Keywords: emergency management; transportation systems; U.S. highways; disaster; hazard

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A COMPREHENSIVE EMERGENCY MANAGEMENT STRATEGY FOR TRANSPORTATION SYSTEMS IN USA

Summary. Transportation systems in USA are an integral part of the current infrastructure systems and involves a huge investment as part of the government and taxpayers. Therefore, transportation systems have economic, social and vital importance for the U.S. Security and safety of transportation systems and infrastructures in case of any possible future disasters and hazards are crucial for state transportation agencies. The objective of this paper is to develop and implement a comprehensive emergency management strategy for transportation systems in the U.S. in case of any disaster and hazards. In this paper, recommendations are provided to define best deployment of updated emergency response into practice. Practical issues are detailed affecting potential implementation of the strategy. Possible actions to address management issues and tools are investigated; and methods of identifying and measuring the impacts associated with implementation of the strategy are explained.

1. INTRODUCTION

In the United States, current transportation systems are an integral part of the current infrastructure systems. The transportation system in U.S. requires big investment on parts of the governmental entities and taxpayers. The current state of the infrastructure is in critical condition and there is a widespread concern stemming from various stake holders to address the condition of this infrastructure elements through implementation of sustainable construction practices.

Overall highway construction industry expenditures are estimated as on the order of $80 Billion annually in the United States. Furthermore, the highways are rated D+ per the Infrastructure Report Card published by the American Society of Civil Engineers (ASCE). Currently, transportation systems have economic, social and vital importance for the country. Security and safety of transportation systems and infrastructures in all over the U.S. in case of any disasters and hazards are crucial for the state transportation agencies. In case of any disasters, the state agencies should have a better understanding on upgrade the traditional activities and integrate them with the national emergency activities. This should be integrated with modern technology and tools to be able to integrate with other governmental institutes. An effective emergency management strategy development is very important [1, 2].

For centuries, disasters have been defined as the events triggered by hazards; in effect, they are potentially negative consequences that have become reality due to the occurrence of hazard. Developing an appropriate emergency management model for transportation systems is a complex process. Emergency management can only be as good as the available spatial information for decision makers. In emergency management tools, emergency cycles include the following stages as given in Fig. 1. Addressing the requirements of emergency managers, planners, government officers and engineers is particularly critical for success in the short and long run.

An emergency preparedness and response framework in the U.S. are being challenged by extensive all-hazards definition of emergency. At all levels of government, practices in place to plan for and respond to emergencies have had to evolve rapidly, driven by the changing risk environment, emergency technology, and new policy direction at both state and federal levels. Therefore, an efficient and applicable emergency management tool for transportation systems should include the capabilities for estimating damage and loss, and emergency management, response and mitigation analysis capabilities and uncertainty qualification in the process for development and application stages. It is very important that state departments of transportation understand how to upgrade their traditional activities and integrate them with the national emergency activities [3-5].

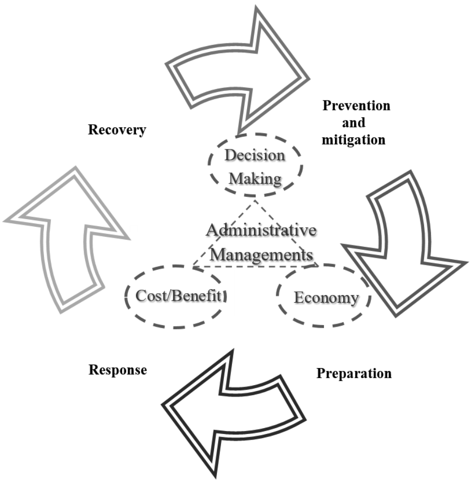

Fig. 1. Emergency management cycle

2. TRANSPORTATION ASSET MANAGEMENT

To develop an effective emergency management approach, transportation asset management should be understood well. Since emergency management will be part of transportation asset management. In Transportation Asset Management, the AASHTO Transportation Asset Management Guide has cover both transportation asset management and emergency management. Fig. 2 gives the framework for Transportation asset management. In Table 1, a list of critical assets includes pavements, bridges, safety assets and multimodal assets are provided. It was developed by Ohio DOT, targeting to integrate into centralized asset database [6].

