AN INTEGRATED BUS - BASED ROUTING AND DISPATCHING APPROACH FOR FLOOD EVACUATION

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Abstract: Floods are among the most persistent natural disasters that lead to massive economic and human loss globally. In this regard, this study has proposed an optimisation model for evacuating people before the occurrence of the flood using bus transit. The process of evacuation commences with the issue of warning and extends up to a certain time before the flood forecasts to strike. This model provides an optimised framework for 1) Locating pickup points and shelters, 2) Assigning pickup points to the nearest shelter by opting the shortest route among the available routes. On the basis of demand, each pickup point is allocated with a certain number of trips. The modelling of dispatch sequence of public buses, random adventing of evacuees at pickup points and evacuees transit to the shelters are presented by developing a simulation tool. The results of simulation serve for assessing the route design and then, a local search heuristic is suggested to improve the route design during the evacuation.

Keywords: Dispatching Schedule, Evacuation Planning, Flood, Optimisation, Route Planning, Simulation Modelling.

1. INTRODUCTION

A flood, one of the deadly water-based natural disasters, can be managed efficiently by means of effective transport and communication facilities before it hits. Water-related disasters are most persistent among all kinds of natural disasters and pose a major threat to human and socio-economic progress (Noji and Lee [17]). The (Adikari and Junichi [3]) reports analyse that water-related disasters are responsible for about 72% of the total economic loss caused by natural disasters, 26% of which are caused by floods alone at the global level. The report further states that the period ranging from 1900 to 2006, of all the natural disasters, flood alone occurs about 30% and as a consequence claims more than 19% of total fatalities and more than 48% of the total population have been impacted at the global level. However, owing to deforestation, climate change, and settling of the population in flood-prone areas, flood losses are anticipated to increase the amount of the population up to two billion worldwide by 2050 (Vogel et al. [29]). The effects of floods become more catastrophic with an increase in urbanization. This has been evidenced in developing nations where economic activities are accommodating more and more individuals in coastal areas.

In the recent times, the authenticity of flood forecasts has improved by merging meteorological and hydrological modelling facilities, advancement in information collection through satellite review and development in knowledge and techniques to assess and communicate uncertainties (Jain et al. [13]). Flood forecasting enables to anticipate approximately three to four days in advance about the arrival of the flood, so facilitating efficient management implementation to all those areas which are facing the chance of flood. For this purpose, the period from the flood forecasts up to the period before the flood strikes has to be fully utilised to evacuate flood-prone inhabitants to the safer zone.

2. REVIEW OF LITERATURE

The study conducted by Cova and Johnson, [10], stated that evacuation is the key process for managing disasters. It is a planning-based decision to minimise the impact of disasters severity on human lives. The evacuation process is defined as the shifting of the people from the risk zone to a safer zone (Southworth [24]). The study of Na et al., [16], indicates that evacuation is one of the effective plans which can minimise the property and human loss before flooding. The process of evacuation may vary by the intensity of disaster, mass movement (people or property), and the level of control of the governing body. Further, it can be recommended, compulsory or deliberately but should be managed in a pre-planned manner. The intensity of disaster plays a significant role in deciding whether to evacuate or not.

Evacuation tactics can integrate different strategies for handling disaster by making use of existing communication, transportation and civil defence facilities.

The study conducted by Stepanov and Smith, [25], suggested a series of events that included detection, threatening, evacuation preparation, transportation from risk zone, arrival at the safer zone, and confirmation about the arrival of evacuees at the shelters to be followed for smoothly handling the evacuation process. Further, the study of Pel et al., [19], advocates many phases to be considered in advance such as warning time, information propagation methods, routes decision for evacuation, traffic flow and its controlling measure for efficient evacuation.

For operating the evacuation plan in an effective way, different authors focus on different aspects of evacuation. The study of Afshar et al., [4]; Chiu et al., [9]; Zheng et al., [30], concentrated on route planning in the evacuation process. The study conducted by Mitchell et al., [15]; Sbayti and Mahamassani [12], focused on departure planning for managing the evacuation process. The role of departure planning is crucial to reduce the clearance time and to avoid any sort of confusion regarding allocation and scheduling of trips on multiple routes by vehicles from shelters to each pickup point during the evacuation process. The selection of shelter is another important aspect of the phase of evacuation. The study conducted by Campos et al., [7], focused on the characteristics of shelters and suggested that those public buildings (school, colleges, universities, sports, medical) having large capacity along with well-developed transportation facilities can be chosen as a shelter for providing humanitarian and medical aid in effective ways.

The study of Taaffe et al., [27], considers a significant role of internet and mobile phone facility for providing communication for the right time to exit and take a route during the evacuation. The special signal timings, suggested by Chien et al., [8]; Parr and Kaiser [18], for managing the vehicles flow, can be effective for executing the evacuation in a smooth manner. Apart from this, to avoid traffic congestion, a crowded hour should be the refrain for evacuation.

