Cyclone Evacuation Route Identification Using ArcGIS, and recommended new cyclone shelter in Koyra Upazila, Khulna, Bangladesh.

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Abstract: Evacuation is a critical preparedness measure to safeguard people from the severe impacts of cyclones. Selecting the right evacuation route is vital for an effective evacuation during cyclones. In our study, we utilized Geographic Information System to plan evacuation routes for Koyra upazila in Khulna, Bangladesh, and to establish an evacuation route using shortest distance analysis. The aim is to identify suitable nearby shelters. The study recommends building 21 new cyclone shelters with a population capacity of 23375. Our findings reveal that only 17% of the total population can be accommodated by the current official shelter capacity. However, by adding the new suggested cyclone shelters, 26% of the total population can be accommodated. This research underscores the significance of optimal evacuation route planning in the coastal regions of Bangladesh.

Keywords: Cyclone shelters, Evacuation route, Geographic information system, Bangladesh.

1. Introduction

Bangladesh is one of the top vulnerable countries to the climate change and the adverse impact on the country will be catastrophic because of convergence of climate change, poverty and large population. The frequency of natural disasters like floods, cyclones etc have increased significantly over the last decade particularly in the coastal line of Bangladesh which is asserted as the impact of climate change. The consequences of these disasters are a huge loss of lives and properties that implicates the economy of the country. So disaster management is now an important concern to minimize all those losses. Disaster management of an event like Cyclone, Flood or Earthquake etc (Md. Sohel Rana, 2010). Cyclones and tidal surges have frequently devastated lives and property in coastal and island Bangladesh(Edris Alam A. E., 2010). Bangladesh is frequently visited by natural disasters such as tropical cyclones, storm surges, floods, droughts, tornadoes, and "norwesters." Of these, tropical cyclones originating in the Bay of Bengal and associated storm surges are the most disastrous. There are various reasons for the disastrous effects of cyclones and storm surges in Bangladesh(Ali, 1996). The number of deaths owing to tropical cyclones in Bangladesh has significantly reduced. Category 4 Cyclone Gorky in 1991 and Sidr in 2007 caused 147,000 and 4,500 deaths respectively, whereas Category 1 Cyclone Mora in 2017 resulted in six. Face-to-face interviews with 362 residents, participant observation, and focus-group discussions answer a research question about how change in coastal areas has contributed to this outcome(Edris Alam A. E., 2023). While there is increasing evidence on the trends and impacts of climate change, both globally and in Bangladesh, there is a limited quantitative analysis on the impacts of natural disasters on population health and the association with socio-economic characteristics(Sayem Ahmed, 2019).Cyclones always affect the livelihood patterns of the human being. Although several studies measured only the immense impact of cyclone Aila which hit in the southern part of Bangladesh in 2009, very few studies concentrated on exploring impacts of the cyclone together with its coping strategies(Chanda1, 2020). Risk assessment as well as risk perceptions play a vital role in disaster risk reduction through formulating and implementing disaster risk reduction (DRR) policies and interventions(Md. Abdus Sattar a b, 2019). Typhoons are tropical revolving storms. They are called `Cyclones' in English, when they occur in the Indian Ocean area. The coastal regions of Bangladesh are subject to damaging cyclones almost every year. They generally occur in early summer (April-May) or late rainy season (October-November). Cyclones originate from low atmospheric pressures over the Bay of Bengal. Due to unique geographic location, Bangladesh suffers a lot from devastating tropical cyclones frequently (Irin Hossain, 2020) .Tropical cyclones affecting south Asia originate over surrounding oceans, especially in the Bay of Bengal. They require at least five conditions to form and develop: low pressure at the surface; abundant moist air capable of convective or upward movement in the atmosphere; ocean surface temperatures over 26–27 degrees Celsius; small wind shear; the rate at which wind strength and direction change with height in the atmosphere (especially for the taller more intense systems); and the power of the Earth's rotation to spin the system into a rotating vortex (Irin Hossain, 2020). Bangladesh is highly susceptible to tropical cyclones. Unfortunately, there is a dearth of climatological studies on the tropical cyclones of Bangladesh. The Global Tropical Cyclone Climatic Atlas (GTCCA) lists historical storm track information for all the seven tropical cyclone ocean basins including the North Indian Ocean (Tanveerul Islam, 2008).Coastal Bangladesh is one of the hotspots of tropical cyclone’s landfall in South Asia. A spatial vulnerability assessment is required to formulate disaster risk reduction strategies (Muhammad Al-Amin Hoque, 2021).This study aims to develop a route map to cyclone shelters so that people can easily access them. Additionally, we aim to determine the shortest time and distance to reach these shelters, as well as calculate their capacity. We also plan to suggest a few buildings suitable for use as cyclone shelters.

2. Materials and Methods

The research is based on secondary data. To find suggested new cyclone shelters, we collected building structure data from Google Maps and Google Earth. We considered buildings with at least two floors as potential cyclone shelters. After collecting the data, we used ArcGIS 10.1 and Microsoft Excel for analysis. ArcGIS 10.1 was utilized for developing maps, geographic data analysis, editing, data management, and geo-processing activities. It was also used to find the closest shelter facility location by Network analysis method. This study proposes realistic evacuation planning with the shortest route to shelters.

2.1 Study Area

The Upazila Koyra of Khulna district, Koyra upazila (Amadi union, Bagali Union , Dakshin Bedkashi union, Koyra union, Maharajpur union, Maheshwaripur union, Uttar Bedkashi union) is one of the most vulnerable upazila to cyclone hazard. Area of Koyra Upazila 1775.40 sq km, located in between 22°12' and 22°31' north latitudes and in between 89°15' and 89°26' east longitudes.Total amount of road is near about 696.09 kilometers, among these paved roads are 434.36 km, herring bond roads are 10 km and earthen roads are 261.73km. There are 67 secondary schools and madrasha, 142 primary schools. Main source of income is agriculture with 8527 acres of cultivable land. Due to the geographical location that union has been severely affected by 2007 cyclone Sidr and 2009 Aila. Figure 2.1 shows the location of study area.

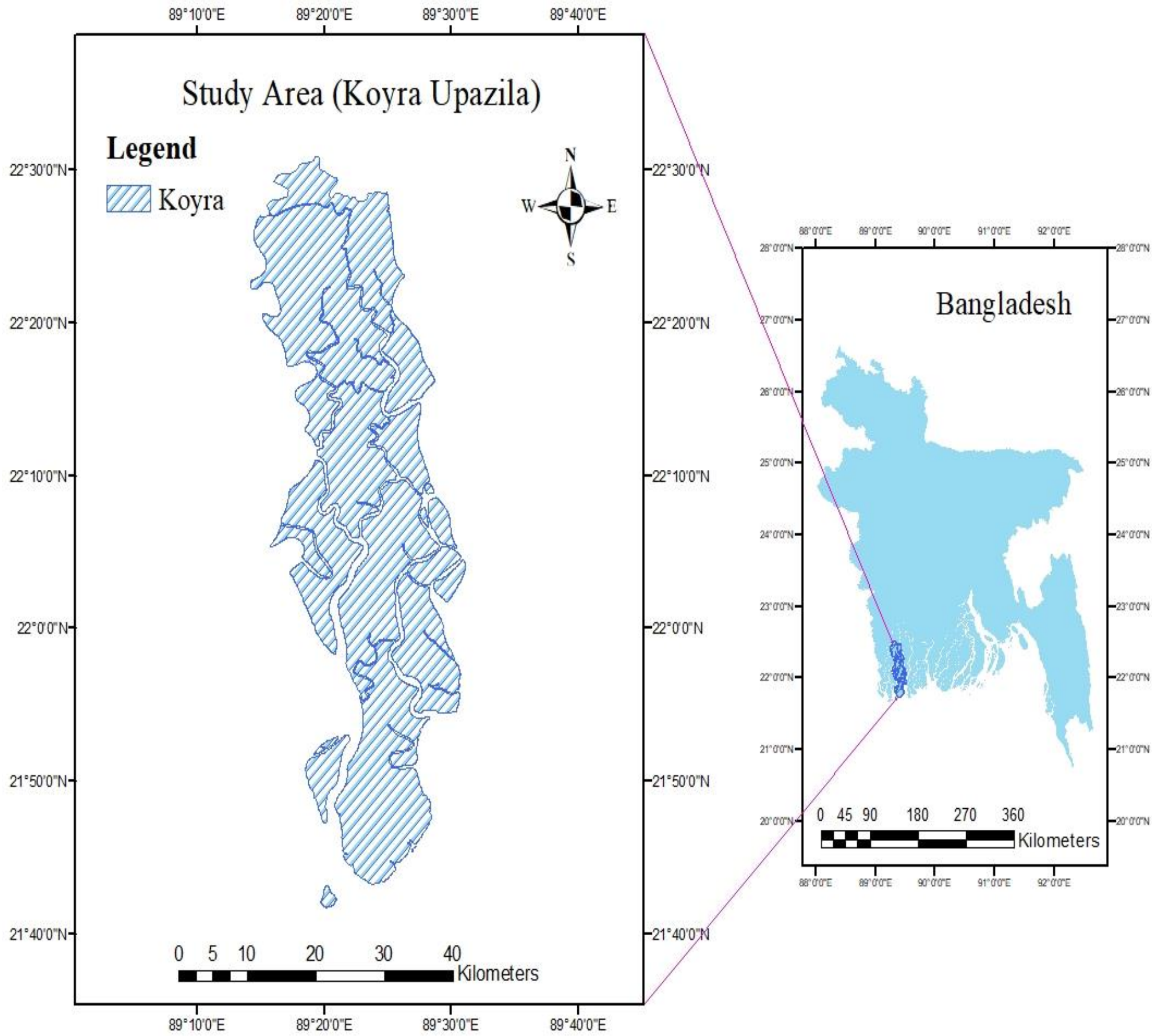


Figure 2.1 Study Area Koyra Upazila

3. Results and Discussion

Koyra Upazila is bounded by the Dharla, Pasur, Arpangachhia, Taldhup, Malancha, Kabadak and Ball, and there are 7 union in this upazila, Koyra has 133 villages. Total population is 238,426. Among them Amadi union population is 40200, Bagali union population is 34177, Dakhin-Bedkashi union population is 28700, Koyra union population is 59080, Mahrajpur union population is 31068, Maheswaripur union population is 29976, and Uttar-Bedkashi union population is 15225. Here most of the people are farmers and small shopkeepers.

3.1 Condition of the Existing Cyclone Shelters.

In koyra upazila area there are 39 cyclone shelters (Table 3.1 and Table 3.2). The shelters buildings are primarily used as schools, high school and union-parishad. Shelters are designed in such a way that both human and livestock can take refuge there. The official capacity of cyclone shelter is 38575 people.

