighting factors between various damage types, in order to evaluate each project. In terms of bridge condition, there are several structural parameters including corrosion, cracking, fatigue, displacement, force, settlement, strain, temperature, tilt, vibration, and etc [36].

Level 5: Projects' Prioritization. The evaluation of proposed investment options will help screen out economically infeasible options. Selection and programming of the remaining economically feasible investment options can then be conducted on the basis of estimated life-cycle benefits and the investment amount for each investment option. Due to limited budget available, only a portion of the economically feasible investment options can be selected for implementation. From the network-level investment decision perspective, the selection and programming of investment options aim to select a subset from all economically feasible investment options to yield the maximized overall benefits subject to budget and other constraints. The optimization modeling for investment selecting and programming is known in the literature as the capital budgeting problem. More generally, it falls in the category of the doubly constrained multidimensional Knapsack problem, where a certain amount of budgets is designated for a specific type of physical asset or system operations and the designated budget is further restricted for each year of the multiyear resource allocation period.

Layer 6: Projects Implementation. It should be noted that there might be institutional or technical issues that will impede implementation of selected projects. In addition, other qualitative factors such as public support may also impact the actual sequence in which projects are deployed. It is important that the analysis be made flexible to keep abreast of the changing needs of highway transportation, yet robust enough to be applicable in a wide variety of areas related to bridge management.

3.1 Proposed Real-Time Decision Making System for Bridge Health Monitoring

Bridge maintenance is a kind of work which requires routine inspection and fast treatment implementation. Proposed framework in Figure 1 discussed a detailed procedure from data collection through conducting the appropriate treatment for fixing bridge related damages. One of the crucial elements which might be a part of limitations in that framework, is the matter of time. When collected data are delivered to central management office, experts could go through them to make best decision for treating the issue, however, the remaining question is how long would it take from data collection, transfer, storage, evaluation till decision making by experts and applying the right treatment? Don't we need to also include road users (drivers) as a part of decision making process?

There might be situations at which bridge damage needs immediate treatment and failing to do so would cause catastrophic consequences on road users. During the time of and also after extreme events, such as earthquakes or blast loading, SHM could be designed to provide real-time or near-real-time, reliable information about the health condition of structure. Sensors could be utilized to provide real time monitoring of various structural changes and transmit them to a remote data acquisition center for decision making. The sensors include accelerometers, strain gauges, tilt sensors displacement transducers, level sensing stations, anemometers, temperature sensors and dynamic weight-in-motion sensors. These sensors are part of the early warning system for bridges, providing the essential information that helps Department of Transportation (DOT) to accurately monitor the general health conditions of bridges. By using these instruments the factors that eventually lead to structural failure can be measured in real time. This monitoring in countries with high potential seismicity, like U.S, has more importance and needs to be preciously conducted. Seismic monitoring of a bridge also starts with the selection and arrangement of a sensing system and associated data acquisition procedure. Commonly used sensors for seismic monitoring of a bridge include seismometers for induced bridge acceleration response. Seismometers are sensors for measuring motion of the ground, including earthquake related waves, and nuclear explosions. Additionally, dynamic displacement response of a bridge to seismic loading can be measured using displacement transducers, tilt-meters and GPS. In case of measuring dynamic acceleration and stress responses of bridge to seismic loading, piezoelectric, servo-type tri-axial acidometers, and strain gauges, optical fiber sensors, can be utilized, respectively [37].

As was discussed earlier, there are situations where bridge needs immediate treatment to fix the damage. However, there are many emergency conditions that bridge damage could not receive immediate treatment. Some of the common types of these situations have been summarized in Table 1. As such, road users are the right decision makers, at these points, who should directly be informed. One of the common ways, in order to communicate with drivers, is via Variable Message Signs (VMS) installed along roadways. SHM sensors embedded on bridges could be designed to send warning messages, regarding the bridge damage or failure, to VMSs installed within at least 1 mile before that bridge. Additionally, sending warning messages to cell phones within a defined region, depending upon the location of bridge, is another way in order to facilitate real time communication with road users. Having done that, drivers could make the right decision accordingly to either stop their trip or take another route towards destination. The challenge is how this many information can be coordinated to address data processing and implementation. Strategy of big data and cloud computing, as was discussed in preceding sections, is an appropriate way to properly manage these tasks.