Several models have been developed in recent years for achieving the optimal results for efficient evacuation planning. Abdelgawad et al., [1], suggested a multi-objective model for minimising waiting time, travel time, and fleet cost by using the combination of public transportation and other vehicles for evacuating in an emergency. The study undertaken by Bish, [6], proposed a bus-based routing model with split delivery for victim evacuation. Pereira and Bish, [20], used a bus-based evacuation model for minimising the total waiting time of evacuees at pickup points. They also analyse the consequence of changing the maximum numbers of pickup points per location on the size of evacuees and the total waiting time. The study of Swamy et al., [26], suggested a routing and dispatching model by operating public buses for evacuating victims in a hurricane. Sabouhi et al., [22], proposed an integrated strategy for routing and scheduling to transport evacuees from risk to safe areas, and provide them with humanitarian aid. The objective of this research is to transit the utmost number of inhabitants of the risk zone to a safer zone with minimal transit costs using public transit buses before the flood strikes.

References	Route type		Scheduling	Capacitated vehicles	The objective of the model
	Open	Close			
Bish [6]	✓			✓	Minimization of maximum evacuation time of evacuees.
Abdelgawad and Abdul-hai [2]	✓		✓	✓	Minimization of routing cost and evacuation time of evacuees.
Wex et al., [28]		✓	✓		Minimization of total weighted completion time of victims.
Pereira and Bish [20]		✓	✓	✓	Minimise the total waiting time of evacuees at pickup points.
Pourrahmani et al. [21]		✓			The minimisation of the total travel time of evacuees in vehicles.
Swamy et al., [26]		✓		✓	Minimise routing cost and the average waiting time of evacuees at pickup points.
Sabouhi et al.,[22]		✓	✓	✓	Minimization of the sum of arrival times of vehicles at-risk areas, shelters and distribution places for both victim evacuation and relief commodities transit.
This paper		✓		✓	Minimising the routing cost for transporting evacuees.

Table 1: Major research on victims evacuation in the past

3. PROBLEM ILLUSTRATION

The aim of this study is to develop an effective method for operating the evacuation process. The evacuation strategy is an integrated framework consisting of several interrelated steps right from the issue of a threat to the arrival of the evacuees at the safer zone as shown in Figure 1.
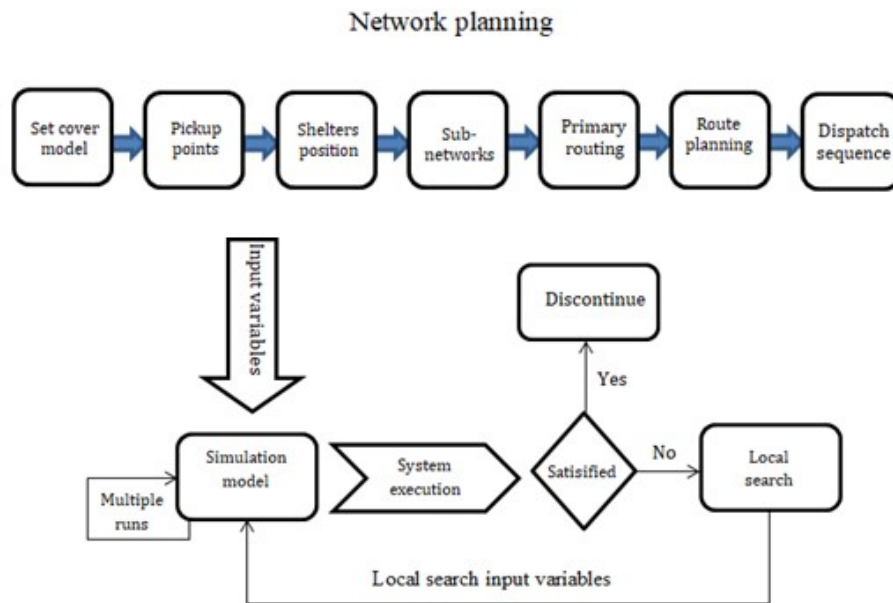
Figure 1: Flow chart depicting the outline of the methodology (source: Swamy et al., [26])

3.1. *Decisions related to pickup points and shelters*

Let the network consists of all the shelters and pickup points in the evacuation regions and a subnetwork consists of a shelter and several pickup points connected to that shelter in a specific region. In each subnetwork, immediately after the warning has been issued to the flood-prone areas, suitable sets of pickup points and shelters have to be selected for smooth management. The next phase is to link the pickup points and corresponding shelters to each of pickup points in each subnetwork. The bus stops already well familiar-ed and nearest to maximum number of affected people are chosen as pickup points for achieving utmost evacuation. The decision of choosing bus stops is modelled as a Set Cover Problem,

constructed as an Integer Program (IP), to attain the suitable set of solutions from the combination of all bus-stops.

The decision of choosing pickup points is followed by shifting of evacuees from pickup points to corresponding nearest shelters. The school, colleges or other public buildings having a certain capacity for settlement and proper transportation facilities are selected as shelters. The shelter capacity is determined after assessing the space, food, and water facility available for each evacuee. The cost of arranging a shelter is excluded from the objective function. The constraint is that the aggregate number of evacuees at a pickup point linked to the corresponding shelter is never bigger than the capacity of the shelter.

Notations:
D : Set of all risk points.
B : Set of all bus-stops.
P : Set of all pick points.
S : Set of all shelters.

