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DEVELOPMENT OF RESPONSE PLAN OF AIRPORT FOR MEGA EARTHQUAKES IN NEPAL

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ABSTRACT

Recent earthquakes in developing countries suggests that an earthquake of large scale near Kathmandu today could cause human casualty and devastation of a degree that has been observed in Kashmir or Port-au-Prince. The consequences for Nepal if a comparable or a bigger disaster happens in Kathmandu would likely be worse than in Haiti because the Kathmandu Valley is landlocked within a rugged mountainous valley and the city's ability to connect with the outside is limited to air transportation as ground transportation is also susceptible to be dysfunctional in major earthquakes. This paper presents the important aspects of recently developed Earthquake Emergency Response Plan of Tribhuvan International Airport, Kathmandu. It also describes the approach and methodology adopted to develop emergency response action items as well as strategies of rapid assessment, recovery and emergency aid handling for the situation where emergency response system is non-existent at any level of government, institutions and infrastructure facilities. The methodology considered the specific setting of the city and the country in terms of geography, demography, hazard, institutional arrangements, resources and technology available in the country and stakeholder's perceived concerns. The developed methodology is considered to provide a standard for development of earthquake emergency response plan for other infrastructures in the country as well as for other airports in the region.

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Development of Response Plan of Airport for Mega Earthquakes in Nepal

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Recent earthquakes in developing countries suggests that an earthquake of large scale near Kathmandu today could cause human casualty and devastation of a degree that has been observed in Kashmir or Port-au-Prince. The consequences for Nepal if a comparable or a bigger disaster happens in Kathmandu would likely be worse than in Haiti because the Kathmandu Valley is landlocked within a rugged mountainous valley and the city's ability to connect with the outside is limited to air transportation as ground transportation is also susceptible to be dysfunctional in major earthquakes. This paper presents the important aspects of recently developed Earthquake Emergency Response Plan of Tribhuvan International Airport, Kathmandu. It also describes the approach and methodology adopted to develop emergency response action items as well as strategies of rapid assessment, recovery and emergency aid handling for the situation where emergency response system is non-existent at any level of government, institutions and infrastructure facilities. The methodology considered the specific setting of the city and the country in terms of geography, demography, hazard, institutional arrangements, resources and technology available in the country and stakeholder's perceived concerns. The developed methodology is considered to provide a standard for development of earthquake emergency response plan for other infrastructures in the country as well as for other airports in the region.

Introduction

The 2010 Haiti Earthquake highlighted the need of effective airport emergency management in a major disaster in a developing country. The 7.0 Mw magnitude earthquake damaged the control tower of Toussaint L'Ouverture International Airport, the main airport of the country [1]. Several aircrafts carrying emergency medical aid had to be turned away from landing in the first few days when they were badly needed [2] in the rescue and emergency relief. Even after several days after the earthquake, humanitarian aid flights were diverted to the Dominican Republic, where their cargoes were unloaded and taken to Haiti by land. This event served as a reminder

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for other airports in the earthquake prone areas, especially in developing countries which need foreign emergency aids in a catastrophe, to adopt a robust emergency response system that can bring the functionality of airport in the immediate aftermath of a major earthquake.

Earthquake emergency management of airport in developing countries may sometime be more challenging than in developed countries. Major airports in developed countries generally have well-defined emergency response plans that include specific procedures for responding to earthquakes and other natural events. In most cases, the physical infrastructure of airport system is made resilient to natural hazards, which significantly limits the burden of emergency response actions. Airport system in developed countries belongs to a comprehensive transportation system that has large degree of redundancy through nearby airports, roads, rails and marines to serve the affected communities. With the redundancy in the transportation network, the airports may not be under acute demand to deliver the relief material to the disaster victims in its catchment area. The airports in the developing countries, on the other hand, may face severe traffic in the immediate aftermath of a major disaster not only because of the need for large volume of relief aid but also due to lack of redundancy in the system. Ground transportation through roads and railways is also likely to be suspended due to damages in poorly designed and ill-maintained bridges and roads connecting the earthquake stricken area from outside. In such a catastrophe, airport in a landlocked city is likely to be the only means of link to the outer world.

Procedures of emergency management in large airports in developed countries are very detailed and sophisticated so as to adhere with existing rules and regulations and with complexity of the airport system. These results in complicated response plans that require extensive training of airport personnel over an extended period of time, and that are not applicable to smaller airports or airports in developing countries. In the developing country's context, it is impractical to create highly detailed emergency response plans since it is very likely that the facility would lack the necessary staff or resources for their successful implementation.

