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A Study of Implementing an Effective Relief Distribution System in Hari Rampur, Manikganj, During a Flood

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Abstract

This study explores the implementation of an effective relief distribution system in Harirampur, Manikganj, during a flood. The primary objective is to establish a central warehouse and optimize the delivery routes to distribution centers using the minimum number of vehicles, thereby ensuring timely and efficient relief distribution. The methodology involves using the Center of Gravity (CoG) method to determine the optimal location for the central warehouse and the Capacitated Vehicle Routing Problem (CVRP) approach to find the shortest delivery routes. Data on population distribution and infrastructure in Harirampur were collected to inform the model. The outcome demonstrates that the proposed system significantly reduces travel distances and ensures that relief supplies reach affected areas efficiently. The total distance covered by the relief distribution routes was minimized, leading to a cost-effective and timely relief operation. This study provides a practical framework for disaster management authorities to enhance the effectiveness of relief distribution during floods.

Keywords
Relief distribution, Flood, Center of Gravity, Capacitated Vehicle Routing Problem, Python Programming.

1. Introduction
Flooding is one of the most devastating natural disasters globally, and in recent years, its frequency and severity have increased due to extreme weather patterns triggered by climate change. Bangladesh, along with West Bengal in India, is one of the most flood-prone regions in the world, largely due to its geographical location in the low-lying area of the Hindu Kush Himalayan (HKH) region. This area is fed by three major rivers—the Ganges, Brahmaputra, and Meghna—forming the GBM river system, one of the largest river basins in the world, covering 1.72 million sq. km. (Rahman 2014). Nearly half of Bangladesh's land lies within 10 meters above mean sea level, making the nation especially vulnerable to frequent flooding.

The monsoon season, from June to October, brings heavy rainfall, with around 85% of the total annual precipitation and inflow from transboundary rivers occurring during this period. Floods destroy infrastructure, displace people, and damage agricultural lands, posing a significant threat to the economy and the livelihoods of rural communities. Over the last 50 years, Bangladesh has experienced at least seven major floods, with catastrophic events in 1988, 1998, and 2004, each causing widespread destruction (Rahman S 2024). The recurring floods, combined with riverbank erosion, displace around one million people annually, severely impacting impoverished rural communities that already struggle to meet basic needs.

This research focuses on the flood-prone area of Harirampur Upazila in Manikganj District, located in central Bangladesh. Harirampur, with a population of over 280,000, is regularly affected by flooding, which disrupts daily life and exacerbates poverty. Relief efforts, while crucial, are often inefficient, with many affected areas receiving inadequate aid. Therefore, the primary objective of this study is to model a more efficient relief delivery process, ensuring that relief goods are distributed effectively and promptly to affected areas. Specifically, the research aims to identify an optimal location for a central warehouse from which relief can be delivered to distribution centers by traveling the shortest possible routes using the minimum number of vehicles. By improving the logistics of relief distribution, the study seeks to mitigate the hardships faced by flood-affected communities, enhancing both the speed and equity of aid delivery.

2. Literature Review

The literature review analyses significant studies and research pertinent to the effective provision of assistance during flooding incidents, emphasizing logistics, warehouse site optimization, and distribution frameworks. This section examines several frameworks for flood relief management, highlighting techniques to reduce response time and resource utilization. Furthermore, it examines the socio-economic consequences of floods in Bangladesh, especially in rural regions such as Harirampur Upazila. This section seeks to provide a robust framework for comprehending contemporary issues in relief distribution and to pinpoint optimal approaches for enhancing disaster response logistics.

2.1 Relief Supply Chain Optimization

A stochastic optimization model for disaster relief supply chains was created, emphasizing preparation and combining inventory and transportation choices to maximize resource allocation and reduce response times under unpredictable catastrophe scenarios (Manopiniwes & Irohara, 2017). Probabilistic models for the prepositioning and distribution of relief goods in unpredictable situations were presented to assure the availability of supplies and decrease catastrophe unpredictability (Abazari et al. 2021). Cooperative maximal covering models for the management of humanitarian aid chains, aimed at optimizing coverage and coordinating efforts among many organizations for efficient resource distribution, were proposed (Li et al. 2018). These studies underscore the significance of strategic decision-making and readiness in the management of disaster relief supply chains.