Parameters:
C_s : The capacity of a shelter $s \in S$.
d_p : The aggregate number of evacuees at the pickup point $p \in P$.
r_{ps} : The distance from the pickup point $p \in P$ to the shelter $s \in S$.
$P_d(r)$: The minimum distance r evacuees have to travel for accessing from risk point $d \in D$ to pickup point p.

Decision variables:
Define $\forall b \in B$

$$y_b = \begin{cases} 1, & \text{if bus stop } b \text{ is selected to act as a pickup point.} \\ 0, & \text{otherwise.} \end{cases}$$

Define $\forall p \in P$ and $s \in S$

$$x_{ps} = \begin{cases} 1, & \text{if pickup point } p \text{ is assigned to shelter } s. \\ 0, & \text{otherwise.} \end{cases}$$

The proposed mathematical model is to minimize:

$$\sum_{b \in B} y_b \tag{1}$$

$$\sum_{s \in S} \sum_{p \in P} r_{ps} x_{ps} \tag{2}$$

Subject to constraints:

$$\sum_{b \in B_d(r)} y_b \geq 1, \ \forall d \in D. \tag{3}$$

$$\sum_{s \in S} x_{ps} = 1, \ \forall p \in P. \tag{4}$$

$$\sum_{p \in P} x_{ps} d_p \leq c_s, \ \forall s \in S. \tag{5}$$

The goal of (1) is to choose the minimum numbers of bus-stops. Equation (2) is used to minimize the total distance that connects pickup points to corresponding shelters. The constraint in (3) assures that every risk point is connected with one or more than one bus-stops within an approachable distance. The constraint in (4) assures that each pick point is connected to only one shelter. The constraint in (5) ensures that the aggregate number of evacuees at each pickup point corresponding to a shelter never exceeds the capacity of the shelter.

3.2. *Primary Routing description*

The routing process involves the search for those combinations of routes which are passing through pickup points as well as the corresponding shelters. The route pattern is developed in the form of Vehicle Routing Problem (VRP) with the shelter serving as a depot in each of the subnetworks. The VRP was initially devised by Dantzig and Ramser, [11], for delivering a certain quantity of goods to different nodes by multiple vehicles from the depot. In our study, the arrival rate of evacuees at different pickup points is not fixed, rather a realistic approach is adopted for evacuees arrival rate at the different instant of time as modelled in Section 4. The case when the number of evacuees accumulated at a pickup point exceeds the available capacity of the bus by the time the bus arrives there is handled by allowing the bus to transit through more than one route.

The VRP is classified as an NP-hard problem (Abdelgawad and Abdulhai [2]). Thus, it is a time-consuming process if using exact methods to solve large scale problem. Hence, a heuristic approach for routing is applied to evacuate only some area as defined in section 5.2. The routes are designed in such a way that highly flood risk areas followed by distant areas from the shelters are planned to be evacuated first.

3.3. *A Sweep Heuristic Approach for Route Planning*

Sweep heuristic is an algorithm for joining nodes with routes, based upon their geographic location, in a rotational manner with respect to the central depot (shelter), for attaining a near-optimal solution. The study conducted by Ballou, [5], revealed that given heuristic achieved an average optimal gap of 10%. In a network $D(W, E)$, let $t_{p,q}$ denote the time required by a bus to pass from a link p to q such that $p, q \in E$. Let d_p denote the rate at which evacuees reach from risk points to pickup point $p \in W - S$, where s denotes a shelter in a subnetwork. Let C denote the capacity, and R denotes the remaining capacity of the bus, respectively during repeatedly traversing the routes. Then, the below given phases suggest a route planning.

1. Connecting the shelter with any of the nodes. Let it be p, the beginning of the evacuation process, i.e., (s, p).
2. _Case-i:_ If the capacity of a bus is equal to the number of evacuees at a pickup point, i.e., $C = d_p \times t_{s,p}$, then $R = 0$ and the bus is allowed to travel directly to the shelter by connecting the link (p, s). Next, close all such routes.
   Case-ii: If the capacity of the bus is greater than the number of evacuees at the pickup point, i.e., $C > d_p \times t_{s,p}$, then, there will remain some of its capacity. Hence, $R > 0$. To handle this case, we convert $R > 0$ into $R = 0$. Let $R = C - d_p \times t_{s,p}$ with condition $C \geq d_p \times t_{s,p}$. Trace the next nearest node, say (q), in the clockwise direction with respect to the shelter. If the capacity of the bus at node q is equal to $d_p(t_{p,q} + t_{s,p})$, then as per case-i, the bus directly travels to the shelter. Otherwise, if the capacity of the bus at node q is greater than $d_p(t_{p,q} + t_{s,p})$, update $R = C - d_p(t_{p,q} + t_{s,p})$. Hence, $R > 0$. Trace the next nodes, say $k, l, m, ..., n$, with respect to the shelter. After a finite number of iterations and by using condition $C \geq d_p \times t_{s,p}$ on $R = C - d_p(t_{p,q} + t_{s,p})$, R becomes zero and the bus is allowed to travel towards the shelter.
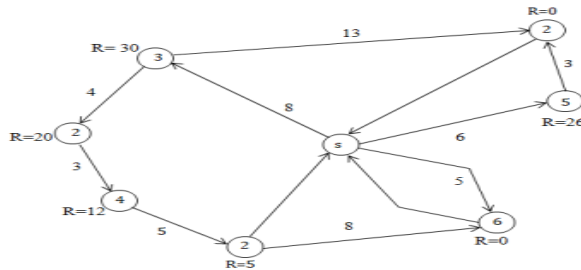3. Repeat case-i and case-ii of step 2, until all the evacuees are evacuated from each of the nodes.