Table 1. Some of the Emergency Conditions when Warning Messages about Bridge Damage should be sent to Drivers via VMS and Cell Phone

Issue Type	Detailed Issue Item	
Emergency recovery	Natural incidents	- Hurricane - Flood - Wildfire - Earthquake - Landslide
	Manmade hazards	- Terrorist attacks - Chemical spills - Nuclear accidents
	Construction	- Deck failures - Bridge sub-structure damage
Evacuation	- Bridge over a railroad - Bridge over a navigation channel	
Site issues	- Accessibility of the construction site is not easy for DOT contractors - Prefabrication of deck, superstructures, substructures, and foundations is required	
Construction time	- Restriction of construction time due to adverse economic impact - Where a project is of a complex nature, for example, on an existing acute hospital site - If there are many number of on-site construction tasks - Rolling spans on runway - Floating spans on barges - Weather constraints - Natural or endangered species	
Safety concerns	- Workers are exposed to dangerous situations like working close to traffic, near power lines, or over water - On complex projects which involve the use of specialized work methods or equipment	
Environmental issues	- Involvement of environmentally sensitive area - Historical bridge - Land use and ecosystem - Drainage	
Standardization	- Availability of Federal, state, industry and local prefabricated bridge standards - Incorporation of aesthetic or context sensitive design requirements - Special superstructures of the trusses, cable stayed and movable (bascule, lift and swing) - High strength bolt installation and inspection	
Maintenance of traffic	- Concerns of excessive work zone induced user delays and crashes - Congested urban areas where costs associated with traffic control increase substantially - Reduce access to the business - Congestion in front of businesses - Improvements in level of service, lane mile hours at LOS E or worse	

Figure 2 illustrates proposed real time decision making process for bridge health monitoring. Depending upon the emergency level of bridge's damage, the appropriate message could be sent to either drivers or experts at associated DOT, to make timely decision.