2.2 Vehicle Routing in Disaster Relief

A genetic approach for the Vehicle Routing Problem (VRP) was presented to optimize vehicle routes while accounting for resource restrictions and delivery timeframes (Baker & Ayechew, 2003). Improvements to vehicle routing with time constraints, using a hybrid estimate of distribution method to enhance delivery precision and punctuality in catastrophe situations, were presented (Pérez-Rodríguez & Hernández-Aguirre 2019). The emergency vehicle routing issue, including variable demand and sustainability aspects while integrating environmental and logistical elements for prompt and sustainable relief, was examined (Qin et al. 2017). A dynamic vehicle routing model including anticipation, allowing real-time adjustments to catastrophic scenarios like obstructed highways or changing demand, was introduced (Wohlgemuth et al. 2012). Models prioritizing relief routing that harmonize fairness, efficiency, and effectiveness to guarantee equitable and prompt resource allocation were established (Huang et al. 2012). These studies provide essential insights on enhancing the delivery of relief supplies, guaranteeing that assistance reaches impacted communities promptly and effectively, particularly under adverse circumstances.

2.3 Location-Routing Problem in Humanitarian Logistics

Optimizing warehouse location and vehicle routing is crucial for disaster relief logistics. Location-allocation models minimizing transportation time during disasters were applied in Nepal (Maharjan & Hanaoka 2017), while a math-heuristic approach addressed the warehouse location-routing problem (Rath & Gutjahr 2014). Efficient routing under capacity constraints was improved using adaptive large neighborhood search (Mattos Ribeiro & Laporte 2012) and memetic algorithms (Ngueveu et al. 2010)

Integrated location-routing models minimizing costs and response times (Wei et al. 2020), hybrid algorithms reducing distribution costs (Escobar et al., 2013), and inventory slack routing to prevent shortages (Yang et al. 2018) offer comprehensive solutions to logistical challenges, enhancing the speed and efficiency of aid delivery.

2.4 Conclusion
The studied literature underscores the essential significance of improving relief supply chains, vehicle routing, and warehouse placement in humanitarian logistics. The use of sophisticated algorithms and cohesive models enhances readiness, accelerates reaction times, and ensures a more equal allocation of relief resources. These findings provide a robust basis for further research on improving disaster relief logistics, especially in flood-prone areas such as Bangladesh.

3. Research Methodology
The following research methodology outlines a systematic approach to optimizing relief distribution during flood events. Each step is designed to ensure efficient planning, resource allocation, and timely delivery of aid to affected areas.