Figure 2: Route Planning Setup

The description of the route planning for a subnetwork is given in Figure-2. The values inside the circle indicate the arrival rate of evacuees at each node, and the number written near the lines connecting to nodes indicates the travel time from one node to another. The remaining capacity R of the bus after picking up evacuees from a node is also mentioned beside each node, and s inside the central circle denotes a shelter.

3.4. *Approach for Dispatching of Buses*

The number of buses is assigned to a subnetwork based upon the total number of evacuees present at each of the pickup points in a subnetwork. Let the total number of available buses is k. Let b_n be the number of buses required in a subnetwork n to carry all the evacuees from each pickup point to the corresponding

shelter. Then $k\left(b_n/\sum_n b_n\right)$ buses are assigned to each of subnetwork. The number of buses dispatched to each of the pickup points is based upon the demand. The dispatch pattern operates in such a manner that the routes which transverse pickup locations with higher demand arrival rates should transverse regularly than those with lesser demand arrival rates. For achieving these goals, one can formulate it as a frequency setting problem.

Let k_s be the number of buses allotted to a shelter s in a subnetwork. The buses are dispatched from the shelter towards the corresponding pickup points in such a way that the bus which returns earliest at the shelter will be dispatched to the next pickup point first.

A heuristic dispatching sequence devised by Maxwell and Muckstadt, [14], is applied in our study for generating dispatch sequences in the evacuation process of the flood. A trip here denotes the number of times a route have to be traversed in the dispatching process.

Let $h(r)$ be the total trips required for all the routes $r \in \{1, 2, 3, ..., R\}$ and m be a multiplying factor. Then the trips required for each route r is calculated by $m\left(\frac{h_r}{\min_r(h_r)}\right)$. Further, the routes are arranged in the ascending sequence on the basis of the number of trips assigned to each route and denoted by k. If $t(k)$ is the number of trips of the arranged list of routes, i.e., $t(k) < t(k+1) \forall k \in \{1, 2, 3, ..., K-1\}$, then the below given phases are operated for determining the trip to each of the route.

1. For each of the arranged route, $k = 1, 2, 3, ..., K$ a list of the trip is produced in such a manner that the series of trips run uniformly. To proceed this, a corresponding trip number is determined for each k; let $n_k(y)$ denotes the corresponding trip number of the trip y on the arranged route k. Then the value of $n_k(y)$ is calculated as following.

$$n_k(y) = \lfloor \frac{\sum_{k=1}^{K} t(k)}{t(k)}(y-1) + 1 \rfloor, \quad \forall\, y = 1, 2, 3, ..., t(k).$$

2. The objective of this phase is to allot trips to the trip number, which is allotted for the list of arranged routes $k = 1, 2, 3, ..., K$ in a manner that unallocated trip numbers are used as a first trip number for all routes. Further, increasing the space between trips allows almost all the trip numbers to appear?. For this:
   - we denote the first unallocated journey number by $x(k)$
   - The visit y of k for all $y = 1, 2, 3, ..., t(k)$ is assigned to the trip number by evaluating the reminder, obtained when dividing $[n_k(y) + x(k) - 1]$ by $\sum_{k=1}^{K} t(k)$; while proceeding this, it is possible that two consecutive trips y on k may be assigned by the same number.
3. This phase deals with resolving the clashes that exist because more than one trip number is allotted to each $x(k) = 1, 2, 3, ..., \sum_{k=1}^{K} t(k)$. For this, after investigating the largest trip allotted to trip number $x(k)$, we re-allotted that trip number to the unallocated one, which is closer to $x(k)$.

These phases provide each selected route with corresponding trip numbers, leading to the generation of dispatching sequence. This sequence is used in simulation only after multiplying the pattern several times to avoid the exhausting of trips before the completion of evacuation time.

4. SIMULATION PROCESS

A simulation model is developed in order to facilitate the decision-maker in analyzing and making certain necessary decisions during evacuation regarding the adventing of evacuees at the pickup points, total travel time for evacuation, congestion-related decisions, etc. These decisions will help in improving the performance of each step taken during the evacuation. These measures are also used for attaining local search variables for advancing the performance of methodology.

4.1. Input Variables in Simulation

The input parameters, given below, are required before the running of the simulation.

1. The pattern of evacuees arrival: The total number of evacuees present at the different pickup points are departed by utilising a proper discrete-time probability function that ideally suited the exit time of evacuees. A best-fit method is used to fit the departure data as explained in the case study. After the fitting of the curve, different instances of the demand spread over time are created in such a way that all of the instances are performed with each element d_{pt} in a matrix. Where d_{pt} denotes the number of evacuees adventing at a pickup point p at a time t. In our case study, we choose one minute as the time the arrival of evacuees at different pickup points. If T_m is the total time (in minutes) required for evacuation and H_p is the number of pickup points to be considered, then the input matrix has dimension $H_p \times T_m$. Multiple times simulations are operated by feeding these instances for each run.

