RESOURCE ALLOCATION SYSTEMS USED IN DISASTER MANAGEMENT

: SYSTEMATIC REVIEW

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DECLARATION

I hereby certify that this research and all the artifacts associated with it is my own work and it has not been submitted before nor is currently being submitted for any other degree program.

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ABSTRACT

Disaster can be defined as a serious disruption occurring for a certain period, which can be a man-made or natural catastrophe that causes loss of human life as well as great damage to the community's daily routine. It might be natural disasters such as floods, droughts, earthquakes, pandemics or, man-made like building collisions, war, etc. Righteous resource allocations are very crucial for recovering and controlling the negativity of the situation because during that time it exceeds the community's ability to cope with their average day-to-day resources. In here as resources, we can take both differently skilled personnel and assets/objects. Police, medical staff, distributors of essentials, water, food are some examples of resources. Failure to schedule and assign those in an effective and efficient manner will lead to more unnecessary fatalities or additional losses and damages of physical assets. Therefore, coordination of emergency responding resources and decisions must be made wisely.

The main objective of this systematic review is to provide an overview of different resource allocation systems by identifying and analyzing studies of the last decade. This research will provide a qualitative perspective of the resource allocation systems pertaining to disaster management while addressing significant details of each proposed system. The gaps that can be identified are stated clearly in this study while stating the suggestions for new research areas and how the covid-19 pandemic situation can be viewed in the resource allocation perspective as well as the role IT in this context is examined. A keyword-based classification using machine learning techniques is done for the collected relevant literature to identify the related areas and papers to discuss under each cluster.

Mainly the model type identification such as static/dynamic, deterministic/stochastic, linear/non-linear as well as heuristics, multi-objective is done in this research. Additionally, transportation, facility and shelter locations, scheduling techniques are discussed as other related topics. This research especially focuses on the response and recovery phases separately also together. The allocation mechanisms build within decision support systems plus the advantages/disadvantages of standalone systems for resource allocation particularly are analyzed. The stochastic models, transportation considered resource allocation can be identified most commonly in the response phase.

In disaster management, decentralized resource allocation mechanisms, volunteer donations, secondary disasters, and disaster chains, multi-hazard context should be improved, and also the recovery phase distributions with new technology trends. Providing beneficial support to the decision-makers in disaster management who are working with or developing resource allocation systems and contribute new knowledge to those who are interested in this research area and produce a better outline to assist other related topics are also objectives of this systematic review.

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LIST OF ABBREVIATIONS

DSS - Decision Support System

ML - Machine Learning

MO - Multi Objective

DDSS - Disaster Decision Support System

IOT - Internet of Things

GIS - Geographic Information System

FCFS - First Come First Serve

MAS - Multi Agent System

DRSP - Disaster Response Scheduling Problem

EA - Evolutionary Algorithm

EU - Emergency Units

DOM - Disaster Operations Management

ABS - Agent Based Simulation

LP - Linear Programming

MCE - Mass Casualty Events

EMS - Emergency Medical Services

MIP - Mixed Integer Programming

ESC - Emergency Supply Chain

DMDC - Disaster Management Data Center

HRAS - Hybrid Resource Allocation System

SRP - Stable Roommate Problem

AHP - Analytic Hierarchy Process

MBMS - Model Based Management System

USAR - Urban Search and Rescue

PFRA - Proportional Fairness for Resource Allocation

CHAPTER 01

1.1 INTRODUCTION

Disaster is a serious disruption of the functioning of a society that impacts community daily life negatively. It can be causing widespread human, material, economic, or environmental losses that will be hard to recover sometimes. When a disaster occurs, it exceeds the ability of the affected community or society to cope using its own resources [64]. Disaster can be categorized into natural or man-made by definition but both situations are mostly managed by decision support systems that contain higher-level technologies and mathematical models. Hurricanes, earthquakes, landslides, floods can consider as natural disasters as well as chemical exposure, building collapse, radiation is under man-made disasters. The disasters have come under emergency events that occur unexpectedly or suddenly. It is the higher level of the disaster scenario and emergency have a very broad area of study which can be categorized as natural disasters, accident disasters, public health incidents, social health incidents [65]. Disaster management is a broad category that includes the phases of mitigation, preparedness, recovery, and response. In 2017 alone, 318 natural disasters affected 122 countries, causing 9503 human deaths, 96 million victims, and estimated damages of US$314 billion [62]. At present, the covid-19 pandemic situation is going on and it can be categorized as a natural disaster. Almost all the countries, around 200 were affected by this virus and many lives have already been lost.

In all the phases of a disaster, we must focus on the resources as well because most of the time the critical resources will be scarce as the demand rise unexpectedly. Here resources can be human such as police, medical staff, rescue teams, or objects like tools, food, water, etc. All these things should be well managed and should be distributed effectively in a way that would be beneficial to a maximum number of affected people. The main target in the response phase is to save lives and stop further losses of both human and assets. In order to do that, we need to manage resource where it is allocated in a fair, open, transparent, and accountable manner and if demand is high it should be scheduled as well. Utilitarianism is also a philosophy that asserts an action is correct if it maximizes the benefits to the most people possible [60].

The severe resource shortage is one of the key characteristics of both large-scale and small-scale disasters [67]. Both the government and private sectors are obligated to use critical resources efficiently in a disaster situation. For, resource allocation includes priority settings including which criteria to use and not to use and these might contain constraints such as social worth, age, first-come-first-served, etc. The ethical aspect of resource-related activities is addressed as guides that must be followed practically and implement [60]. Resource allocation, resource scheduling and transporting, resource tracking and monitoring, resource inventory maintenance are all can be considered resource management activities.

This research focuses mainly on resource allocation mechanisms used in disaster management. With that context some other topics like resource scheduling, transport problems will be lightly discussed as the related topics. Some works under emergency logistics also addressed timely delivery of emergency resources and rescue services into the affected regions [67]. This research is not covering the area of resource preparation but the response phase and the recovery. Even though the resource allocations for both natural and industrial are covered, out of the preventive, reactive, and corrective phases [70], reactive phases studies can be seen most commonly. The mitigation and the preparedness will not be considered because those activities mainly contain resource maintenance and inventory management including sending the resources to facility locations such as emergency centers.

In addition, this research covers the resource allocation systems which are standalone and integrated with the decision support systems. And as well as the disaster-specific resource allocation techniques. Each system has special features, technologies used, advantages and weaknesses/limitations, etc. Those things will be thoroughly analyzed apart from the mathematical models and deep analysis of algorithms that are proposed or used. Currently, many resource allocation systems are proposed but they are not analyzed as a whole, which tends to give the overall idea of that specific subject area. The frameworks for scarce resources especially, medical resources, even allocating medical ventilators [61] in an influenza situation is addressed but in the present pandemic situation, many people suffered from a lack of critical resources. There might not be a correct understanding of resource allocation systems which are scattered not knowing how to choose and make decisions what should be implemented according to the disaster. And also, DSS development needs to be improved, with greater allocation for implementation and monitoring [63]. Mainly the gaps between proposed resource allocation systems will be pointed out in this research plus aiming to provide a better understanding of the studies done so far. As a special feature, this also focuses on the current pandemic situation and pointing out the resource allocation suggestions which would overcome the resource scarcity. Another specialty of this research is that all the keywords of related literature are being analyzed using a machine learning clustering technique to get a broad view of commonly addressed patterns.

The rest of chapter 1 of the thesis consists of the research problem, questions, solutions, scope, background, etc. and next is the literature review on chapter 2 which also provides a summary of the basics. Chapter 3 contains the methodology of the study and the data used along with the evaluation of results and the proposed solution. Chapter 4 is the discussion that will point out the overall picture of the study, benefits, and issues/limitations. And lastly the chapter 5 with the conclusions drawn along with the future works.

1.2 BACKGROUND

In the area of resource management, much research has been conducted specifically for disaster situations. The resource management context includes all the resource-specific tasks like allocation, scheduling and transporting, etc. When we focus on resource allocation it is always integrated with either scheduling or transporting or both. These works contain a massive knowledge, but which is scattered. A very few studies are analyzing all these resource allocation mechanisms in a comparative way to get a deep understanding of each but to my knowledge the resource allocation systems which focusing on disaster scenarios are not analyzed in a systematic way and also, the allocation mechanisms integrated with the decision support systems developed for disaster phases. Resource allocation mechanisms are analyzed in all the phases of a disaster through this study and will point out the gaps of the resource allocations when mapping to the disasters.

The systematic reviews on the allocation of medical resources, relief distribution networks and resource allocations without addressing the recovery phase came across. But those are not analyzing the resource allocation in every disaster phase taking account of every resource possible. This study uses the machine learning technique to analyze and categorize on the keyword basis on each research and will cover the resource allocation mechanisms suggested in every phase of a disaster. And also, this will contain disaster-specific allocation systems, as well as the gaps, which are pointed out as suggestions to fill in future studies. This research will provide a vast amount of knowledge about the resource allocation subject area addressing all the aspects as a benefit for developing decision support systems to handle disaster situations effectively.

1.3 MOTIVATION

Currently, the world is sinking with the COVID-19 virus which was now has taken over all the countries resulting in a pandemic situation. Both pandemics and epidemics related to a certain country fall under the disaster category. Technologies have evolved immensely and how it can be helped to overcome this situation was the first motivation for selecting this research topic. In developing countries, there are more underprivileged families who are unable to survive during this situation. Food, water, medicine, and other necessary materials should be provided to them continuously. On the other hand, medical staff, police, forces are also involved in this process to handle the pandemic situation risen in the country. In Sri Lanka quarantine centers were established, hospitals were modified to treat COVID patients. All these mentioned resource types should be allocated according to demand and emergency situations. That was the motivation for this research, to identify existing resource allocation systems and methods of how they could be used in certain disaster scenarios as well as the effectiveness and efficiency of those systems to be suitable to use for the current situation.

1.4 PROBLEM

In all the phases of a disaster, in order to handle the disaster situation decision support systems are widely used and proposed in many studies. In this disaster management context, another important aspect is resource allocation. Because a disaster will generate a resource scarcity and high demand for critical resources such as medicine, rescue teams, food, water, etc. Even though many studies have been conducted in the area of resource management and also proposed tools, systems are yet to be systematically reviewed to get an overall understanding of where resource allocation systems stand. Resource allocation has many related areas as scheduling, transporting, etc. How those areas connect with the allocations needs to be analyzed and the way those allocation mechanisms build in within decision support systems plus the advantages/disadvantages of standalone systems for resource allocation particularly should yet to be analyzed specifically during a disaster period. Also, the current pandemic situation caused a rise the resource scarcity with the high demand. Many countries suffering from these kinds of issues. Therefore, the suitability of the previously suggested systems for the present is a must to address as well.

Most research has proposed but not evaluated as the whole picture so it is difficult to take decision according to the disaster and the phase that which will be the best resource allocation system to use or to be developed. There can be research gaps in this area of study which has not been caught the eye of researchers. Therefore, systematically reviewing the resource allocation systems used in disaster management is very important for the address above kinds of problems.

1.5 SOLUTION

A systematic review can be defined as a type of review that uses repeatable analytical methods to collect secondary data and analyze it. It aims to identify evaluate and summarize the findings of all relevant individual studies by making the available evidence more accessible to the interested parties and also deliver a clear and comprehensive overview.

As the solution for the above-mentioned problem statement, a systematic review is conducted in order to settle those to some extent. An especially systematic review is chosen because a general literature review won't be able to analyze systems in a way that will give the depth of those resource allocation systems. This research is guiding the audience with the comparisons of the existing models and provides better knowledge.

1.6 OBJECTIVES

There are few main objectives that this research intended to achieve. Out of those most significant objectives is finding the answers to all the research questions while examining the problem area thoroughly. The overview of existing resource allocation studies, identifying the gaps in between, and how these techniques can be applied to the current pandemic situation are the primary questions that will cover from this research.

In addition, there are other few objectives that will be able to achieve from this study. The first one is that providing beneficial support to the decision-makers in disaster management who are working with or developing resource allocation systems. Another one is giving suggestions for future work that can be used to improve this research area. This research's purpose is to contribute new knowledge to those who are interested in this research area and produce a better outline to assist other related topics as well. Lastly, this has an objective of look into the resource allocation as part of disaster management, by analyzing literature in a unique way such as keyword-based analysis of the literature by machine learning techniques and categorizing in multiple ways.

1.7 SCOPE

The research covers many areas of resource allocation systems used in disaster management. The main aspect that covers is the resource allocation techniques or mechanisms used as stand-alone solutions which are mostly theoretical models or mathematical models. This research focuses on the resources of every disaster phase which are preparation, during a disaster, response, and recovery but not the mitigation phase. This will only cover mainly the resource allocation and basics of other topics which are related to resources such as transportation, scheduling, tracking, etc. The assigning of resources to the facility locations which are capable of satisfying the demand of resources are not considered but the resource allocation from facility to a disaster point. There can be multiple points, disaster chains, or different disasters as secondary so resource allocation of all those scenarios are analyzed. Here we consider volunteers, medical staff, forces as people and medicines, ambulances, food, water as objects under the resource category. But infrastructure resources such as water supply, electricity, network resources are not analyzed within the study. Besides, this research provides an overview of resource allocation systems that are integrated with the decision support systems as one. This research also addresses disaster-specific resource allocation systems. The special features, advantages, limitations of these resource allocation systems are discussed and summarized for better understanding and to get an overview of those systems that were proposed in support of disaster management.

CHAPTER 02

2.1 LITERATURE REVIEW

Disaster can be defined as a serious disruption occurring for a certain period, which can be a man-made or natural catastrophe that causes loss of human life as well as great damage to the community's daily routine. It might be natural disasters such as floods, droughts, earthquakes, pandemics or, man-made like building collisions, war, etc. Righteous resource allocations are very crucial for recovering and controlling the negativity of the situation because during that time it exceeds the community's ability to cope with their average day-to-day resources. In here as resources, we can take both differently skilled personnel and assets/objects. Police, medical staff, distributors of essentials, water, food are some examples of resources. Failure to schedule and assign those in an effective and efficient manner will lead to more unnecessary fatalities or additional losses and damages of physical assets. Therefore, coordination of emergency responding resources and decisions must be made wisely. The main objective of this literature review is to provide an overview of different resource allocation systems by summarizing initially identified publications of the last decade. This review will provide a qualitative perspective of the resource allocation systems pertaining to disaster management while addressing significant details of each proposed system.

2.2 INTRODUCTION

Disasters tide with uncertainty where no one knows when a disaster gonna happen and how much damage it will cause. In the past decade, many natural disasters occurred such as earthquakes, pandemics, floods, etc. as well as man-made such as chemical disasters, a building collapsing, etc. [58] Disaster costs human lives or property damage/economic. Natural hazard risk is predicted to be increased in the future [63]. Disasters are divided into large scale and small scale according to the damage it has done and its context (area, state, country, etc.) comparing to the world. Disaster phases are categorized into main two aspects those are the pre-disaster phase and the post-disaster phase. Most of the work must be done in the post-disaster phase. Disaster management systems are also known as emergency decision support systems are used in these phases to overcome and manage the situation by making correct decisions to reduce further damage [65]. They can be data-oriented or model-oriented but prior to deciding must consider the study of hazards, vulnerability, and risk, proper dissemination of information, etc. [66] Here risk is the probability of getting exposed to the disaster. Many benefits can be gained through decision support such as facilitating group interactions, focusing on strategies, addressing decision problems, and providing software solutions, as well as pre-hazard risk-reduction actions, which are taken into account during the pre-disaster phase. Disaster management can be classified into four stages: mitigation, preparedness, response, and recovery [62] and all the stages include resource allocation mechanisms. Mobilization of resources execute immediate relief operations which consist of evacuation to safer places, and provision of food, medical assistance are some of the key challenges in disaster response [64]. During a disaster period, victims may suffer from a lack of medical care and resources 3 therefore, optimize the use of existing resources is a must [59]. The obligation of government and private sectors to provide and use resources efficiently and in an optimal way where many people can benefit [60]. Here resources in the sense can be either human resources or materials such as food, vehicles, water, shelters, equipment (excavators and communication devices), etc. Therefore, resources must be considered as a priority need in a disaster situation. Resources should be allocated and scheduled according to the demand. The activity of assigning a resource to required places is known as resource allocation. Resource scheduling is involved when demand is more than the availability where scarcity is arisen [31]. Resource dispatching and deployment is also fallen under scarce resource management. Lack of ethical guidance is pointed out in many past scenarios but those should be corrected because utilizing scarce resources is an unavoidable requirement in catastrophic conditions. Faire ness, openness, transparency, and accountability should be considered when there are people demanding the same resource at the same time. Relief supplies can be divided into static and dynamic [65]. Static is where resources are organized, stored according to amount and type by analyzing past situations. In contrast, dynamic supply changes according to the demand on different levels. Under the main categorization, literature has addressed resource facility location problems, emergency resource allocation problems, and emergency resource scheduling problems [58]. Emergency resources can be classified into three broad categories those are the rescue supplies, transportation capacity, and rescue personnel. All the human resource types such as police, firefighters, medical teams, volunteers together carry out the response tasks. Typical emergency/disaster includes uncertainty, risks, mass casualties, time pressure and urgency, severe resource shortages, large-scale damages, and disruption of infrastructures like water, communication, transportation, and power [67]. Therefore, resource allocation and scheduling must be taken as a prioritized process in an emergency while considering the factors: damage level, number of casualties, priority demand fulfillment, urgency levels, and delay consequences of humanitarian aids.

2.3 REVIEW

Various types of resource allocation systems are proposed in the disaster management context while considering different kinds of aspects. By analyzing related articles, journals published in the last decade of that area, one can identify that many models have been introduced including new approaches to do resource allocations in an optimal way. Some methods are aligned with the decision support systems by not addressing resource allocation directly. Reviewed literature is summarized below considering all the perspectives that would be involved in resource allocation methodologies.

Ontology-based web geospatial system was proposed by Mao, where it includes discovering, efficiently using, and automatically executing GIS data also analyses of the resources. It has a flexible architecture that can be applied to different domains. User semantics are also analyzed and implemented as a browser/server structure. It consists of 3 layers which are the web resource layer, spatial layer, and user interface layer. The spatial layer includes spatial decision ontology, spatial decision task analysis module, and spatial decision task calculation module, and web resource layer tasks are to access web resources, automatically discover as well as unified management. Spatial ontology construction, natural language-based spatial decision task parsing, and ontology-based heterogenous web resource acquisition are the key technologies focused on this study. The prototype was tested using an earthquake scenario that happened in China. This study is particularly focused on displaying the disaster area according to the user scheme in a thematic manner on the map.

The architecture of the system founded by Kondaveti and Ganz [9], has three components which are the information collection framework, database of available resources, and resource deployment guidelines. Resource database consists of available emergency resources within a 100-

mile radius and in guideline component, all the disaster location clusters include priority rating. This decision support framework is built on rapid information collection and resource tracking functionalities. The algorithm it uses has phases of clustering victims, resource allocation, and resource dispatching. It analyses the risk in both infinite and finite resource availability. This system helps not only to perform emergency response but also to perform emergency resources planning in real-time as well. This system is tested against only a hypothetical disaster scenario of multiple bomb blasts in a state of USA with the help of Google map API.

The system published by Muaafa and Concho [1] has a multi-objective optimal approach that helps with the design of response strategies to a disastrous event by focusing on time and cost. The main objectives of this model are to locate temporary emergency units, dispatching strategies of emergency vehicles to evacuate victims and to get hold of victims to evacuate in each unit. Few assumptions are made prior to using this system they are each vehicle can transport one victim at a time, each unit has unlimited capacity and no severe injuries but need medical attention. An algorithm called PSDA is used to obtain a Pareto set of optimal solutions where each represents an emergency response strategy which enables us to decide what to use according to the time and cost. This model is only used against an illustrative example to test the result.

Hashemipour and Stuban [53] introduced a framework for community based effective disaster response. This framework is known as the Disaster Multi-Agent Coordination Simulation System which evaluates the highest-performing team in the pre-phase of disaster response. Team size, preparedness, distribution, roadblocks, starting point are some of the main design configuration factors of this proposed system. It has the ability to observe operations and agents' movement using a machine-learning technique with the use of a clustering algorithm and consists of geographic information systems (GIS). This framework includes components like the capability to absorb real disaster data, configuration, efficient and consistent communication, evaluation, etc. This conceptual model has 4 parts they are input real disaster data, configuration capabilities, task allocation capability, and DOE (design on experience) and optimization capability.

An IoT approach for resource monitoring and scheduling for post-disaster was proposed by Gamitl [31]. Internet-based real-time data sensing in a clustered environment is focused. For data processing a server, sensor and to visualize an android application that is integrated with Google map is used. Can be launched in a smart device to track and monitor the resources which are scheduled for requested tasks. Architecture has two layers which are the sensor layer and the IoT layer. Sensors sense data at a pre-defined interval and IoT devices are embedded for real-time processing in the IoT layer. Resources are clustered scheduled using time and the distance-based algorithm. This proposed algorithm is tested using a simulated scenario with the clustered environment.

Some of the researches are done for specific disaster types that propose systems and models solely for a particular disaster scenario. Yang introduced an intelligence-based typhoon management system framework. Typhoon risk prediction and mitigation are also included in it. The system provides a disaster prevention and rescue unit to temporarily reduce risk and disaster preparedness as well as recovery. Geographical information is also integrated into the system apart from the mathematical model. Damage prediction is where the resource allocation part comes in. Damage is estimated by the basic principle of the case-based reasoning of artificial intelligence. Another study was done by Cibella [68] for medical disasters such as the release of toxic compounds. This model is called IMPRESS where it has few components like database, interface, data harmonization, and reference semantic model. The prediction of health care resources is also included. IMPRESS is tested using a real-world toxic fire scenario in Italy. Field and hospital resources are considered in addition to optimal deployment and control. Warnars proposed a decision support system for an earthquake disaster scenario. It's built with a database, client, and server programming also system architecture involves client, server, firewall, data warehouse, ETL, and DB server. External environment connections are also considered such as BMG prediction.

Optimal surveillance and patrolling scheme to protect borders are developed by Muaafa and Ramirez. The multi-objective optimization model minimizes the vulnerability and costs in addition an algorithm is used to generate a Pareto set. An optimization algorithm is proposed where it generates a Pareto set to choose between the solutions. Using different combinations of other resources like sensors, cameras, barriers are also considered but this model is tested only for an illustration. Wijerathne [40] has suggested a dynamic resource scheduling approach for a forest fire in Sri Lanka. Focused on three different aspects they are resource tracking, forest fire spread estimation, and dynamic resource allocation. Generated requirements are mapped with the available resources according to the priority level of each requirement as well as the distance in between. Details captured from maps are accurate and up-to-date also the entire climate of the studied area is equal are the assumptions made prior to the system testing. Rebeeh [70] focused his research on industrial disaster management systems for all the preventive, reactive, and corrective phases. Stocking the resources in selected locations, deployment of resources at the quickest possible time, and after evacuation resource allocations in rehabilitation are considered here. It describes resources by elements: human resources (medical staff, security, etc.), tools and equipment (ambulance, rescue tools, etc.), resource distribution. These decisions are taken based on the deterministic or stochastic data types along with the different objectives for each industrial disaster or industrial impact on general disaster scenarios with various contexts. Single or multiple objective functions can be seen with different solution methods like frameworks, programming models.

A system for emergency management at airports is suggested by Mijović [69]. The system is called EMILI-SITE it occupies advanced technologies such as complex event processing, semantic technologies, and web services in mission-critical applications. This framework involves detection, situation assessment, risk assessment/evaluation, and evacuation management, but does not include resource allocation or resource deployment. Technology infrastructure, airport ontology physical model is suggested, and the system is tested against a fire disaster scenario. EMILI-SITE is a system that uses service-oriented architecture, where CEP (to process event streams) approach and ontologies are used to extract the meaning of messages coming from SCADA (supervisory control and data acquisition) emulator. Recently pandemic based resource allocation systematic review was conducted by Romney [42]. It explains the staff triggers as usual staff called in and utilized and supply triggers as cached and usual supplies used. Staff extension and conservation, adaptation, substitution, reuse of selected resources are considered. Extreme operation condition for resources is stated as critical supply lacking, possible reallocation of life-sustaining resources such as ventilators, beds, blood, antivirals, PPE, etc.

Lu and Guo [41] proposed a method for optimal allocation of fire extinguishing equipment in a wildfire situation. The risk index is given according to the high risk to low-risk areas. Fire density forecasting model is used and for allocation system takes all the equipment that is available for dispatch, traffic conditions of roads to supply in minimal time, the capacity of single equipment into the account. After the test case of a real situation, it states that it would be more effective if the zonal allocation is considered. Disaster specific resources allocation systems are very useful when making quick decisions by subject experts.

An approach of a hybrid resource allocation system for large scale disasters is introduced by Tsai [7]. This system was established to analyze scheduling algorithms for the real-time system in two aspects namely, clock-driven such as hospital assignment and priority-driven such as first come first served. Another algorithm is designed to reduce the computing time of the system and to improve the accuracy of the medical resource allocation. Patients are divided according to the severity of the injury and hospital divided into high and low levels. Once the resources are relieved from one patient it is getting reallocated. Therefore, typical algorithms are not suitable so this system uses its own patient and hospital selection procedure. Where minor injured patient waits 30-60 mins and a critical patient maximum of 15 mins so in order to minimize this hospital selection is considered. Only the concept is delivered but yet to test against the actual scenario.

Resource allocation systems do not always act as stand-alone systems, most of the case it is embedded in decision support systems or disaster management systems. Different mechanisms are used or integrated with these systems to overcome the resource allocation problem. In the following table 1 considering just five systems [6], [46], [47], [45], [48] the basic summary is built by analyzing the research article and extracting the key points, resource allocation, advantages, and limitations. In order to get a broad overview, *Determining resource capacity in disaster relief through a model-driven decision support system* [6], *The design of group decision support system for emergency management* [46], *Smart Life Tracking and Rescuing Disaster Management System* [47], *Decision Support System for Earthquake Disaster Management* [45], and *An approach to support decision-making in disaster management based on volunteer geographic information (VGI) and spatial decision support systems (SDSS)* [48] are the five systems that are considered below. These all the systems are decision support systems that are presented in the last decade where resource allocation systems/methods/models are integrated successfully. This kind of tabular outline is helpful to get the overall idea of each system and to get a comparative angle of each system.