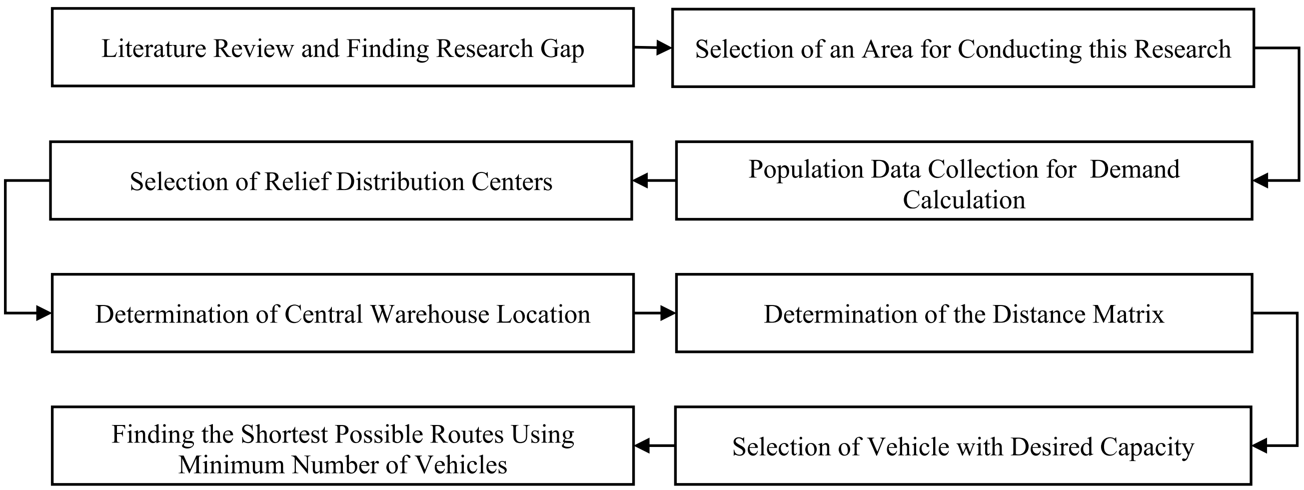

Figure 1. Flow diagram of Research Methodology

3.1 Research Steps
Step 01: This initial step involved reviewing existing literature on disaster relief logistics to identify gaps in current research. The aim was to determine areas where further research can provide valuable insights or improve existing models.
Step 02: In this step, the geographic area affected by disasters, particularly floods, was selected. For this research, the focus is on identifying a specific region where the model for relief distribution will be applied.
Step 03: Population data was collected from the target area to estimate the demand for relief supplies. Accurate population data helps in determining the quantity of supplies needed at each distribution point.
Step 04: This involved selecting key distribution centers within the affected area where relief supplies will be stored before being distributed to those in need.
Step 05: A central warehouse was selected or determined, where relief supplies will be stored before being dispatched to the various distribution centers. The optimal location minimized the distance and cost of distribution.
Step 06: At this stage, a distance matrix was created, showing the distances between the central warehouse and the distribution centers. This matrix helped in optimizing the routes for delivering supplies.
Step 07: Vehicles with appropriate capacities were selected for delivering the supplies. This step ensures that the vehicles used were suitable for carrying the required amounts of supplies efficiently.
Step 08: Using algorithms and optimization models, the shortest routes from the central warehouse to the distribution centers were determined. The goal was to minimize the number of vehicles required for delivery, reducing costs and ensuring quick delivery.

4. Methods and Materials
In this section, the key methodologies and models applied in this research are discussed, focusing on optimizing relief distribution through efficient warehouse location and vehicle routing strategies. The following approaches ensure effective delivery of aid in flood-affected regions.

4.1 Center of Gravity Model

The CoG model is a quantitative method used to determine the optimal location for a central warehouse or distribution center that minimizes transportation costs and distances between supply sources and demand points. This model takes into account the geographic locations of demand centers and their respective demand volumes, ensuring that the warehouse is positioned in a way that minimizes travel time and costs. The gravitational center is obtained using the formula.

$$\boldsymbol{C_x} = \sum \boldsymbol{D_{ix}} \times \boldsymbol{W_i} \Big/ \sum \boldsymbol{W_i}$$
$$\boldsymbol{C_y} = \sum \boldsymbol{D_{iy}} \times \boldsymbol{W_i} \Big/ \sum \boldsymbol{W_i}$$

Here,
C_x = x coordinate of CoG
C_y = y coordinate of CoG
D_{ix} = x coordinate of location *i*
D_{iy} = y coordinate of location *i*
W_i = Weight of location *i*

4.2 Capacitated Vehicle Routing Problem (CVRP)

The CVRP is an optimization problem focused on determining the most efficient way to deliver goods to a set of locations using a fleet of vehicles with fixed carrying capacities. In the context of disaster relief operations, such as flood relief distribution in Harirampur Upazila, the CVRP aims to minimize the total distance or cost of distributing relief supplies while respecting the capacity constraints of the vehicles used.
Formulation:
Sets:

- Node 0: The central warehouse(depot) is considered as node 0
  a) The depot has an unlimited number of goods
  b) The depot does not show any demand but introduce infinite supply
- *N*: The set of all distribution centers (i=1,……,n)
  N={1,………,n}, |*N*|=n

Model Parameters:
p: The number of identical vehicles which can use in distribution
a. p is also the number of routed we need to establish
b. The problem make sense when p<n
dij: The direct distance between node i and node j
i=0,….…,n , j=0,……..,n
Bidirectional distances are the same:
dij=dji ∀ i, j
The distance from a location to itself is simply zero.
d_{ii}=0 i=0,………,n
Decision Variables:
x_{ij}: A binary variable that indicates if the direct route from node i to node j is used(active) by a vehicle. i=0,………,n , j=0,………,n
x_{ij}=1 if a vehicle traverses from node i to node j, and 0 otherwise

The IP Model:
Minimize, $\sum_{i=0}^{n}, \sum_{j=0}^{n} d_{ij} x_{ij}$

Subject to:
$\sum_{i=0}^{n} x_{ij} = 1$ j=0,……….,n
$\sum_{j=0}^{n} x_{ij} = 1$ i=0,……….,n
$\sum_{j=0}^{n} x_{0j} = p$
$\sum_{i=0}^{n} x_{i0} = 1$
$\sum_{i\in s} \sum_{j\in s} x_{ij} \leq |S| - 1$, ∀S⊂N , S≠ϕ

5. Model Application

The Model Application section outlines the practical implementation of the proposed methodology for optimizing relief distribution in Harirampur Upazila. It includes the calculation of shortest routes, demand allocation, and vehicle capacity management using the CVRP approach.

5.1 Distribution Center Location Selection

In the event of flooding, people take shelter in adjacent high-rise buildings, especially educational institutions. Consequently, several elevated school and college structures from various regions of Harirampur have been chosen for the establishment of the relief distribution center. Expenditure on new facilities is unnecessary since the existing infrastructure is already established. Twenty-three distribution facilities shown in Table 1 have been identified, and their locations have been established with Google Maps.

Table 1. Location of Distribution Centers

Serial No.	Name	Latitude	Longitude
1	Patgram Anath Bandhu Govt. High School	23.741107	89.970781
2	Ibrahimpur Iswar Chandra High School	23.682266	90.022904
3	Jhitka Ananda Mohan High School	23.770907	89.914895
4	Boali High School	23.712059	90.038287
5	Diabari High School	23.762502	89.955908
6	Ramkrishnapur M A Jalil High School	23.751856	89.922906
7	Dakshin Chandpur High School	23.738983	90.001913
8	Jatrapur Adarsha High School	23.756978	89.982914
9	Balora Monno Adrsha Uchcha Bidya Niketon	23.750793	90.017993
10	Kobi Jahanara Arzu High School	23.776218	89.972231
11	Firoza Adarsha School	23.770731	89.874667
12	M.A. Razzak Adarsha High School	23.756237	89.972052
13	Notakhola High School	23.676961	89.921475
14	Azimnagar Union High School	23.657316	89.988781
15	Machain Govt. Primary School	23.776208	89.852632
16	M.A Rouf Degree College, Kowri	23.775044	89.935572
17	Govt. Justice Nurul Islam College	23.747367	89.985785
18	Golam Mohiuddin Kamol Ideal High School	23.769574	89.968796
19	Dorikandi Government primary school	23.797401	89.908201
20	Sutalori-Kodaliya Govt. Primary School	23.750564	89.997826
21	Balurchar Government primary school	23.749543	89.948930
22	Sutalari Ramchandrapur govt. Primary school	23.671624	89.965950
23	Kanchanpur Govt Primary School	23.751095	89.874259

A map of Harirampur was made using ArcGIS applications, with the locations of the distribution centers shown in Figure 2.

Figure 2. Distribution centers pointed on the map

5.2 Population Data Collection

The population statistics by union for Harirampur, Manikganj was obtained from the Bangladesh Bureau of Statistics website, as shown in Table 2.