This study focuses on the development of earthquake emergency response system for the airport of the city of Katmandu in Nepal, named as Tribhuvan International Airport (TIA). It presents a case where an airport needs simple yet effective response plan to meet the developing country's need. A methodology of developing response plan is presented which engaged subject matter experts and stakeholders in operations and management of airport.

Seismic Hazard of Kathmandu

Nepal has a long history of destructive earthquakes [3, 4, 5, 6]. From west to east, the sequence includes the 1905 Kangra earthquake (Ms~7.8), the 1934 Bihar–Nepal earthquake (Mw~ 8.1), the 1897 Shillong earthquake (Mw~8.1) and the 1950 Assam earthquake (Mw~8.6) as shown in Figure 1[7]. The Great Nepal-Bihar earthquake in 1934 reportedly killed 8,519 persons and damaged 80,000 buildings just within Nepal's borders. The earthquake destroyed 20 percent and damaged 40 percent of Kathmandu's building stock. The Sikkim/Nepal border earthquake of September 18, 2011 was the latest earthquake (Mw=6.9) in Nepal. In this century alone, over 11,000 people have lost their lives in four major earthquakes. A study of the seismic record of the region suggests that earthquakes producing a shaking level of IX or more in the Modified Mercalli Intensity (MMI) scale occur approximately every 75 years, while smaller ones occur more frequently. Based on the occurrence frequency, a major earthquake is likely to hit the region in the near future [8, 9]. A large earthquake today near Kathmandu, which is the cultural, political and economic heart of the country, would cause a far greater human tragedy, extensive physical damage, cultural loss and economic crisis than was caused by past earthquakes. With the city's burgeoning population, uncontrolled development, and the construction practice that has actually degraded over the last decades, it is becoming increasingly vulnerable to earthquakes with each passing year.

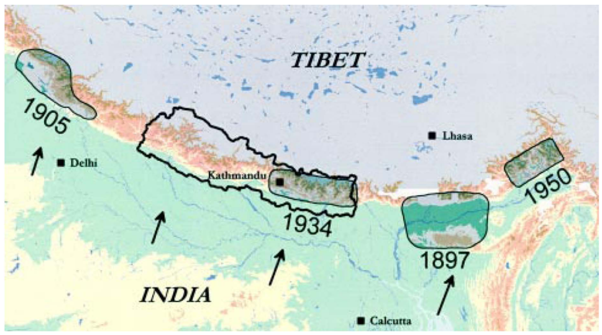

Figure 1. Historical seismicity of Nepal - Distribution of probable rupture zones of the 1897, 1905, 1934 and 1950 earthquakes along the Himalayan arc [7]

Lessons from recent earthquakes in developing countries, particularly those ill prepared to absorb the shock, suggest that an earthquake of large scale near Kathmandu today could cause similar death and devastation of a degree that has been observed in Kashmir, Pakistan and most recently in Port-au-Prince, Haiti. The consequences for Nepal if a comparable or bigger disaster happens in Kathmandu would likely be worse than in Port–au-Prince because the city is landlocked within rugged mountains and its ability to connect with the outside is limited to ground transportation (susceptible to be dysfunctional in major earthquakes) and air transportation.

Tribhuvan International Airport (TIA), located in the Kathmandu city, is expected to be the only means of transportation for international aid and relief operations after a catastrophic earthquake hits the country. TIA had an emergency response plan focused only on aviation accidents. The existing response plan is extended to cover emergencies arising from natural disasters including earthquakes. Without a comprehensive emergency response plan in place, TIA is not designed to meet the operational demands required to properly respond to a catastrophic event, which requires expeditious handling of response and recovery missions. The approach and steps of extending the response plan to earthquake emergency is described in this paper.

Development of Earthquake Emergency Response Plan

Figure 2 illustrates framework of development of Tribhuvan International Airport earthquake emergency response system. Seismicity, physical infrastructure of the airport and status of stakeholders are the baseline parameters in problem identification and situation analysis. Seismic vulnerability assessment of physical components of airport and its territories together with mapping of roles and responsibilities of stakeholders provide likely scenarios of airport functionality at given seismic hazard levels. Assessment of runway system, terminal building, control tower, radar system, CFR facility, fuel farm, cargo building and other operation building provides the information on physical capacity of airport under different scenario earthquakes.

