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Applications of Operation Research in Indian flood management

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ABSTRACT

India has faced more than 300 natural disasters in this millennium which has left the country in shackles and the people to fend for themselves in dire distress. Operation research comes into the picture and plays an important role in disaster management. Right from the positioning of supplies to the delivery, proper poetization and allocation of resources, OR is very important. The objective here is to be able to comprehend and outline the possible techniques that can be used in emergencies and at the same time try and check its feasibility in India. In order to facilitate the attainment of this objective, we went through several papers collected from published journals and used them to provide analysis and models. They helped us in coming to the conclusion that disasters like floods are not preventable and the use of operation research has made the job easier and at the same time leaving room for sufficient improvement in the field.

Keywords— *Emergency, India, Mitigation, Floods, Techniques*

1. INTRODUCTION

"Bihar and Uttar Pradesh: More than 100 dead in fresh India flood chaos", said the BBC news headlines on 30th September 2019 when the states of Bihar and UP were in severe distress as the righteous floods encompassed them in its clutches. Most of the houses were over-flooded with water and boats replaced cars and ambulances in this hour of need. It is said that the city of Patna received 40% of rainfall of the season within a single day. The Indian economy is prone to floods which can be proven by the vast historical evidence relating to the same. In these times of dire assistance, a person's presence of mind and the ability to have strong reflexes is what helps the most. The IMD can only do so much as issue warnings and red flags but when it comes to the correct implementation, our developing nation fails at the hands of these natural disasters. The lack of education bears the weight of thousands of deaths on its shoulders where the lack of sound techniques that can maximize results and minimize effort remains at the footfalls of an individual's mind. Most of these so-called 'strategies' are either relating to how to help the food supply reach a particular point at a particular time, how to transport people from one zone to another and so on. What a layman does not realize is that these are essentially problems that can be solved using effective Operation Research techniques.

According to Randy Robinson, "Operations Research (OR) is the application of scientific methods to improve the effectiveness of operations, decisions, and management." Therefore, OR is also called "Management Science" (MS), "Decision Science" (DS) and "Industrial Engineering" (IE). Earlier, these techniques used to be developed on paper after tedious hours of work and problem-solving. But, due to the advent of technology, various algorithms developing software have been constructed that help in coming up with equations that can strategize the tasks during a disaster for the human race. Does the question lie in whether these techniques would be influential in changing the face of disaster management in India? To answer this, it can be said that OR provides methodology for optimal humanitarian assistance deployment such as supply chain, resource allocation, communication, medical services, etc. In India, more than 12% of India's land is prone to floods and in states like Assam floods occur very frequently, so proper assignment of refugee camps, food supplies, police force can be made by using proper techniques. Therefore, this paper aims to recognize the various efforts being taken, the models that are implemented in this plethora of disasters and the vast amount of research that has been done to come up with effective ideas to curtail the consequences of these natural disasters.

2. OVERVIEW OF THE INDUSTRY

Losses due to disasters have shown a growing trend in terms of lives and property throughout the world due to urbanization, increasing population and increasing degradation of environment. The global efforts to manage disasters are not matched with the frequency and magnitude of disasters. However, for the last 15 years or so, some new thinking on disaster management, particularly floods have emerged at the global level which has led to the development of a new industry altogether that calls for a proactive and preventive approach that integrates disaster management with the ongoing development activities. In India, NDMA- National Disaster Management Authority (INDIA), is set up to spearhead and implement a holistic and integrated approach to Disaster Management in India. The vision of the NDMA is – "To build a safer and disaster resilient India by a holistic, pro-active, technology-driven and sustainable development strategy that involves all stakeholders and fosters a culture of prevention, preparedness, and mitigation." Statistics states that in 2008, worldwide 326 natural and 259 technological disasters occurred which were fewer than any other preceding year. This portrays that OR plays an important role in this industry. It needs to be integrated into activities before the disaster even occurs. Right from positioning of supplies to the delivery, proper poetization and allocation of resources are very important which is facilitated by OR.

Each disaster, here, floods, presents an opportunity to learn from it. The Tamil Nadu Government used the opportunity presented to it after the December 2015 deluge to strengthen disaster preparedness in the State. A year later, on December 2016, the city was face-to-face with another extreme weather event, the tropical Cyclone Vardah. This time around, the government had put in place preparedness measures to deal with any freak rainfall, flood, cloudburst, drought or cyclonic storm incident well in advance. The state government issued instructions complete with a checklist and formats for reporting the implementation and progress of various measures weekly (Annexure XIV). This greatly minimized loss of lives as rescue and evacuation operations could be effectively organized. Massive restoration efforts were launched and the infrastructure was brought back to normalcy within a very short time.