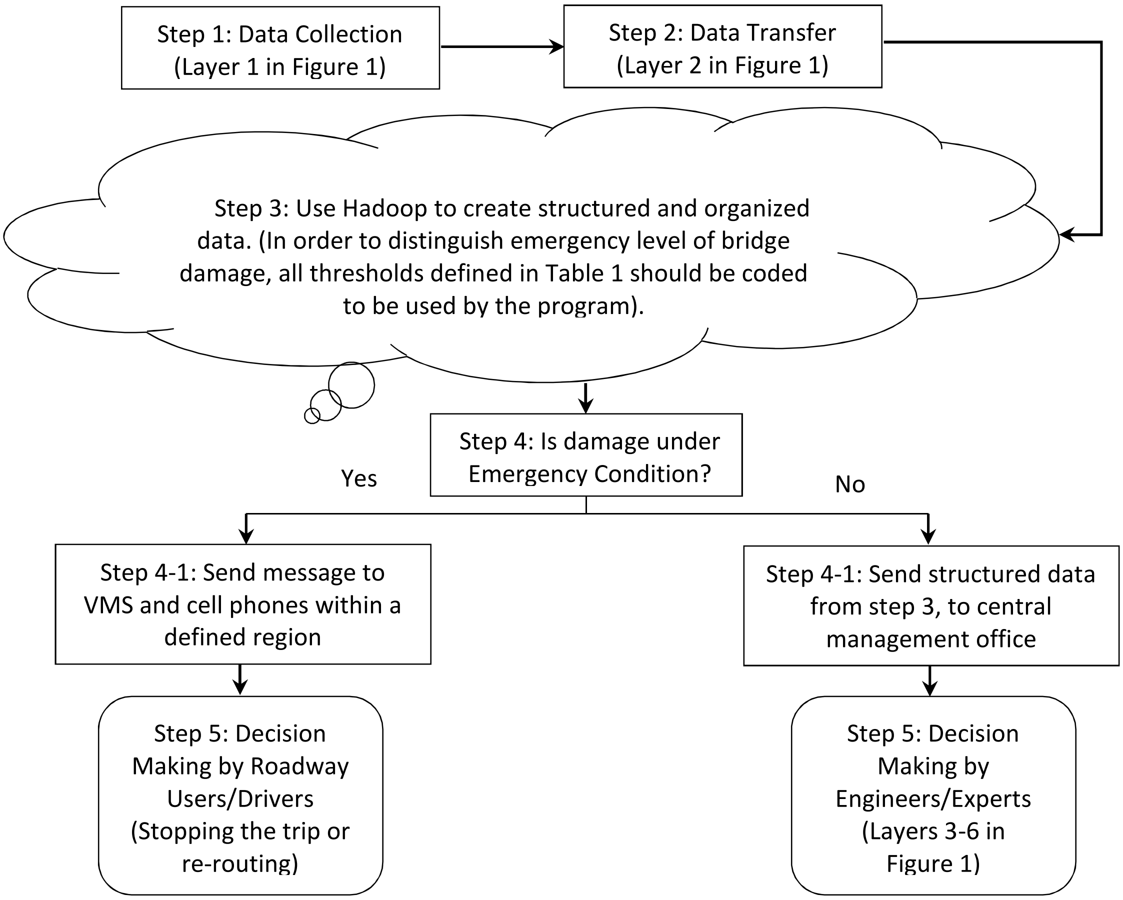

Fig. 2. Proposed Real-Time Decision Making Framework for Bridge Health Monitoring

4 SUMMARY AND CONCLUSION

With the advancement of data-acquisition and storage programs, fast and easier approaches can be conducted for bridge health monitoring. Utilizing social media, mobile devices, sensors, video, and imagery technologies are some examples in this regard. The current study incorporated big data and cloud computing technologies with principles of transportation asset management strategy and developed new framework for bridge data management and health monitoring as well as real time decision making to deal with bridge's health condition. MapReduce which is a framework for distributed computing to address processing large unstructured data sets was discussed. In simple words, MapReduce divides input files into chunks and processes these in different steps. Hadoop was also introduced which is an open source version of MapReduce. Hadoop clusters are useful for processing massive datasets. It was mentioned that MapReduce framework can be leveraged to processes large datasets using “cloud” resources. Cloud computing has received lots of applications along with lower IT costs, which turns into significant efficiency level. A general and simple definition of cloud computing is remote control or software virtualization. A cloud service can determine a very good quality of any transportation assets' location from a raw data using GPS. It can also provide strong fitness and an opportunity for GIS in creating multiple layers of traffic and transportation assets' data.

The conventional framework for bridge data management and health monitoring was upgraded. In this framework, big data application and cloud computing were incorporated with transportation asset management fundamentals. There are two phases involved in this framework, phase 1 is “cloud” based and phase 2 is “decision” based. First phase is comprised of three layers including data collection, data transfer and data storage as well as visualization. These layers could get benefit of cloud computing technology and handle the processing of datasets using cloud resources. In the second phase, which is mainly coming from asset management strategy, experts and decision makers viewpoints are closely embedded into the framework. This phase has also three different layers as i) Data evaluation; ii) Projects prioritization; and iii) Projects implementation.

There are many emergency conditions that bridge damage needs to be immediately fixed, however, due to many circumstances it cannot be done. At these situations, road users are the right decision makers, who should directly be informed about the bridge condition. In order to communicate with drivers, one of the common ways is via Variable Message Signs (VMS) installed along roadways. SHM sensors embedded on bridges could be designed in a way to send warning messages, regarding the bridge damage, to VMSs installed within at least 1 mile before that bridge. Additionally, sending warning messages to cell phones within a defined region, depending upon the location of bridge, is another way in order to facilitate real time communication with road users. To address difficulties of real time communication with road users and/or experts in central management office (like DOT), the emerging technology of big data and cloud computing could be utilized.

Although, the proposed procedure for real time communication with road users and decision makers at DOTs, seems to be a new path in terms of transportation asset management, however, it still requires additional work before implementation.

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