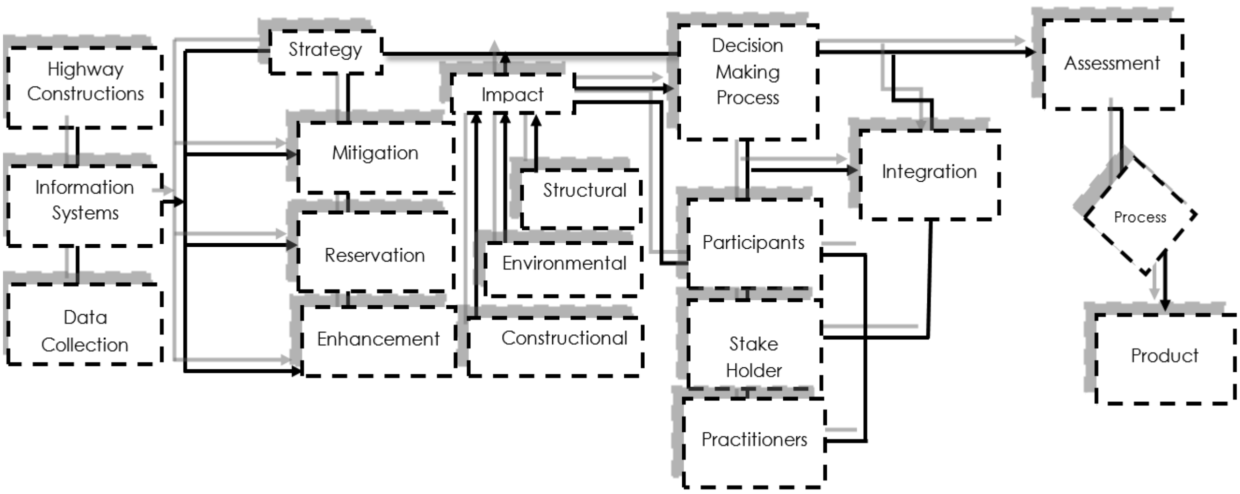

Fig. 2. Framework for Transportation Management System

Table 1

List of Critical Assets

Highway Assets	**Structure Assets**	**Safety Assets**	**Multimodal Assets**
- Pavement - Interchanges and intersections - Liveability and environmental items	-Bridges - Culverts Retaining Walls - Ditches - Catch Basins - Drains	- Barriers - Signals - Signs - Lighting systems - Pavement markings	- Railways - Ports - Bikeways - Airports and Heliports -International Facilities

Considering critical assets for cost analysis, there are various indices in transportation management systems. To define the efficiency of Transportation Management applications, a sample cost calculation is given in Fig. 3. This calculation is carried out by using these equations given below. A sufficiency index (ΣI) and health index (HI) are defined with the collected data in life cycle. Sufficiency index is defined in Eq. 1:

$$\Sigma I = E_1+E_2+E_3-E_4 \qquad (1)$$

The index defined in Eq. 1 is based on structural efficiency (E_1), Essentiality (E_2), Serviceability and functionality (E_3), and reductions (E_4). E_1 cannot exceed 40%, E_2 cannot exceed 20%, E_3 cannot exceed 30% and reduction cannot exceed 10%. The use of the sufficiency index and health index have impacted the business processes of managing highways. Health Index is defined as given in Eq. 2:

$$(HI) = (\sum XE\varsigma \div \sum TE\varsigma) \times 100 \qquad (2)$$

$$\text{Total Element Value } (TE\varsigma) = \text{Total element quantity} \times \text{Failure cost of element } (\Phi X) \qquad (3)$$

$$\text{Current Element Value } (XE\varsigma) = (\sum [\text{Quantity in condition state } i \times \Omega\Phi(i)]) \times \Phi X. \qquad (4)$$