Table 2. Union-wise Population of Harirampur Upazilla (2022 Bangladeshi Census, n.d.)

Name of Union	Area (Acre)	Population		
		Male	Female	Total
Azimnagar	4244	6749	6022	12771
Kanchanpur	7725	3330	3190	6520
Gala	4898	11043	10975	22018
Gopinathpur	4406	7190	6905	14095
Chala	4952	9494	10021	19515
Dhulsunra	4169	3769	4172	7941
Boyra	4037	5846	6540	12386
Balara	2707	8013	9396	17409
Balla	3497	11577	11057	22634
Ramkrishnapur	3897	5354	6011	11365
Lesraganj	8310	6933	6257	13190
Sutalari	2866	3705	3536	7241
Harukandi	3928	1991	2198	4189

The whole population was uniformly allocated among the nearest distribution locations shown in Table 3.

Table 3. Population distribution among Distribution Centers

Union Name	**Distribution Centers**	**Distributed Population**
Balla	Firoza Adarsha School	11317
	Machain Govt. Primary School	11317
Galla	Dorikandi Government primary school	11009
	M.A Rouf Degree College	11009
Chala	Kobi Jahanara Arzu High School	4878
	Golam Mohiuddin Kamol Ideal High School	4879
	Diabari High School	4878
	M.A. Razzak Adarsha High School	4880
Balara	Sutalori-Kodaliya Govt. Primary School	8705
	Balora Monno Adrsha Uchcha Bidya Niketon	8704
Kanchanpur	Kanchanpur Govt Primary School	6520
Gopinathpur	Jhitka Ananda Mohan High School	14095
Ramkrisnapur	Balurchar Government primary school	5683
	Ramkrishnapur M A Jalil High School	5682
Boyra	Patgram Anath Bandhu Govt. High School	4130
	Jatrapur Adarsha High School	4128
	Govt. Justice Nurul Islam College	4128
Harukandi	Dakshin Chandpur High School	4189
Lesraganj	Notakhola High School	13190
Sutalari	Sutalari Ramchandrapur govt. Primary school	7241
Azimnagar	Azimnagar Union High School	12771
Dhulsunra	Ibrahimpur Iswar Chandra High School	3971
	Boali High School	3970

5.3 Setting Up a Central Warehouse

The central warehouse was established via the CoG approach, with Python code created to compute the weighted CoG. The populations of different distribution centers were used as weights, resulting in the designation of the warehouse site as Node 0. Details of the warehouse location are delineated in Table 4 and shown in Figure 3.