Similarly, information on institutional setting of airport system is essential to estimate the functional capacity of institution in the emergency. Since the response system is basically an institutional arrangement, analysis of stakeholders that are involved to the airport operation and emergency aid handling provides basis for command and control system required in the emergency. The relationship between stakeholders under the current legal and administrative protocol and their holding of resources are the key items to be mapped in the stakeholder analysis.

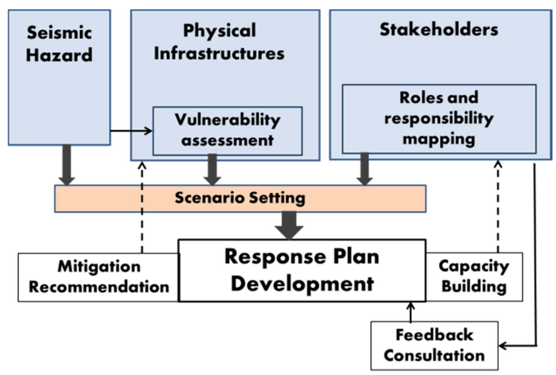

Figure 2. Framework of development of TIA earthquake emergency response system.

With this information in hand, airport earthquake emergency response plan can be developed for a given scenario. The plan document, however, remains a dynamic document as the structural variables and other arrangements are subjected to change for improvement. When seismic vulnerability of some airport facilities is reduced, the demand in emergency response is reduced, which should also be reflected in the response plan. Similarly, the capacity enhancement of airport staff by training will increase the efficiency of emergency response actions. The institutional arrangements prescribed in the plan should be confirmed with the actors in the feedback consultation.

Seismic Assessment of Physical Infrastructure

Assessments of aviation assets at TIA were conducted to determine their seismic vulnerabilities [10]. Vulnerability is expressed in a rating system to emphasize the impact to operability if a facility were damaged or lost in a scenario earthquake that creates Modified Mercalli Intensity (MMI) IX in the airport. Seismic vulnerability was classified as "L" (Low), "M" (Medium), and "H" (High). The classification was determined through the visual inspection of the facilities. Retrofitting priority was classified as "1st", "2nd", and "3rd". Priority rankings were based on the importance of the facility to the operational capacity of TIA. The ranking of different TIA aviation facilities is presented in Table 1.

Table 1. Seismic vulnerability of airfield structures at TIA [11].

Structure/component	Vulnerability			Retrofit Priority		
	L	M	H	1st	2nd	3rd
Runway System			√	√		
CFR Foam Storage Building			√	√		
CFR Foam Mixing Tank			√	√		
ATCT Cab/Shaft Junction			√	√		
Domestic Terminal Building			√	√		
Utility Lifeline Support			√	√		
Runway System Pavement		√		√		
Fuel Farm Water Tanks		√			√	
Runway System Drainage System		√			√	
Radar Tower		√				√
Power House for Radar		√				√
CFR Main Building		√				√
Air Cargo Building		√				√
Fuel Farm Fuel Tanks		√			√	
International Terminal		√				√
Radar Approach		√				√
ATCT Shaft	√					√
VOR/DME	√					√

Assessment of Liquefaction Potential of Airfield

Investigation of subsoil was carried out in the airfield by carrying out field test with bore holes and laboratory testing [11]. Data collected by the field testing were analyzed for carrying out liquefaction analysis for addressing the risk of liquefaction during the event of scenario earthquake (Mw=7.6, PGA=0.35g). The ground investigation of the airport was carried out by drilling thirty two boreholes to varying depths of 4.5 m to 30 m. The prominent soil type existing at the site was found to be silty-sand. It was found that soil is liquefiable in the 10 borehole locations. The result of liquefaction potential is presented in Figure 3.

Pavement Analysis of Runway

Strength/condition test was carried out of the pavement in runway of the airport [12]. The result of the test showed that Pavement Condition Index (PCI) ratings ranged between “Good” and “Satisfactory.” Airfield surfaces have a number of common distresses, which if not monitored and maintained, could lead to severe operational issues. Distresses included bleeding, fatigue cracking, block cracking, corrugation, jet blast erosion, depression, joint-reflection cracking, longitudinal/transverse cracking, oil spillage, patching, weathering, rutting, corner breakage, joint seal damage, pumping, settlement, and spillage cracking. It was found that Asphalt composition and binder to aggregate ratio varied greatly throughout the length of the runway. Results showed significant areas of subsurface weakness on the north side of the airport apron.