3. RESEARCH OBJECTIVES

- To outline the various types of emergencies encountered by India over the years and determine the possible reasons for the failure of efficient emergency evacuation and response in the country.
- To understand the various phases of disaster management in order to react effectively and efficiently to disasters - natural or man-made
- To comprehend the qualitative response in natural consequences that aid human, animal, and capital structures.
- To bring to light the possible operation research techniques in practice during the times of life-altering floods and suggest the possible strategies that can be undertaken to have a better system in place

4. RESEARCH METHODOLOGY

To get a proper view of the current and past scenario of the relationship between OR and disasters, we went through several papers from published journals and used them to provide analysis and models. All the papers which were found worth mentioning have been listed. Various journals and academic resources were used to do a valuable analysis and suggest new ways to improve the response in India.

5. LITERATURE REVIEW

5.1 Steps in line with OR aimed at evading disasters during floods

When floods are ensuing and provoking the mother nature to display its harshest forms, the lessons learned when learning how to evade a disaster are of zero use and at these times, even the basic reflexes and sense of presence can help save a life or two.
For instance, you live in a locality. The fact that the locality is equipped enough not to collapse when the floods hit and that none of the human actions aggravate the effects is a step towards effective *prevention.* When the news of the disaster enthrals, the few good measures that are taken by the citizens of the locality translate into *mitigation and preparedness.* This essentially determines the extent to which the locality would be affected depending upon the *response* shown by the individuals at the time of the disaster. After the deed has been done by the floods, the *recovery* phase is born which could help in minimizing the effects and restoring full-scale normalcy. With operations research in place, these steps can be effectively converted into a network and through the analysis of this network, an efficient plan can be developed that would ensure the minimum loss to life and property along with safety to living beings.

5.2 Practical examples where OR has helped

- An analysis revealed that Northern Africa is least sustainable in case of a natural hazard. Using the least constraint formulation type model, the author predicted that 6 globally placed facilities could service all the nations. This model ignored delays in legal formalities and assumed there is no material handling time. Using OR, the facilities can be placed in a way that supplies can be delivered to any location within an hour. It was suggested that models taking into consideration per capita distance from the nearest facility be minimized. (Akkihal, 2006)
- In case of a disaster, the affected area needs to be supplied with food and non-food supplies which is primarily done by the World Food Programme. Due to the dynamic environment caused by a disaster, the pre-determined supply chain isn't always feasible. The needs of areas keep on changing and so does their vulnerability; accordingly, the WFP has to alter their flight and goods movement schedule. This gave rise to a model taking into consideration flight paths and goods plan while factoring in the constraints. Vehicle Routing Variable Depot Full Load Model was developed to pick supplies from 'depots' to deliver them to 'clients' in an optimal way to ensure proper cost-effective and timely delivery. (Jiuh-Biing Sheu, 2005)
- After some disasters, the relief team gets an idea of what to expect when managing supplies. A basic supply chain is formed and it changes slightly over time. There is a bidding process that goes on for acquirement of supplies then contracts are made and terms are negotiated to supply the goods to the destination. There appeared to be no hard and fast rule to judge the performance of the various aspects of this supply chain. The unpredictable, dynamic and chaotic environment in which relief chains operate is

unique. Strategic goals, demand characteristics and consumer needs and types are ever-changing. A model was suggested to test the resource performance, output and flexibility metrics to consider the stated factors and decide upon the most feasible option. (Benita M. Beamon, 2008)