Table 3.1 List of Old Cyclone Shelter Name of Koyra Upazila.

Old Cyclone shelter Name	Union Name	Floor_Space	Nos Floor	Population Capacity
Bedkashi Borobari Government Primary School		1650	2	825
Bedkashi Government Primary School		1650	2	825
Bedkashi Collegiate School	Uttar Bedkashi	2100	2	1050
Hariharpur Government Primary School		900	2	450
				:3150
Purba Maheshpur Shapla Registered Primary School		1750	2	875
Modhya Moheswaripur Primary School cum Cyclone Shelter		1750	2	875
Dakshin Gilabari Gov Primary School		3600	2	1800
Maheshwari Union Complex Bhaban		4050	3	2025
Govt. Hadda majher chalk primary school		3600	2	1800
2 NO Mosque kur Government Primary School	Maheshwaripur	1750	2	875
Hadda D.M. Secondary School, Khulna		3600	2	1800
Chaukuni Adorsho Govt. Primary School		900	2	450
Maheswaripur high school		3600	2	1800
				:12300
Deara Antabunia primary school		1650	2	825
Maharajpur Union Complex		4050	3	2025
Mothbari Shantimoyi Govt. Primary School	Maharajpur	3600	2	1800
Kalna govt primary school		900	2	450
Kalna Amenia Fajil Madrasha		900	2	450
				:5550

Table 3.2 List of Old Cyclone Shelter Name of Koyra Upazila.

Old Cyclone shelter Name	Union Name	Floor_Space	Nos Floor	Population Capacity
Uttar Madinabad Government Primary School	Koyra	1400	2	700
Gobra Primary school		1650	2	825
41 No. Gobra Ghatakhali Government Primary School		1650	2	825
4 No. Koyra Pallimangal Government Primary School		1650	2	825
Gariabari Government Primary School		1650	2	825
3 No. Koyra Government Primary School		1650	2	825
Koyra Madinabad government model secondary School		1650	2	825
2 No Koyra Government Primary School		1650	2	825
				=6475
Dakshin Bedkashi High School	Dakshin Bedkashi	1700	2	850
GoalKhali Govt. Primary School		1700	2	850
Jorshing Govt. Primary, School		900	2	450
				=2150
Bagali Union Council (Koyra Upazila)	Bagali	4050	3	2025
Sreefaltala Cyclone Centre & Govt. Primary School		1400	2	700
Kushodanga Alim Madrasa		900	2	450
				=3175
Jaygirmohal goverment Primary school	Amadi	1650	2	825
Kheona Gov't Primary School		1650	2	825
2 NO Mosque kur Government Primary School		1650	2	825
Bhanderpole primary school		1650	2	825
Amadi Jagirmahal Takimuddin High School		1650	2	825
1 No Naksha Government Primary School		1650	2	825
43 No Koyra Monglai Government Primary School		1650	2	825
				=5775
			Total Population Capicty	**38575**

3.2 Condition of the New (Suggested) Cyclone Shelters.

In koyra upazila area there are 21 New (Suggested) Cyclone Shelters (Table 3.3). The shelters buildings are primarily used as schools, high school, madrasha and union parishad. Shelters are designed in such a way that both human and livestock can take refuge there. The official capacity of cyclone shelter is 23375 people.

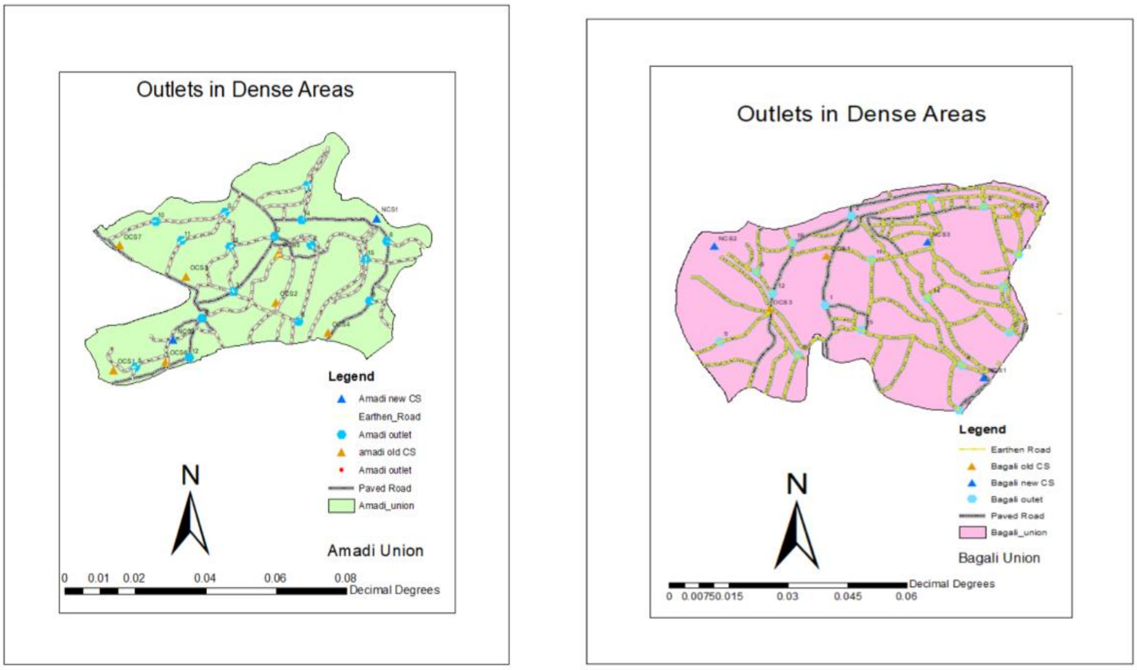
Table 3.3 List of New (Suggested) cyclone Shelter Name of Koyra Upazila.

New Cyclone shelter Name (Suggested)	Union Name	Nos Floor	Population Capacity
Channir Chak LC Collegiate School	Amadi	2	850
Zaliakhali Government Primary School		2	850
			=1750
Malikhali Government Primary School	Bagali	4	1700
Lalua Bagali M.M. High School		2	850
Baropota Govt. Primary School		2	850
			=3400
Dakshin Bedkashi Union Council	Dakhin-Bedkashi	2	850
Angtihara Government Primary School		3	1275
kopothakkho Secondary School		2	1275
			=3400
Koyra Upazila Parishad	Koyra	5	2125
Koyra Government Women's College		2	850
Khejurbagh Govt. Primary School		2	850
			=3825
Purba Bania Khamar Govt. Primary School	Maharajpur	2	850
Mothbari Bauliaghata Govt. Primary School		2	850
46 No Patakhali Govt. Primary School		3	1275
			=2975
Parshemari 54 no govt primary school	Maheshwaripur	2	850
Baniakhali Sundarban Govt. Primary School		3	1275
Kalikapur choukuni High School		2	850
Baburabad Government Primary School		2	850
Vhagba H. B. High School, Koyra, Khulna.		2	850
			=5525
Bedakashi Habibia Dakhila Madrasa	Uttar Bedkashi	2	850
Koyra Shakbaria School & College		4	1700
			=2550
		Total Population	**=23375**

3.3 Evacuation Route Analysis.

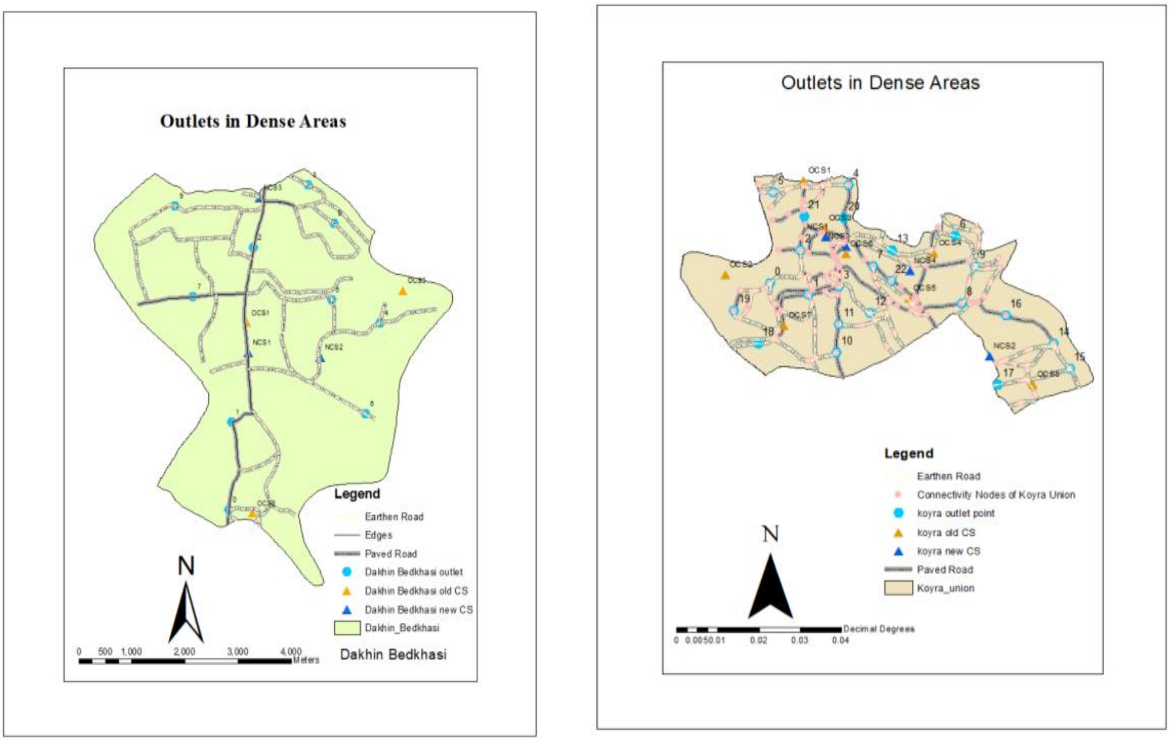
The union currently lacks a proper evacuation plan, despite improvements in Bangladesh's warning system. Evacuation remains a challenge due to the absence of a government plan. If there were designated shortest routes for densely populated areas leading to cyclone shelters, people would be able to reach the shelters efficiently. In our analysis, we considered cyclone shelters as entry points where people could seek refuge, and we identified specific locations within densely populated areas as exit points from which people could gather and evacuate to the shelters. In this study, we identified in total 7 union of 120 evacuation points (outlet points) around the study area based on their accessibility to shelters and distance from main roads. These oulet points are located at or near significant roads.

Figure (3.1 to 3.4) shows the outlets in the densely populated areas from where maximum people can be evacuated to the shelters.