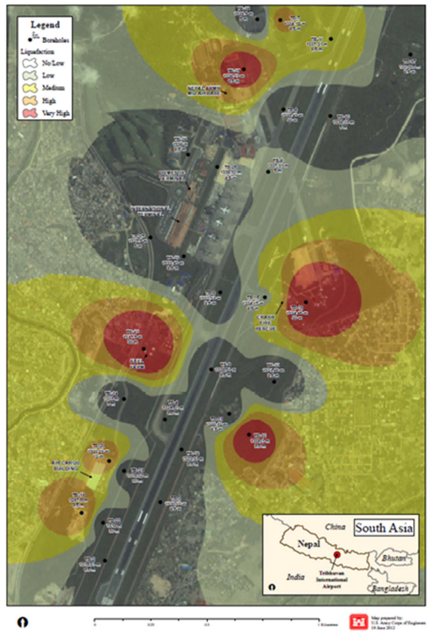

Figure 3. Liquefaction potential of the TIA airport in a scenario earthquake intensity of MMI IX.

Stakeholder Analysis

The analyses of stakeholders' position and capacity were carried out based on the input from stakeholders themselves. Their input was in the form of information sheets, organizations' strategies and programs, representatives' viewpoints etc. The input from stakeholders was received both written and orally in interviews and meetings. Relevant laws, government rules and regulations, by-laws, and existing TIA standard operating Procedures (SOPs) were studied and taken into account. It is found that General Manager's office of the airport has prime responsibilities command and control, communications, operation management and relief aid positioning at the airport. Emergency Control Centre has also major responsibilities in the command and control as well as communication. International organizations including UN agencies have major roles in the relief aid position in the airport.

Earthquake Disaster Scenario

The earthquake response plan considers disaster scenarios in a range from low intensity shaking to a catastrophe. Figure 4 illustrates the alternative course of actions depending on the severity of earthquake shaking. Some or several provisions of the plan may not be activated in small earthquakes. On the other hand, if the earthquake event is very big and destroys most of the airport facilities, the plan is limited to be active to divert the airborne flights inbound to TIA. In such a situation, a complete rehabilitation of the airport is necessary, which falls under the Nepalese government's recovery plan.

The situation that demands activation of most of the provisions in the plan is a large size earthquake that would affect the airport facilities but limited operation is possible with quick repair of the runway. Expected scenario for the plan is that 80% of runway is available right after the earthquake, which is enough to have C-type aircrafts land in daylight Visual Flight Range (VFR).

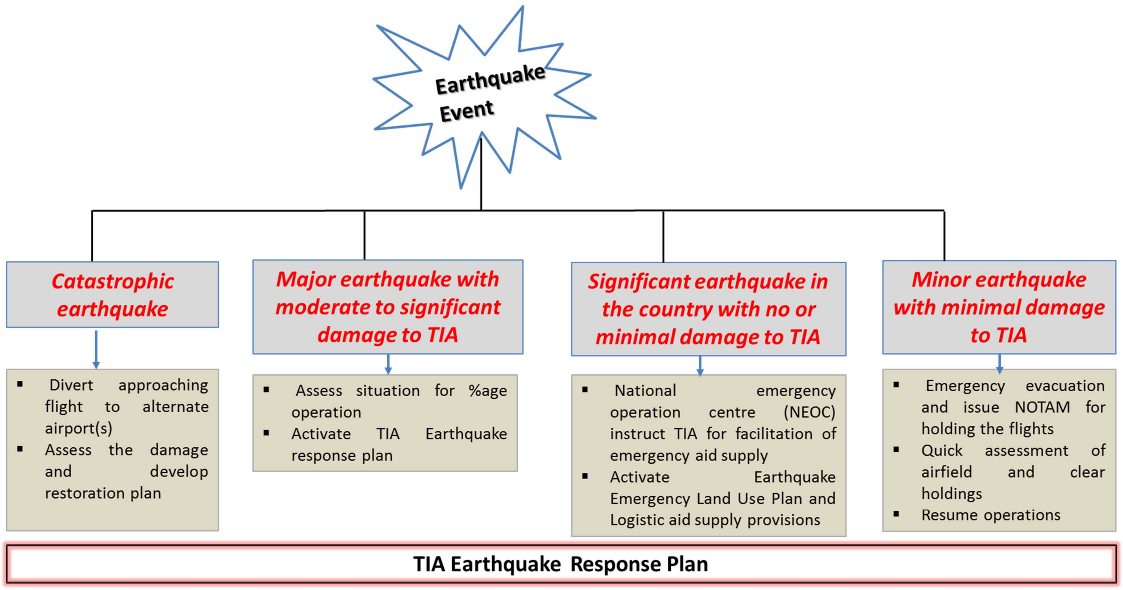

Figure 4. Alternative course of action for events different than scenario event.