The design of group decision support system for emergency management [46], states when an unexpected incident occurs, decision-makers will search the related or similar cases that happened before and extract the information that is important and analyze its differences with the current scenario. If there is a big difference or uncertainty then it needs group decision making. Parallelly emergency plans are activated and schemes are implemented. If a similar or related case is unavailable in the database decision-makers start to solve problems by forming groups to perform tasks such as emergency resource allocation (personnel, funds, material, and support, etc.), and at last final plan formed and implemented. Resource scheduling, analysis are in a group decision platform and a separate database is allocated to store resource information. In order to overcome the real-time decision-making problems, this system adopts web-based architecture. Many decision-making experts can access this system through a browser interface. ASP.NET, C#, Js, SQL server are the software technologies used to implement the system. Based on spatial information and remote sensing visual simulation is developed according to each case as a support for the decision-makers. Rapid assessment and accurate assessment are the two categories in an emergency assessment. Rapid assessment important where we cannot get enough information about the disaster but when need to allocate and schedule emergency resources. An accurate assessment is completed after a long time in the phase of recovery and reconstruction. For each emergency, resource users can select a relevant analysis model and calculate the demand. Data mining is done by a subsystem for the knowledge base in the database for forecasting the demand for resources. Another subsystem is there for resource scheduling, it selects the appropriate model to generate the scheduling table and the path selection because the response is a primary factor. The testing was done using a case study of a food poisoning emergency situation, in China.

Determining resource capacity in disaster relief through a model-driven decision support system [6], it can upload disaster information using mobile terminals. This paper presents a prototype addressing challenges like communication link disruption, not enough geographical data available, etc. Off-line disaster information processing is one of the key features of this system. After a disaster incident and secondary impact, it is not possible to upload data through devices until communication is re-stabilized. As a solution, this is proposed that using a method where it is letting application convert into offline mode and interacts with the user and store data as an XML file which is stamped with the submitting time. Images, sounds, reports can be stored like this until the communication is fixed. A remote management system can parse the received file from the mobile device and can store it in the database. Decision-makers can communicate with each other through instant-messaging tools. The GPS positioning technology is integrated with the database server so can draw tracks according to the device number. After submission of disaster data instructions were made for dispatching the resources and rescue teams to relevant areas using the optimal path identified by the system.

An approach to support decision-making in disaster management based on volunteer geographic information (VGI) and spatial decision support systems (SDSS) [48]. As the topic has been stated this approach consists of a framework that integrates voluntary and conventional data, spatial decision support systems, and processes/methods for decision making. The mathematical model it has helps to predict the outcomes. The centralized system can input data from cell phones and VGI mapping develops effective and more reliable real-time information. Disaster management, decision-making, and maturity model for disaster are in the business layer of the system. State of the resources available and deployment still to be further analyzed in the system.

Smart Life Tracking and Rescuing Disaster Management System [47]. This system is exclusively made for natural disaster scenarios and beneficial in high population density areas as well. The main two services that are provided by this system are rescue and shelter. The shortest distance algorithm is used for deploying medical aid as resources with the rescue team. A database is maintained including the geographical data alone with the rescued people.

Decision Support System for Earthquake Disaster Management [45]. It is a business intelligence system developed by the Jahan. Its conceptual framework is illustrated in the article where the first layer includes a knowledge repository and the second layer for fostering which uses BI rules that are generated from the contextual knowledge. Finally, the third layer is where the decisions are made. Data sources are analyzed thoroughly according to the model and customizing for resource-based decisions is also possible.

Table 1: Basic summary of the above highlighted five systems

Author	**Technique proposed**	**Key points**	**Resource allocation**	**Benefits**	**Limitations**
Deng Jingyi and Chen xusheng, et al. [46]	GDSS (Group decision Support System)	Group decisions are capable which includes case querying, management, and assessment of emergency situations as well as resource allocation. The system architecture is divided into three layers which are interface, network communication, and group decision-making platform. This system is developed as a prototype for catering to public health disaster situations particularly.	Resource analysis is done after the assessment of the emergency and the demand can be forecasted using the knowledge in DB. Resource scheduling is done from the data gained from the analysis and the resource database. Shortest path selection is also a capability of this system.	Geographical information (spatial data) can be integrated with the system. Web-based architecture helps to overcome the time and space to realize remote real-time communication limitations.	Specifically, for public health emergencies/ disaster scenarios
Xinyan Zhu, Kehua Su, Tao Zhu et al. [6]	Remote management with Mobile positioning terminals	The system is based on GPRS where collecting and managing is done through mobile remotely in both offline and online mode. Assuming that the disaster impacted all the landlines of the area and wireless communication devices are disrupted, this system has four levels which are network, data, service platform, and application level. It proposes a method to do offline data processing as well.	After processing the data according to the transaction flow, it is sent to the command center which generates dispatching instructions. This can be either resource deployment, resource allocation, or any other instruction.	The geospatial data collection and analysis part is integrated with the system.	Not considering the buffer analysis and optimal path web spatial analysis for the betterment of the system.

Flavio E. A. Horita and Joao P. de Albuquerque , et al. [48]	Volunteer geographic information (VGI) and Spatial decision support system (SDSS)	Introducing a framework that integrates the volunteers' data and conventional data. Then for decision-making processes and methods are used effectively. The conceptual architecture includes four layers they are data source, data integration, application, and business layer, respectively. The business layer includes a maturity model for disasters.	Resource allocation is suggested for further development. It states that a model built in the business layer may also serve as a strategy to help identify the current state and availability of resources after an emergency and it will allow making decisions of resources in order to recover from the situation.	Before using the SDSS system data is getting evaluated after the user upload	Checking and updating for correct information must be done regularly
Nagashree C, Kavya Rao B, Maria Jyothi Lobo, Harshitha B S, and Antony P J, et al. [47]	Smart life tracking and rescuing disaster management system	Global positioning systems and global service for mobile communication are used in this system which is web-based services. Could be used in a high-density population area and gives a very sharp overview and provides decisions for prior planning of high-risk areas. Rescue and shelter services are focused mainly. The primary mission of the system is to keep track of the current location and movement of people.	Provides the information of getting the medical aid and relief supplies to the deceased victims of the disaster. The system is able to manage inventories and update the status, availability, and status as well as the capacity of the operating shelters and medical facilities. Assignment of rescue teams, identifying the shortest path are related to resource allocation capabilities.	Data banks are updated regularly, and information is provided in a simple way	GSM network should be always available and no offline data acceptance from the system.

Shah Jahan Miah, et al. [45]	BI (business intelligence) approach based DSS	A conceptual framework is proposed where it can be used to enhance the decision-making process resulting in a high success rate for many events. This includes contextual knowledge, data fostering unit, and knowledge repository. Send and receive information through mobile, PDA by notifications or SMS. A rule-based approach is used to ensure the decision that has been made by the system.	Resource allocation is not mainly focused on the system. But knowledge repository has data related to resources that have been collected through sources. After the data fostering, decision-makers can get a clear idea about the state of resources and can make effective decisions based on that information.	Multiuser provisions can be adopted by this system and the use of contextual reflection for decision making.	BI is used therefore specific ontology-based knowledge should be there to use within the real disaster situation

An ordinal optimization-based approach was suggested by Alsubaie and Marti. This proposes a simulation-based tool to assist in finding the optimal distribution of available resources during a disaster. This utilizes the disaster response enabled platform (DR-NEP) which is an infrastructure inter-dependencies simulation platform, a common enterprise service bus, and a database. The main objective is to maximize the capacity of the critical infrastructure, so this ordinal solution addresses the problem using two concepts namely goal softening and order comparison. Ordered performance curve and an optimization algorithm is used and tested against a hypothetical disaster event in a hospital. The architecture is in distributed manner water and power are the main resources considered in the system.

Nguyen introduced a mathematical model that can be used to allocate network resources when the disaster affected the communication system of the area as well as a new trend of communication during that period. This provides an efficient scheme for UAV-enabled networks to set up as well as work with a large number of devices and algorithms are also proposed they are for constrained clustering, for distribution of power. These algorithms include low computational complexity. A post-disaster resource allocation system was suggested by Cheng [36] based on the big data from the social network services (SNS) and spatial scan. It can collect data and analyze big data from social network services and build a platform for efficient resource allocation and communication. Understanding the disaster level and the situation, understanding the distribution patterns of resource needed victims, and solving uncertainty of the big crowd data are stated as challenges that are going to be achieved by that system. Domain-specific and computationally improved machine learning models or natural language processing (NLP) toolkit will be used to understand the disaster situation. Spatial data mining and smoothing the data to reduce uncertainty will address the latter two problems to some extent.

A resource-based decision support tool was presented by Kolios and Milis [29]. As the first phase, a network model is derived to capture the resources flow, and thereafter a mathematical program is formulated to allocate resources in an optimized way. This is a computer-aided support system that enables real-time executions. This study focuses on medical resource management in emergency response during a disaster. An algorithm is developed for iterative decision making and each iteration obtains the data of resources and the responders. Dispatching rescue teams after an alert and transportation of victims is also included and tested for a similar hypothetical scenario. This system can be adapted to other kinds of resources as well as non-medical resources. Uncertainty has been addressed; minimum response time is considered in addition to revising the decision made is included. For the network model, the graph-theoretic network is built and this whole system covers all the five phases of medical emergency response. Those are alert, rescue team on the way, field management, patient transport, first receiver (hospitals/camps).

A study done by Basu and Roy [3], they have introduced a utility-driven post-disaster resource allocation system using a delay-tolerant network (DTN). It is smartphone-based and includes an opportunistic knowledge sharing scheme for gathering and disseminating resources. This model minimizes the resource deficit and total resource deployment time. Besides, resources are distributed in an optimal way to different shelters with the immediate deployment of high-utility resources. This system is evaluated using ONE simulator and LINGO optimization modeling tool through exhaustive simulation to compare performance. An integer programming model is used to make decisions in the control station. The system architecture consists of three layers they are shelter node to identify shelter specific resource needs, forwarder node to share opportunistic knowledge of DTN, control node to make decisions for utility-driven resource allocation. A utility function is derived, and an algorithm is suggested for optimal allocation. Computation and communication overheads can be identified.

Another system is proposed by Aalami [27] for fair dynamic resource allocation in transit-based evacuation planning. The maximum rate, minimum clearance rate, maximum social welfare, and fair allocation are the problems addressed by terms of MR-RA, MCT-RA, MSW-RA, PF-RA, and compared. An algorithm is developed using the Lagrangian approach for distributing, dynamic allocations and to update the evacuation process according to the new information. The percentage of the fleet that is assigned to each pickup location and the number of evacuees who are transported from each pickup location to each shelter is computed within the model. A proportionally fair distributed algorithm is proposed to solve the dual problem and used prior to the evacuation process. Algorithms for executed by pickup location, by transit vehicle dispatch center are there. The severity of danger at the pickup location, uncertainty not getting considered and few unfair allocations are the two of the major shortcomings of the system.

Zhang [4] was able to suggest an innovative approach for optimal resource allocation in emergency situations. In this paper, Zhang proposes a multi-agent-based decentralized resource allocation approach using the domain transportation theory to handle a multitask emergency event. This system can be used to select appropriate resources without global information and to concurrently generate resource deployment plans for multiple tasks by considering the severity level of the emergency. A multi-agent system (MAS) is a computerized system that includes loosely coupled autonomous agents' communication to achieve a common goal. The system is most suitable for metropolitan region emergencies. Reducing the average response time and rationalize the money expenditure is also a target of this system. This approach first converts the situation into multiple tasks, then agents simultaneously propose the allocation proposals to these tasks. In high severity events, the proposed approach considers resource allocation time is more important than the expenditure and here agents can respond as mobile, facility, or deployment agents. A framework is suggested, and an algorithm is developed for the process of resource allocation.

Resource allocation for demand and surge mitigation during disaster response [8] system was introduced by Arora & Raghu. This model describes a way of optimized allocation during public health emergencies. The case study is based on an illustration of a pandemic situation. It states how pre-allocation would be helpful and lead to flexibility during the emergency using a data and simulation model. In addition, mutual aid is beneficial in smaller counties when it is done according to the proportion of the population. Subgroups according to the age, severity, high risk should give greater insights for effective resource allocation. This proposed model has a limitation which is it is only for the static environments, but most cases are dynamic. Another thing is in this study single allocations are made (not re-allocation included). Cost evaluation and reduce the number of infected people can be indicated using this model.

In a study by Xhafa [51] for disaster management, it is recommended to use an event-based approach to support team coordination and decision making. In here coordination is included both inter (among members of a specific team) and intra (among geographically distributed teams) types. This study was aimed to link data sources and processes to automate possible task assignments and process resource allocations for teams in a timely manner. This system is proposed to achieve a few requirements those are, unified data modeling and intelligence data processing, process, and plan generation, and intelligent task and resource allocation. XML technology was used for data modeling and the system can adapt to the dynamic environment; re-allocation and co-allocation are also possible. The event processing layer is integrated with the ECA (event-condition-action) and for decision-making SMAS (situated multi-agent system model) included. Apart from that system uses mobile devices for communication for data flow.

The model-driven approach was suggested by Austero [6] for determining the capacity of resources of a disaster management unit. This model is mainly focusing on organic resources such as food, vehicles, and evacuation centers and its optimized allocation. This model was created based on specific decision variables, constraints, and information requirements of a particular task and it will produce the analysis result, decision alternatives, and generated reports for use in the decision-making process. This conceptual model consists of a decision model which includes rules & algorithm and an analysis model which includes rules and formula. These two models are directly integrated with the database of the disaster management system. After relief, capacity has been identified and it is enough the relief packages can be organized based on mealtime and for the number of days. Evacuation center assigning according to the availability and sizes as well as optimal vehicle selection by using greedy algorithm is also part of this model.

GIS (geographic information system) based decision support system for disaster management was introduced by Gerdan [56] in 2018. Where it states that this system can be used in all the phases of disaster management for effective response and providing practical recommendations of activities with the use of database and technological resources. A conceptual framework is created for a disaster scenario that consists of pre-disaster tasks such as gathering data, risk analysis, risk reduction strategies, planning, etc., tasks during a disaster such as impact analysis, response planning, etc., post-disaster activities such as damage assessment, reconstruction planning, etc. Decisions are made through the information and use of shared resources in a collaborative way. Resource allocation activities come under the disaster period and post-disaster periods. The system states that the decisions regarding resources such as rescue team allocation and scheduling can be drawn using this conceptual framework, but it is not mentioned the way of doing those tasks.

A resource scheduling system was proposed by Kumar [28] which is based on IoT technology. This article addresses the resource scheduling issue and exploited the bankers' algorithm to ensure resource allocation optimization and maximum utilization. It points out that the resource allocation and the scheduling come under the disaster response phase and those can be executed at both the administrative level and on the field level. Tasks and resources are identified prior to the response dispatching where tasks can be determined as establishing communication, medical treatment, rescue, and recovery, and resources include fire engines, volunteers, forces, ambulance, and medical help. A resource scheduling algorithm is proposed for a disaster event by the use of the banker's algorithm. This system is tested against a simulated disaster occurrence. Using this system with the help of IoT, efficient mapping of resources to the entities is possible and the system is integrated into the Google maps.

Cui and Liu [26] have addressed the problem of emergency material allocation during the post-disaster period. Considering supply chain disruption and path risk with the goal of minimum transportation time and cost under the uncertainty is taken into the account of creating this system. Supply point interruption, road interruption, and road impedance are focused in a mathematical way. This mathematical model has been developed constraints and indications such as the material capacity of each vehicle, limit of the quantity of the supply points, etc. The algorithm is built up considering encoding and population initialization, fitness function, and genetics & termination, and also tested for a case study. This multi-objective planning model can analyze data quantitatively prior to the material allocation and distribution but the dynamic change in demand still to be further researched.

The multi-hazard context is focused on Chacko's research [2]. It is a mathematical model developed to improve the quantitative resource allocation for multiple interrelated hazards. It is further focused on long-term disaster operations management (DOM) planning models where multi-hazards unique features are applied. Dependencies have been modeled prioritizing the humanitarian conditions and logistics and by using the Weingartner formulation. Previously mentioned dependencies can be generalized into categories like project dependencies which can cause a negative or positive impact on the benefits and cost dependencies which is for the use of resources could be either savings or expenses. This article provides a comparison of multi-hazard and mono-hazard situation and highlighted the unique features to be addressed in a multi-hazard situation. It states that decision support systems must include very advanced systems for resource allocation and provides suggestions for converting the models into a multi-hazard context.

IoT based system was proposed by Ansari and Liu for allocation of the network resources and for setting up the disrupted communication of the disaster area. It is focusing on setting a UAV-assisted M2M (machine to machine) communication with the allocated resources. Resource allocation for the network is considered at the first then after network setup, it is used to collect data of the disaster to make decisions and to deploy resources needed by victims. The M2M communication model has developed alone with an algorithm. This whole mathematical model was tested via a simulated disaster environment.

In order to improve the efficiency of the emergency in real-time Luscombe introduced a dynamic resource allocation system. Scarce resources could be managed, and dynamic scheduled updates are done within two seconds. In addition, scheduling and task resource allocation are both been focused on the medical field. This solution incorporates dispatch heuristics, disjunctive graph, and search methods to respond as quickly as possible while considering patients' prioritization. The emergency department's patient workflow is modeled in this article in two layers those are bed assignment as parallel machine scheduling with machine groups and task-resource allocation with flexible job shop plus these two layers are interconnected. A dynamic algorithm for the emergency scheduler has been developed as well as an algorithm for assignment and sequencing also has been developed in this model.

Asimakopoulou [5] suggested collective intelligence resource management with a dynamic approach for disaster management. Based on data it has done a quantitative analysis of the occurrence of disaster and the cost of the resources that have been used. This article presents and discusses the need for an integrated resource allocation to balance the requirements that are generating because of the disaster scenarios. It has shown that the increase of disasters past decade and the importance of having a resource management system to reduce the cost. This analysis is done using the data collected by European countries. It states that having a common resource balancing and practicing framework would be beneficial for the European region. Affinity partnership, learning community, communities of practice, action are the key characteristics that should be considered as common among those countries.

Alsubaie presented a way to allocate resources in an emergency by using an interdependencies simulation environment. This article proposed an integrated simulation-optimization tool it utilizes the infrastructure interdependencies simulator (i2Sim), it can model critical infrastructure to provide available resources such as water and power. Maximizing the operational capacity is one of the objectives in this system, in this case, it is based on a hospital. The i2Sim ontology has four components they are cell, channel, token, and control. Physical damage is represented by a physical model while resource modes represent the availability of input resources. The genetic algorithm is used in the system which consists of three main elements those are population, fitness function, and mating. Resource allocation, genetic algorithm (GA) application is the main two problem areas. This system can combine different infrastructures as well such as networks of hospitals and water, but GA needs high computational power.

In the study by Choksi [37], a multi objective-based resource allocation and scheduling approach using IoT for post-disaster have been introduced. Resource management algorithm is developed which deals with both over and under demand situations. And also, a resource scheduling algorithm is proposed based on various parameters, priority-based scheduling. Data collection is done through sensors and the RFID as well as a network is wireless, and IP enabled. For the system demonstration Raspberry Pi, Arduino, and sensor motes are used. The system is integrated with Google Maps which shows real-time traffic for decision-makers in addition, this system uses four different aspects which are priority of the task, transportation cost, resource utilization index, and scheduling time index. The optimization is performed by using the Lingo programming tool. Here the priority is considered to be proportional to the requirement of resources and the system is tested for a disaster scenario in the Gujarat state of India.

A decision support system is suggested by Rolland [55] in 2010. This decision support system is for disaster response and recovery using hybrid meta-heuristics. Disaster response scheduling (DRSP) can be classified as a complex variation of the Multiple resource-constrained project scheduling problem (MRCPSP). An algorithm is proposed to address this DRSP problem while focusing on both scheduling and assignment as well. But in this paper, it is not explicitly concerned with the facility locations because it views as the locations are tied to tasks. Adaptive reasoning techniques and its elements like the solver, local search, updating memory and learning parameters, etc. are used. Experiment to test the system is done using five different data sets and seven problem instances. This system has the ability to deal simultaneously with a combination of scheduling and assignment in near-real-time.

Wang and Pei [34] presented an approach for resource allocation for multi-period post-disaster using a multi-objective cellular genetic algorithm (MOCGA). This considers characteristics of uncertainty and persistence during the disaster rescue process as well as provides a rescue scheme for decision-makers. Effective emergency resource allocation and reasonable transportation road choice simultaneously addressed by this multi-objective model. Another objective of the paper is stated as solving the multi-period problem and dynamic allocation. A real case study was used to validate this model's performance which is an earthquake situation that occurred in China. Few assumptions should be made prior to use this in a real situation such as number and type of resources of storage and the demand is known, inventory supply points do not exceed with supplies and only has one-way delivery, transportation risks are known and single-mode is used for transportation as well as time is proportional to the distance.

A multi-function decision support system based on multi-source dynamic data was suggested by Wang [54] in 2020. It helps to identify optimal solutions from complex data within rigid timeframes, make decisions, and mitigate uncertainty and instability. This model includes information processing (MDBS), statistical analysis, data mining techniques to make more accurate decisions during a disaster by decision-makers. The results are presented using graphics. Medical supply storage, communication equipment maintenance, prediction, real-time data such as roadblocks, supply shortages are also indicated. In addition, determining disaster and trends, disaster timelines, response measures, serving as a simulator, prevention, and rescue are also possible functionalities of this system. This model aims to cover a few objectives those are information relevancy, sequential warning, situation simulation and prevention, and resource scheduling, situation setting, education, training, and evaluation. This system can rapidly transfer resources for rescue and prevention, identifying resource inadequacy. Input sources are big data, external data, internal data where they are used with the fuzzy theory. A functional framework is proposed while discussing the system information procedure, human-machine interaction, module interlink in multi-window development. This system provides a system to system functions such as database establishment, system integration, risk assessment in the form of a smartphone app. The main functions of this decision support system are the creation of an internal database, data mining, graphical display, module interlink in multi-window, planning ideal rescue routes for dispatching, resource assessment, and allocation and training as well as the reserving capacity for expansion.

Altay presented [32] an approach for capability-based resource allocation for effective disaster response. This model is an integer programming model developed for multi-location as well. This is built to allocate response personnel, facilities, supplies, and equipment. This paper states that the analytical model is used for resources assigning for requests within the National Incident Management System–Incident Resource Inventory System (NIMS-IRIS). MINS-IRIS establishes the interoperability of resources. Two cases are considered: supply exceeds demand and demand exceed supply. This optimized model is used in an illustrative environment of the USA for testing. Paper has tremendous managerial implications because it considers the allocation of resources to impact jurisdiction which is a manual process. The model is based on a snapshot of the disaster situation where needs are known and assigned resources satisfying the needs but does not capable of dynamic disaster scenarios.

The model for relief demands in the emergency supply chain system under large-scale disasters is introduced by He and Hu [38]. It is based on a queuing network modeled as a minimal queuing response time model of location and allocation as well as this addresses uncertainty. This problem solution is developed using a genetic algorithm. A case study is done for the emergency in Shanghai, China and the results demonstrate the robustness and applicability. By using the queuing model can obtain the classical performance of the emergency supply chain (ESC) such as average queue length, average waiting time, and optimize relief operations. The main contributions of this study are fulfilling resource requirements and deliveries, calculate performance, solve integrated problems like vehicle routing and location of facility centers. Queuing flow formulation includes the location of supply points, logistics centers, demand points, and upstream/downstream nodes. ESC constitutes producing, sorting, processing, packing, delivering as basic activities. Several hypotheses are drawn in the system operations, some of them are geographical relationships between nodes are available in a government database and can be readily accessible via detection technologies, location of logistic centers are fixed only in given sites and people receive services as first come first served. The mathematical formulation for queuing theory is developed for facility location and path selection in a multistage ESC network. Parameters and decision variables are stated along with the methodology and procedure of the genetic algorithm. Results of a test case done in China have given the average response time of queuing network and for demand in a reasonable range.

Kureshi [52] introduced an info-symbiotic decision support system for disaster risk management. The framework uses cyber-physical sensors to assist decision-making and dynamic data-driven simulation approach plus can target areas and do resource allocation as well. This framework can manage a heterogeneous collection of data resources and uses agent-based models to create multiple possibilities of scenarios in order to determine the best solution or action. This dynamic data-driven application system (DDDAS) can do disaster management from pre-event planning and mitigation strategies to post-disaster response. This system is aligned with the European Commission Report on Risk and Vulnerability Management. This system has multiple functionalities during each stage. Few of them are risk assessment, planning, pre-impact analysis, emergency operations, restoring infrastructures and services, reconstruction, etc. The optimal allocation of resources is focused on the post-disaster stage. This heuristic approach incorporates the concept of tangible and intangible loss to help to prioritize risks and the corresponding response.

Kimeli [33] has developed a decision aid model for disaster management and resource allocation. The multi-hazard context is focused and pointed out the need for disaster recovery centers. The employees, labor hours, victims are considered when proposing the emergency recovery centers and determine the number of centers and resources needed for each area as well. In addition, a mono-hazard and multi-hazard comparative study is conducted and how to convert from one context to the other is also discussed. Model is developed using software technologies while getting data from technical users (decision-makers), non-technical sources (patient) as inputs. This system consists of incident management, resource management, reporting capacity, and availability, capturing information, and enabled system security as functions. Authentication, reusability, verification, and maintainability are some core non-functional requirements that have been covered by this system.

When doing this literature review by searching through Google scholar, IEEE explorer, research gate, science gate, etc. many related articles, journals, conference papers were identified. There is a probability that some of the related articles of the past decade can be missed out when searching by keywords like ‘resource allocation’, ‘disaster management’, ‘decision support systems’, ‘emergency’, ‘relief distribution’, and so on. A few literature reviews and systematic reviews were founded where they are not addressing the same topic but related to this topic area. [67], [58], [65], [62], [60], [63], [66], [59] and [64] are some of those articles that have been referenced prior to writing this literature review of resource allocation systems in disaster management. Anaya’s [57] review on distribution networks states that many disaster logistics are based on the location and transportation of resources and patients apart from the networks.