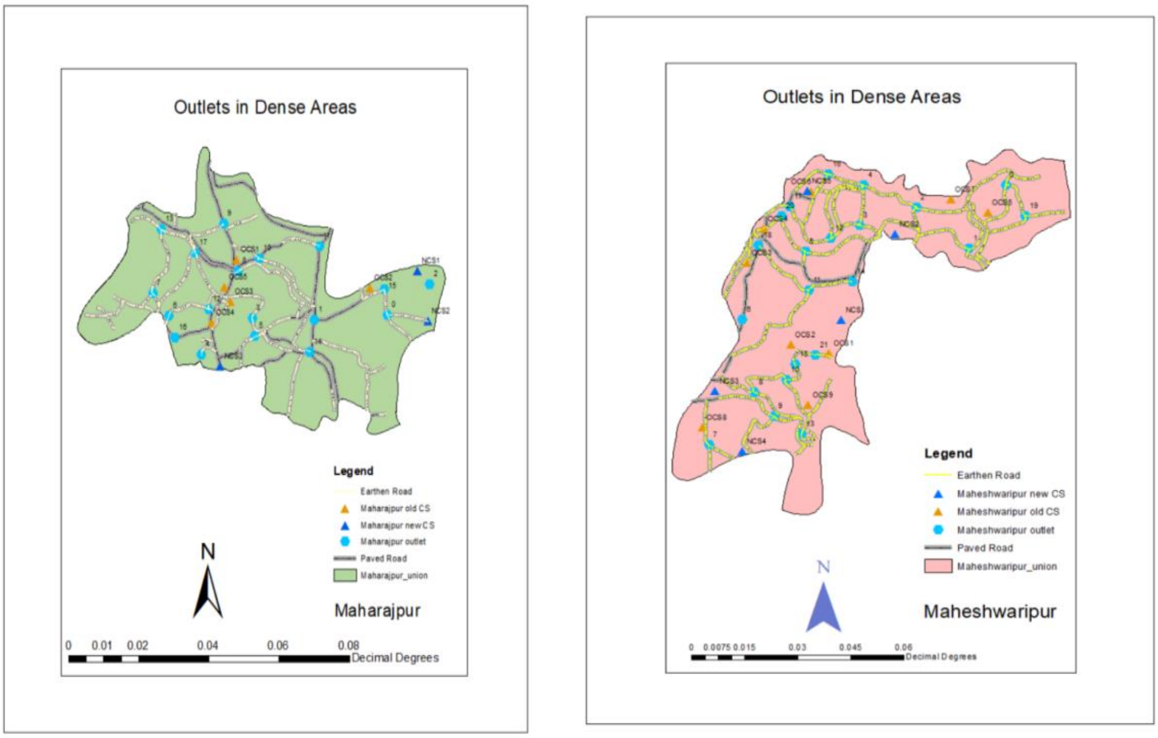
(a) (b)

Figure 3.1: (a) Outlets and Inlets in Amadi Union (b) Outlets and Inlets in Bagali Union



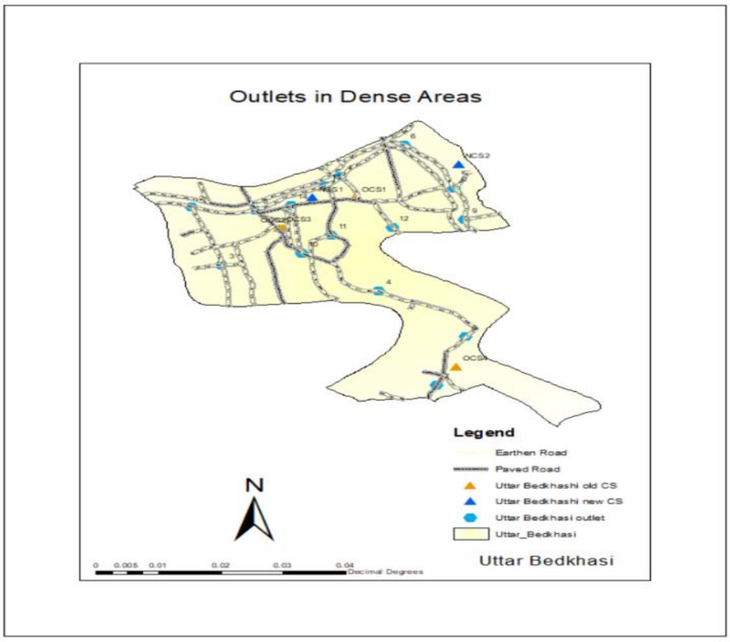
(a) (b)

Figure 3.2: (a) Outlets and Inlets in Dakhin-Bedkashi union (b) Outlets and Inlets in Koyra union



(a) (b)

Figure 3.3: (a) Outlets and Inlets in Mahrajpur union (b) Outlets and Inlets in Maheswaripur union



(a)

Figure 3.4:(a) Outlets and Inlets in Uttar-Bedkashi union

In figures (3.5 to 3.11) the shortest distance from each outlet to the nearest shelter is displayed. The shortest distance from every outlet to the inlet has been analyzed using the

Network Analysis Tool in ArcGIS 10.1 There are a total of 60 inlets. For shelter (figure 3.5) the shortest distance is 694.53 meters from the outlet marked as OCS1O5 (where OCS1 represents Old Cyclone Shelter 1 and O5 represents outlet 5). The shortest distance is 1122.55 meters from the outlet marked as NCS2O4 (where NCS2 represents New Cyclone Shelter 2 and O4 represents outlet 4).

We have developed this analysis with the outlets as centers and a 700m radius to assume the number of people covered for evacuation. The analysis reveals the following numbers of people who can be evacuated to shelters, representing 80% of the total population of each union: Amadi union: 32160 Bagali union: 27342 Dakhin-Bedkashi union: 22960 Koyra union: 47264 Mahrajpur union: 24855 Maheswaripur union: 23981 Uttar-Bedkashi union: 12180.Time is also a crucial factor for real-time evacuation. The shortest distance, along with the shortest time, can be the best solution to estimate the time it will take to move to the shelters. However, during cyclones, factors such as connectivity nodes may affect the travel time.

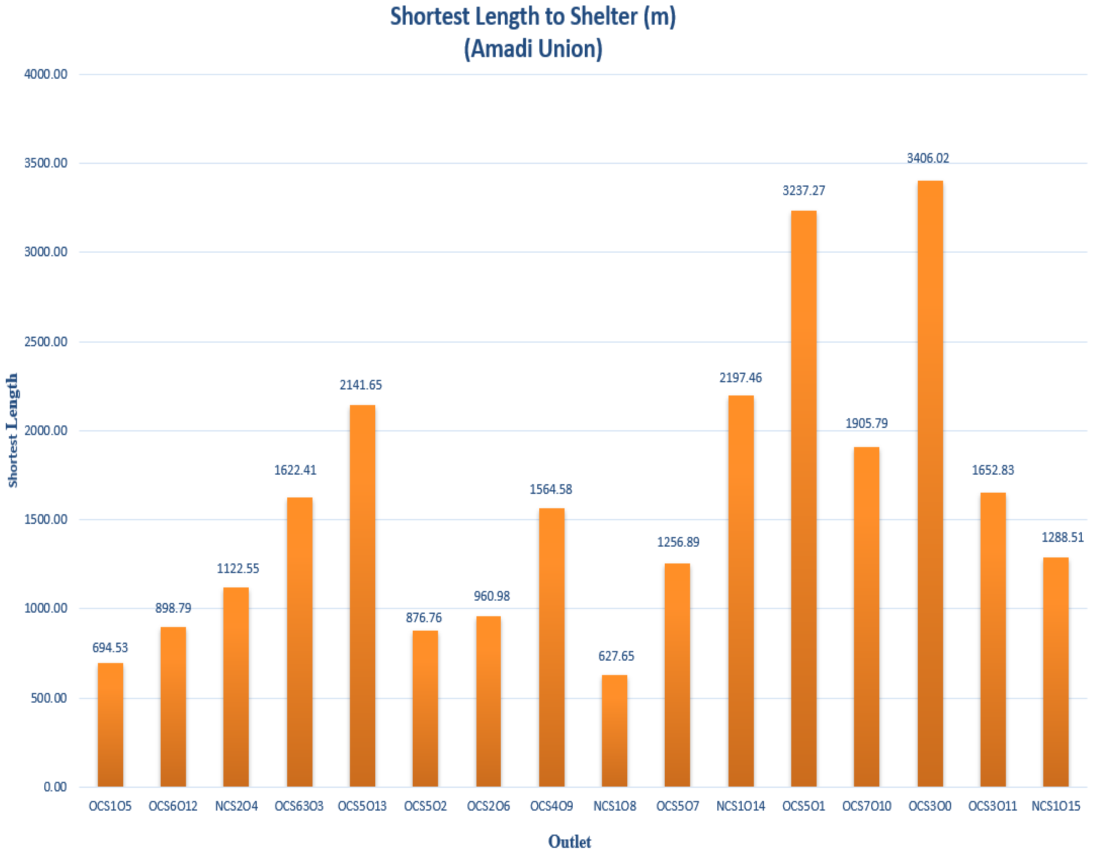


Figure 3.5**:** Shortest length to Shelters (Amadi Union)

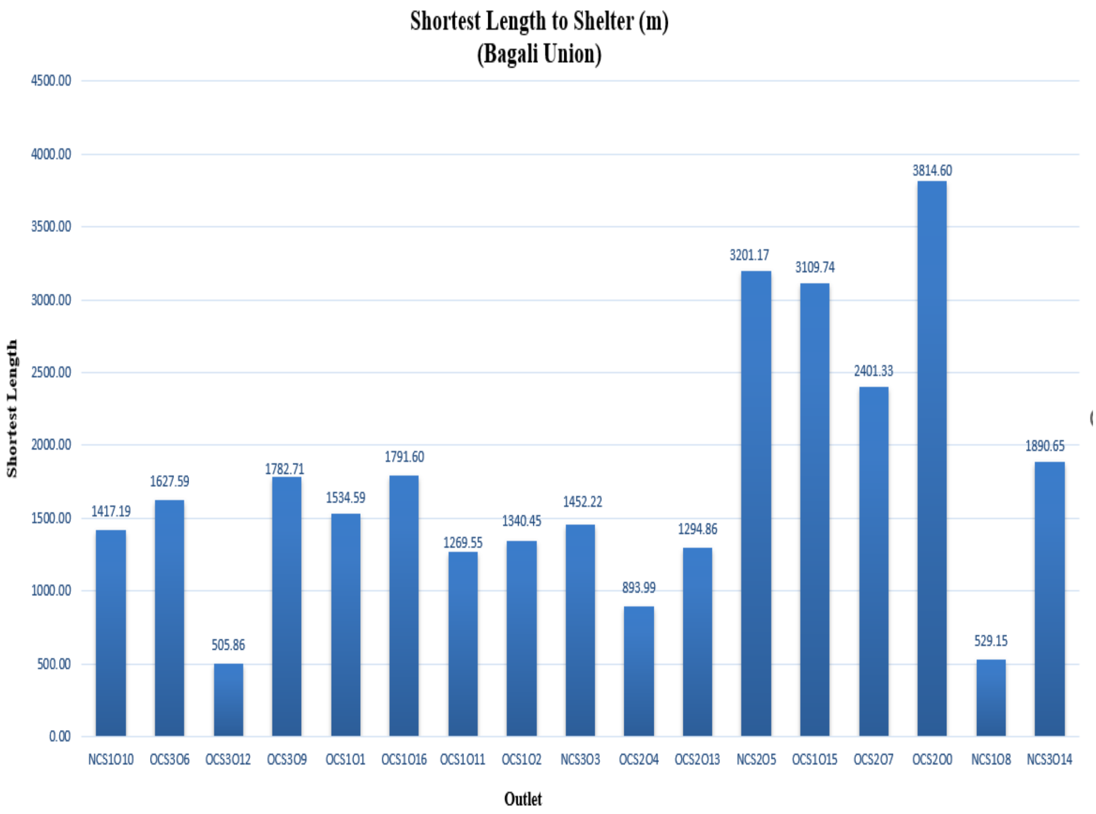


Figure 3.6: Shortest length to Shelters (Bagali Union)