2. Set of routes: Every route among the selected routes is linked with a list of pickup points. The initial and final component of this list act as the mark for the shelter linked to that route to indicate the start and close of the route at the shelter.

3. Travelling plan: On dividing the shortest route distance by average speed along selected routes between the pickup points and the shelters, the shortest route travel-time is obtained and is stored in the form of a matrix. Then the obtained dimension of the matrix is $(H_p + S) \times (H_p + S)$ for the S number of shelters.

4. Shelters: The positions of shelters in Section 3.1 provide us with an optimum allocation of pickup points to the shelters. The shelters along their corresponding pickup points act as the input to the model.

5. Dispatching series: The repeatedly routing pattern during travelling in Section 3.4 for the set of routes from the shelters to the pickup points is generated and is saved. Further, a proper data arrangement is used for the list of routes linked to each shelter.

6. Bus-based parameters: The total number of buses having certain capacities assigned to each of the shelters in the network plays a major role in input parameters.

7. The evacuation time period T_m also serves as another input variable for analyzing evacuation efficiency.

4.2. Discrete event simulation for bus decisions

After the assigning of buses to each of the shelter in the network, the buses initiate their journey from the shelters following the dispatching sequence towards the assigned pickup points.

1. If a bus leaves the shelter at time t, then it is planned to reach the pickup point at time $t + t_1$, where t_1 is the travel time.

2. The arrival of the bus at pickup point: After arriving at a pickup point, a bus takes some boarding time t_2, before it leaves from a pickup point to the next destination. The next destination can be nearer pickup point or shelter, it is based upon the remaining capacity of the bus (R) after boarding the evacuees. If $R = 0$ then bus directly travels to the shelter. Otherwise, it travels to the next pickup points according to the route assigned until $R = 0$.

3. The arrival of the bus at a shelter: After arriving at a shelter, a bus takes certain de-boarding time (t_3) before it leaves for the next destination as per the dispatch sequence.

4. The buses are refuelled at the shelter during the de-boarding of evacuees for saving time. It can help in assessing the fuel requirement for the complete process and storing the fuel in advance.

5. Well maintained and sound machinery public buses are used to avoid any sort of disturbance during the evacuation period.

4.3. Quantification of System Performance

Different variables in each of the simulation run change their state from time to time. Some of the variables are marked for achieving the useful metrics that could help in measuring the efficiency of the system. The computation of percentage evacuation rather than an absolute number of evacuees acts as a better technique to achieve the goal of maximum evacuation. As each simulation run includes the stochastic arrival of evacuees, percentage computation is an efficient way of achieving the standardised metrics for these variations.

The multiple cases of the demand distribution are generated and simulation is run in each of these cases for the given set of input parameters. The percentage evacuation is proximate in most of the runs. A discontinuation rule, depending upon the convergence of mean, is adopted. At the end of each iteration t, let $y(t)$ evaluate the value of the average of total percentage evacuated up to that iteration.

Then, for a small value of ϵ, we discontinue the process in the tth iteration when the condition $|y(t) - y(t-1)| \le \epsilon$ is attained.

4.4. Local Search Decisions

After determining the initial route pattern from sweep heuristic, the emphasis is to vary only the route pattern while keeping the all others variables fixed. The subnetwork that has no more than two routes have been selected in a random manner from either of the two selected pickup points, and their positions are interchanged. For this, a small iterative variation is made of the routing pattern and then, the variation is assessed by operating the simulation. If the new route pattern achieves no refinement, we neglect this solution and carry out further interchanges until attaining the first met criteria between an upper limit on the number of iterations and calculation time of percentage evacuation for terminating the mean convergence. This way, we can attain those routes which achieve the highest value of the objective function.

5. A CASE STUDY

The algorithm has been tested on a real-world problem for one of the highly flooded districts of Jammu and Kashmir (J&K) of September 2014, recognized by the state as one of the most destructive floods in the past six decades. The flood was triggered by the torrential rainfall for several days, which led to overflowing of the Chenab, Jhelum, Ravi, and Tawi rivers above the risk mark. The massive flood affected about 5.5 million people, making thousands homeless, and cost hundreds of lives in the state. The reports of Sheema et al., [23], analyzed the condition of all the 108 worst affected villages of J&K. Out of the assessed 108 villages, the water entered into the houses of 87 villages.

5.1. Location of the Flooded Districts

The flood on September 2014 hit 11 districts out of 22 in the state. Among these 11 districts, 4 districts were completely cut-off from other districts while the rest 7 districts were badly affected.

The maximum destruction was caused by river Jhelum in the areas of district Srinagar. In light of this fact, our study considers only those areas which lay in the vicinity of the Jhelum river in district Srinagar. i.e., Sonwar Bagh, Shivpora, Batwara, Soitang, Lasjan, Padshai bagh, Natipora, Pandrathan, Lal Chowk, Rajbagh, Jawahar Nagar, Gogji Bagh, and Wazir Bagh etc.