8.0%	Discount rate	Estimated annual costs			Part distribution (Random Monte Carlo Selection)	Net Present Value Calculation (Year)		
Cost Descriptions	Contingency	Lower	Mean	Upper		1.00	0.93	0.86
						0	1	2
New costs (A) - Replace columns and install LED luminaires								
Installation of new columns and cabling and removal of old poles		$1,296,750.00	$ 1,365,000	$ 1,638,000	$ 1,463,468			$ 1,463,468.37
Additional cost for the alternative (2, 10, 25% of based cost)		$ 29,269.37	$ 146,346.84	$365,867.09	$ 110,718			$ 110,717.83
6 yearly testing after year 10 for new poles		$ 23,750.00	$ 25,000	$ 30,000	$ 24,919			
Design and procurement		$ 47,500.00	$ 50,000	$ 60,000	$ 49,057	$ 24,528.37	$ 49,056.74	
New Luminaires		$ 153,900.00	$ 162,000	$ 194,400	$ 162,309			$ 162,309.26
General maintenance costs (Start and end)		$ 18,183.00	$ 19,140	$ 22,968.00	$ 19,368			
General maintenance costs (mid)		$ 13,637.25	$ 14,355	$ 17,226.00	$ 14,622			
Annual power costs		$ 17,621.27	$ 18,548	$ 22,258.44	$ 17,848			$ 17,848.02
						$ 24,528.37	$ 24,528.37	$ 24,528.37

Fig. 3. A Sample Cost Calculation for Assessment

3. TRANSPORTATION POLICY IN THE U.S.

In the U.S., transportation policy is one of the most important policies all over the country. There is considerable guidance on traffic incident management using an all-hazards approach. However, that makes the problem very complex. In the transportation policy, emergency management has a special importance. In this manner, emergency management is an ongoing and developing process for the state transportation agencies.

The line goes above it, which most state transportation agencies have largely accomplished, is the most challenging due to its complexity. With variety of components, emergency management becomes ineffective for such a huge transportation network. In Fig. 4, the complexity matrix is given. As given in Fig. 4, Degree of Hazards/Threats, strengthen the incidents and the responses [7]. As given in the graph, federal level, state level, and local agency level management responses are determined regarding frequency of incidence. In Table 2, various levels of incidents are given in a matrix form. In this matrix, emergency responses are given based on the level of the incidences. Planned Activities, minor, major and natural disasters are defined as different incidences and each incidence has different nature.