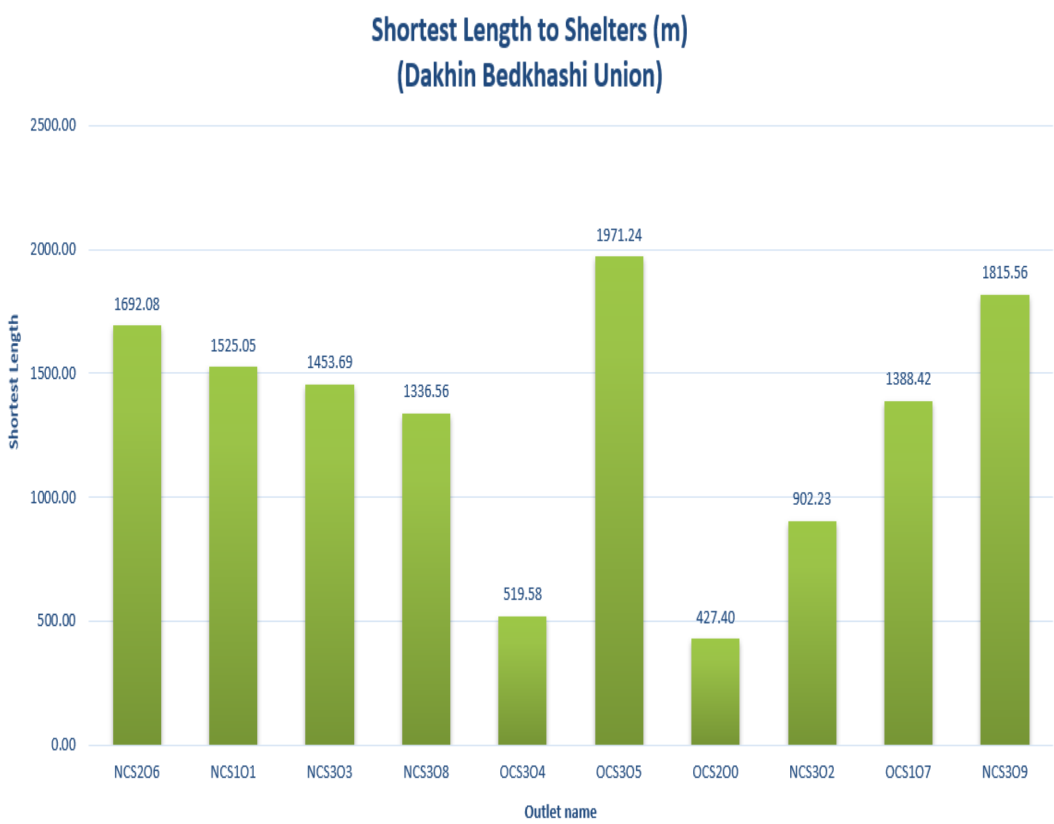


Figure 3.7: Shortest length to Shelters (Dakhin-Bedkashi Union)

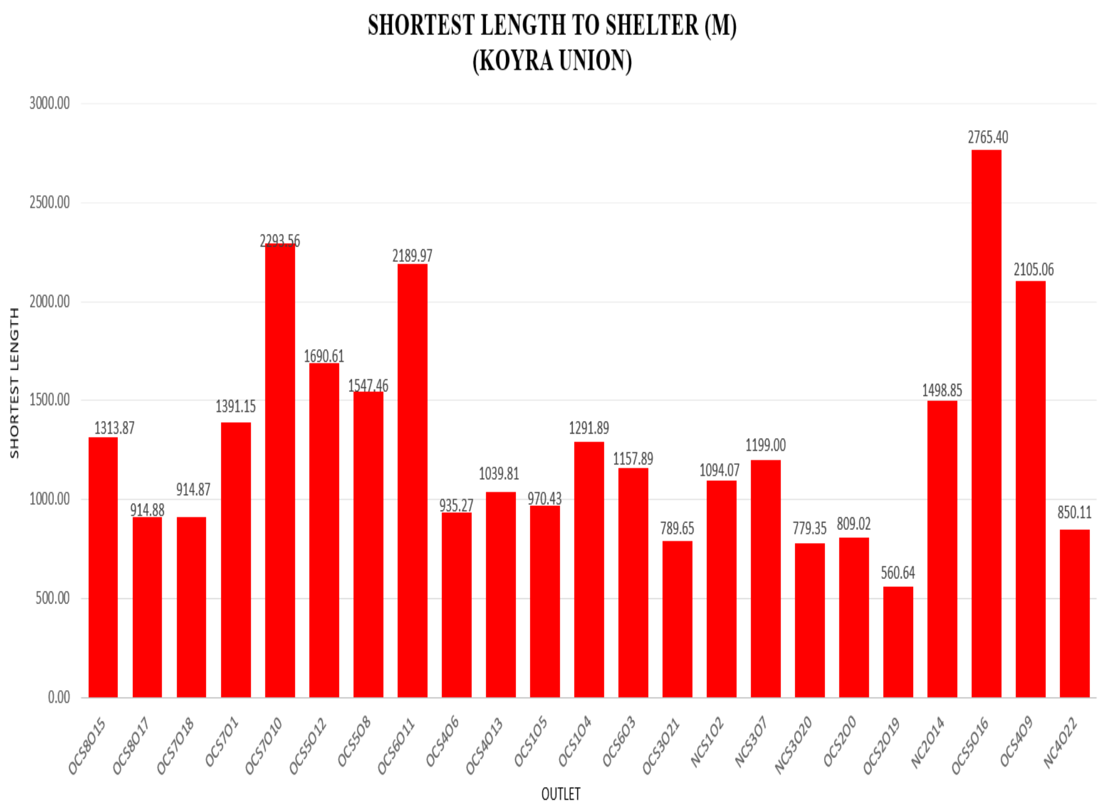


Figure 3.8**:** Shortest length to Shelters (Koyra Union)

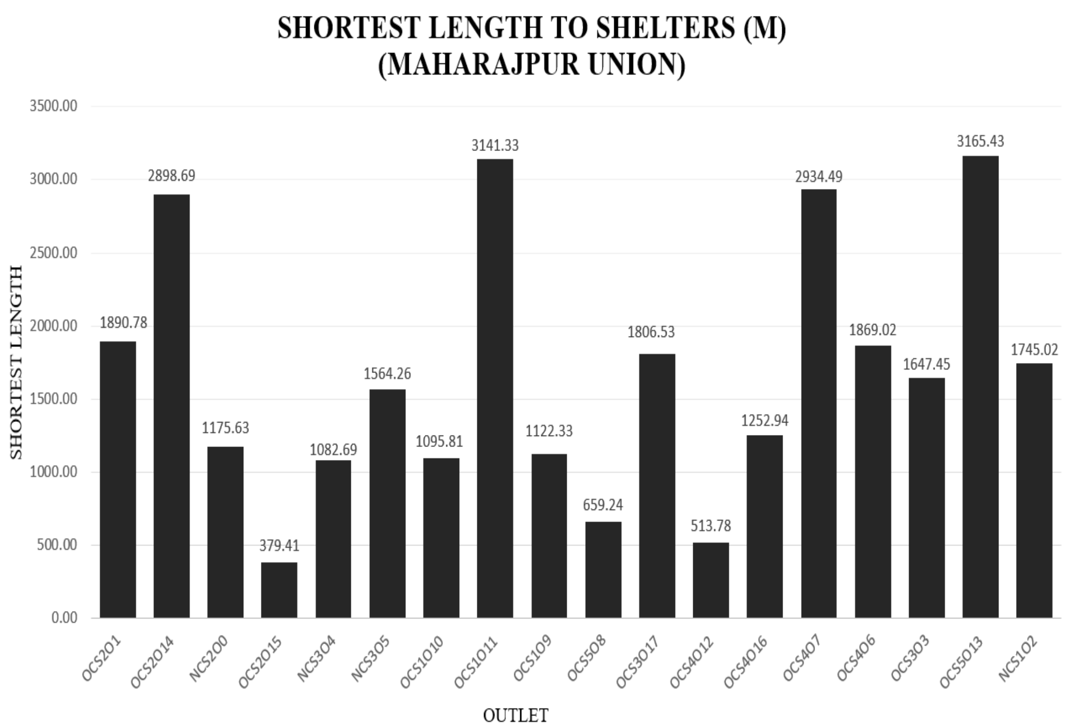


Figure 3.9**:** Shortest length to Shelters (Maharajpur Union)