Performance Objective of Emergency Response Plan

The TIA DRP aims to achieve the optimum use of available resources of TIA with continued flight operations to support disaster rescue and relief in the country during the earthquake disaster situation. Earthquake emergency restoration by achieving maximum possible flight operations to meet the needs of the emergency situation as quickly as possible is also the part of the performance goal of the plan. The continued operation of the airport will be achieved by use of emergency command and control mechanism. Emergency actions are set to ensure the activation of command and control structure and safety of airport tenants and passengers. Emergency communication systems will support these objectives. Rapid assessment of facilities and quick repair actions are designed to restore the facilities at the earliest. The earthquake emergency land use plan and logistic operations are designed to support the country's disaster rescue and relief operations. The following priorities are set to the expected performance of the airport operations. Restoration of flight operations are set and established, in increments, for Visual Flight Rules (VFR) in daylight and Instrument Flight Rule (IFR):

i. Restore Airport Perimeter Security
ii. Restore Flight Operations
   a. Restoration of Runway, Taxiway, and Ramp Areas
   b. Restore Navigational Aid (NAVAID) and Air Traffic Control systems
iii. Restore Fuel Operations
iv. Establish Emergency Customs and Immigration
v. Restore Terminal Facilities
vi. Support Logistics Cluster Operations
vii. Maximize Aircraft Throughput

Features of Earthquake Emergency Response Plan

Institutional Framework

The Emergency Response Plan is prepared under the existing arrangement of the Nepal's law, National Disaster Response Framework (NDRF) and civil aviation rules and regulations. In the event of an earthquake, the Airport Emergency Control Centre (ECC) will be in continuous communication with National Emergency Operation Centre (NEOC) regarding the status of the airport and flight operations. Civil aviation office at the airport (TIACAO) will prioritize restoration of the airport facilities and flight operations to provide space for United Nations Logistics Cluster operations and to maximize aircraft throughput. NEOC will coordinate the priority disaster relief requirements with coordinating body of international agencies in Kathmandu.

Emergency Communication

The response plan has communication structure for three phases: Immediate Response (0-24 hrs.), Response (24-72 hrs.) and Recovery (72+ hrs.). It provides the details of who communicates to whom and the content of the message. The structure includes both internal as well as external communication. Communications are categorized into two types: order or instruction and reporting/ notification. The section also includes back up procedures and equipment and air traffic frequencies. Figure 5 shows a comprehensive Emergency communication flow chart.