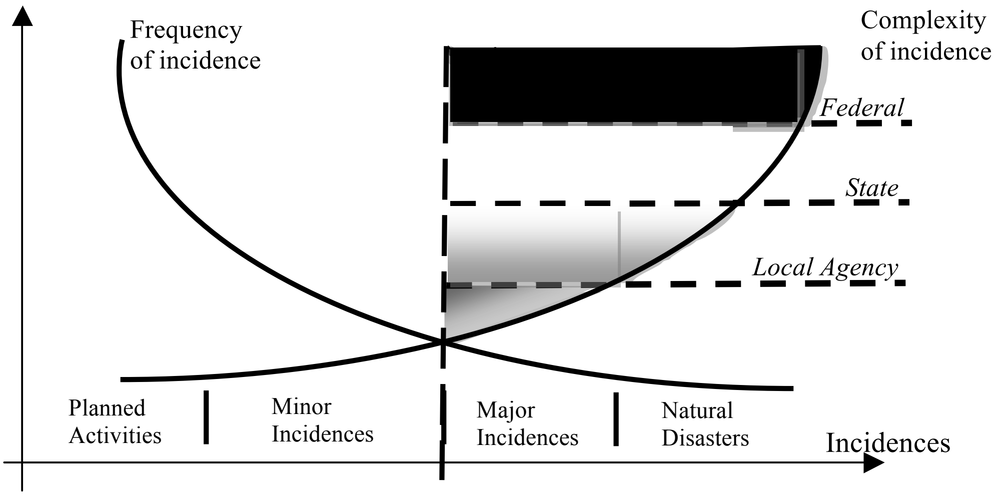

Fig. 4. The complexity matrix of emergencies and response

Table 2

General incident characteristics matrix

Level	Definition	Cause	Duration	Effect	Response
Planned Activities	Planned special events	Entertainment, sports, social, political	Hours to weeks	None to minor	As Scheduled
Minor Incident	An incident generally resolved by local agencies	Minor-moderate traffic, minor flooding or fires	Minutes to Several hours	Minor	Manageable
Major Incident	An incident requiring multiple jurisdictions	Major traffic, suicide attempt	Hours to days	Medium to Major	Urgent
Natural Disaster	Any naturally occurring major emergency	Weather, agricultural, earthquake	Days to months	Major	Vital

4. A COMPREHENSIVE EMERGENCY MANAGEMENT

The emergency management approach, as a disaster assessment strategy, serves to provide usable tools for modelling hazard and disaster response for transportation systems in the U.S. [8]. As afro mentioned, developing a suitable disaster management tool is a complex process. Addressing the requirements of emergency managers, planners, government officers and engineers is particularly critical for success, especially for such a huge pool as the U.S. transportation systems. The emergency management tool should include the overcome capabilities for estimating damage and loss, and also emergency management, response and mitigation analysis capabilities, and uncertainty qualification.

Risk assessment tools development for the U.S. transportation agencies can be accomplished in such developments as given in Table 3 [9]:

1. First Level Development: Development of comprehensive tools;
2. Classification Development: Development of the tool capabilities;
   a. Data management, hazard characterization and damage analysis;
   b. Damage detection, assessment and damage analysis;
   c. dependent infrastructure assessment;
   d. Total loss and damage analysis;
3. Second Level Development: detailed structural assessment;
4. Application Development: Development of risk management sources that provide a total assessment development.

Table 3

Accomplishment of Emergency Management Tools

First Level Development	Development of comprehensive tools beginning with needs assessment
Classification Development	Development of the system capabilities
a. Data management, hazard and damage analysis b. Damage detection, assessment and analysis c. Total loss and damage analysis d. Probablistic approches	
Second Level Development	Includes structural assessment
Application Development	Development of project to establish a software and risk management sources

The cycle of emergency management is given in Fig. 5. Created cycle is defined for emergency management procedure. Emergency management is a continuous process and integrated with assessment approach [10]. Assessment is related with site information and GIS based technology. Fig. 6 depicts an emergency management organization shame with emergency management stages. Each of the phases of the process within the emergency management phases are defined in the GIS based environment for data collection in an accurate way and in a short period [11].