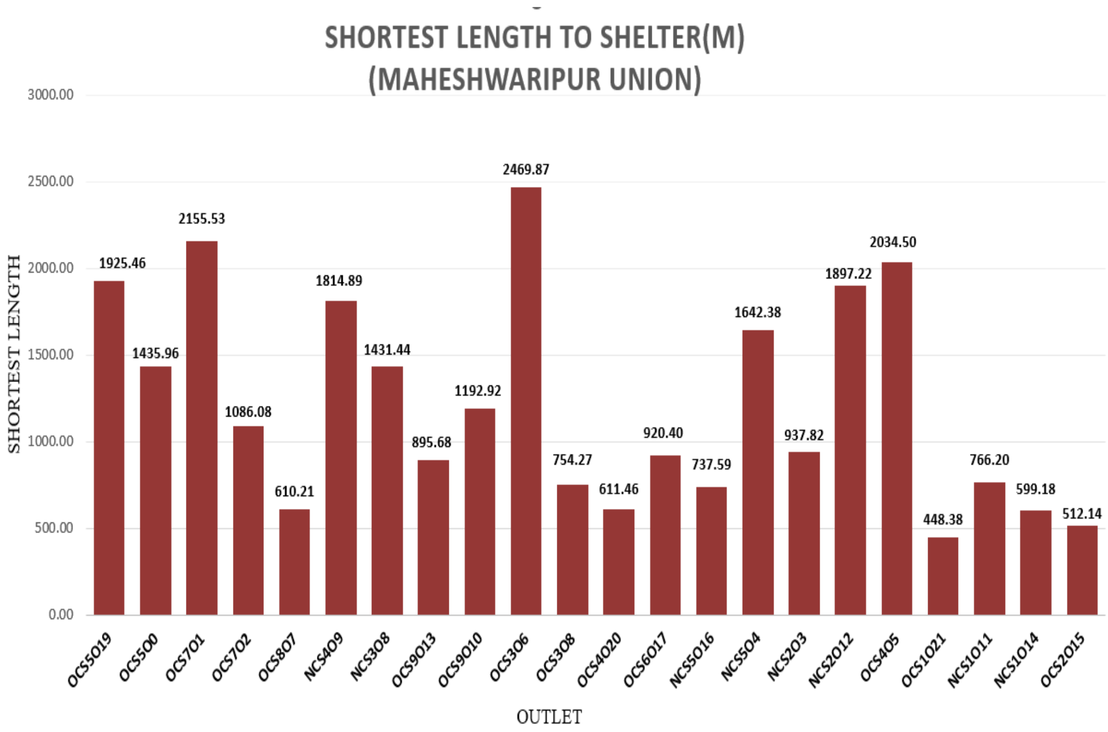


Figure 3.10**:** Shortest length to Shelters (Maheshwaripur Union)

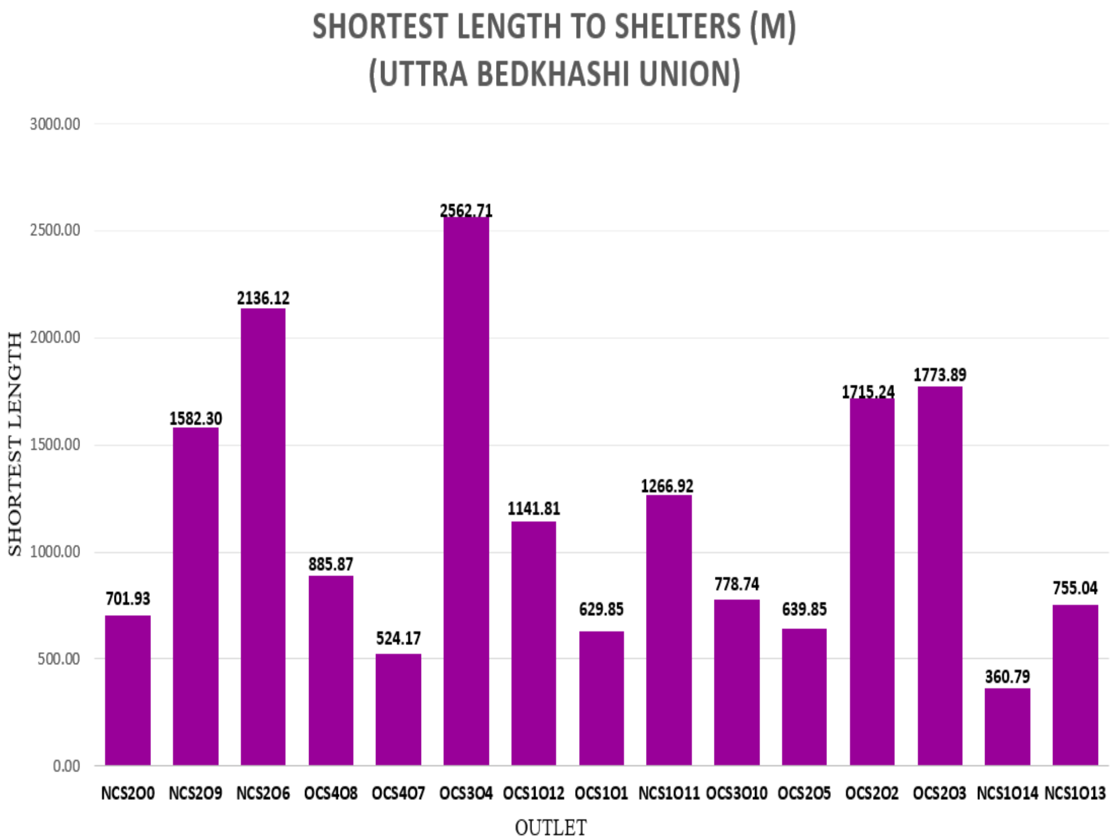
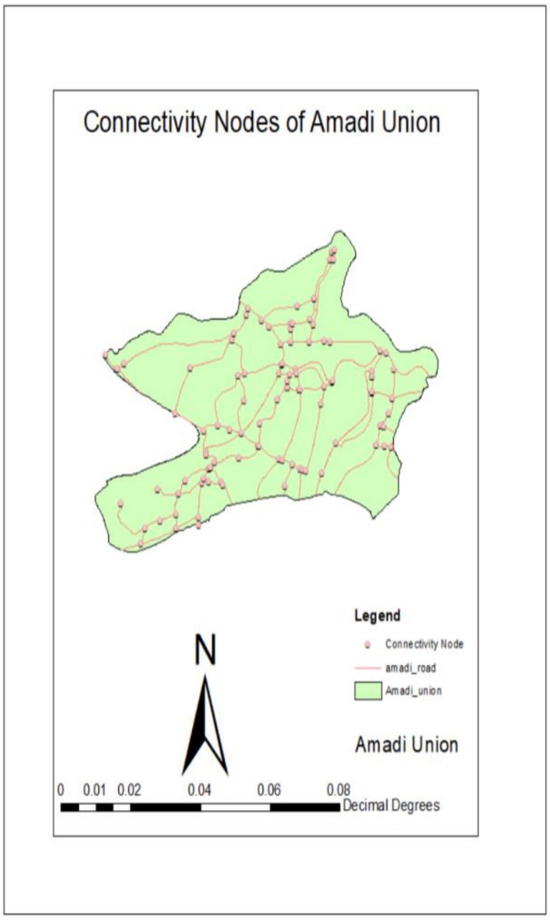
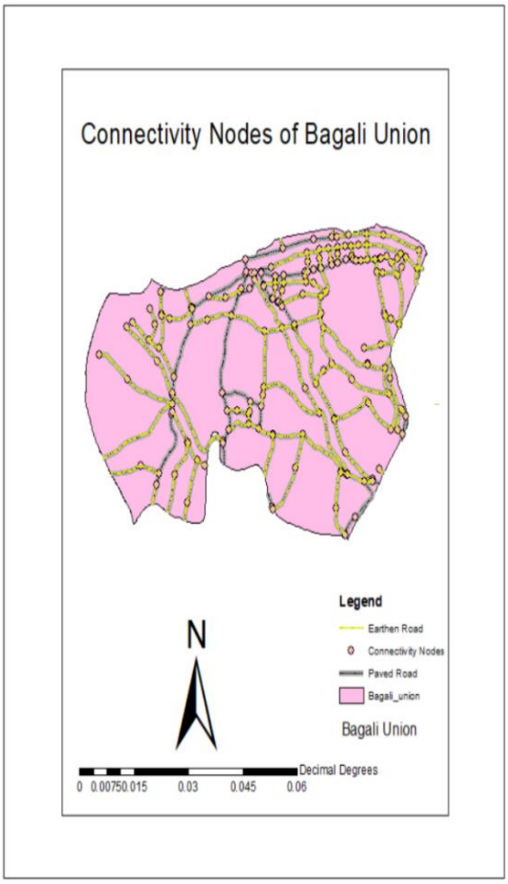


Figure 3.11**:** Shortest length to Shelters (Uttar-Bedkashi Union)

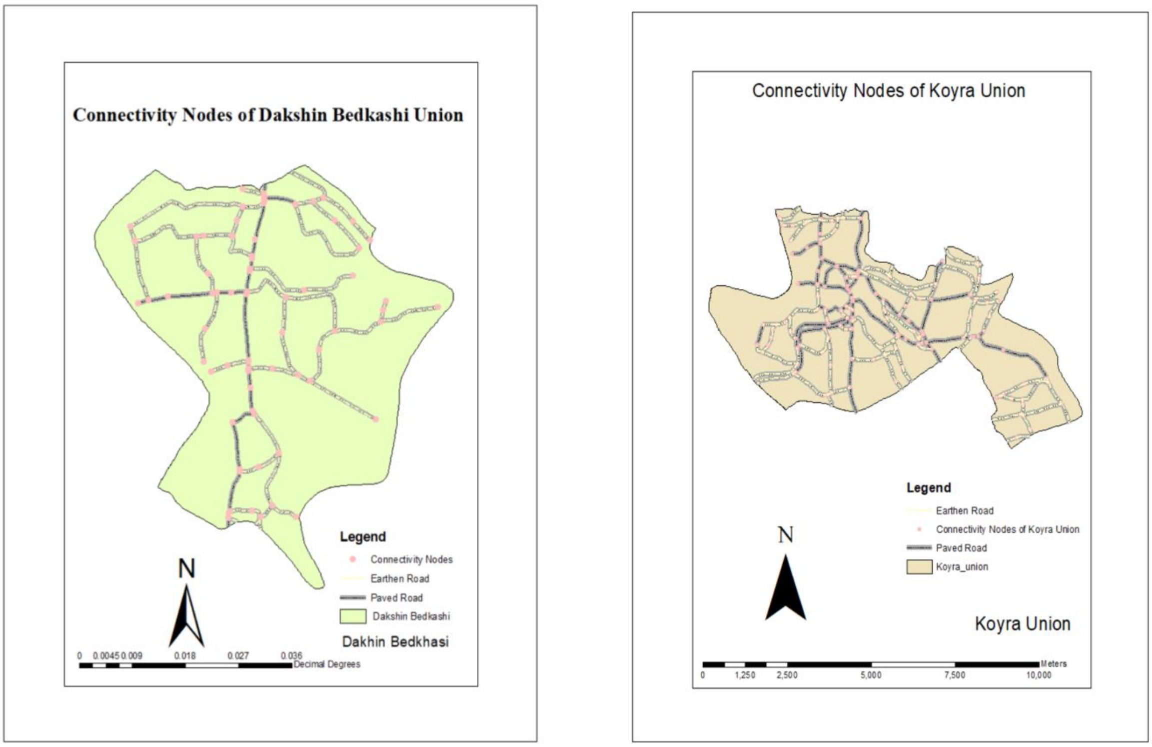
In figures 3.12 to 3.15, we can see the different connectivity nodes in the road network that cause delays. These nodes are placed at points where people would change to other roads and where roads intersect. In Table 3.4, we've created a map of bent node network in the connectivity node network. We have assumed a 4-second delay at the connectivity node for every shortest length to shelter. Walking distance has been calculated at 3.6 kilometers per hour or 60 meters per minute.