Hazra and Shah [35] introduced a novel network architecture for resource-constrained post-disaster environments. Rationally allocating network resources such that each shelter point has at least one network resource and minimizing the end-to-end network delay in communication between volunteers/workers to control stations are the main objectives that are aimed to cover by this system. To address this problem non-linear programming (NLP) optimization is formulated and then proposes an effective sub-optimal heuristic for solving it. The system is tested against the real map of Durgapur, India on top of the opportunistic network simulator. A network model is implemented considering available network resources, message transmission and volunteers of the rescue team are the ones who communicate through this model with the control center. Algorithms are developed for grouping of shelter points and for calculation of data mule trajectory. Build and SWAP are considered as phases of the heuristic solution, in that reallocation is also included.

Liu and Zeng [30] presented a method to model and analyze emergency response processes by taking uncertain activity execution duration, resource quantity, and resource preparation duration into account. This model includes E-Net which is a Petri net-based formal model for an emergency response process, and it is classified into the worst, delayed, and best cases. This paper finds the duration to execute each activity for the delayed case based on a priority-activity-first strategy and corresponding algorithms and ensures shorter durations for the whole process. Before using a few assumptions that need to be made such as the duration of each activity is uncertain, a resource preparation time is needed before using and resources can be reusable only after the previous activity ends. This model is only focused on the emergency response process in the post-disaster phase. Resource conflicts can be detected that are mainly happening from resource re-usage by using algorithm within the model.

Sharma suggested a system based on IoT [50] and the obstacles in using that technology in disaster scenarios. Wireless sensing networks are focused on this study and it states that by using IoT technology-based devices people and decision-makers can get the actual idea of the situation to make correct decisions. Disasters like landslides, flooding, and forest fire are taken as examples to explain as a case study in the context of areas in India. Resource-based decisions as well as medical service assigning can be done and can gather information via resource-based information accessing methodology. When considering the architecture of such a system, in all the phases of a disaster IoT can perform to boost all the processes. Another resilient cloud-based IoT system is introduced by Khan and Ghosh in 2019. For reliable data exchange, interoperability, and integration which is challenging in disaster management is addressed by this system which is utilizing a cloud-based IoT framework with data-interoperability and load balancing. This system is evaluated by using an android application, IoT toolkit, and cloud-based middleware platform to exchange data and to load balance. The cloud-based broker messaging platform allows the exchange of data among heterogeneous devices. The system architecture is designed while considering the individuality and privacy of the stakeholders allowing decoupling, scalability plus security. This system consists of three layers which are an android client: developed using Java and designed to send/receive text, images, location, etc. with the use of MQTT protocol, raspberry PI client: the objective is that emergency services are able to produce better response and lastly MoM (message-oriented middleware): a mediator between senders and receivers to mediate events and messages amongst publishers and subscribers. A testbed architecture is also designed with two layers those are visualization and cloud. It acts as a private cloud infrastructure to accumulate and to serve requests. The experiment is done using a particular scenario but the decision-making as disaster response is not addressed in this. Apart from that system resource utilization is tracked.

Summary

Resource allocation is a very important process during a disaster period. Many resource allocation systems and models are available or suggested theoretically by various researchers. Most of them are tested and illustrated as prototypes by using a real or imaginary scenario. Some resource allocation methods are embedded with decision support systems in disaster management where others are stand-alone. These resource allocation systems consider resources as both material and labor such as medical aid, food, water, rescue team, vehicles, etc. Few are only focused on allocating the resources to building up a temporary network because the actual network is disrupted because of the disaster. Disaster-specific resource allocations are suggested in some studies. IoT, web, big data, mobile technologies are used in most of the systems and mathematical models are also proposed along with those. Resource allocation is happening in every disaster phase. It is considered in mitigation, preparedness, response, and recovery stages. Resource allocation always comes together with resource scheduling when it is scarce in availability. Dynamic, static, fuzzy, and stochastic models are proposed, and algorithms are developed while addressing resource scheduling and allocation. These emergency allocations are capable of handling both large-scale and small-scale as well as natural and man-made disasters. Resource monitoring is also focused by few and some are customized for multi-hazard context as well. Only the conceptual framework is proposed in some, but many are integrated with geospatial information systems (GIS/GPRS). Resource utilization, optimization, uncertainty are the main concepts focused on both the pre and post-disaster periods. Agent-based, event-based models are suggested along with group decisions, team coordination, community, and volunteer engagement. Risk analysis, management, and reduction are also focused on this context. Apart from that prototype testing and results have been analyzed in every system. literature has addressed resource facility location problems, emergency resource allocation problems, and emergency resource scheduling problems, and transportation problems vastly. Multi-objective, single-objective, or both can be seen in these systems. Re-allocation and re-scheduling are also taken into account by some researchers. Capacities of vehicles, shelters, hospitals, evacuation, and supply points are also considered in this study area. In addition, both exact and heuristic approaches can be seen.

CHAPTER 03

3.1 PROBLEM

In the context of resource allocation systems, many individual studies can be seen with different unique approaches. When a sudden disaster occurs how those can be evaluated in a comparable way and make use of the best approach for resource allocation during that period. When narrowing the scope of resource allocation systems to which are used or suitable to use only in a disaster scenario, there are plenty of individual studies conducted by researchers covering every phase (mitigation, preparedness, response, recovery) of disaster management.

The most important and critical operations are related to response and recovery, but how to extract the knowledge of those studies to apply the best or develop the best for a certain disaster. At present, the Covid-19 pandemic is going on where people mostly in developing countries don't have very effective resource allocation systems to use. Therefore, people suffer from critical resource scarcity. This implies the need of extracting the knowledge into one particular point so it will be beneficial for decision-makers when making decisions during a disaster.

This problem indicates the need for a comparison of existing resource allocation systems that can be used in disaster management.

3.2 QUESTIONS

The primary objective of this study is to systematically review related articles of resource allocation systems that are used in disaster scenarios. The existing studies are compared and the special features, limitations, advantages, and the phase or the specific disaster where it can be used are declared.

The specific questions that are guiding this research as follows:

a) How is the resource allocation is handled in response and recovery phases of a disaster as per the current studies?

b) Are there any gaps existing in between research that are yet to be addressed and how it can be filled?

c) Is there a possibility to use the existing knowledge of systems to face the resource scarcity that generates during the present covid-19 pandemic?

d) What is the role of IT in the disaster related allocation systems?

3.3 SOLUTION

As a solution for the above mention problem statement and for the questions, a systematic review is conducted in this research. It will include the overall analysis of the existing resource allocation mechanism which can be used during a disaster scenario. Especially a systematic review is suitable because it will go through all the features, advantages, limitations of each individual study in a systematic way to provide the knowledge comparatively.

The primary objective of this study is to answer the previously mentioned research questions while providing evidence for such conclusions. This systematic review will help decision-makers and people who are planning to develop such resource allocation systems. This research will address all the significant areas, most common areas of disaster context, and provide the complete knowledge of existing resource allocation mechanisms.

3.4 METHODOLOGY

This research is conducted as qualitative research but it includes some of the qualitative measures. Here, all the literature gathered is analyzed based on the qualitative aspects like features, advantages, limitations and case studies, etc. Even though a few quantitative aspects are covered this research is a qualitative-based one. The research is done by reviewing of literature but in a systematic way. Therefore this research comes under the category of a systematic review. It aims to identify evaluate and summarize the findings of all relevant individual studies by making the available evidence more accessible to the interested parties.

When conducting the research few obstacles came in the way. But got a pass-through those by workarounds in most cases. A few of those challenges are, when collecting literature some databases don’t give full access to the papers, when doing keyword analysis some of the collected papers did not contain any keywords, handling and summarizing such around 70 papers were very challenging. But those obstacles were able to overcome successfully by adapting to those. The Mendeley tool was used to handle papers, papers that didn’t contain keywords were not taken into the keyword analysis and deep browsing was done in order to collect papers from free sites were some of the workarounds which followed to overcome.

A systematic review is more thoroughly analyzing what the individual studies have contributed to the knowledge area more than a literature review. Because just a literature review does not address research papers deeply. The general understanding will be generated with evidence so this approach is effective for summarizing all the existing knowledge comparing to other approaches.

3.5 DATA AND DATA DESCRIPTION

The main sources for this research are research articles collected from various sites while browsing the internet. These articles are mostly regarding individual studies conducted related to this research context. The technical literature was collected via the following databases.

- IEEE Xplore
- Science Direct
- Research Gate
- ACM (Association for Computing Machinery) digital library

Apart from those websites, other papers were browsed through random search using ‘Google’ search engine, Google scholar and using techniques like snow bowling where it uses one research article for analyzing the references given to find more related ones.

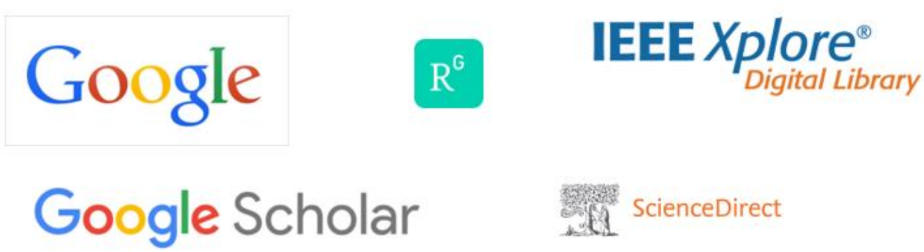


Figure 1: The sources of literature

The research was conducted by only including papers that were published during the past decade (2010 - 2020). It doesn't contain articles that are only abstracts or that were published before 2010. In addition, when considering the search strings of literature browsing, mainly used the context keywords which were like:

"Resource Allocation in Disaster Management", "Resource Allocation Systems", "Decision Support Systems for Disaster", "Resource Management in Disasters" etc.

Reference Category	No: of Papers Identified
Individual Studies	72
Reviews	09

Table 2: Reference papers

As per the above table altogether **81** papers were collected prior to this research and among those 9 were literature surveys which was covering the decision support systems and several were about resource allocation especially. The other 72 papers were all about individual studies of the past decade.

3.5.1 TOOLS

When conducting the research in order to handle the research papers in an easy manner few tools were used. Mainly, Mendeley is the reference tool used and Microsoft Excel is used for maintaining all the keywords of papers.

<u>Mendeley Reference Tool</u>

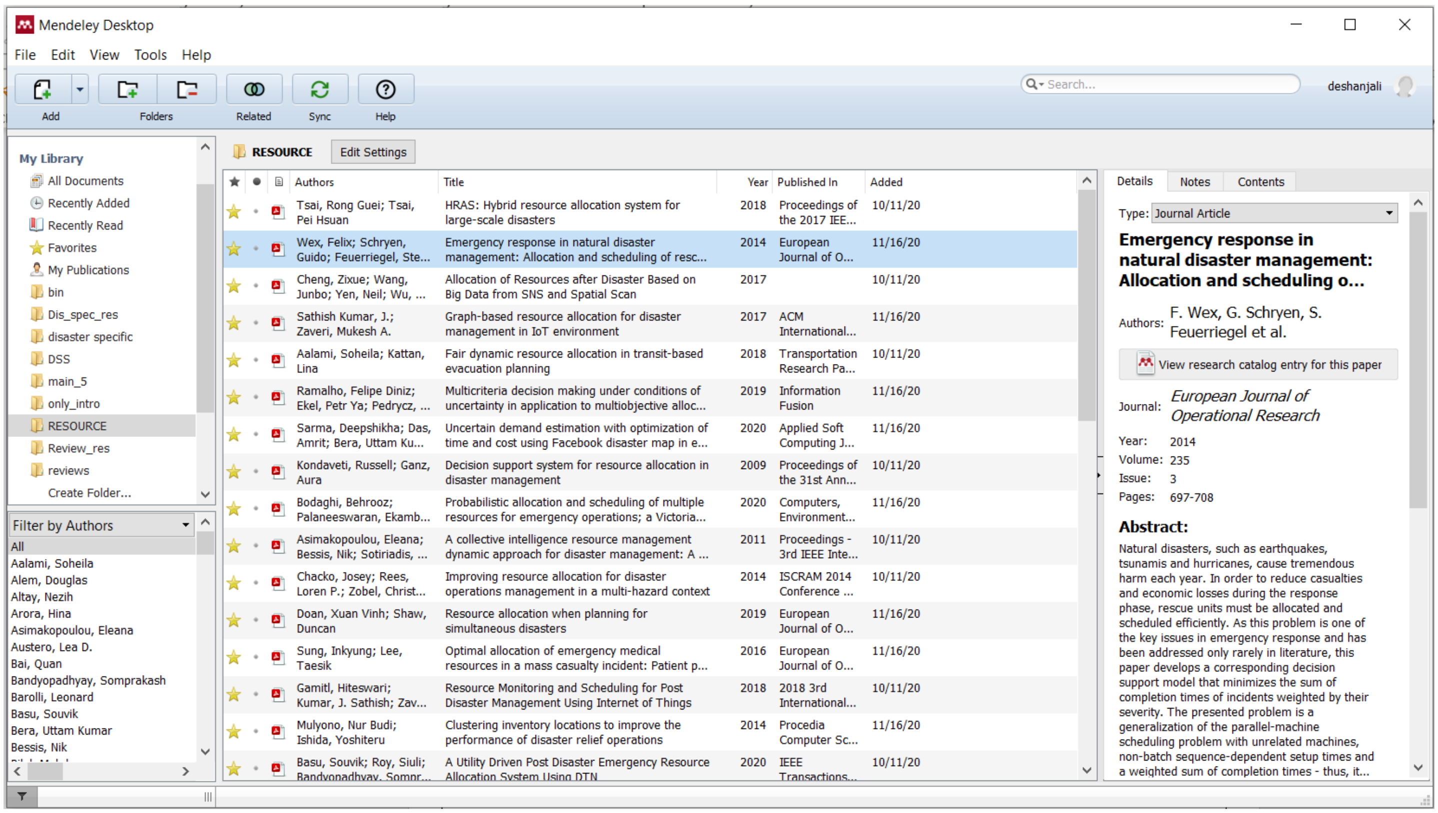


Figure 2:Mendeley reference tool

3.5.2 PRISMA

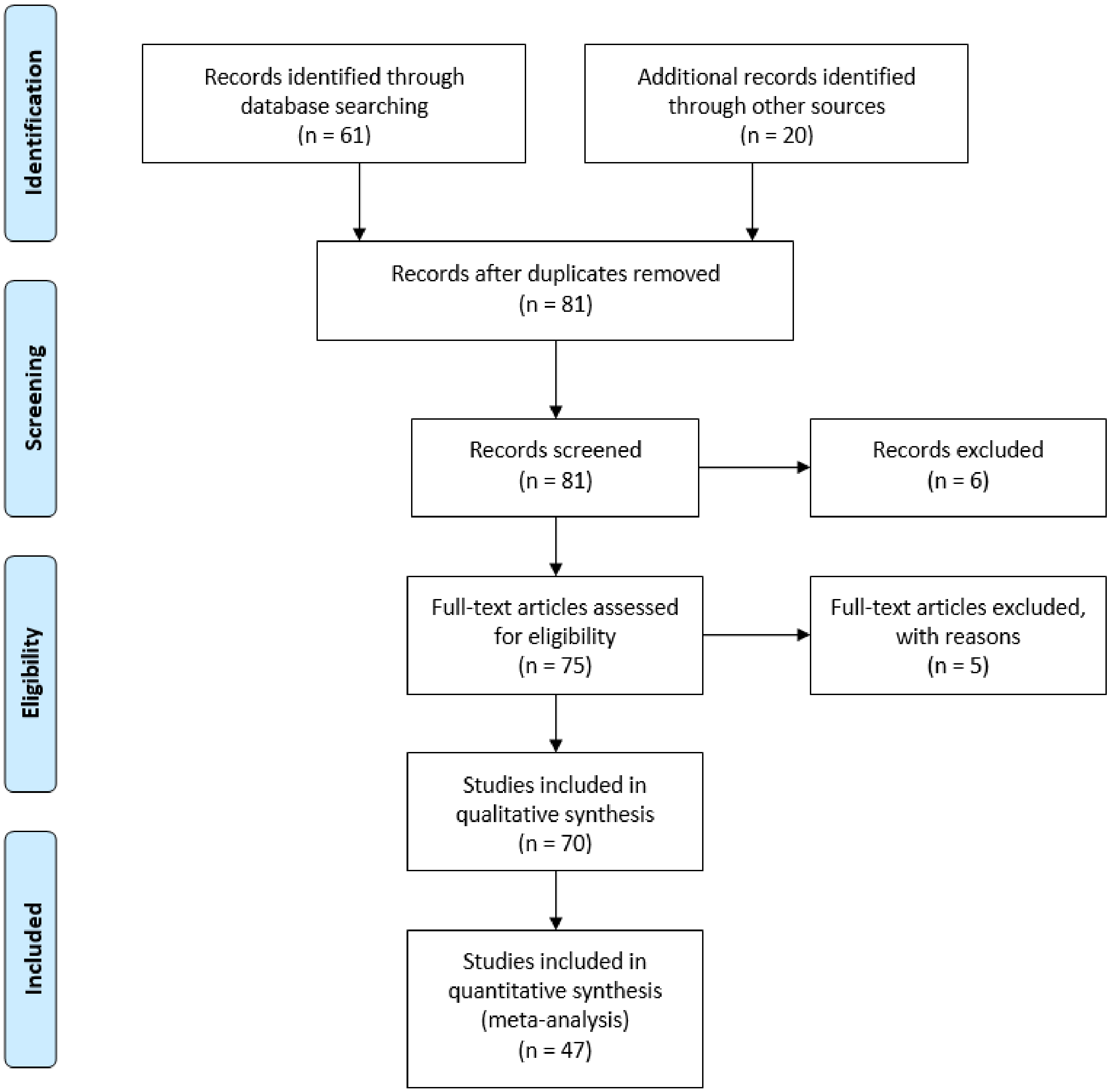


Figure 3:Prisma

The PRISMA standard is used as the guide for the systematic review. This standard is globally recognized as a guideline for systematic reviews. This standard used in this research especially for excluding and including criteria when choosing research articles.

The above diagram indicates the flow chart of selecting paper articles while filtering according to the standard. This flow chart has five main sections those are identification, screening, eligibility, and inclusion. A detailed description of selecting criteria is mentioned below:

Altogether 81 papers were identified by context keyword searches through databases and other random searches. The research gate, science direct, and IEEE Xplore are the main databases used to collect 61 papers and did some random searches and snow bowling for the other 20 papers. No duplicates were identified through that process therefore altogether 81 uniquely identified papers were there at the initial stage of the research. Then all the records were screened but excluded 6 papers out of it because of the irrelevancy. The remaining 75 papers were eligible for the research but had to exclude 5 papers because of the scope restrictions imposed within the research. At last, 70 papers were there, those are the ones used for this research for qualitative analysis, and out of that 47 were chosen which were solely focusing on resource allocation systems for the quantitative analysis of Keywords.

3.5.3 KEYWORD CLASSIFICATION

The uniqueness of this research is, a keyword-based classification is done in order to analyze how well research can be divided into clusters based on the keywords. From all the 70 research papers, the number of papers that directly addressing only resource allocation techniques was 47 (including 3 reviews found). Out of those 47, only 42 articles had the keywords defined other 5 didn’t have the keywords in them. Therefore, using 42 papers, a keyword classification is conducted. For this, the Machine Learning technique which is clustering was used.

As for the preprocessing, removing stop words, characters, converting to the lower case was done. The feature extraction was done using the Tf-idf vectorizer and used the Affinity Propagation algorithm which is an unsupervised machine learning algorithm available for clustering while identifying inner patterns. For the technologies, Anaconda is used for Jupyter Notebook, Python is used as the programming language. Apart from that pandas, NumPy, nltk, sklearn libraries are used for the data analysis.

There were altogether 195 keywords, and it gave 9 cluster labels.

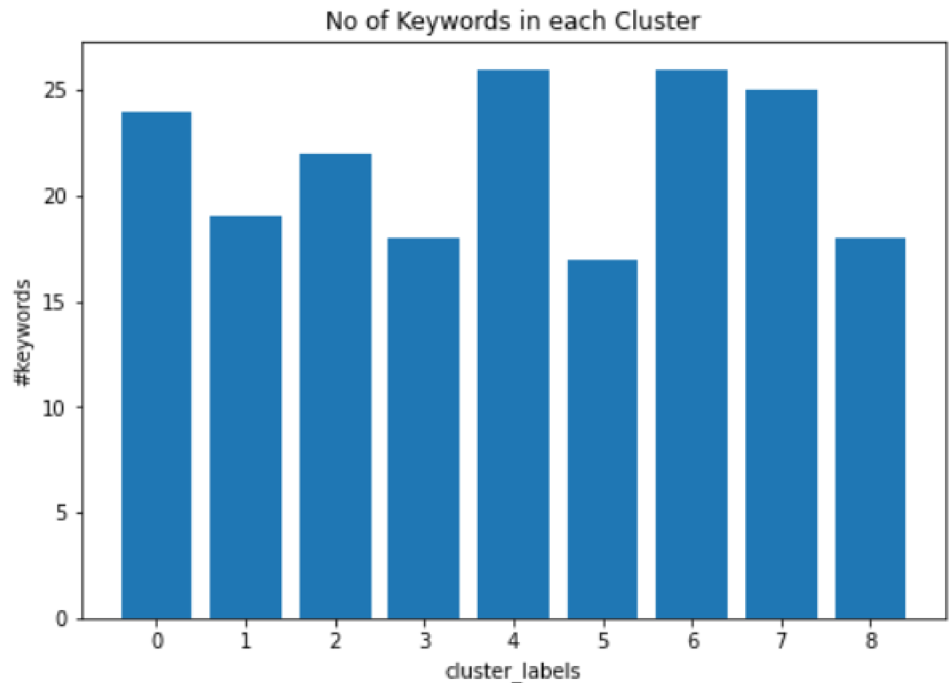


Figure 4:Keyword classification

3.6 EXPERIMENTAL EVALUATION/RESULTS

3.6.1 WORD CLOUDS

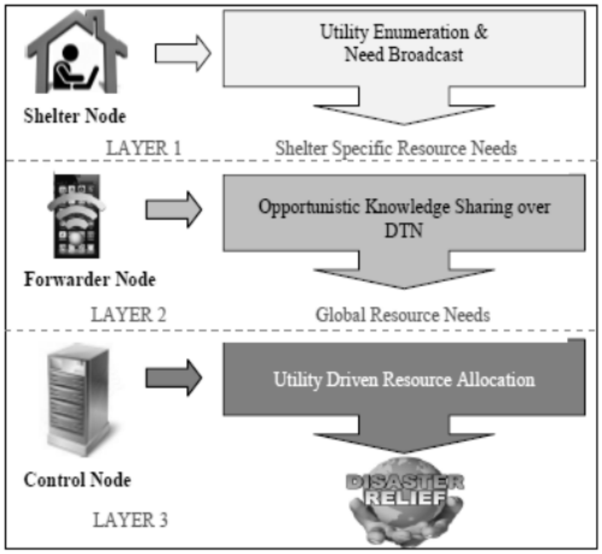
The word clouds are generated to get a clear view of the word clusters. From now on, each word cluster is presented and analyzed with the relevant papers.

Here, all the clusters of the keywords are analyzed according to their relevant studies. One thing identified was, when one paper has several keywords they mostly belong to multiple clusters. Therefore, the analysis is done according to the cluster that one article has most of the keywords contained.

Cluster – 0

In the study by Basu and Roy [3] utility-driven post-disaster emergency resource allocation system using DTN (Delay Tolerant Network). It states that post-disaster challenges in resource allocation as understanding utility in a dynamic scenario and collecting – transmitting to control stations. An infrastructure for resources while proposing an opportunistic knowledge sharing scheme for DTN. This paper talks about a utility-driven optimal resource allocation system which also includes shelter allocations. This model is able to deploy high utility resources faster and the effectiveness of this model is evaluated by ONE simulator and LINGO optimization as well as the comparative performance by exhaustive simulation. And also, this does shelter allocations according to the priority with the use of a utility function. The utility function is doing several tasks such as, monitoring and recording demand, distribution of volunteers, getting and sharing of knowledge using an algorithm, etc. The needs are transmitted through DTN to control stations with intervals and an integer programming model for distributing multiple resources to multiple shelters. The main objectives of this integer programming model were to minimizing emergency resource deficit and decreasing the total resource deployment time plus the optimal allocation. For this, available resources and vehicles are considered, and it states that high utility resources from the nearest warehouse will meet the objectives but has limitations of computation and communication overhead. A case study was conducted in Uttarakhand, India. A volunteer has to meet one another at least once to share knowledge and this study indicates the reduction of resource deficits by 94% in full connectivity. As for the future extensions it states that distributed resource allocation model, so shelters can pool resources in a decentralized way and transporting multiple resource types at a time. A collective intelligence resource management dynamic approach [5] is suggested in another study that aims to balance resources according to needs and importance and also provide quantitative evidence of increasing disaster occurrence in terms of cost during preparedness, recovery, and mitigation. It is conducted as a density survey of disaster occurrence and the importance of resource management. For balancing cost and resources partnership models are suggested between countries. In addition, it shows the need for integrated disaster management with the shortages and the need for expert knowledge that cannot be found locally. This study address affinity partnership, learning community, practice, and project communities for sharing infrastructures, knowledge, resources, and tools. For the future, it indicates the policies, agreements, agencies, and dynamic collective intelligence of resources are needed.