Table 4. Warehouse Location

Node	**Latitude**	**Longitude**
0	23.742795	89.944637

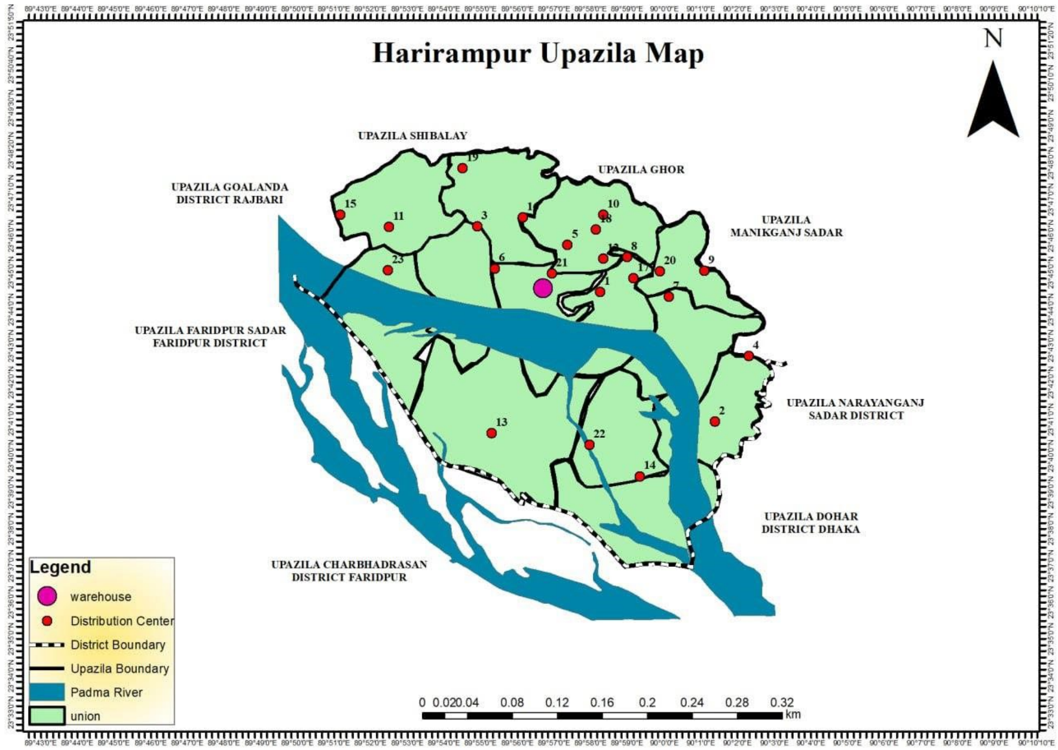

Figure 3. Warehouse location in the map of Harirampur

5.4 Determination of Distance matrix

A total of 24 nodes were discovered, including the warehouse. The direct distances between all nodes were measured using Google Maps and combined into a distance matrix. The computed distances, measured in kilometers, are shown in the distance matrix, provided in Table 5.

5.5 Finding the Shortest Routes

The CVRP approach was used to ascertain the most efficient routes for relief distribution. Python code was created to address this issue, using the distance matrix, demand for each distribution center, and vehicle capacity (25 tons per boat) as inputs. The distance matrix has already been calculated. Demand at each distribution center was determined using population statistics, supposing 4.3 people per family, with each household allocated 5 kg of emergency supplies (Esri, 2022). Table 6 displays the demand for each distribution facility.

Findings revealed that nine routes were generated for the vehicles, each covering different nodes:

1. Vehicle 1: Route 0 > 2 > 1 > 0, Distance: 21.52 km, Load: 9.425 tons.
2. Vehicle 2: Route 0 > 5 > 3 > 0, Distance: 11.1 km, Load: 22.065 tons.
3. Vehicle 3: Route 0 > 11 > 7 > 6 > 0, Distance: 31.8 km, Load: 24.640 tons.
4. Vehicle 4: Route 0 > 13 > 8 > 4 > 0, Distance: 36.23 km, Load: 24.760 tons.
5. Vehicle 5: Route 0 > 14 > 9 > 0, Distance: 28.84 km, Load: 24.975 tons.
6. Vehicle 6: Route 0 > 15 > 12 > 10 > 0, Distance: 29.3 km, Load: 24.510 tons.
7. Vehicle 7: Route 0 > 18 > 17 > 16 > 0, Distance: 16.54 km, Load: 23.280 tons.
8. Vehicle 8: Route 0 > 20 > 19 > 0, Distance: 23.09 km, Load: 22.930 tons.
9. Vehicle 9: Route 0 > 23 > 22 > 21 > 0, Distance: 48.84 km, Load: 22.615 tons.

The total distance covered by all routes was 247.26 km, and the total load carried across all routes was 199.2 tons. This analysis effectively demonstrates how relief supplies can be distributed efficiently using a limited number of vehicles over the shortest possible routes.