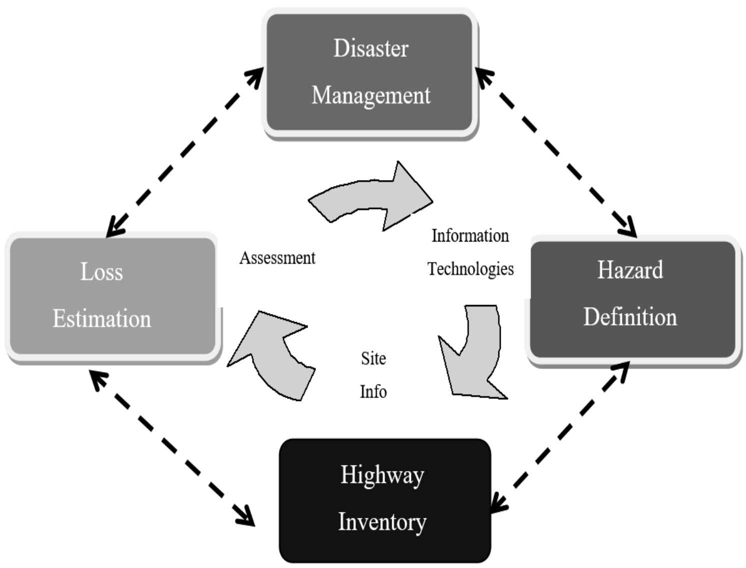

Fig. 5. Cycle of emergency management

In the emergency management for infrastructure and transportation system procedure, methodology has been integrated with critical assessments an evaluation processes that can be emerged with other segments concurrently. Selected area investigation, economic investigation, hazard investigation and loss investigation have been used in post assessment for an accurate result. In the procedure, gained results are used for implementation better emergency management procedure for infrastructures and transportation systems. Application of the emergency management systems is varying in different states with different parameters and components in the equation of the statement [12-14].

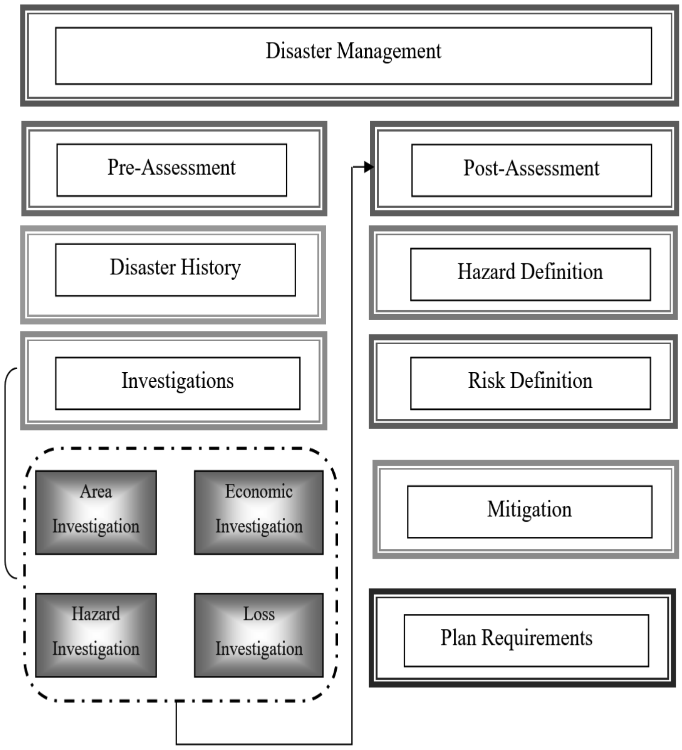

Fig. 6. Cycle of emergency management

For risk assessment analyses, site conditions and observed damages are very important. An emergency case considers economic loss, existing problems, road blockage, fire, and explosions. The disaster assessment, with the all structural considerations supports a realistic post-disaster period. The emergency management evaluation methodology is given in Fig. 7. To assess disaster effectively, the approach covers:

1. Determining the disaster sources and potentials;
2. Calculating possible damages;
3. Supporting logistics for response and recovery;
4. Determining losses and damage levels;
5. Analyzing vulnerability;
6. Probabilistic assessment.

Considering these features makes the emergency management effective. With an effective emergency management approach, recovery after disasters becomes more resourceful and feasible. Most importantly, all developments should be considered with the governmental strategies and limitations in the U.S. [15-17].