5.3 Problems that can occur without the use of OR

Since the inception of OR, hundreds of models have been made to optimize various activities. Even after this, every disaster response teams face problems in ensuring the proper provision of relief activities. Aspects that are the bigger sources of problems for them have brown noted and worked on by researchers. As mentioned in Robert E. et all 2011, humanitarian logistics is an incredibly challenging process. The level of disaster combined with the complexities makes it extremely hard for logisticians to implement proper aid. During a disaster the damage in terms of humans and infrastructure is unknown. Logisticians may be unaware of the hazards and usability of infrastructure. Businesses can deal with delays in supply chain for them only because a loss but a delay in humanitarian logistics can cause death. The operations are funded by donations and politicians both of which have huge uncertainty, to add to this the presence and reporting of journalists cause troubles. Often the residents of a disaster struck locations live in remote areas and hard to reach locations which make provision of relief for them hard. Logistics coordination lack in several areas and according to an observation by the UN, there is delay in supply of time-sensitive materials and hence an overall delay in relief process (Adinolfi et al., 2005). Four million people are rendered homeless annually as a result of natural disasters (EM-DAT, 2006); not all of them are able to relocate and their recovery process becomes troublesome. Relief facilities become hard to reach areas for them. It is essential to manage the schedule of various transports keeping the need for the affected, parking, fuel and resource availability in check. (De Angelis et al. 2005)

5.4 Situation of floods in India

In the history of the world, there has hardly been a country that has not faced a disaster. In a similar manner, India, one of the most populous countries in the world is posed with serious threats that have known to cause widespread loss of human life as well as a considerable amount of deterioration of the flora and fauna. As we are marching ahead on the path of evolving as a developed country, the response to these disasters does pose as rocks in the road to success and progress. Some of the major disasters that have rendered our motherland helpless include the great famine of 1876 that took over 3 crore lives, the Gujarat earthquake of 2001 that had a death toll of 20,000 plus people, the Indian Ocean tsunami that took over 2 lakh lives. The most prominent disaster that India faces is the yearly floods that do get out of control sometimes. The average annual losses faced by the city of Mumbai with the amount of protection that it has in the 2005 floods was US$284 million (0.47% of GDP) which was very high against US$23 billion of assets exposed to the 100-year flood (Stephane Hallegatte, 2013). In a similar manner, Kolkata faced a loss of US$99 million against US$14 billion of assets exposed to the 100-year flood (Stephane Hallegatte, 2013).

In India, owing to the temperate-tropical monsoon climate structure and lack of efficient drainage system in the remote lands and even some urban centers of tier 1, 2, 3 categories. It is noted that as per Economic Times and India today reports, approximately 200 people are dead in four major states of India- Gujarat, Kerala, Karnataka, and Assam. And many more as 169 are said to be dead in south and western regions of India. How climate change has increased flood events in India is a worrying trend because it has seen rise in temperatures which in turn leads to flood events to be frequent in this century. In 2005, the Maharashtra floods including large areas of the metropolis of Bombay, city located on the coast of the Arabian Sea, on the western coast of India, in which approximately 1094 people died as per the Business Standard report. This calamity paralyzed the entire city. And this year, 2019 Assam witnessed its epic-annual tryst with floods which captivated lives of humans as well as 204 animals with it. At least 853 relief camps were set-up to provide aid-as per live Mint articles on flood-affected areas of Kaziranga National Park. In totality, taking all the affected people due to all the reasons would be 1.24 crores, as per the statistics and reasons mentioned in Business Today. This leads us to conclude that information and communication technologies are thus among the lifelines. The right kind of information communicated at the right time can save lives, livelihoods, and resources of the chain itself.

5.5 Reasons for this widespread devastation caused by floods

The question remains, whose fault is it? Are the authorities who fail to take appropriate corrective measures when required or the citizens of the country who do not abide by the quick evacuation procedures in order to reach safety? Why do some people evacuate ahead of natural disasters while others do not despite the warnings issued by the concerned authorities? Situations usually cultivate wherein the phases of disaster, in theory, do not articulate in the practical initiation of salvation. Some reasons where the taxpayers fail to adapt the easy process of prevention, mitigation, preparedness, response, and recovery are: -

- The human brain's perception of risk is subjective in nature and the judgment that a person goes through in assessing a hazard is different. Therefore, the decision to evacuate may indeed be affected not only by whether people think they will encounter the hazard, but also ideas of how the hazard might affect them and whether they could cope.
- The reaction of an individual to an emergency also depends on their socio-economic status. For example, people will not care about the risk of an earthquake if they struggle to get food on the table.
- Some people just do not believe in precautionary actions because they have yet to encounter the same. Their negligence of reality makes them suffer.
- There have been cases where it has been proved that trust is one of the fundamental factors in delivering the risk perception to individuals.
- Disaster evacuation also depends on the level of communication within the organization and with the citizens that greatly hamper the preparedness and mitigation. (Walch, 2018)

Despite the widespread devastation caused by these floods in various parts of India, there have been several attempts (including operational research techniques) that minimize the losses to a certain extent. Emergency response teams of the Indian Army and Navy relentlessly spearhead rescue and relief operations which results in helping thousands of stranded due to severe flood situations (article, 2019).