Table 5. Distance matrix

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
0	0	2.67	10.43	4.35	10.13	2.47	2.43	5.85	4.2	7.52	4.66	7.77	3.17	7.69	10.51	10.07	3.7	4.22	3.86	7.11	5.48	19.93	8.21	7.22
1	2.67	0	8.42	6.58	7.59	2.82	5.02	3.18	2.15	4.93	3.91	10.32	1.69	8.72	9.5	12.64	5.2	1.68	3.17	8.95	2.95	2.41	7.74	9.87
2	10.43	8.42	0	14.77	3.66	11.23	12.79	6.66	9.25	7.64	11.65	18.01	9.72	10.35	4.45	20.24	13.62	8.17	11.16	17.33	8.01	10.45	5.92	16.96
3	4.35	6.58	14.77	0	14.16	4.28	2.27	9.54	7.09	10.73	5.86	4.09	6.04	10.47	14.7	6.36	2.15	7.67	5.49	3.02	8.74	4.2	12.2	4.69
4	10.13	7.59	3.66	14.16	0	10.09	12.55	4.76	7.53	4.78	9.8	17.89	8.34	12.52	7.9	20.2	12.58	6.63	9.54	16.29	5.94	10	8.63	17.25
5	2.47	2.82	11.23	4.28	10.09	0	3.56	5.37	2.82	6.44	2.25	8.32	1.78	10.14	12.17	10.62	2.49	3.47	1.52	6.21	4.47	1.62	10.16	8.41
6	2.43	5.02	12.79	2.27	12.55	3.56	0	8.17	6.13	9.67	5.7	5.35	5.02	8.33	12.47	7.65	2.88	6.41	5.06	5.29	7.62	2.66	9.09	4.95
7	5.85	3.18	6.66	9.54	4.76	5.37	8.17	0	2.78	2.09	5.13	13.43	3.6	10.71	9.18	15.75	7.86	1.9	4.8	11.54	1.36	5.48	9.94	13.06
8	4.2	2.15	9.25	7.09	7.53	2.82	6.13	2.78	0	3.63	2.41	11.13	1.11	10.88	11.1	13.43	5.23	1.1	2.01	8.84	1.68	3.56	9.65	11.08
9	7.52	4.93	7.64	10.73	4.78	6.44	9.67	2.09	3.63	0	5.45	14.75	4.71	12.8	10.81	17.06	8.81	3.3	5.43	12.31	2.05	7.02	10.27	14.63
10	4.66	3.91	11.65	5.86	9.8	2.25	5.7	5.13	2.41	5.45	0	9.95	2.22	12.19	13.33	12.17	3.74	3.5	0.82	6.93	3.87	3.8	11.65	10.35
11	7.77	10.32	18.01	4.09	17.89	8.32	5.35	13.43	11.13	14.75	9.95	0	10.04	11.47	17.15	2.32	6.22	11.6	9.58	4.53	12.74	7.92	14.42	2.18
12	3.17	1.69	9.72	6.04	8.34	1.78	5.02	3.6	1.11	4.71	2.22	10.04	0	9.99	11.13	12.35	4.26	1.71	1.52	7.95	2.7	2.47	9.43	9.97
13	7.69	8.72	10.35	10.47	12.52	10.14	8.33	10.71	10.88	12.8	12.19	11.47	9.99	0	7.19	13.08	11	10.2	11.37	13.47	11.29	8.54	4.57	9.54
14	10.51	9.5	4.45	14.7	7.9	12.17	12.47	9.18	11.1	10.81	13.33	17.15	11.13	7.19	0	19.15	14.16	10.02	12.65	17.6	10.41	11.03	2.82	15.64
15	10.07	12.64	20.24	6.36	20.2	10.62	7.65	15.75	13.43	17.06	12.17	2.32	12.35	13.08	19.15	0	8.44	13.92	11.84	6.13	15.05	10.24	16.38	3.56
16	3.7	5.2	13.62	2.15	12.58	2.49	2.88	7.86	5.23	8.81	3.74	6.22	4.26	11	14.16	8.44	0	5.97	3.43	3.73	6.9	3.15	11.91	6.78
17	4.22	1.68	8.17	7.67	6.63	3.47	6.41	1.9	1.1	3.3	3.5	11.6	1.71	10.2	10.02	13.92	5.97	0	3.01	9.66	1.28	3.75	8.66	11.36
18	3.86	3.17	11.16	5.49	9.54	1.52	5.06	4.8	2.01	5.43	0.82	9.58	1.52	11.37	12.65	11.84	3.43	3.01	0	6.89	3.64	3	10.9	9.84
19	7.11	8.95	17.33	3.02	16.29	6.21	5.29	11.54	8.84	12.31	6.93	4.53	7.95	13.47	17.6	6.13	3.73	9.66	6.89	0	10.5	6.75	15.17	6.2
20	5.48	2.95	8.01	8.74	5.94	4.47	7.62	1.36	1.68	2.05	3.87	12.74	2.7	11.29	10.41	15.05	6.9	1.28	3.64	10.5	0	4.98	9.36	12.58
21	19.93	2.41	10.45	4.2	10	1.62	2.66	5.48	3.56	7.02	3.8	7.92	2.47	8.54	11.03	10.24	3.15	3.75	3	6.75	4.98	0	8.84	7.6
22	8.21	7.74	5.92	12.2	8.63	10.16	9.09	9.94	9.65	10.27	11.65	14.42	9.43	4.57	2.82	16.38	11.91	8.66	10.9	15.17	9.36	8.84	0	12.85
23	7.22	9.87	16.96	4.69	17.25	8.41	4.95	13.06	11.08	14.63	10.35	2.18	9.97	9.54	15.64	3.56	6.78	11.36	9.84	6.2	12.58	7.6	12.85	0