Figure 3: Depicting the location of flooded districts adjoining to river Jhelum (Source: Sphere India)

5.2. *Location of the bus stops and shelters*

We obtain an optimal list of 41 out of 78 bus stops lying in flood-prone areas for serving as pickup points after running the Set Cover Model. The list of 41 pickup points linked to 9 selected shelters has been used for evacuating about 55567 peoples (excluding those self-evacuated) from the adjoining areas of the Jhelum river, based on the data collected from Kashmir Irrigation and Flood Control Department. After that, the subnetworks are created by running the shelter assignment model. This step calculates the least distance from the shelter to each pickup point in every subnetwork. In order to assess the travel time matrix for these locations (between shelters and pickup points), the distance covered by a vehicle is divided by the average vehicle speed on the route. This act as an input to the primary routing generation model and all of such outcomes obtained from these models serve as an input to the simulation model.

A total of 47 Jammu and Kashmir State Road Transport Corporation (JK-SRTC) buses for 720 minutes having 50 as the seating capacity of each bus at an average speed of 30km/hour is used for the purpose of evacuation. The least possible approachable range up to which each of the risk zones have minimum bus stop inside its range is 1.6 km. The above data is fed into the simulation in addition to the specified in section 4.1.

5.3. *Results*

This section provides the results that have been obtained after running the simulation. The simulation is run for different instances of each route on the basis of randomly generated demand arrival curve. The given below Table 2 provides the results of an initial solution, which ends by mean convergence after ten iterations. The completion of a local search approach has been enabling us to attain the set
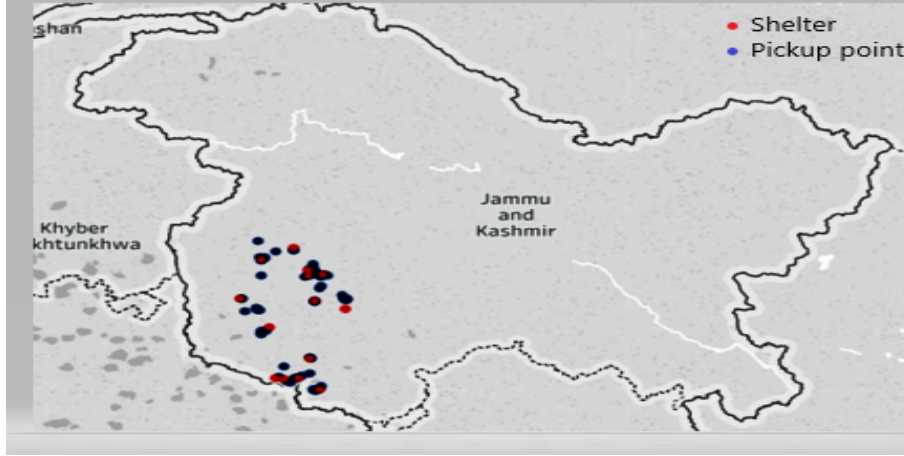
Figure 4: Location of all the shelters and pickup points

of best optimal route pattern using the input parameters. After attaining the optimal route pattern, we will analyse the evacuation process.

Iteration (t)	Percentage evacuated	$||y(t) - y(t-1)||$	Operation period (sec)
1	66.394	—	14.15
2	66.345	0.324	14.06
3	67.798	0.084	15.63
4	67.732	0.432	15.24
5	68.245	0.342	16.41
6	67.451	0.058	14.86
7	69.438	0.045	17.32
8	68.934	0.076	16.89
9	68.245	0.019	16.67
10	69.363	0.011$\leq$0.012	17.02

Table 2: Results of multiple runs obtained from a sample route pattern for $\epsilon = 0.012$

The waiting time of evacuees at different pickup points during evacuation with time is depicted in Figure 5.

Figure 5. represents the relationship between the numbers of evacuees waiting for evacuation at various pickup points of each subnetwork with respect to time. Further, the graph shows the increase in the number of arrival of evacuees at various pickup points in comparison to the early hours. The numerous large intensity of drops in the graph represent the simultaneous arrival of many buses at different
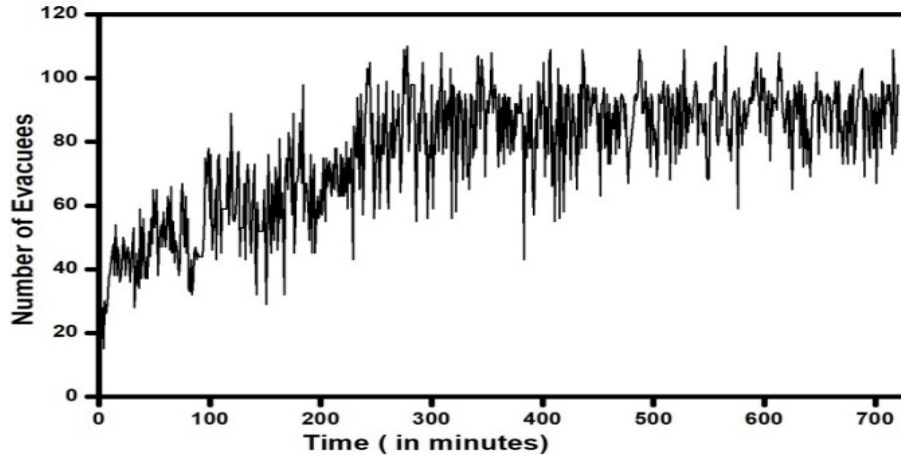
Figure 5: Evacuees at different time points.