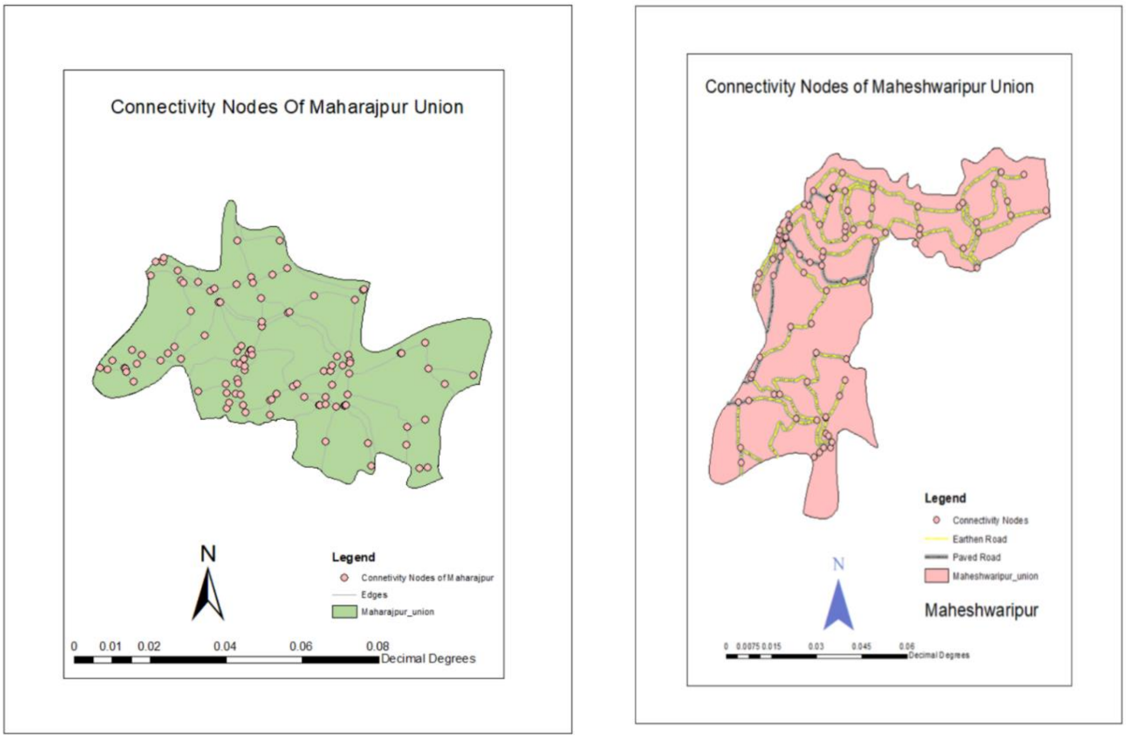
(a) (b)

Figure 3.12: (a) Connectivity Nodes of Amadi Union (b) Connectivity Nodes of Bagali Union



(a) (b)

Figure 3.13: (a) Connectivity Nodes of Dakhin-Bedkashi union (b) Connectivity Nodes of Koyra union.



(a) (b)

Figure 3.14: (a) Connectivity Nodes of Mahrajpur union (b) Connectivity Nodes of Maheswaripur union

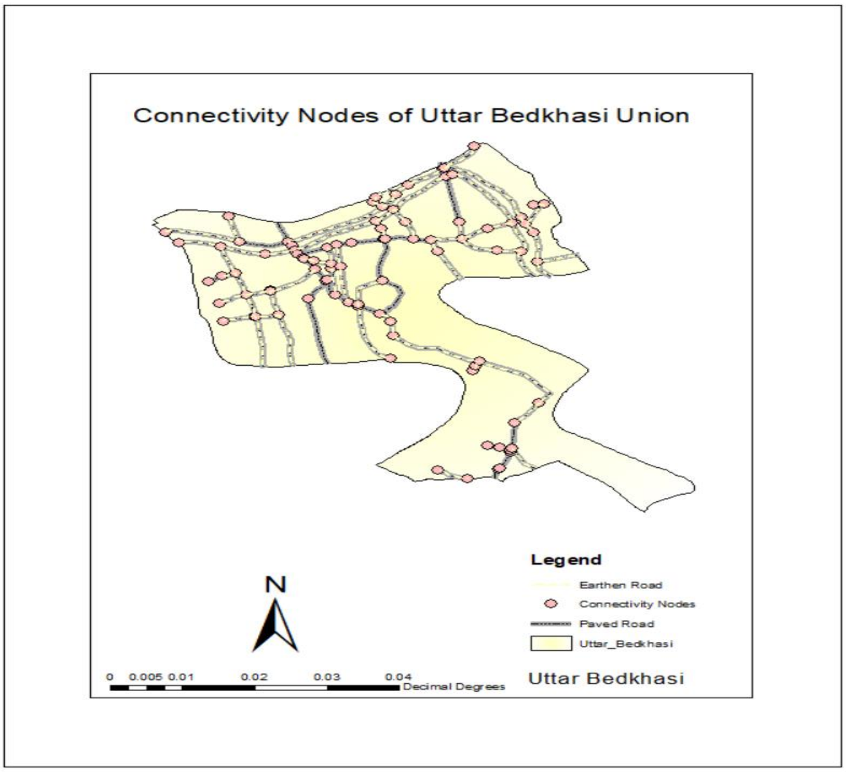


Figure 3.15: (a) Connectivity Nodes of Uttar-Bedkashi union

Table 3.4: Shortest Time Analysis considering factors (Amadi Union)

SL No	Outlet name	Shortest length (m)	Walking speed= 60 m/min*	Shortest time without bents (min)	Numbers of Connectivity Nodes	Time consuming for connectivity node (4s)	Total time consumed due to the connectivity (min)	Final shortest time (min)
1	OCS105	694.53	60	11.575	1	4	0.0667	11.642
2	OCS6012	898.79	60	14.980	2	8	0.1333	15.113
3	NCS204	1122.55	60	18.709	4	16	0.2667	18.976
4	OCS6303	1622.41	60	27.040	4	16	0.2667	27.307
5	OCS5013	2141.65	60	35.694	5	20	0.3333	36.027
6	OCS502	876.76	60	14.613	5	20	0.3333	14.946
7	OCS206	960.98	60	16.016	9	36	0.6000	16.616
8	OCS409	1564.58	60	26.076	1	4	0.0667	26.143
9	NCS108	627.65	60	10.461	3	12	0.2000	10.661
10	OCS507	1256.89	60	20.948	3	12	0.2000	21.148
11	NCS1014	2197.46	60	36.624	4	16	0.2667	36.891
12	OCS501	3237.27	60	53.955	9	36	0.6000	54.555
13	OCS7010	1905.79	60	31.763	2	8	0.1333	31.896
14	OCS300	3406.02	60	56.767	4	16	0.2667	57.034
15	OCS3011	1652.83	60	27.547	2	8	0.1333	27.681
16	NCS1015	1288.51	60	21.475	5	20	0.3333	21.809

Table 3.5: Shortest Time Analysis considering factors (Bagali Union)

SL No	Outlet name	Shortest length (m)	Walking speed= 60 m/min*	Shortest time without bents (min)	Numbers of Connectivity Nodes	Time consuming for connectivity node (4s)	Total time consumed due to the connectivity (min)	Final shortest time (min)
1	NCS1O10	1417.19168	60	23.620	1	4	0.067	23.687
2	OCS3O6	1627.58503	60	27.126	6	24	0.400	27.526
3	OCS3O12	505.864776	60	8.431	1	4	0.067	8.498
4	OCS3O9	1782.70906	60	29.712	2	8	0.133	29.845
5	OCS1O1	1534.59003	60	25.577	2	8	0.133	25.710
6	OCS1O16	1791.59972	60	29.860	2	8	0.133	29.993
7	OCS1O11	1269.55491	60	21.159	5	20	0.333	21.493
8	OCS1O2	1340.44743	60	22.341	6	24	0.400	22.741
9	NCS3O3	1452.22241	60	24.204	5	20	0.333	24.537
6	OCS2O4	893.987421	60	14.900	6	24	0.400	15.300
11	OCS2O13	1294.86168	60	21.581	4	16	0.267	21.848
12	NCS2O5	3201.16996	60	53.353	5	20	0.333	53.686
13	OCS1O15	3109.73792	60	51.829	3	12	0.200	52.029
14	OCS2O7	2401.33016	60	40.022	6	24	0.400	40.422
15	OCS2O0	3814.59962	60	63.577	8	32	0.533	64.110
16	NCS1O8	529.152151	60	8.819	6	24	0.400	9.219
17	NCS3O14	1890.65056	60	31.511	19	76	1.267	32.778

Table 3.5: Shortest Time Analysis considering factors (Dakhin-Bedkashi Union)

SL No	Outlet name	Shortest length (m)	Walking speed= 60 m/min*	Shortest time without bents (min)	Numbers of Connectivity Nodes	Time consuming for connectivity node (4s)	Total time consumed due to the connectivity (min)	Final shortest time (min)
1	NCS2O6	1692.08075	60	28.201	1	4	0.067	28.268
2	NCS1O1	1525.04678	60	25.417	8	32	0.533	25.951
3	NCS3O3	1453.69393	60	24.228	7	28	0.467	24.695
4	NCS3O8	1336.55919	60	22.276	7	28	0.467	22.743
5	OCS3O4	519.575939	60	8.660	2	8	0.133	8.793
6	OCS3O5	1971.24286	60	32.854	0	0	0.000	32.854
7	OCS2O0	427.396797	60	7.123	2	8	0.133	7.257
8	NCS3O2	902.22546	60	15.037	8	32	0.533	15.570
9	OCS1O7	1388.4163	60	23.140	5	20	0.333	23.474
10	NCS3O9	1815.55685	60	30.259	8	32	0.533	30.793

Table 3.7: Shortest Time Analysis considering factors (Koyra Union)