Table 6. The Demand of the Distribution Centers

Serial No.	Name	Demand (Tons)
1	Patgram Anath Bandhu Govt. High School	4.805
2	Ibrahimpur Iswar Chandra High School	4.62
3	Jhitka Ananda Mohan High School	16.39
4	Boali High School	4.62
5	Diabari High School	5.675
6	Ramkrishnapur M A Jalil High School	6.61
7	Dakshin Chandpur High School	4.87
8	Jatrapur Adarsha High School	4.8
9	Balora Monno Adrsha Uchcha Bidya Niketon	10.125
10	Kobi Jahanara Arzu High School	5.675
11	Firoza Adarsha School	13.16
12	M.A. Razzak Adarsha High School	5.675
13	Notakhola High School	15.34
14	Azimnagar Union High School	14.85
15	Machain Govt. Primary School	13.16
16	M.A Rouf Degree College, Kowri	12.805
17	Govt. Justice Nurul Islam College	4.8
18	Golam Mohiuddin Kamol Ideal High School	5.675
19	Dorikandi Government primary school	12.805
20	Sutalori-Kodaliya Govt. Primary School	10.125
21	Balurchar Government primary school	6.61
22	Sutalari Ramchandrapur govt. Primary school	8.42
23	Kanchanpur Govt Primary School	7.585
Total		**199.2**

6. Conclusion

This study introduces a detailed model for enhancing flood relief distribution in Harirampur Upazila, Bangladesh, using the CVRP to tackle the complexities of post-disaster relief logistics. The research illustrated a strategy for the optimal allocation of relief goods during flood situations by evaluating geographical data and determining the shortest paths between 23 relief distribution stations and a central warehouse. The model included essential parameters such the population density of each distribution zone, the need for emergency supplies, and the capacity of watercraft.

The analysis demonstrated substantial improvements in resource use via the optimized routes, resulting in lower travel lengths and a streamlined distribution procedure that minimized the required visits. The cumulative distance traversed by all vehicles was 247.26 km, carrying a total load of 199.2 tons of relief supplies. This method emphasizes the need of incorporating real-time data, including population distribution and transportation capacity, into crisis management strategies. Utilizing mathematical models like as CVRP enhances the efficiency, timeliness, and cost-effectiveness of relief operations, therefore guaranteeing that essential help reaches impacted areas more swiftly.

This research provides a pragmatic framework for relief efforts that may be modified for other flood-prone areas with comparable logistical difficulties. The use of these optimization models might revolutionize disaster management procedures by facilitating fair and efficient relief distribution, alleviating suffering, and preserving lives during future flood occurrences.

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