pickup points in different subnetworks at the given time The multiple small drops and rise in the graph represent the variation of the number of evacuees waiting at all the pickup points in different subnetworks at a given time
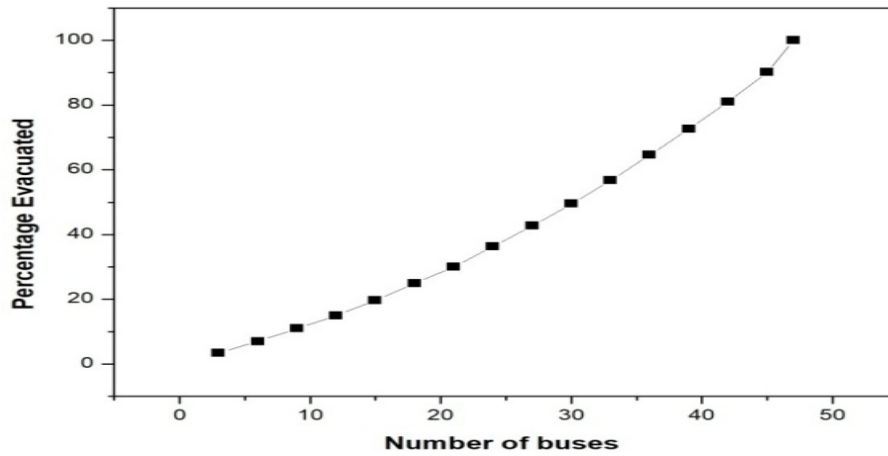

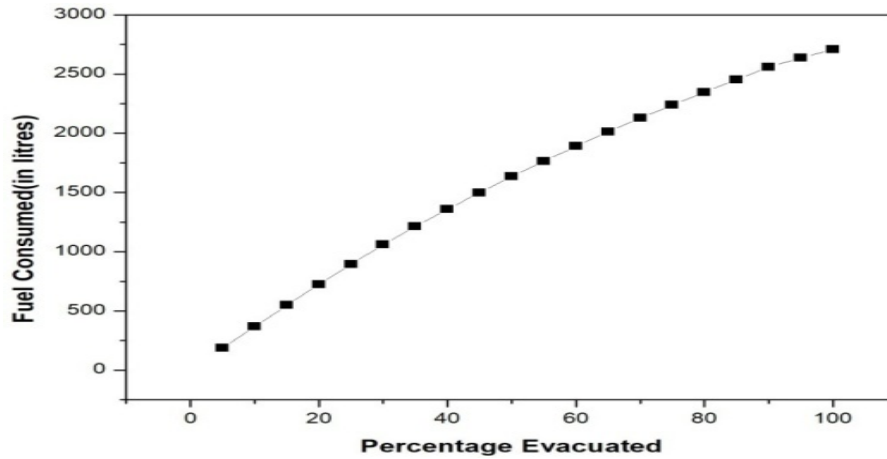Figure 6: Percentage evacuated versus Number of buses.

Figure 7: Amount of vehicle fuel consumed versus percentage evacuated.

6. CONCLUSION

The unpredictable nature of most of the natural disasters makes it requisite to attain the highest degree of potential preparation in the immediate pre-disaster period to evacuate the population at risk for minimizing the loss. This research has formulated a strategic routing and dispatching approach for carrying out the evacuation before the occurrence of flood in one of the most flood-prone districts of J&K for minimizing the routing costs. The given approach has been proved quite effective for acquiring better outcomes inside a limited span of time to arrange rescue operations before any kind of disaster. The characteristics of the approach make the process smooth for evacuating the people from any kind of disaster in any region of the globe equipped with suitable transportation facilities.

REFERENCES

[1] Abdelgawad, H., Abdulhai, B., and Wahba, M., "Multi-objective optimization for multi-modal evacuation", *Transportation Research Record Journal of the Transportation Research Board*, 2196 (1) (2010) 21-33.

[2] Abdelgawad, H., and Abdulhai, B., "Large-scale evacuation using subway and bus transit: Approach and application in the city of Toronto", *Journal of Transportation Engineering*, 138 (10) (2011) 1215-1232.

[3] Adikari, Y., and Junichi. Y., "Global trends in water-related disasters: an insight for policymakers.", *World Water Assessment Programme Side Publication Series, Insights*, The United Nations, UNESCO, International Centre for Water Hazard and Risk Management, (ICHARM) (2009).

[4] Afshar, A.M., and Haghani, A., "Heuristic framework for optimizing hurri-cane evacuation operations", *Transportation Research Record*, 2089 (2089) (2008) 9-17.

[5] Ballou, R.H., *Business logistics/supply chain management: planning, organizing, and controlling the supply chain"*, *Pearson Education*, Prentice Hall, New Jersey, 1999.