SL No	Outlet name	Shortest length (m)	Walking speed= 60 m/min*	Shortest time without bents (min)	Numbers of Connectivity Nodes	Time consuming for connectivity node (4s)	Total time consumed due to the connectivity (min)	Final shortest time (min)
1	OCS8O15	1313.87	60	21.898	2	8	0.133	22.031
2	OCS8O17	914.88	60	15.248	2	8	0.133	15.381
3	OCS7O18	914.87	60	15.248	2	8	0.133	15.381
4	OCS7O1	1391.15	60	23.186	2	8	0.133	23.319
5	OCS7O10	2293.56	60	38.226	6	24	0.400	38.626
6	OCS5O12	1690.61	60	28.177	9	36	0.600	28.777
7	OCS5O8	1547.46	60	25.791	5	20	0.333	26.124
8	OCS6O11	2189.97	60	36.499	9	36	0.600	37.099
9	OCS4O6	935.27	60	15.588	1	4	0.067	15.654
10	OCS4O13	1039.81	60	17.330	1	4	0.067	17.397
11	OCS1O5	970.43	60	16.174	4	16	0.267	16.441
12	OCS1O4	1291.89	60	21.532	5	20	0.333	21.865
13	OCS6O3	1157.89	60	19.298	7	28	0.467	19.765
14	OCS3O21	789.65	60	13.161	2	8	0.133	13.294
15	NCS1O2	1094.07	60	18.234	5	20	0.333	18.568
16	NCS3O7	1199.00	60	19.983	5	20	0.333	20.317
17	NCS3O20	779.35	60	12.989	5	20	0.333	13.323
18	OCS2O0	809.02	60	13.484	4	16	0.267	13.750
19	OCS2O19	560.64	60	9.344	2	8	0.133	9.477
20	NC2O14	1498.85	60	24.981	5	20	0.333	25.314
21	OCS5O16	2765.40	60	46.090	7	28	0.467	46.557
22	OCS4O9	2105.06	60	35.084	3	12	0.200	35.284
23	NC4O22	850.11	60	14.168	4	16	0.267	14.435

Table 3.8: Shortest Time Analysis considering factors (Maharajpur Union)

SL No	Outlet name	Shortest length (m)	Walking speed= 60 m/min*	Shortest time without bents (min)	Numbers of Connectivity Nodes	Time consuming for connectivity node (4s)	Total time consumed due to the connectivity (min)	Final shortest time (min)
1	OCS2O1	1890.78	60	31.513	3	12	0.200	31.713
2	OCS2O14	2898.69	60	48.312	8	32	0.533	48.845
3	NCS2O0	1175.63	60	19.594	2	8	0.133	19.727
4	OCS2O15	379.41	60	6.323	1	4	0.067	6.390
5	NCS3O4	1082.69	60	18.045	4	16	0.267	18.312
6	NCS3O5	1564.26	60	26.071	4	16	0.267	26.338
7	OCS1O10	1095.81	60	18.264	4	16	0.267	18.530
8	OCS1O11	3141.33	60	52.355	6	24	0.400	52.755
9	OCS1O9	1122.33	60	18.705	3	12	0.200	18.905
10	OCS5O8	659.24	60	10.987	1	4	0.067	11.054
11	OCS3O17	1806.53	60	30.109	2	8	0.133	30.242
12	OCS4O12	513.78	60	8.563	8	32	0.533	9.096
13	OCS4O16	1252.94	60	20.882	3	12	0.200	21.082
14	OCS4O7	2934.49	60	48.908	8	32	0.533	49.441
15	OCS4O6	1869.02	60	31.150	2	8	0.133	31.284
16	OCS3O3	1647.45	60	27.457	0	0	0.000	27.457
17	OCS5O13	3165.43	60	52.757	6	24	0.400	53.157
18	NCS1O2	1745.02	60	29.084	1	4	0.067	29.150

Table 3.9: Shortest Time Analysis considering factors (Maheshwaripur Union)

SL No	Outlet name	Shortest length (m)	Walking speed= 60 m/min*	Shortest time without bents (min)	Number of Connectivity Nodes	Time consuming for connectivity nodes (4s)	Total time consumed due to the connectivity (min)	Final shortest time (min)
1	OCS5O19	1925.46	60	32.09	3	12	0.2000	32.291
2	OCS5O0	1435.96	60	23.93	1	4	0.0667	23.999
3	OCS7O1	2155.53	60	35.93	2	8	0.1333	36.059
4	OCS7O2	1086.08	60	18.10	1	4	0.0667	18.168
5	OCS8O7	610.21	60	10.17	1	4	0.0667	10.237
6	NCS4O9	1814.89	60	30.25	1	4	0.0667	30.315
7	NCS3O8	1431.44	60	23.86	3	12	0.2000	24.057
8	OCS9O13	895.68	60	14.93	2	8	0.1333	15.061
9	OCS9O10	1192.92	60	19.88	1	4	0.0667	19.949
10	OCS3O6	2469.87	60	41.16	3	12	0.2000	41.364
11	OCS3O8	754.27	60	12.57	2	8	0.1333	12.705
12	OCS4O20	611.46	60	10.19	11	44	0.7333	10.924
13	OCS6O17	920.40	60	15.34	3	12	0.2000	15.540
14	NCS5O16	737.59	60	12.29	5	20	0.3333	12.627
15	NCS5O4	1642.38	60	27.37	6	24	0.4000	27.773
16	NCS2O3	937.82	60	15.63	2	8	0.1333	15.764
17	NCS2O12	1897.22	60	31.62	4	16	0.2667	31.887
18	OCS4O5	2034.50	60	33.91	11	44	0.7333	34.642
19	OCS1O21	448.38	60	7.47	1	4	0.0667	7.540
20	NCS1O11	766.20	60	12.77	1	4	0.0667	12.837
21	NCS1O14	599.18	60	9.99	1	4	0.0667	10.053
22	OCS2O15	512.14	60	8.54	1	4	0.0667	8.602

Table 3.10: Shortest Time Analysis considering factors (Uttar-Bedkashi Union)

SL No	Outlet name	Shortest length (m)	Walking speed= 60 m/min*	Shortest time without bents (min)	Numbers of Connectivity Nodes	Time consuming for connectivity node (4s)	Total time consumed due to the connectivity (min)	Final shortest time (min)
1	NCS2O0	701.93	60	11.699	3	12	0.200	11.899
2	NCS2O9	1582.30	60	26.372	5	20	0.333	26.705
3	NCS2O6	2136.12	60	35.602	4	16	0.267	35.869
4	OCS4O8	885.87	60	14.765	2	8	0.133	14.898
5	OCS4O7	524.17	60	8.736	4	16	0.267	9.003
6	OCS3O4	2562.71	60	42.712	14	56	0.933	43.645
7	OCS1O12	1141.81	60	19.030	3	12	0.200	19.230
8	OCS1O1	629.85	60	10.498	2	8	0.133	10.631
9	NCS1O11	1266.92	60	21.115	2	8	0.133	21.249
10	OCS3O10	778.74	60	12.979	2	8	0.133	13.112
11	OCS2O5	639.85	60	10.664	5	20	0.333	10.998
12	OCS2O2	1715.24	60	28.587	3	12	0.200	28.787
13	OCS2O3	1773.89	60	29.565	8	32	0.533	30.098
14	NCS1O14	360.79	60	6.013	2	8	0.133	6.147
15	NCS1O13	755.04	60	12.584	4	16	0.267	12.851

*Walking speed 3.6 km/h or 60 m/min (Hasnat, 2016).

Figure (3.16 to 3.22) shows time to reach to the shelters from each outlets using the shortest routes

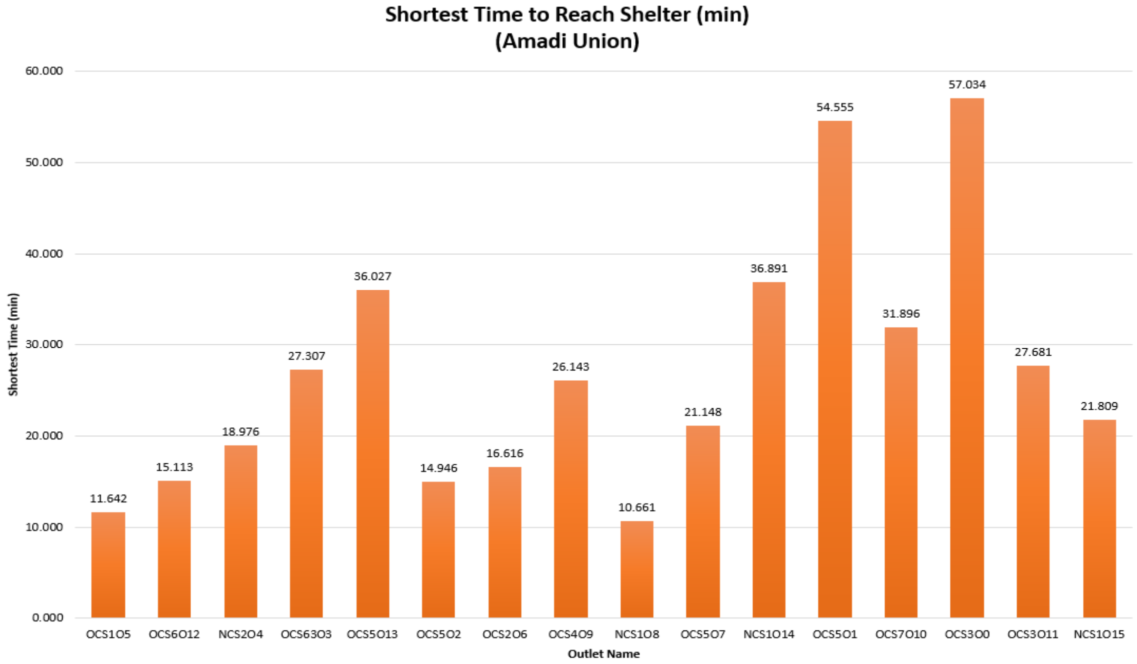


Figure 3.16: Shortest Time (minutes) from each Outlet (Amadi Union)