Figure 5:[3] Architecture of proposed emergency resource allocation system



A novel network for resource-constrained post-disaster environments is proposed by Hazra [35] which contains the underlying idea of rationally allocates resources here the main focus is on network-related resource allocation, not just critical resources. This point-out the fact that each shelter is served by at least one resource and latency is minimized. This paper formulated the problem as non-linear programming and showing it is NP-hard so then proposing a sub-optimal heuristic for solving it. The case study for experiment analysis like performance is done in Durgapur, India. As technologies google maps are used, the network model is stated with the architecture, an algorithm is used for grouping of shelter points. An innovative approach is proposed by Zhang and Ren [4] for optimal resource allocation in emergency management. It is a multi-agent-based decentralized approach that uses domain transportation theory to handle multi-task events with a linear programming method. This system selects resources without global information and generates deployment plans considering the severity level of a disaster. This is an optimal solution for cost and time also. This MAS's (multi-agent system) agents can be software that can communicate with each other to achieve goals. The MAS consists of abilities of autonomous reasoning, intelligent modeling, management, and dynamic reaction as well as collective decision making and group collaboration. This converts the allocation problem of a single event to different allocation tasks then multiple agents simultaneously propose allocation strategies for each task. Here domain transportation theory is used to find the optimal by considering the minimum cost. The resource allocation algorithm is used with a cost function but according to the severity, it considers time over money. This system defines, environment, resource, task, event, and allocation proposal and the most important part is it converts the single event resource searching to multi-task resource searching which can handle tasks simultaneously without demand conflicts and centralized control node. The resource mapping to tasks is focused and agents like response agents, mobile agents, facility agents, deployment agents generate the deployment plan and allocation proposal. Technologies such as JADE (Java agent development framework), BDI (Belief- desire-intention) architecture, KQML (Knowledge Query and manipulation language) used for the development of the system. An experiment is done using Google maps while considering fire stations, hospitals, police stations in Australia. It indicates good performance and also focusing on multiple severity levels of a disaster. For the future extensions, they are considering handling concurrent events where time overlaps with other events and also resources with concurrent requests in multiple events plus the dynamic rescheduling.

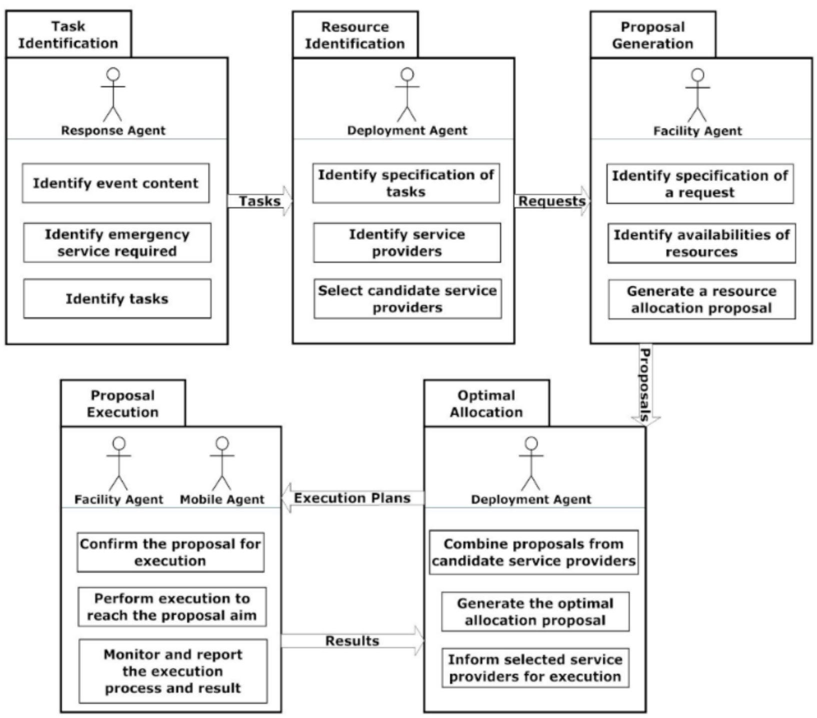


Figure 6: [4] multi-agent system

Cluster – 1

An agent-based simulation of emergency response plan in the allocation of resources for a hypothetical two-site major incident [10] study had most of the keywords belong to this cluster. This reduces the latest hospital arrival time and takes the distribution of casualties for optimal allocations to account, for the finite number of resources. It includes a pre-hospital response that contains prioritizing casualties, treatment, and transport to the hospital. The fire-rescue services and ambulance services can be taken as examples. Considering the trade-offs, it simulates the emergency response as a part of preparedness. The aim of this study is to determine optimized response using ABS – STORMI (agent-based simulation – simulation of the tactical and operational response to major incidents) that has two goals of reducing the time to the hospital and optimal resource allocation. The agents are coupled with the model and the model is experimented with using a hypothetical case study in England taking two sites. This indicates the Pareto-optimal results and reduced time according to casualties distribution. The response objective is that the final critical injured arrival time to the hospital should be minimized. It concludes that high casualty rates increase resource demand and need. As for the future work they are planning for multiple incidents and considering location variables, possible routes as well as the use of ML (machine learning) for 'meta model' to analyze parameters. The balancing of pre-disaster preparedness and post-disaster relief is addressed in a study [11]. It proposes a two-stage dynamic programming model for obtaining optimal allocation in preparedness and in post-disaster relief as decision variables. This brings new insights by sensitivity analysis and this model studies trade-offs to lower the damage and cost. In this model disaster magnitude is considered including binary, normal, exponential distributions. The backward induction is used to solve the model and also this states that preparedness and relief are substitutes to each other as well as that proportion of damage is positively correlated to magnitude & severity. Therefore, when greater the effectiveness of relief, less preparedness is needed. In this, relief is not implemented when disaster is less likely to happen. This model minimizes the total loss in both pre-and post-disaster stages with optimal relief both analytically and numerically. For the future, they focus on a budget constraint, independent locations, all-hazard context, multiple period decision making, and validate the model with real data.

In the study of clustering inventory locations to improve the performance of disaster relief operations [12], re-distribution of stocks to other shelters is addressed with the high performance of lateral transshipment through cluster formation of shelters. But shelters are, planned before the disaster, and also an algorithm of stable roommate problem (SRP) is used. The model validity is evaluated by simulation results of a volcano disaster. The part that is related to this research is, distributing resources to evacuees. An inventory system is proposed with social, strategic, and defense attributes. For that, three inventory models are suggested when communication and teamwork are unavailable, they are fixed review model with a fixed time interval, continuous review, and single period. The lateral transshipment is allowed for balance resources, so performance is measured by the inventory level of shelters. The performance is increased by using shelter clustering but there is a constraint which is the number of vehicles available. Here resources that are considered are food, medicine, clothes, tents, etc. The clustering mechanism takes distance, inventory capacity, demand rate, and support level. In the pre-disaster phase, shelters are established according to the population. The limitations of this study are demand and support levels are constraints in the recovery period also consider one cluster has a maximum of two shelters. In the initial state, shelters are put into clusters by single linkage cluster or nearest neighbor clustering algorithms. An algorithm is used to determine the stability and another thing is can get support from outside members of clusters with priority based on time. The multi-criteria decision-making under conditions of uncertainty in application to multi-objective allocation of resources [13] research is based on a possibilistic approach or framework. A fuzzy set-based generalization is used to deal with uncertainty and both qualitative, quantitative information is used. This is a multi-criteria robust solution that proposes the formulation of specific allocation objectives. This approach includes multi-objective allocation of resources and shortages of resources while the allocation is associated with the linear objective functions. Here, three models are discussed those are the allocation of available resources, shortages with unlimited and limited cuts. The solution is presented using deterministic information and considers uncertainty by mathematical formulation, constructing pay-off matrices. The example stated is about financial resources under strategic planning. For the qualitative information at presence by expert's involvement, preference vectors generated through AHP (analytical hierarchical process) while aggregating the preferences. The fuzzy formats are used to establish the preferences.

The level of detail in ABSs of emergency response.

ABS	Aspects of response modeled										Implementation		
	Ambulance service						Fire Service						
	Incident control point	Casualty clearing station	Primary and secondary triage	Hospital triage	Air Ambulance hospital transport	Non-ambulance hospital transport	Sectorization	Search and rescue	Extrication	Fire-fighting	GIS topography (e.g. buildings)	Road network	Multiple levels of detail

Figure 7: [10] ABS aspects of the model and implementation details

Cluster – 2

An exact branch-and-price algorithm for scheduling rescue units during disaster response [14] was suggested by Rauchecker and Schryen. This algorithm can be used in exact or heuristic procedures when time is scarce. The effectiveness is high of this optimal solution. The research is modeled as a scheduling problem, binary linear minimization problem, branch-price algorithm, and experiment with sensitivity analysis. A DRSP (disaster response scheduling problem) model is suggested in this study and overall harm is derived by the weighted sum of completion time of rescue units when an incident occurs. The objective functions of the model are the sum of completion times and maximum completion time that is suitable for the collaboration of multiple units for the same incident doing different tasks at the same time. A novel formulation is presented with the ability of decision variables to indicate schedule usage of a unit. This branch-and-price algorithm for DRSP can solve linear relaxation of the root node, node selection, and branching strategy and solve child nodes linear relaxation. As for the experiment of the study, four different scenarios are taken with the units that have multiple capabilities as well as travel time plus processing time are taken into the account. The execution times of the specialized units were analyzed according to the severity level of the incident. The sensitivity analysis was done using a regression model. In the discussion, it states that it had an average execution time of 0-40 minutes, and travel intensity could be high or low, the heuristics and effectiveness of the algorithm are also stated. The number of incidents and units below 40 can be solved within 10 minutes and also can abort algorithm execution to take an immediate decision out of generated solutions. For the future stochastic model to address uncertainty, validate the algorithm by real data, parallel execution of the algorithm is mentioned. This proposed approach has limitations on unit interrupts processing incidents and the time window integrated with the model. The study of uncertain demand estimation with optimization of time and cost using Facebook disaster map in emergency relief operation [15], is a multi-objective solid transportation model for distribution. In order to measure demand, it uses Facebook disaster map and safety check feature. Both the deterministic and non-deterministic algorithms are used to solve the mathematical model. Those algorithms are LINGO optimizer and genetic algorithm. Four techniques are used and compared with the goal of minimizing total cost and response time. The solution approach of MOSTP (multi-objective solid transportation problem) is a neutrosophic compromise, interactive fuzzy saticing, Pareto optimal solution, and goal programming. The products are stored in facilities near affected areas and there is an intensity factor for required resources. For example, high for medical resources and low for clothes and food. Here, limited resources are considered, and the model is explained with a numerical example with a statistical study and analysis for its performance is stated. The uncertain situation and demand, patient severity, multi-stage formulation for demand change according to severity and disturbances will be expecting to cover in the future of the study.

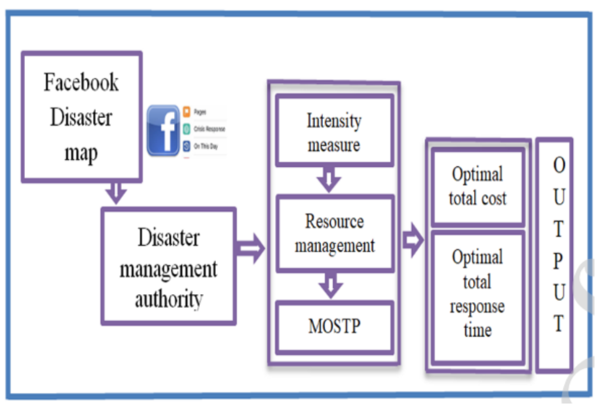


Figure 8: [15] optimization using Facebook disaster map

The coordination for dynamic weighted task allocation in disaster environments with time, space, and communication constraints [16] research is conducted because of difficulty in handling those features through centralized coordination. So, no need to have a global knowledge of the environment because dynamic group formulation is there to share information. The urgency of tasks is considered and there is a utility function to find a suitable task allocation solution. The coordinator allocates agents according to the tasks and the resource provider is in charge of finishing the tasks. An algorithm is used for group formation with decentralizing concept. This solution provides the estimation of useful allocation solutions and utility calculation of allocation solutions while considering the cost-benefit. In the experiment, they conducted three experiments to evaluate performance those are group formation through DNGF and INGF (direct neighbors and indirect neighbors), task allocation under different communication ranges of agents, and impact of urgent degrees. As the summary of the study, it has used INGF because of more agents and this can be stated as good as a centralized approach as well as can finish more weighted tasks while efficiently handling multiple constraints. For the future extensions, they are suggesting allocation in more complex environments such as agents can only have sparse interactions. Wex and Schryen [18] proposed an emergency response in natural disaster management allocation and scheduling of rescue units. It is a decision support model which minimizes the sum of completion time of incidents weighted by severity. They compare several heuristics such as monte Carlo-based, construction heuristics, improvement heuristics, GRASP heuristics, etc. The experiment shows 40 incidents can be solved in less than a second with 10.9-33.9% higher than the optimal values as well as overall harm can be reduced by up to 81.8%. This approach allocates emergency rescue units and this model formulated as a binary quadratic optimization problem which is also referred to as RUASP (rescue unit assignment and scheduling problem). This study first proves NP-hard and then suggests the heuristic-based allocation with an optimization model for the response phase of natural disaster management. This model validates a large set of heuristics for centralized decision making and evaluates heuristics against two benchmarks which are best practice solutions and lower bounds of optimal solutions. The routing and scheduling both are considered with a mathematical model as well as data generation, evaluation, and runtime are addressed. The experiment tested 40 incidents with 40 rescue units indicated that applying heuristics improving response situations. The greedy heuristics represent current best behavior but the limitation of this study is it can be used up to 40 rescue units only. This model assists decisions in high complexity and time pressure and as for future extensions performance degradation, time windows, collaborations, uncertainty are planned. Considering secondary disaster situations, a multi-stage assignment optimization for emergency rescue teams is proposed in a study [19]. The model dynamically responds to disaster chains with priority scheduling. The fuzzy methods are developed and performance is at a satisfactory level with a secondary disaster. The priority strategies depend on the maximum rescue time allowed by the disaster. A vehicle navigating system is planning the routes (GIS) observing traffic and maintenance. The response units with soldiers, doctors, nurses, volunteers connect with each stage to get a response. The demand for resources is cumulated with the population and the survivors. Disaster priority, distance priority, and balancing disaster and distance are the three strategies used. The algorithm NSGA-II (non-dominated sorting genetic algorithm) is used with an iterative optimization process. The NSGA-II contains chromosome coding, constraint handling, selecting optimal Pareto solution while giving the best compromise solution. The case study of this approach is taken earthquake example in southwest China. When disaster situations allow teams to arrive after a long time disaster priority is prepared. Otherwise, if urgent distance or mix priority strategy works better according to the experiment conducted. Improving the response efficiency with other algorithms and collaborative filtering for the assignment of teams are planned for future development.

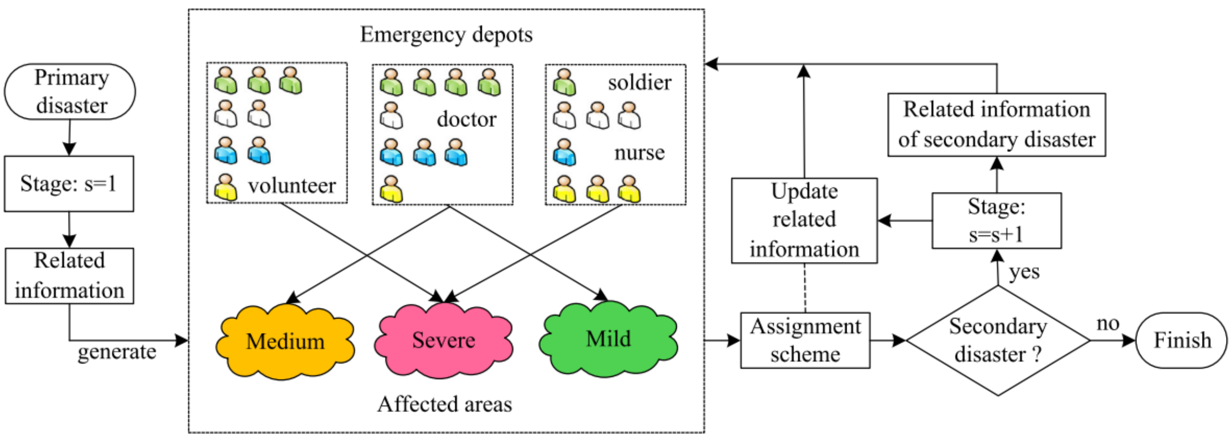


Figure 9: [19] multi-stage assignment model for disaster chain

Cluster – 3

Lee and Sung [17] proposed a model for optimal allocation of emergency medical resources in a mass casualty incident using patient prioritization by column generation. They develop a branch-and-price algorithm for MCI (mass casualty incidents) and also this model is flexible to diverse factors of the real-world and provides solutions. The problem is modeled as an ambulance routing problem considering the order and destination hospital for evacuation. The goal is to achieve near optimality with a short computation time and it is better than fixed-priority resource allocations. The triage, order of the treatments, and multiple locations are considered here. An integer formulation is presented assuming transport one at a time but not until critical patients, all ambulances are available and ready as well as hospitals are in the same region with the same capability but differ only with the size. This study focuses on ambulances and hospital allocations mainly and the experiment was conducted computationally with immediate first and delayed first for pessimistic, moderate, and optimistic. The conclusion states that using this technique can prioritize and allocate other resources as well. This uses the number of victims and triage category to determine the order of transport and destination. As the limitations, require complicated operations not easy and the availability of information for the betterment can be stated. A survey is conducted for evolutionary optimization for disaster relief operations [20]. It indicates the advances of EAs (evolutionary algorithms) that are applied to disaster relief. This provides readers a general overview of major development emerged and strengths/shortcomings of the state-of-arts with giving the ability to find valuable approach. And also provide potential directions for future research and stimulate more interest in this cross-disciplinary field. It has discussed the transport planning, facility location, routing problems, roadway repair, and other integrated problems. The optimization methods are discussed thoroughly in this study which are genetic algorithms, evolution strategies and evolutionary programming, particle swarm optimization, meta-heuristic algorithms, ant colony optimization, biogeography optimization, and other hybrid algorithms. The uncertainty, randomness, multi-objective optimization, Pareto-based optimization, multiple populations are the key characteristics considered in this study. This research includes experimental analysis on an integrated transportation problem. By the results of the analysis, states that the balance between exploration and exploitation can achieve performance as well as self-adaptive mechanisms may not be effective for emergency problems. The strengths and weaknesses of EAs are stated and conclude this study declaring that genetic algorithms are mostly used but no algorithm is better in all aspects, multi-objective combine to one in most cases and experiments are done for tests generated randomly. More real-world scenario testing is needed for the future.

Moazeni and Collado [22] proposed a resource allocation system for contingency planning: an inexact proximal bundle method for stochastic optimization. A risk-averse inexact bundle method with scenario clustering is developed and the oracle which needed to be implemented for this method is also developed. After the correctness is theoretically established, numerical results demonstrate the computational benefits and accuracy. This solution indicates a significant reduction of the resource allocation solving time even comparing to the exact bundle method also. This approach is suitable for both man-made and natural disasters because this gives a high optimality rate within a shorter time. The model is heuristically applied to the resource allocation problem and also it considers disruptions as well. In addition, it allocates resources in terms of cost and reliability, in uncertain inputs. An algorithm is imposed and computationally derived resulting in lower time while considering as a two-stage stochastic problem. Alternative scenario clustering mechanisms are planned to use in the future. Research is conducted on a stochastic network model for logistics planning in disaster relief [23]. It is a dynamic two-stage stochastic network flow model with MIP (mixed integer programming) for both preparedness and response phases. For any severity level and for any disaster this model does risk aversion via min-max, semi deviation, and conditional value at risk approaches. A two-phase heuristic is developed as an alternative for solving larger instances. This model also considers budget, the fleet size of multiple types of vehicles, varying lead time, procurement, etc. The model is tested against a flood and landslide scenario in Brazil as well as it considers the location of relief centers. The mathematical model extension via risk management is there and computational tests (16 variants) showed high performance and efficiency. This dynamic, multi-period model depends on the type of disaster and resources while considering pre-positioning as well. Apart from those, fairness (equity) is focused but has a limitation of no expert-based knowledge involved. The management of the relief fleet with the heterogeneity such as multiple vehicle capacities and extension to multi-stage stochastic model pointed as future extends.

Cluster – 4

Muaafa and Concho [1] have proposed an evolutionary approach for emergency resource allocation for disaster response. The disaster response is a complex process because of the casualties and urgency for the fast response. A multi-objective optimization model is suggested for the medical response with strategies of a temporary location, dispatching, and the number of victims. The algorithm capable of finding optimal solutions with reduced time and cost. As for the post-disaster plans this research address providing services and rapid deployment of resources such as medical, food, cloth, shelter. Resource scheduling strategies are also considered and multi-objective (MO) are the total time to evacuate to TEU (temporary emergency unit) and cost for vehicles, operations, etc. The design is characterized by TEU location, routes for vehicles, the number of victims that must be transported. As the evolutionary algorithm, PSDA (probabilistic solution discovery algorithm) is used to generate an approximate Pareto set of non-dominated solutions. One vehicle can carry one victim, unlimited capacity is in TEUs, transport only non-life-threatening victims are some of the assumptions made throughout the study. The medical centers dispatch the vehicles to evacuate and an experiment is conducted in 3 different sections with seven incidents and gave out the conclusion of cost increasing while the decrease of response time. Finding the shortest path, victim classification by level of injury, and considering stochastic events are pointed for future improvements. Research for determining resource capacity in disaster relief through a model-driven decision support system [6] is suggested. Here, resources can be food, vehicles, evacuation centers, etc., and the model addresses response capacity and optimized allocation. A beta-testing with end-user validation is done for the algorithm suitability. The model determines the capacity of resources as well as it can re-optimize if supplies got damaged. The disaster relief context was taken as rescue, relocation, food and water, repair services, prevention, and medicine. The real-time information is shared by smartphones and priority value is assigned to the victims. The model is implemented via using UML, PHP, MySQL technologies following extreme programming. And also model can detect resource capacity by the data available in the disaster management office. In this study evacuation center assignment and optimal vehicle selection with greedy algorithm considering capacity, time, cost, etc. It states that when functionality and portability are increased reliability and maintainability are reduced. Sathish and Zaveri proposed a graph-based resource allocation approach for disaster management in an IoT environment [25]. A bipartite graph is employed with nodes and edges resulting allocation of maximum resources to a given task. In this study, this is compared with the greedy algorithm for fairness of utility and for the execution time. The use of IoT is indicated by focusing on the response phase of a disaster and also for different tasks. The emergency resources are allocated for critical tasks. A resource allocation algorithm is proposed which considers traffic and minimum distance and produce a graph for requesting resources including maximum bipartite matching, effective plus maximum utilization. There is a theorem imposed with the proof which is an allocation A is maximal if and only if there does not exist an augmenting path with respect to A. The algorithm iterates and finds the augmented path in order to improve allocations. For the simulation Java, android is used and determines usage and execution time. The simulation gives the results of high fairness in utility when the number of tasks is larger. With the use of IoT real-time data can be accessed and gives high efficiency for allocation. For the future, they are planning to extend with evaluation using other parameters where there is non-uniform demand in the system.

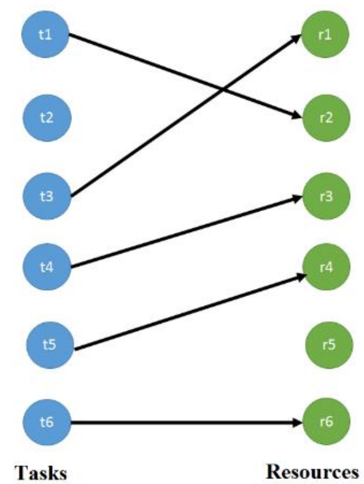


Figure 10: [25] maximum bipartite allocation of tasks and resources

An emergency material allocation problem is addressed by Cui and Liu [26] considering the post-disaster impact. This is developed for the response phase focusing on supply chain disruption and path risks. The main goal of the study is to achieve minimal transportation time and cost. This also considers the uncertainty of damages to the emergency facilities and destruction of roads plus vehicle scheduling therefore genetic algorithm is used. For transport, the model focuses on facility point interruptions, road interruptions, and road impedance. The model formulation consists of nomenclature, factor analysis, and a mathematical model. An algorithm is designed to generate an optimal solution it contains encoding and population initialization, fitness function, genetics, and termination. A material distribution case study is conducted for testing four different conditions. This model is a multi-objective planning model which can quantitatively analyze. Multiple transportation modes and materials plus dynamic changes to the demand and supply will be addressed in the future. Wang and Pei [34] suggested an emergency resource allocation for multi-period post-disaster using MOCGA (multi-objective cellar genetic algorithm). The model's performance has experimented with comparisons and this model allocates resources dynamically while considering uncertainty and persistence. The transportation aspect is also focused here assuming that available resources are known, one-way transport with only one mode, transport risks are identified before. The case study is done for an earthquake in Wenchuan while comparing it to other algorithms. This model proved that it provides better rescue schemes and sensitivity analysis shows MOCGA needs auxiliary population and sorting while preserving the diversity.

The limitation of this research is it is hard to compare because few studies related are available and also constraints are satisfied in the initial state by limiting the scope of search than penalty functions. For the future, they are planning to take other constraint optimization methods into account and consider disaster chains as well.

Cluster - 5

A probabilistic allocation and scheduling of multiple resources for emergency operations study is done by Bodaghi and Palaneeswaran [21]. They suggest an emergency operation model for scheduling and sequencing resources using multiple stochastic scenarios. For this model build GIS and MIP (mixed integer programming) is used while considering the uncertainty. The case study was done by analyzing several probabilistic scenarios for a bushfire disaster in Victoria, Australia. This study highlights a number of available non-expendable resources like rescue units, medical staff affects the processing time. The GIS is used for locating distribution centers, demand points, and routes for transportation while considering the road disruptions as well. The main objective of this approach to minimize the operational time. The demand points are weighted by severity levels and then a stochastic multiple resource scheduling framework (MRSU) is developed. This paper focuses on both allocation and scheduling and shows that it is more efficient than deterministic approaches. Some of the key characteristics of MRSU are considering multiple vehicles with various capacities as well as both non-expendable and expendable resources, randomly distributed processing times and incident severities, predetermined demand point locations, and vehicle capacities with uninterrupted relief processes. A mathematical formulation which is a stochastic algorithm is used and also a clustering method is used for reducing the complexity. The case study indicates the time decreased by utilizing the vehicles and the impact of severity level. This approach gives managers choices that are good for changing conditions and unknown resource requirements. The main limitation of this study is solution time could be varying seconds to hours but as for the future by addressing the uncertainty of travel time, it has the potential to develop as a tool where the approach can be applied to non-emergency projects as well.