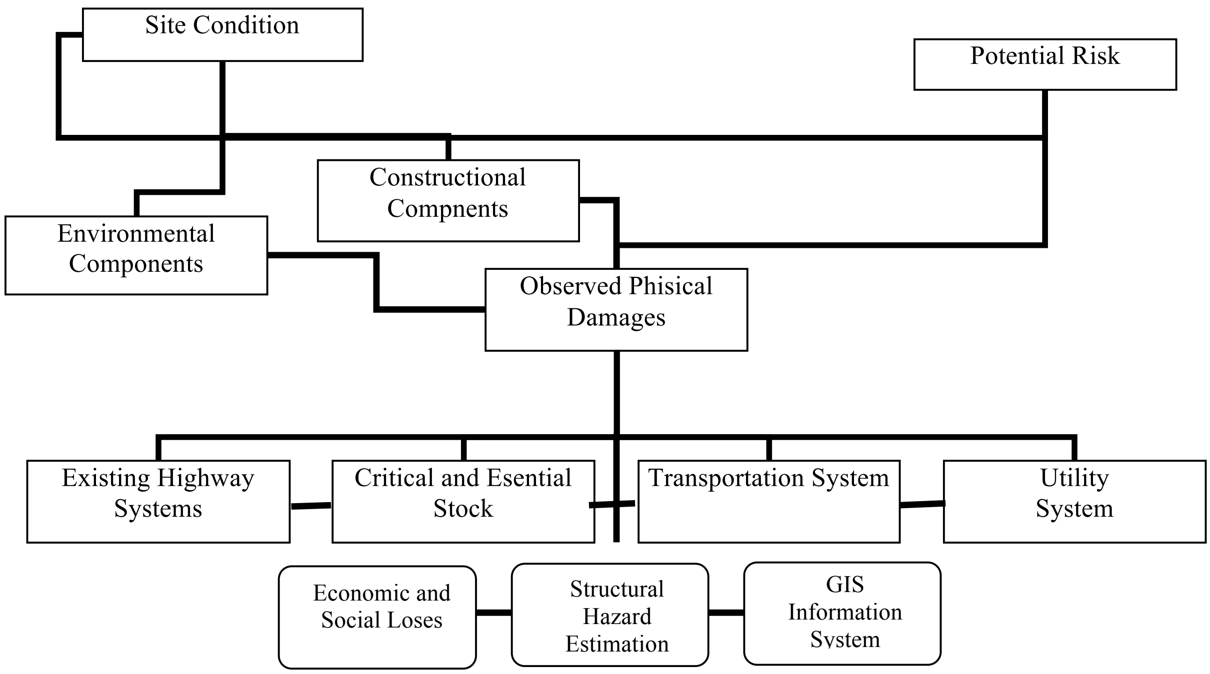

Fig. 7. The emergency management flow chart for disaster assessment methodology

5. EMERGENCY MANAGEMENT PLAN

In emergency management, various agencies have proposed various approaches. FEMA has proposed “all-hazards” approach to emergency response, defining functions and activities that are common to all types of emergencies, rather than planning responses differently for each type of emergency. As given in Fig. 8, four steps have been defined as mitigation, preparedness, response, and recovery in managing and containing the effects of an emergency [18-20].

Mitigation refers to actions taken to minimize potential risks and hazards. Mitigation for transit systems may include vehicle and facility design considerations, training in safety procedures and standards, and other activities that promote safe operating conditions.

Preparedness is the groundwork that should be laid for crisis intervention. Emergency capability assessment, responsibilities and communications within and between organizations, emergency procedures, and training are all issues that need to be addressed in advance.

Response begins when the emergency situation has occurred when warning signs indicate that an emergency is imminent.

Recovery takes place after the crisis has passed and involves repairing damage and restoring normal operations. Debriefing and assessment of the response and its success are also part of the recovery phase.