5.6 Operation Research techniques used/could be used

5.6.1 Rule curve: According to the experts, the blame for these life-threatening floods needs to be put on the flawed operations of the dam workers and the Central Water Commission who manipulate the *rule curve strategy* that indicates the correct time of emptying the dams into the rivers (MS, 2019).

5.6.2 Linear programming: There have been several suggestions to efficiently regulate the reservoir operations. Amongst the various optimization techniques is linear programming along with alternative methods. Here, the functions need to be linear but in reality, most functions are non-linear in plenty of relevant cases in water resource management. From all the progress made on LP, we can point to binary linear programming, integer linear programming, and mixed-integer linear programming, which are very useful to describe nonlinear and nonconvex statements in the objective function and the constraints. Optimization models are usually used for hydroelectric power reservoir operations with various time scales which can prove influential in controlling the disasters caused by floods (Mohammad Heydari, 2014).

5.6.3 Data mining models: Apart from advanced weather forecasting models, data mining models also have been used. Another line of research, has concentrated on disaster management and floods, appropriate flow of information, channelizing the relief work and analysis of needs or concerns of the victims. Diverse data is collected on a regular basis by satellites, wireless and remote sensors, national meteorological and geological departments, NGOs, various other international, government and private bodies, before, during and after the disaster.

5.6.4 Hydrological disaster operations management: There have been a large number of methods used in hydrological disaster operations management. Mathematical programming, heuristic methods, probability theory and statistics, and simulations are some of them. Based on that review, mathematical programming, and heuristic methods were used most often. Probability theory and inferential statistics were used second most frequently with simulations are also one of the most common approaches. Decision theory and queuing theory were also used in specific cases.

5.6.5 Others: Various other methods adopted all over the world which could beneficial in India as well are:

- Model for Flood damage estimation in residential areas
- Flood damage estimation in agricultural lands where both depth and duration factors are considered for development of agricultural flood damage functions
- Reservoir operation optimization model in which a penalty-type GA has been used to solve the flood operation optimization model
- K-NN application for the development of real-time operating rules which is a method for classifying objects based on nearest training examples in the feature space.
- (Bahram Malekmohammadi, 2010)

6. FINDINGS

a) Our research was influential in proving the fact that evading emergencies is not an option for any individual in any part of the world.
b) India has been prone to various disasters since the advent of the universe and with the on-going climate changes, these disasters just seem to increase.
c) Operation Research has been effective in evading disasters and helping in efficient emergency evacuations in several parts of the world.
d) The use of the phases/process of disaster/emergency evacuation is crucial in order to yield fruitful results and mitigate and minimize the loss of life and property.
e) A possible recommendation can be the use of drones which are evolving with the increment in technology in that field. Drones can effectively minimize human effort and proper use of OR in allocating drones to various zones can prove as a relief measure that helps in times of need.
f) Disaster response models should be designed to address real-world flood-disaster response problems and should be made available for use by planners who, however, should be in a position of understanding how to use the models and how to interpret the results. This implies a judicious balance between computational complexity and usability.
g) Responding effectively to annual flood situations arising in the sub-continent becomes necessary for saving time, human and monetary costs incurred in a calamity like this.
h) Communication and information sharing is essential. Hence, social media awareness through networking with the mass majority, world relief agencies like UNICEF, WHO, etc. becomes more agile, making aid and attention quick and reachable.
i) India has been efficient enough to implement some techniques (especially during times of floods) but still needs improvement in areas where prevention and mitigation fail.
j) Although there have been substantial improvements in the process of emergency evacuation and response techniques used over the years in India, sufficient room for improvement still prevails.

7. CONCLUSION

We could say that our research has helped in building a layer of transparency that facilitates viewing the progress made in the field of emergency evacuation and response. Globally, the use of operation research techniques has been much more compared to India. Sound mitigation and prevention practices need to be in order to enhance the quality of evacuation and hence the quality of life. In retrospection, although there have been considerable improvements through the various disasters engulfing India, scope of betterment prevails that could prove to be a helping hand in bridging the gap between possibilities and realities.

8. LIMITATIONS

The unavailability of concrete statistics supporting our research proved to be a hindrance. Not much research has been done in this field which could be influential in changing the way the industry operates.

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