Liu and Zeng have done an E-Net modeling and analysis of emergency response processed constrained by resources and uncertain durations [30]. This proposed approach considers uncertain activity execution duration, resource quantity, and resource preparation duration. It is based on Petri net-based formal model and uses a priority-activity-first strategy with an algorithm for conflict detection. This ensures a shorter execution duration of the whole process than a conventional one. As for the case study of chlorine tank explosion was considered, where it validates improved performance with a shorter time of execution. According to the resource availability classified worst, delayed best cases and without considering resource constraints can get ideal duration for execution. With available resources conflicts are detected, strategies are used for optimization. A formal specification is introduced assuming the duration of activity is uncertain, resource needs preparation time and resources should be released in order to use by others. Two modeling approaches are there, emergency response process and E-Net for a single activity. The limitation of this study is that it only gives static analysis based on specification, build time, and uses fixed data. As for the future extension they consider dynamic analysis so can obtain actual execution time.

Cluster – 6

A hybrid resource allocation system (HRAS) for large-scale disasters was suggested [7] focusing on medical resources and ambulances. This approach includes real-time scheduling with priority-driven and clock-driven algorithms. For example, hospital assignment, earliest deadline first (EDF). These algorithms reduce the computing time and increase the accuracy. The patient selection, hospital selection are both addressed here and patients are handled by clock-driven also graded according to severity. The model problem is that it is hard-real-time, but it reduces average waiting time and accurate efficient allocation. The high-level hospitals are for critical patients and low level for others. The service centers are responsible for handling data. The priority-driven approach used major injuries which cost a maximum wait of 15 minutes and for minor injuries with clock-driven costing a maximum time of 60 minutes according to the experiment. According to the scheduling, algorithm resources should be released to treat another while considering the cost matrix also. The comparison of results for situations, improving the effectiveness are the main targets for the future. The architecture of the system founded by Kondaveti and Ganz [9], has three components which are the information collection framework, database of available resources, and resource deployment guidelines. Resource database consists of available emergency resources within a 100-mile radius and in guideline component, all the disaster location clusters include priority rating. This decision support framework is built on rapid information collection via emergency response service agencies and resource tracking functionalities together with scheduling. The algorithm it uses has phases of clustering victims, resource allocation for each cluster, and resource dispatching from the nearest warehouse in order to reduce cost then algorithm lastly outputs an allocation table. It analyses the risk in both infinite and finite resource availability with multiple resource types. In the case study, it gave 80% risk mitigation on finite resources and 100% on infinite. This system helps not only to perform emergency response but also to perform emergency resource planning in real-time as well. This system is tested against only a hypothetical disaster scenario of multiple bomb blasts in a state of the USA with the help of Google map API. The allocation and dispatch are solved by a linear programming problem solver (LPSolve) and uses the C# language and .Net framework. Doan and Shaw proposed a resource allocation system when planning simultaneous disasters [24]. It uses a stochastic optimization technique for the allocation of scarce national resources. The case study considers three simultaneous disasters which are bomb blasts in the UK. There is three model analysis done in the study those are, reducing the risk of not achieving performance targets, needed for meet target performance labels and a hybrid model with different financial budgets. A penalty-based and resource-based mathematical model are developed to deal with current resource capabilities and minimum resources for satisfaction. This study reflects the need for advanced modeling to recognize the abilities of the users and the availability of realistic assumptions. Urban search and rescue (USAR) are focused here and as for future development, robust optimization models to handle ambiguities, probabilities with uncertainty, and also heuristics are targeted. Another important fact of this study is it has many second-stage decision variables and constraints because of the multi-period structure.

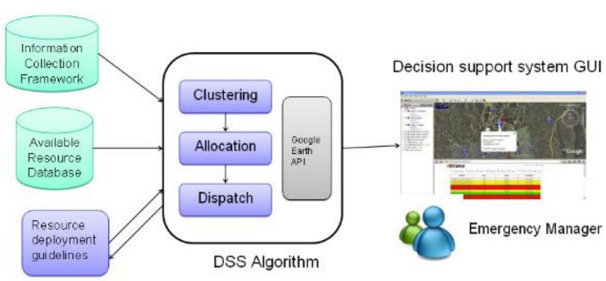


Figure 11: [9] resource-based decision support system architecture

An IoT approach for resource monitoring and scheduling for post-disaster was proposed by Gamitl [31]. Internet-based real-time data sensing in a clustered environment is focused. For data processing a server, sensor and to visualize an android application that is integrated with Google map is used. Can be launched in a smart device to track and monitor the resources which are scheduled for requested tasks. This system addresses the challenge of detecting event-based on sense data and do scheduling and consider ambulances, medical aids, fire trucks, etc. as resources. Architecture has two layers which are the sensor layer and the IoT layer. Sensors sense data at a pre-defined interval and IoT devices are embedded for real-time processing in the IoT layer. Resources are clustered scheduled using time and the distance-based algorithm. This proposed algorithm is tested using a simulated scenario with the clustered environment while assuming there is a resource center for the disaster region. A time-based approach and a distance-based approach are used within the study while considering the completion, arrival, waiting time. The case study for the experiment is done in Gujarat, India with three disaster locations while assuming the resource center is having up-to-date information about the availability. The time-based approach gave a total waiting time of 8 minutes and an average time of 2.6 minutes then the distance-based approach gave a total waiting time of 5minutes and an average time of 1.6 minutes. The future extensions on data variation monitoring, different tasks, and resource allocating and scheduling (heterogeneity) will be focused on. Altay presented [32] an approach for capability-based resource allocation for effective disaster response. This model is an integer programming model developed for multi-location as well. This is built to allocate response personnel, facilities, supplies, and equipment. The multi-resources and multi-location both addresses in this study while using the resource classification schema of FEMA (federal emergency management agency). Two cases are considered: supply exceeds demand and demand exceed supply. This optimized model is used in an illustrative environment of the USA for testing using three resource types, two response locations, and three supply locations. Paper has tremendous managerial implications because it considers the allocation of resources to impact jurisdiction which is a manual process. The model is based on a snapshot of the disaster situation where needs are known and assigned resources satisfying the needs but does not capable of dynamic disaster scenarios. For further improvements inquiring into solution algorithms and computational studies, improve for a dynamic scenario with scheduling and operational time slots, and consider constraints like budget, etc. Kimeli [33] has developed a decision aid model for disaster management and resource allocation. The multi-hazard context is focused and pointed out the need for disaster recovery centers. The employees, labor hours, victims are considered when proposing the emergency recovery centers and determine the number of centers and resources needed for each area as well. Besides, a mono-hazard and multi-hazard comparative study is conducted and how to convert from one context to the other is also discussed. Model is developed using software technologies like SQL, PHP, CodeIgniter framework, Dreamweaver CS5 while getting data from technical users (decision-makers), non-technical sources (patient) as inputs. This system consists of incident management, resource management, reporting capacity, and availability, capturing information, and enabled system security as functions. Authentication, reusability, verification, and maintainability are some core non-functional requirements that have been covered and give multiple interfaces by this system. The case study was conducted in Kenya and it states the ability to generalizable to disaster-specific context. In the future use of AI and geospatial analysis will be considered.

• Transportation	• Health and medical
• Communications	• Search and rescue
• Public works and engineering	• Hazardous materials response
• Firefighting	• Food and water
• Information and planning	• Energy
• Law enforcement and security	• Public information
• Mass care	• Animals and agricultural issues
• Resource management	• Volunteers and donations

Figure 12: [32] resource categories used in national resource protocol

<u>Cluster – 7</u>

The multi-hazard context is focused on Chacko's research [2]. It is a mathematical model developed to improve the quantitative resource allocation for multiple interrelated hazards. It is further focused on long-term disaster operations management (DOM) planning models where multi-hazards unique features are applied. Dependencies have been modeled prioritizing the humanitarian conditions and logistics and by using the Weingartner formulation. Previously mentioned dependencies can be generalized into categories like project dependencies which can cause a negative or positive impact on the benefits and cost dependencies which are for the use of resources could be either savings or expenses. This article provides a comparison of multi-hazard and mono-hazard situations and highlighted the unique features to be addressed in a multi-hazard situation. It states that decision support systems must include very advanced systems for resource allocation and provides suggestions for converting the models into a multi-hazard context. This model is restricted to only second-order dependencies and higher-order dependencies will be considered in the future. Use benefits matrix and cost matrix to capture data but the issue is if there is no historical data is available it needs expert opinions. Therefore, for that, they suggest AHP – based method, getting the most optimistic, pessimistic, and most likely to form a triangular fuzzy set. Resource allocation for demand and surge mitigation during disaster response [8] system was introduced by Arora & Raghu. This model describes a way of optimized allocation during public health emergencies and the optimizing of regional aid. The case study is based on an illustration of a pandemic situation so here resources are beds, vaccines, medicines, doctors, and nurses. It states how pre-allocation would be helpful and lead to flexibility during the emergency using a data and simulation model. Besides, mutual aid is beneficial in smaller counties when it is done according to the proportion of the population. Subgroups according to age, severity, high risk should give greater insights for effective resource allocation. This proposed model has a limitation which is it is only for the static environments, but most cases are dynamic. Another thing is in this study single allocations are made (not re-allocation included). Cost evaluation and reduce the number of infected people can be indicated using this model while considering the pandemic spread as well. A system is proposed by Aalami [27] for fair dynamic resource allocation in transit-based evacuation planning. The maximum rate, minimum clearance rate, maximum social welfare, and fair allocation are the problems addressed by terms of MR-RA, MCT-RA, MSW-RA, PF-RA, and compared. An algorithm, PFD2A which can update real-time is developed using the Lagrangian approach for distributing, dynamic allocations and updating the evacuation process according to the new information. The percentage of the fleet that is assigned to each pickup location and the number of evacuees who are transported from each pickup location to each shelter is computed within the model, so it considers the locations and capacities of the shelters. A proportionally fair distributed algorithm (PF-RA) is proposed to solve the dual problem and used prior to the evacuation process. Algorithms for execution by pickup location, by transit vehicle dispatch center, are there. The severity of danger at the pickup location, travel time population, deadlines is considered. The test results show the ability of the algorithm to converge quickly and adapts to the changes in the parameters. The uncertainty not getting considered in location, time, and supply/demand also few unfair allocations are the two of the major shortcomings of the system. In the future study will be extended to accidents of mass panics and multi-modal evacuations.

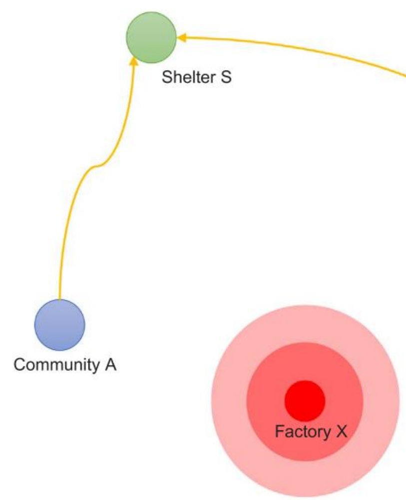


Figure 13: [27] evacuation scenario

A task-based resource scheduling system was proposed by Kumar [28] which is based on IoT technology. This article addresses the resource scheduling issue and exploited bankers' algorithm to ensure resource allocation optimization and maximum utilization. It points out that the resource allocation and the scheduling come under the post-disaster phase and those can be executed at both the administrative level and on the field level. Tasks and resources are identified prior to the response dispatching where tasks can be determined as establishing communication, medical treatment, rescue, and recovery, and resources include fire engines, volunteers, forces, ambulance, and medical help. This system is tested against a simulated disaster occurrence. Using this system with the help of IoT, efficient mapping of resources to the entities is possible and the system is integrated into the Google maps. The tasks are clustered by an IoT location algorithm. This model is evaluated by execution time and fairness for allocation utility. The allocation considers distance, traffic, and scheduling consider demand, availability, etc. The comparison with the brute force approach which uses FCFS is done. The simulation conducted in Surat city, Gujarat with using three types of resources and google maps and shows the result that it is good for a large number of tasks, and the limitation is not tested for many inputs of IoT.

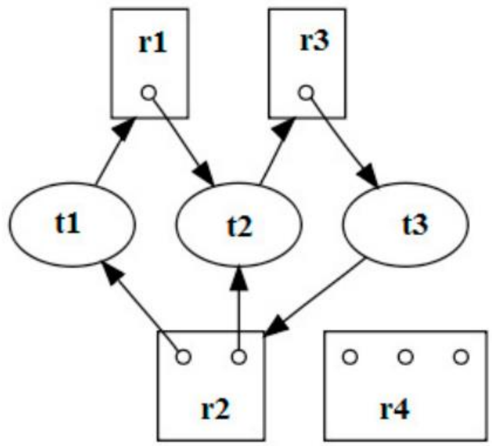


Figure 14: [28] resource allocation to relevant tasks

A resource-based decision support tool was presented by Kolios and Milis [29]. As the first phase, a network model is derived to capture the resource flow, and thereafter a mathematical program is formulated to allocate resources in an optimized way. This is a computer-aided support system that enables real-time executions. This study focuses on medical resource management in emergency response during a disaster. An algorithm is developed for iterative decision making and each iteration obtains the data of resources and the responders. Dispatching rescue teams after an alert and transportation of victims is also included and tested for a similar hypothetical scenario. This system specially addresses medical resources but can be adapted to non-medical resources as well. Uncertainty has been addressed; minimum response time is considered in addition to revising the decision made is included. For the network model, the graph-theoretic network is built and this whole system with mathematical model covers all the five phases of medical emergency response. Those are alert, rescue team on the way, field management, patient transport, first receiver (hospitals/camps). The hospital capacity is considered, and estimations are done on historical data. The experiment is conducted assuming that resource availability maintains uniform distribution. As for the future, reducing the number of assumptions and addressing the uncertainty of available resources also implement it as a tool are planned.

Cluster – 8

A dynamic resource scheduling in forest fire situations research is done by Wijerathne and De Silva [40] in the context of Sri Lanka. The solution can dynamically utilize the available resources and this can track resources, estimate fire spread also. According to this approach, forest officers generate resource requirements that are mapped with priority level to available resources. This priority level is the calculation, of the distance from resources to the incident is considered. A framework is introduced with a module together with architecture. This is an ICT-based approach built upon assuming data from maps are up-to-date and accurate, disaster is not changing by the time and weather is constant. The limitation of this study is the lack of technology to capture data Sri Lankan context. The optimal allocation of fire extinguishing equipment for a power grid under widespread fire disaster study is done by Guo and Jian [41]. It prioritized on risk index of power grids and regional risk index. The allocation is done in advance which gives high effectiveness, and it has low computational time. When shorter the firefighting distance the timely rescue can be achieved. The fire density and transmission line alignment are considered and also the equipment is used by patrol officers and are pre-allocated within a 25km radius. Few assumptions are made those are, all equipment is available, no traffic impacts, and one piece of equipment can handle one fire. A case study is done using china and obtained an optimization schema with shorter distances. A comprehensive analysis for multiple fire fault risk indicated high effectiveness and efficiency. Romney and Fox [42] have conducted research regarding the allocation of scarce resources in a Pandemic situation as a review with crisis standards. This study is done according to the USA guides and focusing on the entire population. The main aspect was the allocation of critical resources and the ethical implications. The resources can be anti-viral medications, masks, ventilators, etc. In addition, multiple state plans were built according to pediatric considerations, age considerations. This research provides an ethical aspect of the resource allocations and about the patient prioritization with some guidelines to all-hazard approaches.

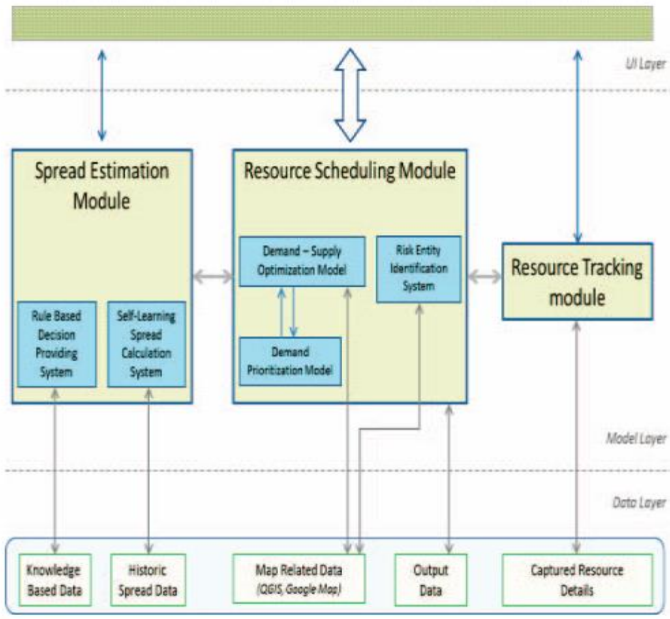


Figure 15: [40] architecture of resource allocation with resource scheduling

Du and Sai [43] proposed a data-driven optimization approach for multi-period resource allocation in cholera outbreak control. This addresses the location-specific resource allocation problem which requires periodically acquired state information from the information centers. The model is developed as a non-linear optimization model with ordinary differential equations. This model integrates with single-period parameter filtering plus scenario-based stochastic programming to handle uncertain scenarios. A comparative study is done for performance and effectiveness evaluation. Apart from that policy development topic is discussed as well. Here resources are vaccines and drugs, but the specialty in this approach is it incorporates determinate parameter space updating and scenario-based stochastic optimization in a rolling-horizon decision scheme. This approach uses spatiotemporal transmission dynamics and a meta population model. The disaster dynamics are considered and there are some data-driven approach steps. Those are parameter and system state estimation, resource allocation under uncertainty, and parameter space updating. The case study used Haiti and it compares with a static strategy that allocates constant amount and a reactive strategy that allocates varied amount but only for chosen areas. The vaccines with allocation uniformity plus drug allocation for priority-based infected areas are focused here. The resource commitment is also studied with budget constraints. For the future robust optimization to make allocations under non-probabilistic models, sources through sensing and mobiles, distributed and decentralized resource allocation are planned. Decentralizing means making own decisions even without knowledge of other areas which is more realistic. A study of disaster preparedness in humanitarian logistics was done by Albores and Brewster [44]. It is a collaborative approach for resource management in floods. This model is proposed to optimize decisions with a multi-objective approach and reduce agencies. Here resources can be people, vehicles, relief items, etc. The model is tested against a real-world scenario of Mexico. The main focus is on coordination and interoperability. Even though this is a preparedness system it includes the location of emergency facilities, stock prepositioning, resource allocation, relief distribution. The model’s performance is high in cost and service wise. The number of actors involved is considered while getting the geographical information through GIS. The GIS displays the surviving roads, shortest path, and damaged areas. This disaster management framework is able to avoid shortages or convergence by efficient use of available resources. This is a mathematical model which gives the qualitative aspects as well. The fulfillment rate of demand is calculated by the presence of relief items, medical, and other staff. The assumptions made are centralized decision-maker, resources are always ready for distribution, resource information is up-to-date, facilities are set up according to the available resources, etc. Multiple organizations can contribute as agencies to this model and a demand estimation algorithm is used to determine the number of people to serve. The disaster severity is also considered in this model and get Pareto set as the model solution. This research states that having more resources doesn’t guarantee better performance and operations. As for the future, they plan to extend by communication hub between agencies and improve the data of the resource availability.

Figure 16: Cluster 0 - Word Cloud

Figure 17: Cluster 1 – Word Cloud

Figure 18: Cluster 2 – Word Cloud

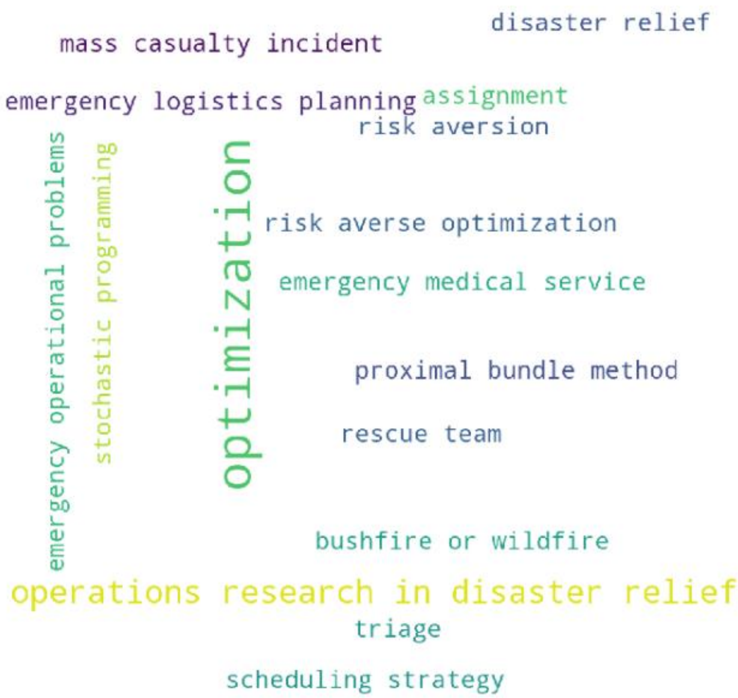


Figure 19: Cluster 3 – Word Cloud

Figure 20: Cluster 4 – Word Cloud

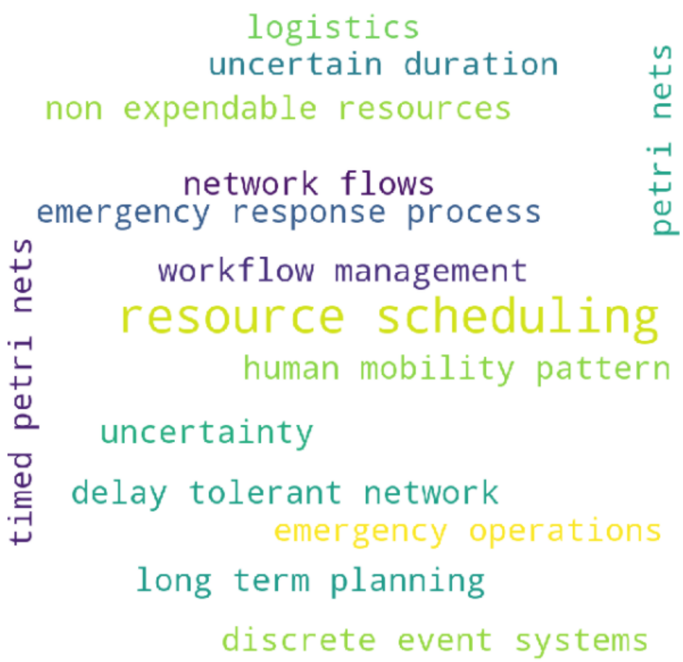


Figure 21: Cluster 5 – Word Cloud

Figure 22: Cluster 6 – Word Cloud

Figure 24: Cluster 7 – Word Cloud

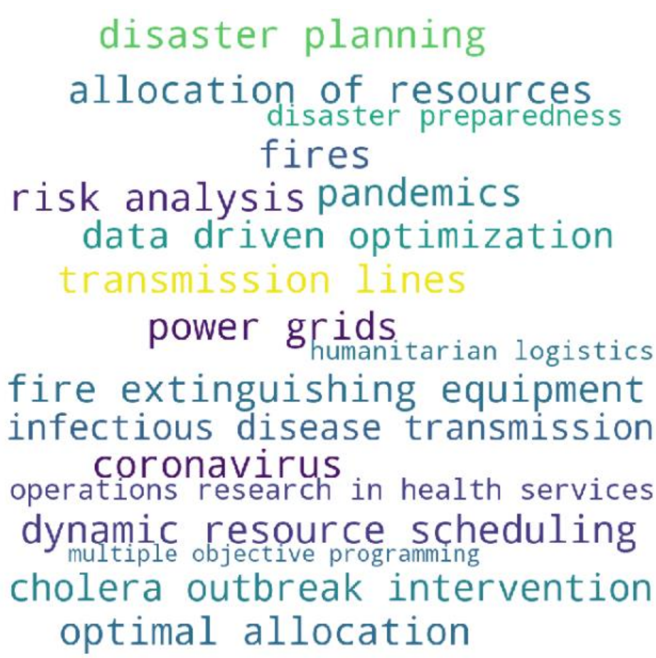


Figure 23: Cluster 8 – Word Cloud

Word Cloud for all the Keywords

Figure 25: Word Cloud for all the Keywords

There were altogether 47 papers that filtered through the PRISMA flow chart and selected for the Keyword classification. Those included only resource allocation-related papers including the reviews found. There were five papers that did not contain any keywords but has high relevancy for this research. Therefore, after excluding the reviews, the individual studies which did not contain any keywords were 4. Those 4 studies are discussed below while pointing out the main features of each.

A post-disaster resource allocation system was suggested by Cheng [36] based on the big data from the social network services (SNS) and spatial scan. It can collect data and analyze big data from social network services and build a platform for efficient resource allocation and communication. Understanding the disaster level and the situation, understanding the distribution patterns of resource needed victims, and solving uncertainty of the big crowd data are stated as challenges that are going to be achieved by that system. Domain-specific and computationally improved semantic analysis that is machine learning (ML) models or natural language processing (NLP) toolkit will be used to understand the disaster situation. Spatial data mining and smoothing the data to reduce uncertainty will address the latter two problems to some extent. The challenging part of the study is that computational complexity and handling the uncertainty. In the study by Choksi [37], a multi-objective-based resource allocation and scheduling approach using IoT for post-disaster has been introduced. A resource management algorithm is developed which deals with both over and under-demand situations. And also, a resource scheduling algorithm is proposed based on various parameters, priority-based scheduling. Data collection is done through sensors and the RFID as well as a network is wireless, and IP enabled. For the system demonstration Raspberry Pi, Arduino, and sensor motes are used. The system is integrated with Google Maps which shows real-time traffic for decision-makers in addition, this system uses four different aspects which are priority of the task, transportation cost, resource utilization index, and scheduling time index. The optimization is performed by using the Lingo programming tool. Here the priority is considered to be proportional to the requirement of resources and they are handled as a management workflow with entity counts of service or resource. The system is tested for a disaster scenario in the Gujarat state of India while comparing it to other approaches. Extending the parameters according to the need and type of disaster will be considered in the future.