[6] Bish, D. R., "Planning for a bus-based evacuation", *OR Spectrum*, 33 (3) (2011) 629-654.

[7] Campos, V., Bandeira, R., and Bandeira, A., "A method for evacuation of route planning in disaster situations", *Procedia-Social andbehavioural sciences*, 54 (2012) 503-512.

[8] Chien, S. I., and Korikanthimath, V. V., "Analysis and modelling of simultaneous and staged emergency evacuations", *Journal of Transportation Engineering*, 133 (3) (2007)190-197.

[9] Chiu, Y.C., and Mirchandani, P. B.,"Online behaviour-robust feedback infor-mation routing strategy for mass evacuation", *Intelligent Transportation Systems, IEEE Transactions*, 9 (2) (2008) 264-274.

[10] Cova, T., and Johnson, J., "A network flow model for lane-based evacuation routing", *Transportation Research Part A*, 37 (7) (2003) 579-604.

[11] Dantzig, G. B., and Ramser, J. H., "The truck dispatching problem", *Management Science*, 6 (1) (1959) 180-191.

[12] Hayssam, S., and Mahmassani, H. S., "Optimal scheduling of evacuation operations", *Transportation Research Record*, 1964 (1) (2006) 238-246.

[13] Jain, S. K., Pankaj, M., Sanjay, K. J., Prakash, P., Singh, V. P., Tullos, D., Kumar, S., Agarwal S. P., and Dimri, A. P., "A Brief review of flood forecasting techniques and their applications", *International Journal of River Basin Management*, 16 (3) (2018)329-344

[14] Maxwell, W.L., and Muckstadt, J.A., "Design of automated guided vehicle systems", *IEEE Transactions*, 14 (2) (1982) 114-124.

[15] Mitchell, S .W., and Radwan, E., "Heuristic priority ranking of emergency evacuation staging to reduce clearance time", *Transportation Research Record*, 1964 (1) (2006) 219-228.

[16] Na, L., Xueyan, S., and Mingliang, Q., "A bi-objective evacuation routing engineering model with secondary evacuation expected costs", *Systems engineering procedia*, 5 (2012) 1-7.

[17] Noji E.K., and Lee, C.Y., *Disaster preparedness. Environmental health: from global to local*, CA: Jossey-Bass Publishers, San Francisco, 2005.

[18] Parr, S.A., and Kaisar, E., "Critical intersection signal optimization during urban evacuation utilizing dynamic programming", *Journal of Transportation Safety & Security*, 3 (7) (2011) 59-76.

[19] Pel, A., Bliemer, M., and Hoogendoorn, S., "A review on travel behaviour modelling in dynamic traffic simulation models for evacuations", *Transportation*, 39 (1) (2012) 97-123.

[20] Pereira, V.C., and Bish, D.R., "Scheduling and routing for a bus-based evacuation with a constant evacuee arrival rate", *Transportation Science*, 49 (4) (2015) 853-867.

[21] Pourrahmani, E., Delavar, M. R., Pahlavani, P., and Mostafavi, M. A., "Dynamic evacuation routing plan after an earthquake", *Natural Hazards Review*, 16 (4) (2015) 040150061-8.

[22] Sabouhi, F., Bozorgi, A.A., Moshref, J. M., and Heydari, M., "An integrated routing and scheduling model for evacuation and commodity distribution in large-scale disaster relief operations: A case study", *Annals of Operations Research*, 283 (2019) 643677.

[23] Sheema, S., Hassan, M., and Khan, S. M. S., "Rapid Need Assessment of District Srinagar, Post September 2014 Floods", *Global Journal of Medical Research*, 19 (3) (2019) 23-27.

[24] Southworth., F., "Regional evacuation modeling: A state-of-the-art review", *Oak Ridge National Laboratory*, (1991) 1769-27.

[25] Stepanov, A., and Smith, J., "Multi-objective evacuation routing in transportation networks", *European journal of operation research*, 198 (2) (2009) 435-446.

[26] Swamy, R., Kang, J.E., Batta, R., and Chung, Y., "Hurricane evacuation planning using public Transportation", *Socioeconomic Planning Sciences*, 59 (2017) 43-55.

[27] Taaffe, K., Garrett, S., Huang, Y.H., and Nkwocha, I., "Communications role and technology preferences during hurricane evacuations", *Natural Hazards Review*, 14 (3) (2012) 182-190.

[28] Wex, F., Schryen, G., Feuerriegel, S., and Neumann, D., "Emergency response in natural disaster management: Allocation and scheduling of rescue units", *Natural European Journal of Operational Research*, 235 (3) (2014) 697-708.

[29] Vogel, R.M., Yaindl, C., and Walter, M., "Non-stationarity: flood magnification and recurrence reduction factors in the United States", *Natural Journal of the American Water Resources Association*, 47 (3) (2011) 464-474.

[30] Zheng, H., Chiu, Y.C., Mirchandani, P. B., and Hickman, M., "Modeling of evacuation and background traffic for optimal zone-based vehicle evacuation strategy", *Transportation Research Record*, 2196 (1) (2010) 65-74.