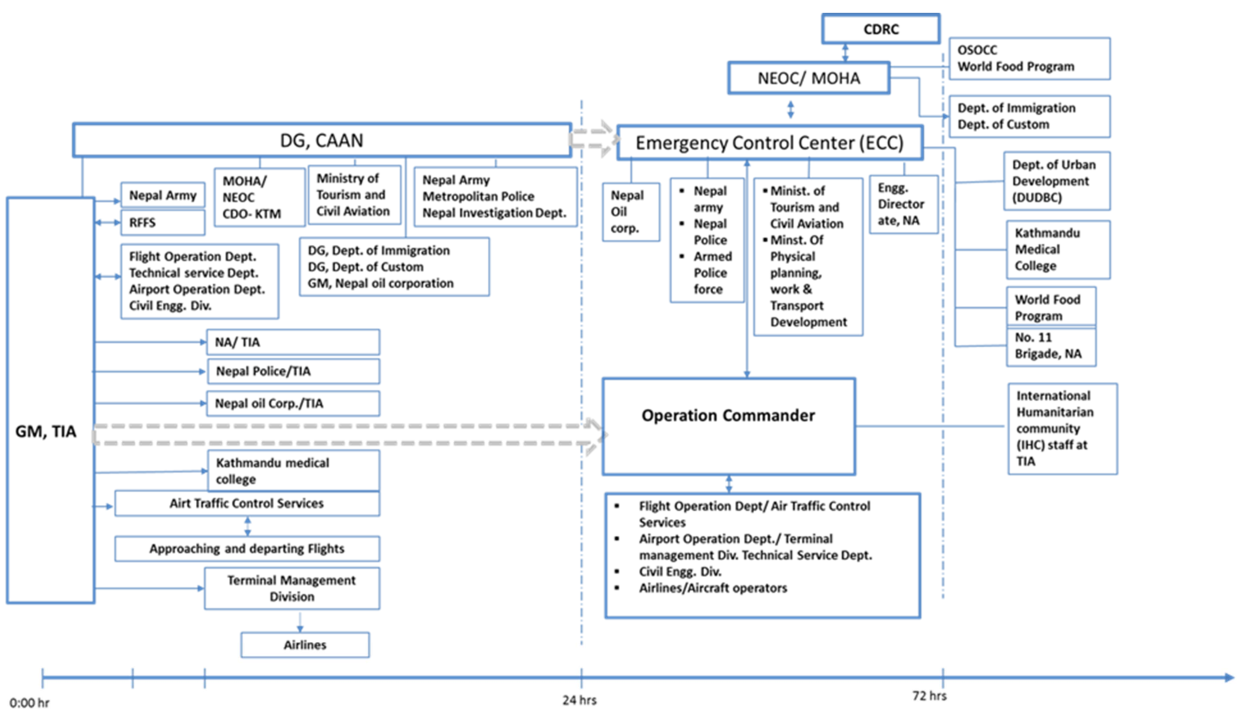

Figure 5. Emergency Communication Flow Chart.

Characteristics of the Plan

The methodology and approach of developing this plan is generally applicable for the cases of developing countries. At the same time, it has provisions to cater the specific needs Nepal and Tribhuvan International Airport (TIA). Any standard provisions in the international practice of the emergency response plan that do not fit the Nepalese condition are dropped out. For example, provisions in the plan are made to have command & control structure channeled through the Ministry of Home Affairs (MOHA) instead of city office as practiced in North American airports. Administrative arrangements were made simple to reflect the small institutional infrastructure. The plan has emergency land-use map developed in consideration of provisions of Humanitarian Staging Area (HSA) in the airport made by United Nations (UN) logistic cluster for disaster preparedness. The UN cluster is provisioning HSA considering the country's need to get help from outside for rescue and relief. The emergency land-use plan is a dynamic document and gets updated with the change in infrastructure and other arrangements in the airport.

One of the important aspects of the earthquake emergency response plan document is that stakeholders and concerned agencies have buy-in in the development process and final form of it. This is made possible by consulting them for their input, taking them into confidence while developing the document and getting their feedback on the draft document. All of their concerns were addressed and the document was finalized with them. Their standpoint took precedence unless they contradicted the very function and objectives of the plan. The plan has been recently adopted and enforced by the government of Nepal. The earthquake emergency plan will be fully exercised in the fall of 2014.

Lesson Learned

We learned some important lessons derived from observations, interaction with agencies and outcomes of study. Important observations and major lessons learned are as follows.

Vulnerability Assessment as a Prerequisite for Emergency Response Plan

In the meetings, the officials of Civil Aviation Authority of Nepal (CAAN) and Tribhuvan International Airport mentioned that results of vulnerability assessment and geotechnical investigations are eye-openers to them. The fact that earthquake emergency response plan is a must to any airport that has seismic hazard might not simply enough to convince the stakeholders to go for the emergency response plan. Results of those studies provided convincing evidence of the risk and instigated the agencies to take actions for remedies. The results of the studies, hence, not only provided the basis for planning, but also served as catalysts.

Need of Logistic Plan for Humanitarian Assistance

Existing airport earthquake emergency response plans for other airports have limited or no provisions of managing foreign humanitarian assistance supply in the airport. This is due to the fact that those plans are prepared for developed countries that may not need large volume of foreign assistance. TIA, which is the only international airport in land-locked developing countries, is the only means to supply the humanitarian assistance. These unique characteristics demand that the logistic plan be the integral part of the airport emergency response plan. This would be applicable to other airports of developing countries that need foreign assistance in disasters.

Conclusions

Emergency management of airport system in a major earthquake in a developing country demands three operations: immediate response command, recovery of operation and transit facilitation of international humanitarian aid. Kathmandu Airport (Tribhuvan International Airport) received its first Earthquake Response Plan in the course of this study. Approach and methodology of establishing chain of command in airport operation in earthquake emergency serve as a basis and template work for airports in landlocked developing countries.

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