The model for relief demands in the emergency supply chain system under large-scale disasters is introduced by He and Hu [38]. It is based on a queuing network modeled as a minimal queuing response time model of location and allocation as well as this addresses uncertainty. This problem solution is developed using a genetic algorithm. A case study is done for the emergency in Shanghai, China and the results demonstrate the robustness and applicability. By using the queuing model can obtain the classical performance of the emergency supply chain (ESC) such as average queue length, average waiting time, and optimize relief operations. The main contributions of this study are fulfilling resource requirements and deliveries, calculate performance, solve integrated problems like vehicle routing and location of facility centers. Queuing flow formulation includes the location of supply points, logistics centers, demand points, and upstream/downstream nodes. ESC constitutes producing, sorting, processing, packing, delivering as basic activities. Several hypotheses are drawn in the system operations, some of them are geographical relationships between nodes that are available in a government database and can be readily accessible via detection technologies, location of logistic centers are fixed only in given sites and people receive services as first come first served. The mathematical formulation for queuing theory is developed for facility location and path selection in a multistage ESC network. Parameters and decision variables are stated along with the methodology and procedure of the genetic algorithm. Results of a test case done in China have given the average response time of queuing network and for demand in a reasonable range. As for the future extensions, they considering addressing facility blocking problems and demand priority, using other random distributions, more efficient multi-objective optimization methodology.

Vereshchaka and Margaglio [39], suggested an approach for reducing risks during natural disasters with optimal resource allocation by multi-agent optimization. The level of importance of the region and cost parameter is taken into the account as well as can be applied to the stochastic environment for dynamic allocations. The main contribution is a hierarchical multi-agent framework with two levels of agents. The lead agent is making decisions and this approach reduces the redundancy of allocations. The assumptions made are agents have identical goals at the lower level, the algorithm chooses the actions based on the most recent observations. This aiming to satisfy autonomy, low communication complexity, and scalability. The proximal policy optimization algorithm is used for agents and could be applied for limited resources. The case study on heavy snowfall and wind incident at New York indicate the better performance than the uniform cases. As for future improvements utilizing training agents and implementing this approach as a risk management tool are considered as well as extending to the stochastic action phase to facilitate more robust predictions.

3.7 EVALUATION OF THE PROPOSED SOLUTION

The Keyword classification approach is a unique way of analyzing the work that has been done and gets a generalizable knowledge of the resource allocation context. When the string search has been done, few similar reviews were identified with regards to the disaster resource allocation systems. Even though those are systematic reviews, as per my knowledge there is not this kind of research that has been conducted. When focusing on the systematic reviews that were found the first one was conducted by Anaya and Renaud [57] which was about relief distribution networks. But it is only focusing on two major areas: (1) location and network design problems (2) transportation and routing problems. The next review was done by Wang and Chen [58], which was about emergency resource coordination under conventional emergencies. This review focuses on resource facility location problems, emergency resource allocation problems, and emergency resource scheduling problems. But it doesn't focus on resource allocations in the recovery phase and related topics like considerations of shelter locations etc. The last review found that addresses the same context is done by Timbie and Ringel [59], which is a systematic review of strategies to manage and allocate scarce resources during mass casualty events. This considers only medical resources (under the critical resource category) during the response phase and not focuses on the interrelated topics.

This research has many specialties when comparing to previously mentioned reviews. Those are both response and recovery phases will be analyzed simultaneously, and high interrelated topics of resource allocation will be thoroughly discussed such as transportation, scheduling, facility location, shelter locations, etc. Another thing is this research will be focused on different kinds of resource allocation systems like dynamic/static, deterministic/stochastic with uncertainties, multi-objective based, heuristic approaches, etc. The use of technologies and how those are implemented will be also addressed in this research. Apart from those multi-stage, multi-agent, multi-period allocation approaches are considered as well. The DSS (decision support systems) that address solely resource allocation mechanisms are analyzed in this study and also taken to the keyword classification. In addition, analyzing how the multi-purpose DSS are handling resource allocation is another uniqueness of this study.

All the highly relevant individual studies were taken to the keyword classification model built using the affinity propagation algorithm and python language. The evidence of the relevancy of individual studies to the resource allocation in disaster management context is displayed in the Keyword cloud that was generated for all the keywords. Then, clusters are identified. This is another novelty of this systematic review. According to the cluster observations, conclusions are drawn about the current studies of resource allocation systems used in disaster management where it will be able to answer the research questions as well. The patterns, trends are identified and clearly stated in this qualitative-based research. The cluster that each paper belongs is decided via the most common cluster label of the keywords. According to that papers are discussed under each cluster in the previous sub-topic and next the summarization will be discussed as the evaluation of the results. The below evaluation gives a rough idea of the current stand of resource allocation systems used in disaster management which is the first question that is answered by this research. But this will be deeply analyzed under the discussion section.

Cluster 0 highlights the emergency management, emergency resource allocation, and humanitarian logistics keywords. It is all about the general keywords that are used in this research context. The research papers that fall into this category are [3], [4], [5], and [35]. The common features of this cluster are most of the papers are addressing the recovery phase along with the response phase. These consider shelter locations, dynamic approaches as well as using linear programming techniques. The tools and technologies used are also focused on these papers. Cluster 1 highlights the disaster, relief, preparedness, inventory location, and agent-based keywords. The main point is this cluster has most papers containing allocation systems in the response phase and recovery, but which are also capable of the preparedness phase allocations. This feature is known as multi-stage resource allocation and also multi-agent technique is considered. The research papers that fall into this cluster are [10], [11], [12] and [13]. Cluster 2 highlights the resource allocation, disaster relief, scheduling keywords. All the papers are addressing the response phase of a disaster scenario. Transportation and scheduling are suggested with mathematical models. Also, the technological approaches and heuristics are focused within the cluster. The severity of a disaster, weighted tasks, and rescue units are the common variables considered here. The research papers fall into this cluster category are [14], [15], [16], [18], and [19].

Cluster 3 highlights the optimization keyword mainly and the operations research (O/R) in disaster relief is another keyword that is used commonly it express the research category in the disaster relief context. The static/dynamic, heuristics, stochastic/deterministic approaches are mixed in this cluster. All the papers address the response phase of the disaster and the mathematical models are introduced. The research papers fall into this cluster category are [17], [20], [22] and [23]. Cluster 4 highlights the disaster management, multi-objective optimization, internet of things, and emergency logistics keywords. The resource distribution context is focused here especially within the response phase. The distribution is mainly considering the transportation of the resources some including the scheduling as well. The stochastic/deterministic, multi-objective approaches are common in this cluster and the technology used is high. The research papers fall into this cluster category are [1], [6], [25], [26] and [34]. Cluster 5 highlights the resource scheduling and uncertainty keywords. But all are addressing the disaster response phase. The scheduling is the main focus of research papers that fall into this category which are [21] and [30].

Cluster 6 highlights the DSS and resource allocation keywords which are basic concepts used in this area but here DSS comes because resource allocation is the main functionality of those decision support systems. Apart from that scheduling and the use of technologies are focused within the response phase. The research papers fall into this cluster category are [7], [9], [24], [31], [32] and [33]. Cluster 7 highlights the disaster management, resource allocation, multi-hazard, decision support keywords. The all the papers are addressing the response phase of resource allocation and mainly dynamic approaches are stated. Mathematical models regarding transportation, stochastic/deterministic models are used. The research papers fall into this cluster category are [2], [8], [27], [28] and [29]. Cluster 8 highlights the fire, diseases, pandemics, cholera keywords. Those are directly related to the disaster-specific resource allocation systems. Most of them are under the response phase and static/dynamic features are also focused on IT-based solutions.

CHAPTER 04

4.1 DISCUSSION

Disaster can be classified into natural or man-made but the common feature is that all the disasters have three phases which are pre-disaster phase, during the disaster, and post-disaster phase as per the diagram shown below.

Figure 26: Disaster stages

Disaster should be managed in order to reduce the risk of loss. Disaster management contains four phases. Those are mitigation, preparedness, response, and recovery. Even though resource allocation is mainly related to the response phase, other phases also address resource allocation to some extent. For example, in the preparedness phase, the resources which are mostly non-critical are allocated to facility locations as a precaution step and in the recovery phase, both critical resources such as medical teams, medicines, ambulances as well as non-critical resources such as food, water, volunteers are allocated. Here recovery phase is assumed to be after the evacuation process, assigning to shelters or the tasks which include restoring the lives of people who are affected.

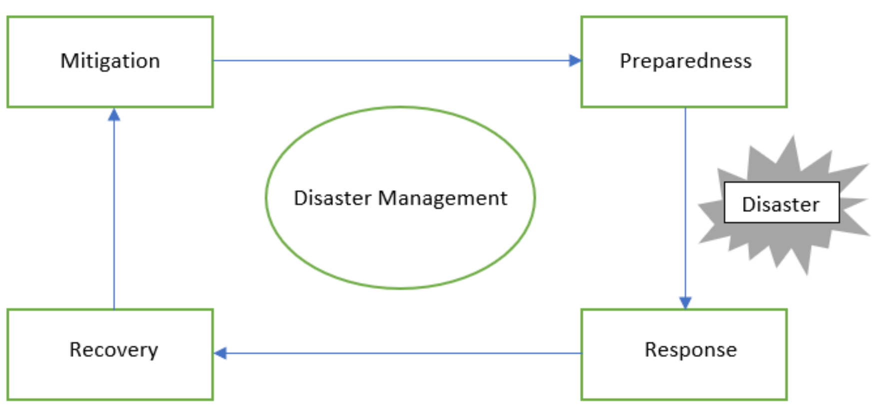


Figure 27: Disaster Management

The above chapter discussed the outcome of the keyword classification related to the literature. It gave out the overall understanding of what aspects are focused in resource allocation context and what are the related topics as well as the current stand of the allocation systems. In this chapter, the main discussion is carried out deeply while declaring the findings of this systematic review.

4.2 FINDINGS

The findings of this research are stated from this onwards and will be discussing them in an analytical manner. The optimal resource allocation reduces the damage of a disaster. When studying the literature resource allocation is hugely addressed in the response phase of a disaster. In other words, it is considered a post-disaster activity. But resource allocation studies were done for other phases as well. As for the scope, this research only focuses on the response and recovery phase of the disaster management cycle. Therefore, the literature collected can be categorized into response and recovery phases as shown in the below table.

Disaster Management Phase	Related Papers
Response	[4], [21], [30], [10], [11], [14], [15], [16], [18], [19],[17], [20], [22], [23], [1], [25], [26], [34], [41], [40],[42], [43], [7], [9], [24], [31], [32], [33], [2], [8],[27], [28], [29], [36], [37], [38], [39]
Recovery	[3],[5], [35], [12], [13], [6], [44]

Table 3: Literature according to the phases of disaster management

The above table indicates how the studies have been conducted for response and recovery phases under the resource allocation. There are some individual studies conducted focusing on resource allocation in both phases at the same time but the above table is made according to the most weighted topic in each study. The relief distribution falls under mostly the recovery phase and it includes resources like shelters, food, water, and other non-critical resources which helps to rebuild the victims' day-to-day life. The multi-period allocations, agent-based allocation systems are proposed in both scenarios but mostly the resource allocation studies are based on the response phase including both critical and non-critical resources.

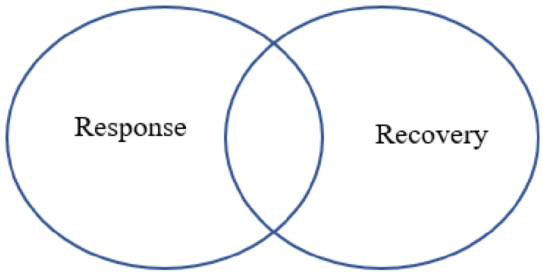


Figure 28: Resources in response and recovery

The response and recovery phases of disaster management cannot distinctly identify in the resource allocation context. Because the response stage might include recovery stage allocations such as non-critical resources and sometimes the recovery stage may include critical allocations depending on the disaster type and the situation.

Division of Papers	Research Paper
Resource Allocation Systems	[4], [21], [30], [10], [11], [14], [15], [16], [18], [19],[17], [20], [22], [23], [1], [25], [26], [34], [7], [9], [24], [31], [32], [33], [2], [8],[27], [28], [29], [36], [37], [38], [39], [3],[5], [35], [12], [13], [6]
Disaster Specific Allocation Systems	[40], [41], [42], [43], [44]
Integrated with Decision Support Systems	[45], [46], [47], [48], [49], [50], [51], [52], [53], [54], [55], [56]
Integrated with Disaster Specific DSS	[68], [69], [70]

Table 4: Division of papers according to the system type

While conducting the research, another categorization could be identified, that was according to how the allocation system exists. Such as is it about a stand-alone system that can be implemented into an individual tool or a system that is integrated with another and act as a whole DSS. But here the decision support system could be either disaster specific or not. How the literature is distributed according to the previously mentioned categorization is indicated in the above table. The DSS addresses the inside resource allocation system briefly and explains how it is done. And both disaster-specific DSS and independent systems mainly focus on disasters like fire, medical, industrial, pandemic, etc.

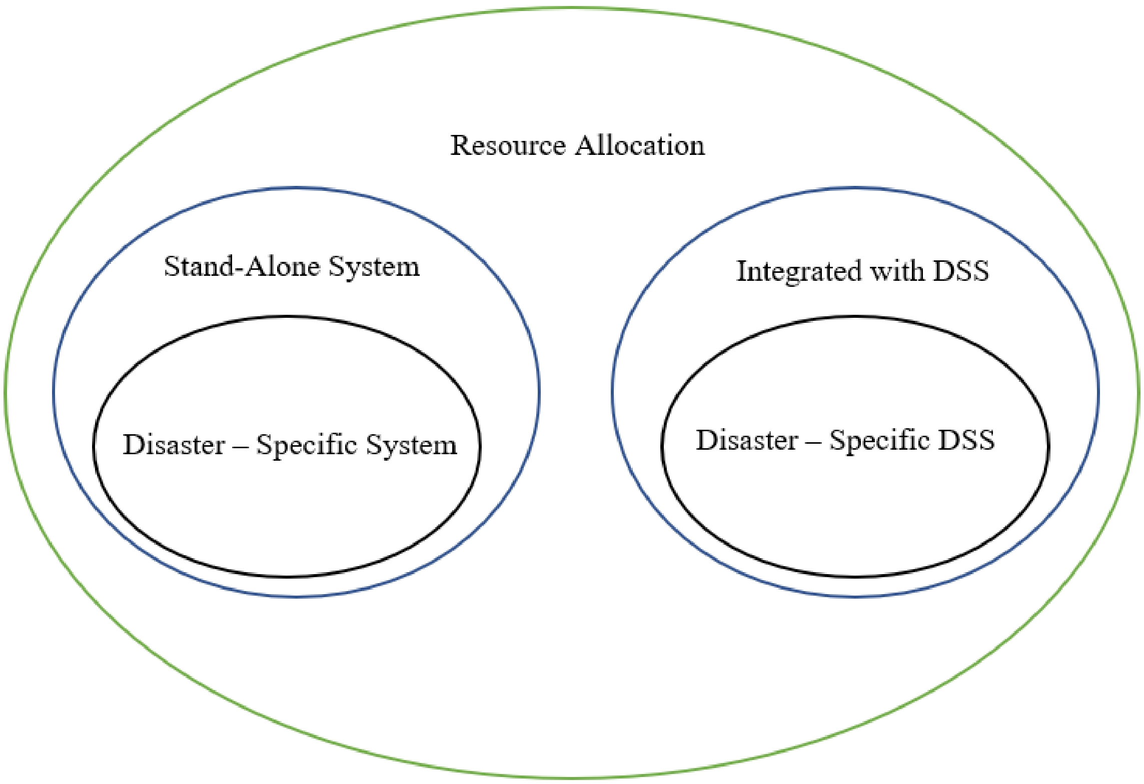


Figure 29: The categorization of resource allocation systems

In the next section, the resource allocation techniques which are integrated with the decision support systems are analyzed and discussed. Here both DSS and disaster-specific DSS will be considered for the resource allocation system analysis. For each DSS main features, resource allocation mechanisms, advantages, and limitations of the studies will be stated.

An example of a DSS system that is capable of handling resource allocation:

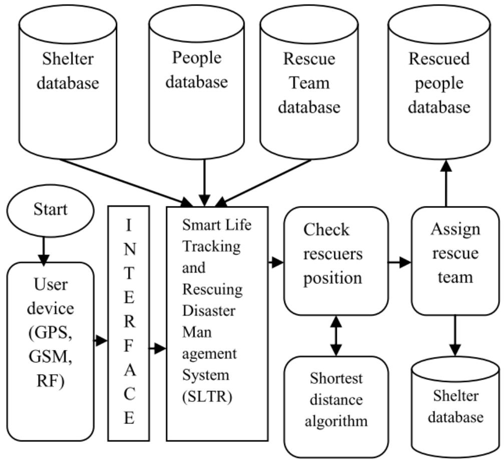


Figure 30: [47] architecture of DSS capable of handling resources

When focusing on DSS (decision support systems) there are many individual systems proposed and out of those some of them as a part of the research considered the resource allocation to some extent. Those DSS are chosen here to analyze the resource allocation aspect in them while discussing other related facts as well. In here some DSS are customized for specific disasters as well.

The literature reviews done regarding the DSS systems do not specifically talk about the resource allocation aspect as well. Those studies at the most time cover the overall overview of the DSS only. The technology-wise DSS systems are improved and those are addressed in those reviews also including its architectures. In one review, they address the infrastructure resources such as water, supply, power, etc., and how the environmental resources should be managed after a disaster [66]. There is another DSS review conducted for disaster situations by Liu and Zhao [65] which focuses on the resource allocation aspects in those systems but only addressing the static and dynamic categorization of the problem. The study done by Jian and Yuan [67] summarized few aspects of resource allocation such as demand, priority, and scarcity. In addition, it specially states the stochastic approaches and the infrastructure resources as well. Diaz and Imitola [62] conducted a review on perspectives of disaster operations management which focuses on network design and inventory allocations.

Table 5: Resource allocations integrated with DSS systems

DSS proposed	Key points	Resource allocation	Benefits/Limitations
GDSS (Group decision Support System) [46]	Group decisions are capable which includes case querying, management, and assessment of emergency situations as well as resource allocation. The system architecture is divided into three layers which are interface, network communication, and group decision-making platform. This system is developed as a prototype for catering to public health disaster situations particularly.	Resource analysis is done after the assessment of the emergency and the demand can be forecasted using the knowledge in DB. Resource scheduling is done from the data gained from the analysis and the resource database. The shortest path selection is also a capability of this system.	Geographical information (spatial data) can be integrated with the system. Web-based architecture helps to overcome the time and space to realize remote real-time communication limitations. Specifically, for public health emergencies/ disaster scenarios
Remote management with Mobile positioning terminals [49]	The system is based on GPRS where collecting and managing is done through mobile remotely in both offline and online mode. Assuming that the disaster impacted all the landlines of the area and wireless communication devices are disrupted, this system has four levels which are network, data, service platform, and application level. It proposes a method to do offline data processing as well.	After processing the data according to the transaction flow, it is sent to the command center which generates dispatching instructions. This can be either resource deployment, resource allocation, or any other instruction.	The geospatial data collection and analysis part is integrated with the system. Not considering the buffer analysis and optimal path web spatial analysis for the betterment of the system.

Volunteer geographic information (VGI) and Spatial decision support system (SDSS) [48]	Introducing a framework that integrates the volunteers' data and conventional data. Then for decision-making processes and methods are used effectively. The conceptual architecture includes four layers they are data source, data integration, application, and business layer, respectively. The business layer includes a maturity model for disasters.	Resource allocation is suggested for further development. It states that a model built in the business layer may also serve as a strategy to help identify the current state and availability of resources after an emergency and it will allow making decisions of resources in order to recover from the situation.	Before using the SDSS system data is getting evaluated after the user upload Checking and updating for correct information must be done regularly
Smart life tracking and rescuing disaster management system [47]	Global positioning systems and global service for mobile communication are used in this system which is web-based services. Could be used in a high-density population area and gives a very sharp overview and provides decisions for prior planning of high-risk areas. Rescue and shelter services are focused mainly. The primary mission of the system is to keep track of the current location and movement of people.	Provides the information of getting the medical aid and relief supplies to the deceased victims of the disaster. The system is able to manage inventories and update the status, availability, and status as well as the capacity of the operating shelters and medical facilities. Assignment of rescue teams, identifying the shortest path are related to resource allocation capabilities.	Data banks are updated regularly, and information is provided in a simple way. GSM network should be always available and no offline data acceptance from the system.

BI (business intelligence) approach based DSS [45]	A conceptual framework is proposed where it can be used to enhance the decision-making process resulting in a high success rate for many events. This includes contextual knowledge, data fostering unit, and knowledge repository. Send and receive information through mobile, PDA by notifications, or SMS. A rule-based approach is used to ensure the decision that has been made by the system.	Resource allocation is not mainly focused on the system. But knowledge repository has data related to resources that have been collected through sources. After the data fostering, decision-makers can get a clear idea about the state of resources and can make effective decisions based on that information.	Multiuser provisions can be adopted by this system and the use of contextual reflection for decision making. BI is used therefore specific ontology-based knowledge should be there to use within the real disaster situation
Disaster management: using IoT [50]	IoT devices contribute to the information feed. Earthquakes, fires, floods are some of the common use cases that IoT can be used. The government web portal integration is used in this system. The databases, mobility attribute, and cloud integration are the special features of the architecture. The IoT helps in preparedness, detection, and prediction as well. This IoT approach contributes to information feed with the weather, traffic, police, medical services, etc.	The resource information gathering is done in this system and later achieving effective resource allocation. Under response management, resource management is considered in this DSS. The response, recovery, and mitigation phases of resource allocation are addressed in the study.	This system can assess risks, improve quality and preciseness as well a personalized early warning. The main challenge of this system is that network connectivity must be stable.

An event-based DSS supporting team coordination [51]	The intra and inter-coordination of team members are considered. It is a computational approach to data processing. The collection of data from a data center and multiple agencies. The process modeling is done and has the usage of GIS. The task allocation is done according to the team expertise, profile, and task specification. For data modeling, XML technology is used and for decision-making, SMAS (multi-agent) model is used.	The resource allocation to the teams is focused here including the team re-allocation and co-allocation. The resource allocation is done according to optimization problems and methods (meta-heuristics). The resource requests are querying to the system, which will generate an event to the system. The resource monitoring through summary reports sent by mobiles.	The meta tasks are assigned with resources not atomic and have a dynamic workflow. The limitation is that timely decision-making is not guaranteed.
An info-symbiotic decision support system [52]	This includes a dynamic data-driven simulation approach. Use cyber-physical sensors for decisions. This contains up-to-date information with heterogeneous data sources while using an agent-based model for the evacuation process. Predicts where rescue workers need to concentrate, and the heuristics models are created through sensor data. One of the main post-event objectives of this study is to produce advisory information using external information.	Another main objective of this study is to make the best use of available resources. The prioritizing of vulnerable assets to optimal allocation is done here together with tracking the losses which are tangible. Mobilizing response resources according to the information received from the agents to the system is another feature contains especially for resources. The agent-based model handles the resources like ambulances, fire trucks, etc.	The geospatial hot zones for prioritizing rescue resources. The model is upgraded timely according to the deep learning patterns. The effort for mapping ontologies of data is high and simulations cannot be considered as real-world scenarios.

A community-based disaster coordination framework [53]	This is especially for preparedness and response. A multi-agent coordination simulation system that helps for search and rescue operations in the response phase. This tests and evaluates all possible team design configurations and selects the highest performing team in the pre-phase of response. The task force, NGOs, volunteers are also included in a team. The team with locality-specific information can carry out tasks within the shortest time period.	Here the main resource allocation can be considered as the team allocation to the disaster regions. This is done by considering several parameters such as team size, team distribution, starting point, etc. The data mining techniques are used for team allocation and monitoring. For the development agent-based simulation, ML, GIS, and an optimization algorithm are used.	The conceptual model consists of input data, configuration capability, optimization, communication, and task allocation. The deployment and scheduling of the teams are yet to be addressed.
Multi-function DSS based on multi-source dynamic data [54]	This helps to identify optimal solutions from complex data within rigid timeframes, make decisions, and mitigate uncertainty and instability. This model includes information processing, statistical analysis, data mining techniques to make more accurate decisions during a disaster by decision-makers. This system provides system-to-system functions such as database establishment, system integration, risk assessment in the form of a smartphone app.	Medical supply storage, communication equipment maintenance, prediction, real-time data such as roadblocks, supply shortages are indicated. In addition, determining disaster and trends, disaster timelines, response measures, serving as a simulator, prevention, and rescue are also possible functionalities of this system. This system can rapidly transfer resources for rescue and prevention, identifying resource inadequacy.	The resources can be allocated from other sources when in need. The resource database is not managed by a single unit but by various disaster prevention units for different disasters.

DSS for disaster management [55]	This decision support system is for disaster response and recovery using hybrid meta-heuristics. Disaster response scheduling (DRSP) can be classified as a complex variation of the Multiple resource-constrained project scheduling problem (MRCPSP). Adaptive reasoning techniques and its elements like the solver, local search, updating memory and learning parameters, etc. are used.	An algorithm is proposed to address this DRSP problem while focusing on both scheduling and assignment as well. But in this paper, is not explicitly concerned with the facility locations because it views as the locations are tied to tasks.	This system has the ability to deal simultaneously with a combination of scheduling and assignment in near-real-time. The heuristics are complex and information mostly is estimated so might be incorrect.
GIS-based DSS [56]	GIS technology is used because of limited time and task criticality. The response plan, GIS tool, and priority and challenges of GIS using are mainly addressed. The damage estimations and impact analysis can also be done using this decision support system.	In this approach, GIS technology is used in all the phases of a disaster and the conceptual framework includes the rescue and aids handling activities during a disaster. In addition, overall response planning is done including the medical resources by the use of GIS.	Suitable for both natural and man-made disaster scenarios. The comparison with other technologies is yet to be done.
Decision support for medical disasters [68]	This model is called IMPRESS where it has few components like database, interface, data harmonization, and reference semantic model.	The prediction of health care resources is also included. IMPRESS is tested using a real-world toxic fire scenario in Italy. Field and hospital resources are considered in addition to optimal deployment and control.	The live exercises, coupled with an ad-hoc methodological approach, could be used in individuating directions to be addressed.