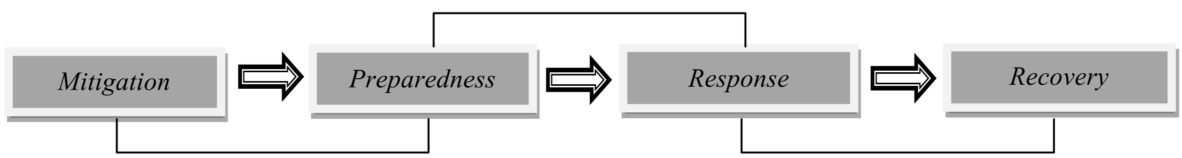

Fig. 8. Steps in emergency management plan

6. EMERGENCY MANAGEMENT IN ADMINISTRATION

Emergency management in administration level is a multi-dimensional transformation and administration process of site information, engineering knowledge and seismic hazard evaluation to response, recovery and mitigation after an earthquake. One of the main challenges of disaster management concerns to proper information. A dependable emergency management is related to accurate hazard evaluation. In the recent years, emergency management has attracted a great deal of attention from both researchers and practitioners. Complexity and uncertainty in many practical problems require new methods and tools. Emergency management in administration and coordination is assembled and organized at the headquarters level, particularly to address incidents that cross regional borders or have broad geographic or system-wide implications [21-23].

Fig. 7 depicts a possible emergency management organization including the link to the commonwealth for national-level support. The main links for the emergency management are: local government, disaster district, state government and commonwealth government. Each of the phases within the state emergency management phases has as its basis a committee structure supported by a coordination center. The committees and coordination centers are activated when required to manage and coordinate support for disaster stricken communities [24].

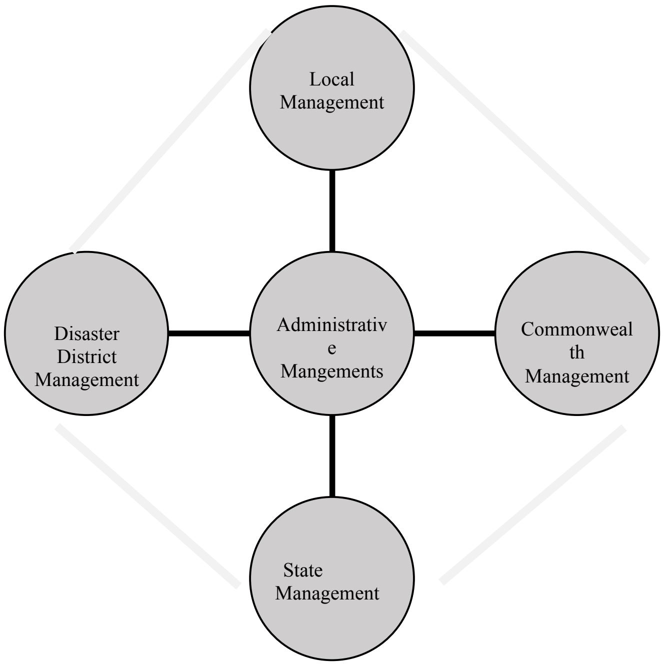

Fig. 9. Emergency management administration organization chart

Most Cabinet-level departments and agencies have at least one headquarters-level operations center. A wide range of such centers maintain situational awareness within their functional areas and provide relevant information to the DHS National Operations Center (NOC) during an incident. These operation centers also coordinate various activities and communicate with other operations centers. Examples of Federal Operations Centers include [25-27]:

- National Operations Center (NOC);
- National Response Coordination Center (NRCC);
- National Military Command Center (NMCC);
- Strategic Information and Operations Center (SIOC);
- Joint Operations Center (JOC).

7. CONCLUSION

The present study proposes a comprehensive emergency management strategy for transportation systems in the U.S. in case of any disaster and hazards. The research has been carried out based on the findings of previous research work [10, 11]. In the paper, recommendations are provided to define best deployment of updated emergency response into practice. Issues are detailed affecting potential implementation of the strategy. Possible actions to address management issues and tools are investigated; and methods of identifying and measuring the impacts associated with implementation of the strategy are explained. The proposed methodology utilizes assessment components. By involving current emergency management in asset management, a detailed and combined methodology has been defined for transportation systems in the U.S. Through the proposed methodology, an effective, fast and dependable disaster assessment is planned.

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Received 09.10.2016; accepted in revised form 07.12.2017