Ontology enabled DSS for emergencies [69]	The system is called EMILI-SITE it occupies advanced technologies such as complex event processing, semantic technologies, and web services in mission-critical applications. A technology infrastructure, airport ontology physical model is suggested, and the system is tested against a fire disaster scenario. EMILI-SITE is a system that uses service-oriented architecture.	This framework involves detection, situation assessment, risk assessment/evaluation, and evacuation management, but does not include resource allocation or resource deployment.	Only for airport emergency situations. Not capable of handling other emergencies.
Disaster management in industrial areas [70]	An industrial disaster management system for all the preventive, reactive, and corrective phases. These decisions are taken based on the deterministic or stochastic data types along with the different objectives. Single or multiple objective functions can be seen with different solution n methods like frameworks, programming models.	Stocking the resources in selected locations, deployment of resources at the quickest possible time, and after evacuation resource allocations in rehabilitation are considered here. It describes resources by elements: human resources (medical staff, security, etc.), tools and equipment (ambulance, rescue tools, etc.), resource distribution.	This study is limited mainly to large-scale disaster management in industrial areas.

Resource Allocation Related Problems	Literature
Transportation	[21], [10], [29], [28], [15], [18], [19], [17], [20], [1],[6], [25], [26], [34], [44], [38]
Scheduling	[14], [18], [19], [21], [37], [1], [26], [40], [7], [9], [31], [28]
Facility Location	[23], [26], [44], [38], [20], [21]
Shelter Location	[3], [35], [12], [27]

Table 6: Related areas of resource allocation in a disaster

When analyzing the literature related to resource allocation, there were several interrelated problems that many individual studies have addressed. In the above table, those papers are stated separately, from analyzing that the transportation problem is the main aspect considered when talking about the resource allocation. Next to that scheduling is another popular problem related to resources. Then facility location and shelter locations are discussed respectively. After discussing these topics in detail in chapter 3, the final overview of the topics is discussed from now on.

The first problem is transportation, it is a broad area but when it comes to resource allocation it can be narrowed down to a few areas related to disaster context. Here transportation comes with two broad topics which are resource transportation and evacuees transportation. The evacuees' transportation to the shelter or to the hospitals is addressed in few studies while the resource transportation is addressed in many. Here, the focus is on resource transportation especially. The resources could be people like medical teams, rescue teams, forces, etc., or objects such as medicines, food, water, equipment, etc. The ambulances, fire trucks like emergency vehicles are also considered as resources in these studies. These resources must be allocated first to transport to the disaster area. Apart from the resources, there are few kinds of research that have addressed and focused on the road parameters. Such as traffic, under maintenance, affected by the disaster likewise. Therefore to overcome these mainly the studies have used the GIS as a technology. But several transportation modes are yet to the analyzed.

The next is the scheduling problem, the scheduling is needed when the resources are scarce. In the individual studies collected they mainly pointed out solutions to this problem via algorithms. The ambulances, resources like medicine are commonly targeted for scheduling procedures. The facility locations are also known as emergency centers, supply facilities/centers they can be either temporary or permanent. These are pre-located places that are capable of dispatching resources for disaster response and managing the inventories which is a preparedness task. These are collecting data and are mostly managed by a centralized control system. The establishing of facility locations is not considered but the supply chains for the facility centers are considered in some logistics-related researches. The shelter locations are considered in some studies, analyzing where to built shelters, how to transport and also allocate evacuees to those as well as how to allocate resources for those shelters. But it has been addressed by the minimum number of studies. The shelter location critical and non-critical resource allocations were not thoroughly analyzed.

Mathematical Models

The resource allocation problem is all about allocating limited resources to meet the demand or to achieve some objectives or tasks. The emergency resource allocation also belongs to the same context as disasters. The main goal of resource allocation is to reduce the further losses of a disaster in the response phase and provide until the reinstate of human lives in the recovery phase. Many mathematical models are proposed in the context of disaster resource allocation systems trying to achieve the optimal solution to this real-world problem. These models are discussed in detail in each individual studies and they are pointed out in the chapter 3 analysis. As for the briefing the several findings will be stated here. The main use of those mathematical models in resource allocation is achieving optimization. Basically many algorithms are used to build such models and also some are customized as per the requirements as well. Some studies are stated directly the use of a mathematical model or a formulation [13], [15], [1], [26], [34], [44], [37] and some studies are focusing only on the mathematical model of allocation without addressing a system as a whole. These mathematical models can be further categorized into sub-categories like static and dynamic, deterministic and stochastic, linear and non-linear. But in the literature collected the mathematical models that are mainly focused was static and dynamic categorization and deterministic and stochastic, and few linear and non-linear models were identified. Here, the final overview is conducted for those common model types.

Static and dynamic resource allocation

A static resource allocation has a steady-state which represents the logical view of the system in equilibrium, therefore doesn’t vary with time. Also known as time-invariant and generally represented by basic algebra equations and mostly used in supply-demand scenarios. The dynamic models are time-variant that means to depend on the time and the behavior can be described as a set of state that occur in a sequence. This type is represented by either differential equations or difference equations. The literature collected had many static and dynamic models. In the resource allocation context not only the resource allocation is dynamically addressed. The attributes in the resource allocation which are directly impacting the allocations are also dynamically addressed in some papers. The efficient models for dynamic allocations [39], [34], dynamic scenario-based [3], dynamic resource management [5], two-stage dynamic programming model [11], [23], dynamic data collection network [28], dynamically utilizing available resources [40], dynamic weighted task allocations [16], considering a disease dynamics [43] models are proposed and focused under the dynamic models. Apart from those studies some approaches are there to address static models as well such as static analysis based on specification at build time and uses fixed data [30], static disease environment [8], static demand together with scheduling [32].

Linear and non-linear models

The study of scheduling rescue units to the disaster region is modeled as a binary linear minimization problem [14] and another study [35] which is a novel architecture for resource-constrained post-disaster environments is formulated this resource allocation problem as non-linear programming (NLP) optimization problem.

Stochastic and deterministic models

The deterministic and stochastic are the optimization models that are used most commonly when addressing the resource allocation problem. In studies, different kinds of algorithms are used inside the models to tackle the problem in an effective optimal way. In deterministic models output is similar every time for the same parameter values and set of initial conditions. But in stochastic, it possesses some randomness where the same set of parameters and initial conditions will generate different outputs. The uncertainties are included with the stochastic models and they are also referred to as probabilistic approaches. A probabilistic allocation and stochastic multiple resource scheduling frameworks [21], a probabilistic approach under uncertainty conditions [13], uncertain demand considerations [15], an inexact proximal bundle method for stochastic optimization [22], stochastic network model [23], use of probabilistic solution discovery algorithm [1], considerations of uncertainties in roads and facility centers [26], considering uncertainty and persistence [34], a stochastic optimization [43], [24], handling uncertainty is by scenario-based simulations [29] and an approach that can be applied to online stochastic environments [39] are the works that can be identified using the literature. In addition, both deterministic and non-deterministic algorithms have been used for transportation problems [15] in a study. Some studies don’t consider uncertainties and some are non-probabilistic approaches as well.

Multi-Objective Optimization -multi-agent, multi-period

Several independent objectives solving in an optimized way is the brief idea of the multi-objective optimization. Some studies have addressed the resource allocation problem as a multi-objective model [1], [37]. The multi-objective allocation of resources and multi-objective of allocation of shortages of resources [13], multi-objective solid transportation problem handling [15], multi-objective planning model [26], use of multi-objective cellular genetic algorithm [34], and for optimized decision model [44] are the use case scenario of research that can identify using the multi-objective concept. Apart from that multi-agent systems [4], [39] and multi-period concepts [34], [43] are also in use.

Heuristics – based resource allocation

Heuristics can be defined as shortcuts when it comes to solving problems or making decisions. It saves time and allows people to take quick actions. Even though the problem domain is complex it most likely makes correct decisions. When considering the researches one paper proposed a sub-optimal heuristic for solving [35], another paper suggested an algorithm which can be used in heuristics procedure when time is scarce [14]. In addition to those, heuristic-based resource allocation [18], [22], two-phase heuristic [23] are proposed in the studies.

The role of IT in resource allocation: Technologies

When analyzing the resource allocation systems, the use of technologies is another main topic that needs to be focused on. Many papers have proposed systems or models together with the details of the technologies used. The resource allocation systems prototypes have been built and tested in many studies. Information technology is doing a major part when it comes to applying the concepts to real-world scenarios or to test cases. The models that have been proposed were run as simulations to evaluate each approach. The flow of each system which includes steps of data collection, processing data, and providing solutions for resource allocation contains IT-related solutions. Since this research is focusing on resource allocation and its related areas, the DSS that have been proposed with the integration of resource allocation mechanisms are not considered in this technological analysis. Those DSS have broader usage of IT technologies because they are functioning not only for resources.

The most common technology used in the proposed approaches was GIS which stands for Geographic Information System. The information about the disaster locations, resource monitoring from facility to disaster region, identifying available routes, tracking evacuees are some of the main tasks that are done by using GIS. The use of Google Maps can be seen in several studies [35], [4]. The study of multi-stage assignment optimization for emergency rescue teams in the disaster chain [19] uses GIS for the vehicle navigation system in order to plan the routes. Sarma and Das [15] suggested a system for emergency relief operations that uses the Facebook disaster map for the collection of data as the input for the system. So, it indicates that social media platforms are used in disaster contexts as well for collecting relevant data for decision making. Another resource allocation study uses a high-level programming language like python to derive the computational results of the approach [22]. The real-time data collection by smartphones is also focused on a study [6]. In this, resource allocation is addressed as a DSS where it uses extreme programming containing UML, PHP, and MySQL as technologies for the implementation of the system.

A graph-based resource allocation research uses the android platform and Java programming language for the development of the simulation [25]. It also includes an IoT environment for collecting data in real-time and track resources. The dynamic resource scheduling in forest fire [40] also uses an ICT-based approach and a floods specific resource management approach [44] uses GIS for trace surviving roads, shortest paths, and damaged roads. Another research uses

Google Map API, C# with .Net framework, and LPsolve package as technologies to tackle the resource allocation problem [9]. The study by Gamitl and Kumar [31] uses IoT devices for communication and for the collection of data. A decision aid model for disaster management and resource allocation uses SQL, PHP, CodeIgniter framework and Dreamweaver CS5 for the system implemented [33]. Research of task-based resource scheduling [28] and a multi-objective-based allocation [37] done in an IoT-based environment. Am allocation of resources after a disaster based on Big Data from SNS (social network services) and spatial scan [36] is proposed by Cheng and Wang. And it uses ML and NLP as semantic analysis methods for situation understanding with user requirements.

4.3 SUGGESTIONS AND GAPS

This systematic review of resource allocation systems was conducted to answer the questions built in chapter 1. In the previous sub-sections, the current stand of systems and technologies overview was analyzed. Now, under this topic, the gaps that can be identified and the suggestions that can be made to improve the resource allocation in disaster management context are clearly stated. These resource allocation systems must focus on risk reduction more than cost constraints. When it comes to saving lives the cost of deaths is invaluable. Therefore, the risk of more damage must be reduced in these planned resource allocations, especially in the response phase. When it comes to critical resources like medicines, rescue staff, ambulances the ethical aspect is to not consider the monetary values or budget constraints, but the cost of time is an important factor. The non-critical resources food, water, etc. can be allocated according to a beneficial way for both sides.

When analyzing the DSS that have addressed resource allocation in some way, are not considering complex allocation mechanisms. In many cases, they are lacking in considering uncertainties, dynamics in a disaster scenario for resource allocation. But mainly DSS are collecting and processing resource data in their systems to provide an outcome. The models suggested in individual studies could be used in such DSS for addressing complex disaster scenarios to achieve effective allocation. The resource allocation systems are mostly considering transportation of one resource type at a time which must be improved to multiple resource transportation in large-scale disasters. Another aspect that should be more focused on is the allocation of non-expendable resources such as medical teams, ambulances, etc., and the re-allocation of those resources to other affected areas from previously allocated disaster areas according to the demand and requirement priority.

More studies should be conducted for disaster resource allocations in multi-hazards scenarios, disaster chains with secondary disasters, and also for the ripple effect of disasters. The resource allocations could be improved by taking historical data into consideration which will help to predict the demand and predicting resource requirements. The past disaster data are maintained by the disaster control centers so those can be taken when another disaster occurs.

Even though volunteer data collection is focused on few studies, volunteer resources are not considered at all. The research areas like this could be improved for both critical and non-critical resources. When allocating resources, the volunteers' donations tend to impact resource availability massively.

In many cases, resource-based decisions are mainly taken from a centralized control center. This approach has both advantages and disadvantages, but if there are decentralized control centers, they will provide more efficiency for the allocation process. Both distributed and decentralized approaches could be considered in further studies. The technologies have been used in building these resource allocation systems in prototypes and commonly those studies have stated in the future improvements that their approaches have the potential to develop as a tool. So, when building for real-world scenarios there are many aspects to consider. Those should be analyzed separately how to implement it as tools with the given architectures and models. The new technology trends such as cloud computing, IoT, ML approaches good to be used in those systems to make them more compatible for users.

Resource allocation in Covid-19 pandemic.

Examining and applying the existing knowledge, how can resource allocation is done in an effective and efficient way will be discussed under this topic. The ethical aspect of pandemics and how resources should be allocated fairly and ethically is analyzed in several studies such as a systematic review of crisis standards of care in a pandemic resource allocation [42], and ethical guidance of disaster response [60] by Leider and Debruin. Apart from that medical (critical) resource allocation [59] such as vaccines, ventilators [61] are also discussed in a few studies. Another research about resource allocation for demand surge mitigation during health emergencies [8] is there which states that regional optimal response involves delaying the distribution from central stockpile as much as possible and also that smaller counties stand to benefit most from the mutual aids.

The current moment pandemic has spread all over the world, but few countries were able to successfully control the pandemic situation. From those well-controlled countries, when analyzing countries like New Zealand, Singapore, and Australia which are at the top of the charts there is a common way that the tackle this disaster situation. That is the cluster-based spread controlling technique. Even in Sri Lanka the first covid wave was controlled by this technique.

Each cluster has its own lifetime and consists of stages like detecting, isolation, releasing, etc. Each process has many sub-tasks attached to it such as tracing the infected, running PCR tests, vaccinations, treating the infected, transporting the infected, etc. Therefore, resource allocation is a must in these scenarios. Many have addressed the ethical guidance, policies, standards for the covid-19 but the need for a better resource allocation system is there. Each cluster identified is in need of both critical and non-critical resources until the releasing period.

An important analysis is that each cluster goes through the response and recovery phases in disaster management. Here, a particular cluster is not the whole pandemic disaster but for the resource allocation, each cluster can be identified as that. So, for the covid-19 pandemic, the resource allocation system should be able to support decisions for a considerable time for each cluster (14-28 days). A cluster changes dynamically through response and recovery phases with time. The need for long-term disaster management including both critical and non-critical resource allocation can be identified.

For such a resource allocation system, the most suitable model would be a stochastic or probabilistic model which deals with uncertainties of the situation while being a dynamic model as well. And many individual studies have been conducted proposing those types of models for such scenarios and it would be a great support for the current situation if implement one of those as a tool with specific modifications accordingly and also with the latest technologies like IoT, Cloud, etc. But it should have the ability to do multi-period allocations and have multi-agent integrations while addressing both response and recovery phases because the clusters might be addressed as a disaster chain with secondary impacts. Other related areas such as transportation, scheduling, facility, and shelter location considerations would be a privilege. The resources can be critical like PCR test kits, vaccines, ambulances in the response phase and non-critical like food, water especially in the recovery phase and also in both phases like medical staff, etc.

With time, the number of clusters identified will rise when it comes to the peaks of each wave of the pandemic. Therefore, the most suitable way to allocate resources will be a decentralized and distributed manner which will also benefit the non-expendable resource re-allocations. In developing countries like Sri Lanka, volunteer resource donations especially food, other necessities will have a great impact on resource availability, so in such countries that attribute could be used in the recovery phase of a cluster in the resource allocation system. The most effective pandemic control technique identified here is cluster-based controlling and it can be conducted in an efficient way with the use of a resource allocation system.

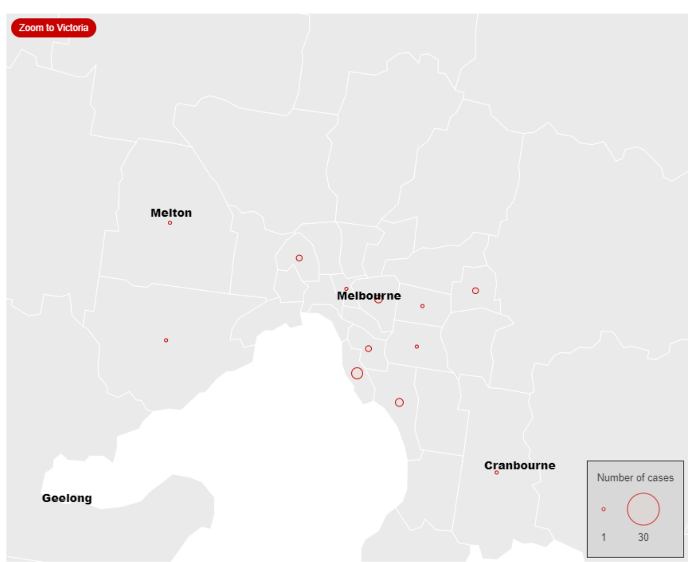
Figure 31: New Zealand and Australian clusters

Cluster details

Cluster under investigation	Location	Total to date	New cases in last 24 hours	Current active cases	Origin	Status*
Auckland February Cluster	Auckland	15	0	4	Under investigation	Open
International Mariners	Christchurch	33	0	0	Overseas exposure	Closed
Auckland August Cluster	Auckland	179	0	0	Under investigation	Closed
Aged Residential Care Facility (2)	Auckland	13	0	0	Overseas exposure	Closed
Aged Residential Care Facility (1)	Auckland	51	0	0	Unknown	Closed
Aged Residential Care Facility (1)	Christchurch	56	0	0	Unknown	Closed
Aged Residential Care Facility (2)	Christchurch	19	0	0	Unknown	Closed
Private Function	Auckland	40	0	0	Unknown	Closed
Group travel to USA	Auckland	16	0	0	Overseas exposure	Closed
Ruby Princess Cruise Ship Cluster	Hawke's Bay	25	0	0	Overseas exposure	Closed
Community	Auckland	30	0	0	Unknown	Closed
Hospitality Venue	Matamata	77	0	0	Overseas exposure	Closed
Wedding	Bluff	98	0	0	Overseas exposure	Closed
Community	Christchurch	14	0	0	Overseas exposure	Closed
Marist College	Auckland	96	0	0	Unknown	Closed
World Hereford Conference	Queenstown	39	0	0	Overseas exposure	Closed
Aged Residential Care Facility	Waikato	15	0	0	Overseas exposure	Closed
Group Travel to USA	Wellington	16	0	0	Overseas exposure	Closed
Wedding	Wellington	13	0	0	Overseas exposure	Closed

Recent cases of Covid-19 in Victoria

Showing the number of confirmed cases in the last 30 days. Click on the circles for more information, or use the zoom button to switch between metropolitan and state views.



4.4 ISSUES

There are several issues that came across while conducting this systematic review. The main issue was some journal articles did not contain any keywords there even they are highly relevant to the study but unbaled to take those into the keyword-based classification method used in this review. Because of that, the keyword clustering doesn't contain all the relevant individual studies or reviews. Therefore, it must be considered as an error in this study. Here, five papers were discussed but don't include in the clustering process. Another issue is that the keyword clustering doesn't have 100% accuracy. Here an unsupervised learning method is used which the clustering technique for machine learning. For that Affinity propagation algorithm is used to identify patterns and similarities between keywords to a cluster. That generated nine different clusters, but each cluster contains a percentage of erroneous clustering. In some clusters it can clearly see this miss by recognizing the same keyword is on several clusters. Even though this talks about the DSS that address resource allocation to some extent, those are not considered for the resource allocation keyword classification method because that cannot specifically indicate the resource allocation context. This is mainly qualitative research therefore no identifiable technical issue is faced. Because the technologies used are mainly for the data analysis itself.

4.5 LIMITATIONS

There are several limitations within this systematic review, mainly the keyword clustering is done using only one algorithm which is affinity propagation. But other clustering algorithms can be used, and they are containing different accuracy levels. Agglomerative Clustering, BIRCH, DBSCAN, and K-Means are some of the other algorithms which can be used for clustering and could conduct a comparison analysis base on the results. And the accuracy of the results of the classification depends on the algorithm used. Most of the models are having a mathematical approach that gives out the allocation mechanism inside the system. But in this review, only the system is overall analyzed deeply not the mathematical model and its features. Another limitation of this study is the scope limitation. Here the research only focuses on the response and recovery phase of the disaster management and not focusing on mitigation and preparedness phases. Lastly, there was no data limitation because all the relevant papers were accessible via the internet.

CHAPTER 05

5.1 CONCLUSION

In this study, different kinds of resource allocation systems were discussed which are either stand-alone or integrated with DSS. Mainly the response phase is addressed in those systems and few are considering the recovery phase as well. The mathematical models were identified with different kinds of categorizations such as stochastic /deterministic, static/dynamic, linear/non-linear, etc. The most commonly used type was stochastic and dynamic models. The multi-objective, heuristic-based aspects also focused on several studies. A detailed overview of the current stand of resource allocation systems is explicitly stated. The objectives of this study are providing knowledge for decision-makers during a disaster, pointing out the research gaps existing and yet to be addressed, and the covid-19 pandemic scenario resource allocation as well as the technologies used in other words the role of IT. The keywords classification method using a machine learning technique is used as the base of this study and discussed relevant papers for each cluster. The related topics of resource allocation were identified which are transportation, scheduling of resources, facility, and shelter locations. The response phase allocation studies are there more than the recovery phase and also the critical and non-critical resources both are addressed in this study. In addition, covid-19 pandemic resource allocation suggestions were made in this study. Another main outcome of the study is identifying the existing gaps of resource allocation in the disaster context such as decentralized approaches, disaster chains, and secondary disasters, multi-hazard scenarios, distributed and volunteer resources, etc.

5.2 FUTURE WORKS

Further categorizing, analyzing the proposed systems by researchers, more detailed overview and deep analysis of algorithms along with the pros and cons of those as well as the contradictions stated will be clearly described with more facts in future work. How to fill the mentioned gaps, making use of significant findings, avoiding limitations of each system, case studies will be thoroughly analyzed and stated. Recommendations will be made while proposing the approaches in a detailed manner to fill the gaps along with covering a broader area more than this scope.

CHAPTER 06

6.1 REFERENCES

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6.2 APPENDIX

GitHub:

https://github.com/deshanjali/Resource-Allocation-Systems

Covid – 19 pandemic controlled countries:

https://www.endcoronavirus.org/countries

https://www.movehub.com/blog/best-and-worst-covid-responses/

The Cluster based controlling of Covid – 19:

https://www.health.govt.nz/our-work/diseases-and-conditions/covid-19-novel-coronavirus/covid-19-data-and-statistics/covid-19-source-cases

https://www.theguardian.com/australia-news/datablog/ng-interactive/2020/oct/20/coronavirus-australia-map-cases-covid-19-tracking-stats-live-data-update-by-state-suburb-postcode-how-many-new-active-case-numbers-today-statistics-corona-deaths-death-toll

https://www.theguardian.com/australia-news/2020/jul/09/coronavirus-victoria-melbourne-covid-19-cases-clusters-hotspot-suburbs-hard-lockdown-family-outbreak-towers-flemington-keilor-downs-albanvale-hallam-coburg-brimbank-wollert-ascot-vale-maribyrnong-fawkner-tullamarine-truganina

https://infographics.channelnewsasia.com/covid-19/coronavirus-singapore-clusters.html

https://infographics.channelnewsasia.com/covid-19/singapore-map.html

6.2.1 PRISMA CHECKLIST

Section/topic	#	Checklist item
TITLE		
Title	1	Identify the report as a systematic review, meta-analysis, or both.
ABSTRACT		
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.
INTRODUCTION		
Rationale	3	Describe the rationale for the review in the context of what is already known.
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).
METHODS		
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).

Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.
RESULTS		
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).

Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).
DISCUSSION		
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.
FUNDING		
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.

Table 7: Prisma checklist

6.2.2 ONTOLOGY

RAS: Resource Allocation System Ontology

Scope

Developing a domain ontology that will cover the domain of resource allocation systems used in disaster management. We can use this ontology to handle the information about each resource allocation system introduced inside the Semantic Web. All the people who are interested in or doing research about resource allocation systems under disaster management can use this ontology and also can contribute to the semantic web by following the ontology schema to add SWDs as instances in the semantic web.

Competency Questions

1. Which characteristics should I consider when describing a resource allocation system?
2. What type of resources are distributed?
3. In which disaster phase that resource allocation is happening?
4. How the resource scheduling is combined with the allocation process?
5. How the human resources are handled in a disaster situation?
6. What are the resource allocation methods used in disaster preparedness?
7. When is the relief allocation and distribution happen?
8. How resource allocation is done in an evacuation process?
9. What are the emergency resources?
10. How the resource scarcity is managed?

What is RAS?

Many resource allocation systems used for disaster management are introduced on the internet through an innumerable number of websites. Most of the systems are introduced as research articles, journals, or chapters but other methods are there as well such as government websites, commercial websites, etc. These published systems are most common in academic websites such as science direct, research gate, IEEE explorer, etc. In this ontology, I consider the domain knowledge of research allocation systems where it gives the research information such as type of resources, allocation stage, pros cons, tasks performed, etc. such information is suitable for humans but cannot be easily processed through an automatic agent. If these typical details could be readable by machines it would have been more beneficial. In order to make these general information machines readable, I am using OWL to create an ontology about the domain of resource allocation systems.

Few of the basic terms that will be used to describe a system are:

ResourceAllocationSystem, Pre-AllocationSystem, AssigningSystem, Resource, Location, etc.

RAS Ontology Diagram:

[Classes, subclasses, and properties are indicated]

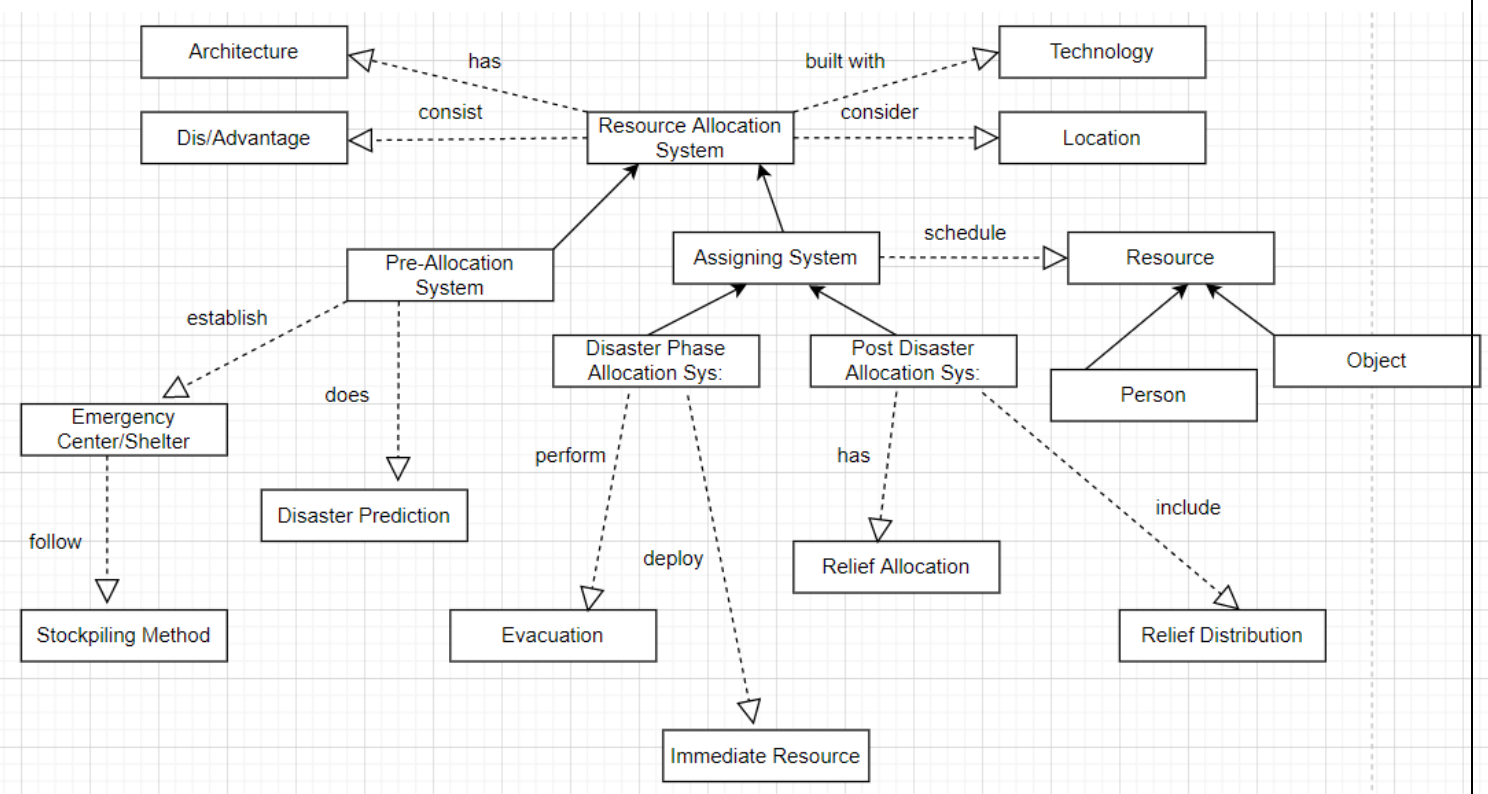

Figure 32: RAS Ontology Diagram

Taxonomy – (class hierarchy)

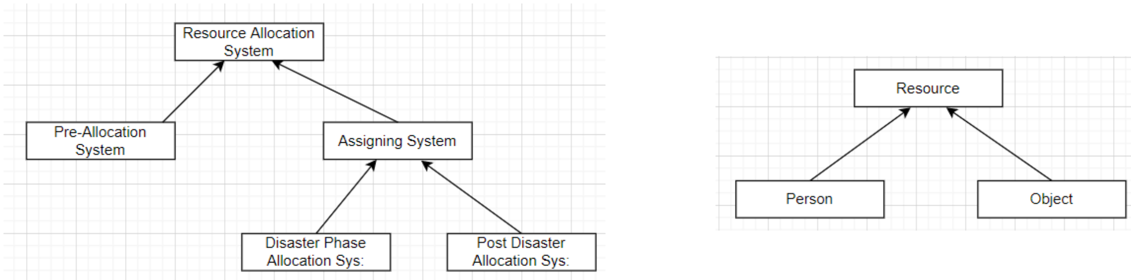

Figure 33: Taxonomy

<u>RAS.owl</u>

```xml
<?xml version="1.0"?>
<rdf:RDF xmlns="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#"
     xml:base="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0"
     xmlns:owl="http://www.w3.org/2002/07/owl#"
     xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
     xmlns:xml="http://www.w3.org/XML/1998/namespace"
     xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
     xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
     xmlns:ras-ontology-1="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#">
    <owl:Ontology rdf:about="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0"/>
    <!--
    ///////////////////////////////////////////////////////////////////////////////////////
    //
    // Object Properties
    //
    ///////////////////////////////////////////////////////////////////////////////////////
     -->
    <!-- http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#built_with -->

    <owl:ObjectProperty rdf:about="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#built_with">
        <rdfs:domain rdf:resource="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#ResourceAllocationSystem"/>
```

```
        <rdfs:range rdf:resource="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#Technology"/>
    </owl:ObjectProperty>

    <!-- http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#deploy -->

    <owl:ObjectProperty rdf:about="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#deploy">
        <rdfs:domain rdf:resource="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#DisasterPhaseAllocationSystem"/>
        <rdfs:range rdf:resource="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#ImmediateResource"/>
    </owl:ObjectProperty>

    <!-- http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#does -->

    <owl:ObjectProperty rdf:about="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#does">
        <rdfs:domain rdf:resource="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#Pre-
AllocationSystem"/>
        <rdfs:range rdf:resource="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#DisasterPrediction"/>
    </owl:ObjectProperty>

    <!-- http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#establish -->

    <owl:ObjectProperty rdf:about="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#establish">
        <rdfs:domain rdf:resource="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#Pre-
AllocationSystem"/>
        <rdfs:range rdf:resource="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#EmergencyCenter"/>
    </owl:ObjectProperty>
```

```
<!-- http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#follow -->

<owl:ObjectProperty rdf:about="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#follow">
    <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#FunctionalProperty"/>
    <rdfs:domain rdf:resource="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#EmergencyCenter"/>
    <rdfs:range rdf:resource="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#StockPilingMethod"/>
</owl:ObjectProperty>

<!-- http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#has -->

<owl:ObjectProperty rdf:about="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#has">
    <rdfs:domain rdf:resource="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#PostDisasterAllocationSystem"/>
    <rdfs:range rdf:resource="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#ReliefAllocation"/>
</owl:ObjectProperty>

<!-- http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#has_archi -->

<owl:ObjectProperty rdf:about="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#has_archi">
    <rdfs:domain rdf:resource="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#ResourceAllocationSystem"/>
    <rdfs:range rdf:resource="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#Architecture"/>
</owl:ObjectProperty>

<!-- http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#include -->
```

```
    <owl:ObjectProperty rdf:about="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#include">
        <rdfs:domain rdf:resource="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#PostDisasterAllocationSystem"/>
        <rdfs:range rdf:resource="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#ReliefDistribution"/>
    </owl:ObjectProperty>

    <!-- http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#perform -->

    <owl:ObjectProperty rdf:about="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#perform">
        <rdfs:domain rdf:resource="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#DisasterPhaseAllocationSystem"/>
        <rdfs:range rdf:resource="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#Evacuation"/>
    </owl:ObjectProperty>

    <!-- http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#schedule -->

    <owl:ObjectProperty rdf:about="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#schedule">
        <rdfs:domain rdf:resource="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#AssigningSystem"/>
        <rdfs:range rdf:resource="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#Resource"/>
    </owl:ObjectProperty>
    <!--
    ///////////////////////////////////////////////////////////////////////////////////////
    //
    // Data properties
    //
    ///////////////////////////////////////////////////////////////////////////////////////
     -->
```

```
    <!-- http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#consider_loc -->

    <owl:DatatypeProperty rdf:about="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#consider_loc">
        <rdfs:domain rdf:resource="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#ResourceAllocationSystem"/>
        <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
    </owl:DatatypeProperty>

    <!-- http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#consist_of -->

    <owl:DatatypeProperty rdf:about="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#consist_of">
        <rdfs:domain rdf:resource="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#ResourceAllocationSystem"/>
        <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
    </owl:DatatypeProperty>
    <!--
    ///////////////////////////////////////////////////////////////////////////////////////
    //
    // Classes
    //
    ///////////////////////////////////////////////////////////////////////////////////////
     -->
    <!-- http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#Architecture -->

    <owl:Class rdf:about="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#Architecture"/>

    <!-- http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#AssigningSystem -->

    <owl:Class rdf:about="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#AssigningSystem">
```

```
        <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#ResourceAllocationSystem"/>
    </owl:Class>

    <!-- http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#Dis-Advantage -->

    <owl:Class rdf:about="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#Dis-Advantage"/>

    <!-- http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#DisasterPhaseAllocationSystem -->

    <owl:Class rdf:about="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#DisasterPhaseAllocationSystem">
        <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#AssigningSystem"/>
    </owl:Class>

    <!-- http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#DisasterPrediction -->

    <owl:Class rdf:about="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#DisasterPrediction"/>

    <!-- http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#EmergencyCenter -->

    <owl:Class rdf:about="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#EmergencyCenter"/>

    <!-- http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#Evacuation -->

    <owl:Class rdf:about="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#Evacuation"/>

    <!-- http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#ImmediateResource -->
```

```
    <owl:Class rdf:about="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#ImmediateResource"/>

    <!-- http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#Location -->

    <owl:Class rdf:about="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#Location"/>

    <!-- http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#Object -->

    <owl:Class rdf:about="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#Object">
        <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#Resource"/>
        <owl:disjointWith rdf:resource="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#Person"/>
    </owl:Class>

    <!-- http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#Person -->

    <owl:Class rdf:about="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#Person">
        <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#Resource"/>
    </owl:Class>

    <!-- http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#PostDisasterAllocationSystem -
->

    <owl:Class rdf:about="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#PostDisasterAllocationSystem">
        <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#AssigningSystem"/>
    </owl:Class>

    <!-- http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#Pre-AllocationSystem -->
```

```
    <owl:Class rdf:about="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#Pre-
AllocationSystem">
        <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#ResourceAllocationSystem"/>
    </owl:Class>

    <!-- http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#ReliefAllocation -->

    <owl:Class rdf:about="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#ReliefAllocation"/>

    <!-- http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#ReliefDistribution -->

    <owl:Class rdf:about="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#ReliefDistribution"/>

    <!-- http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#Resource -->

    <owl:Class rdf:about="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#Resource"/>

    <!-- http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#ResourceAllocationSystem -->

    <owl:Class rdf:about="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#ResourceAllocationSystem"/>

    <!-- http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#StockPilingMethod -->

    <owl:Class rdf:about="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#StockPilingMethod"/>

    <!-- http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#Technology -->
```

```
    <owl:Class rdf:about="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#Technology"/>
    <!--
    ///////////////////////////////////////////////////////////////////////////////////////
    //
    // Individuals
    //
    ///////////////////////////////////////////////////////////////////////////////////////
     -->
    <!-- http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#EmergencyCenter01:_Colombo
-->

    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#EmergencyCenter01:_Colombo"/>

    <!-- http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#Evacuation01:_vehicle_deployment -->

    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#Evacuation01:_vehicle_deployment"/>

    <!-- http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#ImmediateResource01:_medicine -->

    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#ImmediateResource01:_medicine"/>

    <!-- http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#Object01:_FirstAid_Kit -->

    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#Object01:_FirstAid_Kit"/>

    <!-- http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#RAS01:_Pre-
Allocation_System_ABC -->
```

```
    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#RAS01:_Pre-Allocation_System_ABC">
        <rdf:type rdf:resource="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#Pre-AllocationSystem"/>
        <establish rdf:resource="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#EmergencyCenter01:_Colombo"/>
        <follow rdf:resource="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#StockPiling01:_JKL"/>
        <consider_loc>pre allocation locations within 5km radius</consider_loc>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#RAS02:_Post_Disaster_Allocation_System_XYZ -->

    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#RAS02:_Post_Disaster_Allocation_System_XYZ">
        <rdf:type rdf:resource="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#PostDisasterAllocationSystem"/>
        <built_with rdf:resource="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#Technology01:_SQL"/>
        <has rdf:resource="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#ReliefAllocation01:_Food_Allo"/>
        <schedule rdf:resource="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#Object01:_FirstAid_Kit"/>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#RAS03:_Disaster_Phase_Allocation_System_PQR -->

    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#RAS03:_Disaster_Phase_Allocation_System_PQR">
        <rdf:type rdf:resource="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#DisasterPhaseAllocationSystem"/>
```

```
        <deploy rdf:resource="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#ImmediateResource01:_medicine"/>
        <perform rdf:resource="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#Evacuation01:_vehicle_deployment"/>
        <consist_of>adv: real-time disaster information collection</consist_of>
    </owl:NamedIndividual>

    <!-- http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#ReliefAllocation01:_Food_Allo
-->

    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#ReliefAllocation01:_Food_Allo"/>

    <!-- http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#StockPiling01:_JKL -->

    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#StockPiling01:_JKL"/>

    <!-- http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#Technology01:_SQL -->

    <owl:NamedIndividual rdf:about="http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-
1.0#Technology01:_SQL"/>
</rdf:RDF>
```

Triples

86 triples were generated, and a sample of triples are stated in below:

Triples of the Data Model

Number	Subject	Predicate	Object
1	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://www.w3.org/2002/07/owl#Ontology
2	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#built_with	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://www.w3.org/2002/07/owl#ObjectProperty
3	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#built_with	http://www.w3.org/2000/01/rdf-schema#domain	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#ResourceAllocationSystem
4	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#built_with	http://www.w3.org/2000/01/rdf-schema#range	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#Technology
5	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#deploy	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://www.w3.org/2002/07/owl#ObjectProperty
6	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#deploy	http://www.w3.org/2000/01/rdf-schema#domain	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#DisasterPhaseAllocationSystem
7	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#deploy	http://www.w3.org/2000/01/rdf-schema#range	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#ImmediateResource
8	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#does	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://www.w3.org/2002/07/owl#ObjectProperty
9	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#does	http://www.w3.org/2000/01/rdf-schema#domain	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#Pre-AllocationSystem
10	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#does	http://www.w3.org/2000/01/rdf-schema#range	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#DisasterPrediction
11	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#establish	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://www.w3.org/2002/07/owl#ObjectProperty
12	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#establish	http://www.w3.org/2000/01/rdf-schema#domain	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#Pre-AllocationSystem
13	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#establish	http://www.w3.org/2000/01/rdf-schema#range	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#EmergencyCenter
14	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#follow	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://www.w3.org/2002/07/owl#ObjectProperty
15	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#follow	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://www.w3.org/2002/07/owl#FunctionalProperty
16	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#follow	http://www.w3.org/2000/01/rdf-schema#domain	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#EmergencyCenter
17	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#follow	http://www.w3.org/2000/01/rdf-schema#range	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#StockPilingMethod
18	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#has	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://www.w3.org/2002/07/owl#ObjectProperty
19	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#has	http://www.w3.org/2000/01/rdf-schema#domain	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#PostDisasterAllocationSystem
20	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#has	http://www.w3.org/2000/01/rdf-schema#range	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#ReliefAllocation
21	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#has_archi	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://www.w3.org/2002/07/owl#ObjectProperty
22	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#has_archi	http://www.w3.org/2000/01/rdf-schema#domain	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#ResourceAllocationSystem
23	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#has_archi	http://www.w3.org/2000/01/rdf-schema#range	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#Architecture
24	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#include	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://www.w3.org/2002/07/owl#ObjectProperty
25	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#include	http://www.w3.org/2000/01/rdf-schema#domain	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#PostDisasterAllocationSystem
26	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#include	http://www.w3.org/2000/01/rdf-schema#range	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#ReliefDistribution
27	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#perform	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://www.w3.org/2002/07/owl#ObjectProperty
28	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#perform	http://www.w3.org/2000/01/rdf-schema#domain	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#DisasterPhaseAllocationSystem
29	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#perform	http://www.w3.org/2000/01/rdf-schema#range	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#Evacuation
30	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#schedule	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://www.w3.org/2002/07/owl#ObjectProperty
31	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#schedule	http://www.w3.org/2000/01/rdf-schema#domain	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#AssigningSystem
32	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#schedule	http://www.w3.org/2000/01/rdf-schema#range	http://www.semanticweb.org/desha/ontologies/2020/11/ras-ontology-1.0#Resource

Figure 34:Triples

Graph Data Model

Graph link:

https://www.w3.org/RDF/Validator/ARPServlet.tmp/servlet_52201327702975011141.png

Figure 35: Graph Data Model

6.2.3 KEYWORD CLASSIFICATION

Keyword	Cluster	Name	No:
'disaster response',	4	Emergency Resource Allocation for Disaster Response: An Evolutionary Approach	1
'emergency logistics',	4		
'evolutionary algorithm',	4		
'multi objective optimization',	4		
'resource allocation',	0		
'decision support systems',	6	Improving Resource Allocation for Disaster Operations Management in a Multi-Hazard Context	2
'disaster operations management',	7		
'long term planning',	5		
'multi hazard events',	7		
'delay tolerant network',	5	A Utility Driven Post Disaster Emergency Resource Allocation System Using DTN	3
'human mobility pattern',	5		
'integer programming',	0		
'opportunistic knowledge sharing',	0		
'optimal resource allocation',	0		
'post disaster situation awareness',	0		
'utility function',	0		
'resource allocation',	0	An Innovation Approach for Optimal Resource Allocation in Emergency Management	4
'domain transportation',	0		
'emergency management',	0		
'multi agent system',	0		
'collective intelligence',	0	A collective intelligence resource management dynamic approach for disaster management: A density survey of disasters occurrence	5
'computational resource',	0		
'management',	0		
'emerging technologies',	4		
'european disasters',	4		
'integrated disaster management',	4		
'decision support system',	6		6

'disaster',	1	Determining resource capacity in disaster relief through a model-driven decision support system	
'disaster management',	4		
'resource capacity',	4		
'resource management',	4		
'clock driven',	4	HRAS: Hybrid resource allocation system for large-scale disasters	7
'priority driven',	6		
'resource allocation',	6		
'scheduling algorithm',	6		
'decision support',	7	Resource allocation for demand surge mitigation during disaster response	8
'optimization',	3		
'pandemic flu',	6		
'resource allocation',	7		
'data mining',	6	Decision support system for resource allocation in disaster management	9
'knowledge discovery',	6		
'and personalized',	6		
'enterprise resource optimization',	1		
'healthcare information systems',	1		
'agent based simulation',	1	Agent-based simulation of emergency response to plan the allocation of resources for a hypothetical two-site major incident	10
'emergency response',	1		
'resource allocation optimization',	0		
'disaster',	1	Balancing pre-disaster preparedness and post-disaster relief	11
'preparedness',	1		
'relief',	1		
'cluster of inventory location',	1	Clustering inventory locations to improve the performance of disaster relief operations	12
'disaster relief operation',	1		
'humanitarian logistic and inventory',	1		
'lateral transshipment',	1		
'stable roommate problem',	1		
'allocation of resources or their shortages',	1		13

'multicriteria robust solutions',	1	Multicriteria decision making under conditions of uncertainty in application to multiobjective allocation of resources	
'multiobjective decision making',	1		
'possibilistic approach',	1		
'qualitative information processing',	1		
'transformation functions',	1		
'branch and price',	2	An exact branch-and-price algorithm for scheduling rescue units during disaster response	14
'disaster operations management',	2		
'operations research in disaster relief',	6		
'scheduling',	2		
'disaster relief',	2	Uncertain demand estimation with optimization of time and cost using Facebook disaster map in emergency relief operation	15
'facebook disaster map',	2		
'genetic algorithm',	2		
'intensity of demand',	2		
'lingo',	2		
'social media',	2		
'agent coordination',	2	Coordination for dynamic weighted task allocation in disaster environments with time, space and communication constraints	16
'disaster environments',	2		
'intelligent agents',	2		
'resource allocation',	2		
'column generation',	2	Optimal allocation of emergency medical resources in a mass casualty incident: patient prioritization by column generation	17
'emergency medical service',	3		
'mass casualty incident',	3		
'operations research in disaster relief',	3		
'triage',	3		
'assignment',	3	Emergency response in natural disaster management: Allocation and scheduling of rescue units	18
'decision support systems',	6		
'heuristics',	2		
'natural disaster management',	2		
'scheduling',	2		
'disaster chain',	2		19

'multistage optimization',	2	Multistage assignment optimization for emergency rescue teams in the disaster chain	
'non dominated sorting genetic algorithm',	2		
'rescue team',	3		
'scheduling strategy',	3		
'disaster relief',	3	Evolutionary optimization for disaster relief operations: A survey	20
'emergency operational problems',	3		
'evolutionary algorithms',	4		
'optimization',	3		
'bushfire or wildfire',	3	Probabilistic allocation and scheduling of multiple resources for emergency operations; a Victorian bushfire case study	21
'disaster management',	7		
'emergency operations',	5		
'non expendable resources',	5		
'optimization',	7		
'resource scheduling',	5		
'uncertainty',	5		
'logistics',	5	Resource Allocation for Contingency Planning: An Inexact Proximal Bundle Method for Stochastic Optimization	22
'proximal bundle method',	3		
'risk averse optimization',	3		
'stochastic programming',	3		
'emergency logistics planning',	3	Stochastic network models for logistics planning in disaster relief	23
'humanitarian logistics',	0		
'operations research in disaster relief',	3		
'risk aversion',	3		
'two stage stochastic programming',	6		
'operations research in disaster relief',	6	Resource allocation when planning for simultaneous disasters	24
'resource allocation',	6		
'simultaneous disasters',	6		
'stochastic optimisation',	6		
'bipartite graph theory',	4		25

'disaster management',	4	Graph-based resource allocation for disaster management in IoT environment	
'internet of things',	4		
'resource allocation',	2		
'emergency logistics',	4	Emergency Material Allocation Problem Considering Post-Disaster Impact	26
'distribution optimization',	4		
'material distribution',	4		
'road impedance',	4		
'distributed algorithms',	4	Fair dynamic resource allocation in transit-based evacuation planning	27
'emergency evacuation',	7		
'fairness',	7		
'optimization',	7		
'resource allocation',	7		
'disaster management',	7	Task Based Resource Scheduling in IoT Environment for Disaster Management	28
'graph theory',	7		
'internet of things',	4		
'resource scheduling',	5		
'emergency management',	0	A resource-based decision support tool for emergency response management	29
'decision support',	7		
'medical resource allocation',	7		
'network flows',	5		
'discrete event systems',	5	E-Net modeling and analysis of emergency response processes constrained by resources and uncertain durations	30
'emergency response process',	5		
'petri nets',	5		
'resource allocation',	6		
'timed petri nets',	5		
'uncertain duration',	5		
'workflow management',	5		
'data monitoring',	6	Resource Monitoring and Scheduling for Post Disaster Management Using Internet of Things	31
'disaster management',	7		
'internet of things',	4		

'resource scheduling',	5		
'wireless sensor network disaster response',	6		
'emergency management',	0	Capability-based resource allocation for effective disaster response	32
'modeling',	6		
'resource allocation',	6		
'multi hazard events',	7	DECISION AID MODEL FOR DISASTER MANAGEMENT & RESOURCE ALLOCATION	33
'decision support systems',	6		
'disaster operations management',	7		
'disaster recovery center',	6		
'long term planning',	6		
'cellular genetic algorithm',	6	Emergency resource allocation for multi-period post-disaster using multi-objective cellular genetic algorithm	34
'disaster relief',	2		
'emergency logistics',	4		
'emergency resource allocation',	0		
'multi objective optimization',	4		
'delay tolerant net work',	0	A Novel Network Architecture for Resource-Constrained Post-Disaster Environments	35
'disaster management',	7		
'post disaster environments',	0		
'resource allocation',	0		
'disaster management',	4	Dynamic resource scheduling in forest fire situations in Sri Lanka	40
'dynamic resource scheduling',	8		
'fire extinguishing equipment',	8	Optimal allocation of fire extinguishing equipment for a power grid under widespread fire disasters	41
'fires',	8		
'optimal allocation',	8		
'power grids',	8		
'risk analysis',	8		
'transmission lines',	8		
'allocation of resources',	8		42
'coronavirus',	8		

'disaster planning',	8	Allocation of Scarce Resources in a Pandemic: A Systematic Review of U.S. State Crisis Standards of Care Documents	
'pandemics',	8		
'cholera outbreak intervention',	8	A data-driven optimization approach for multi-period resource allocation in cholera outbreak control	43
'data driven optimization',	8		
'infectious disease transmission',	8		
'operations research in health services',	8		
'resource allocation',	7		
'disaster preparedness',	8	Disaster preparedness in humanitarian logistics: A collaborative approach for resource management in floods	44
'humanitarian logistics',	8		
'multiple objective programming',	8		
'operations research in disaster relief'	6		
'emergency logistics',	4	Relief distribution networks: a systematic review	57
'emergency management',	0		
'humanitarian logistics',	0		
'relief distribution networks',	7		
'response optimization',	7		
'emergency facility location',	7	Review and prospect of the emergency resource coordination under unconventional emergencies	58
'emergency resource allocation',	0		
'emergency resource scheduling',	7		
'optimization models',	7		
'unconventional emergencies',	7		

Table 8: Keyword classification