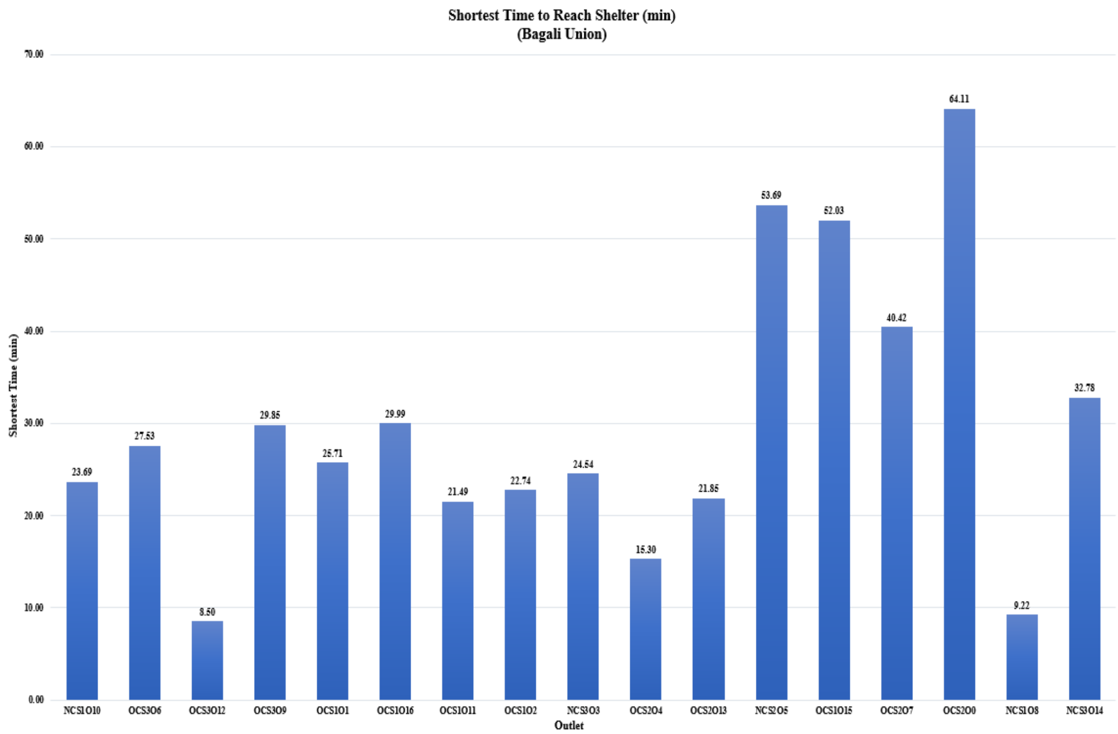


Figure 3.17: Shortest Time (minutes) from each Outlet (Bagali Union)

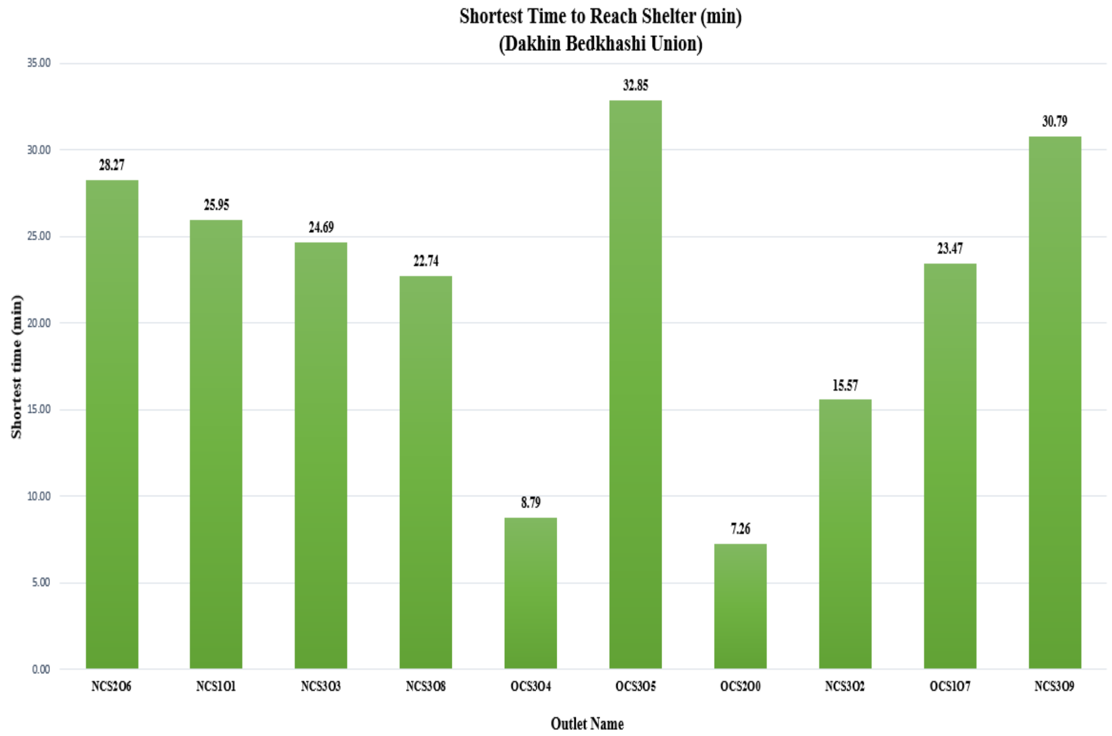


Figure 3.18: Shortest Time (minutes) from each Outlet (Dakhin-Bedkashi Union)

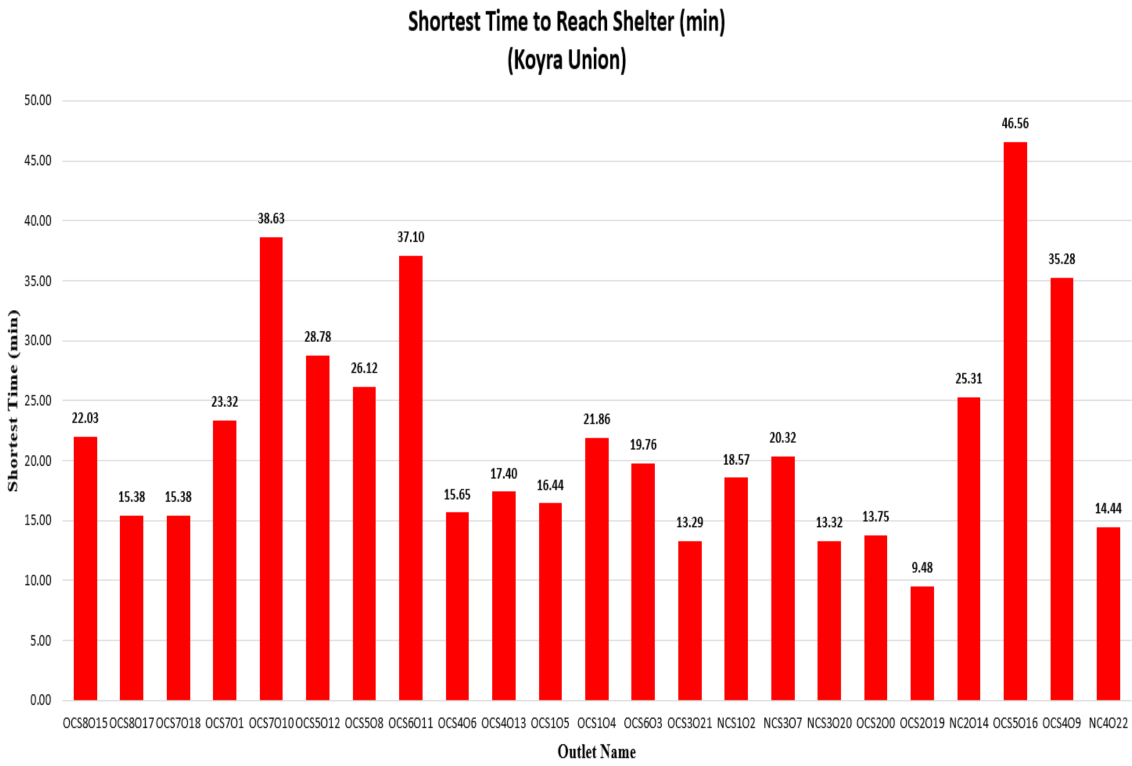


Figure 3.19: Shortest Time (minutes) from each Outlet (Koyra Union)

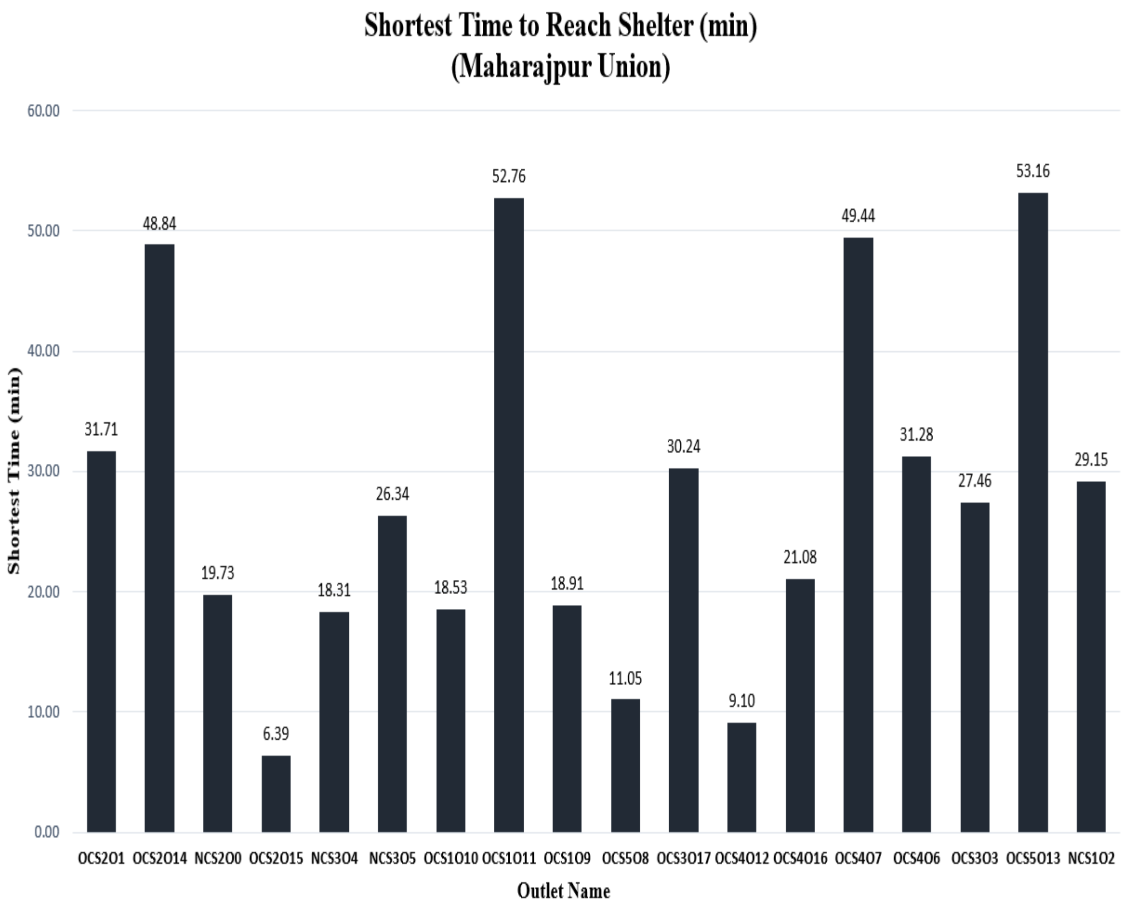


Figure 3.20: Shortest Time (minutes) from each Outlet (Maharajpur Union)

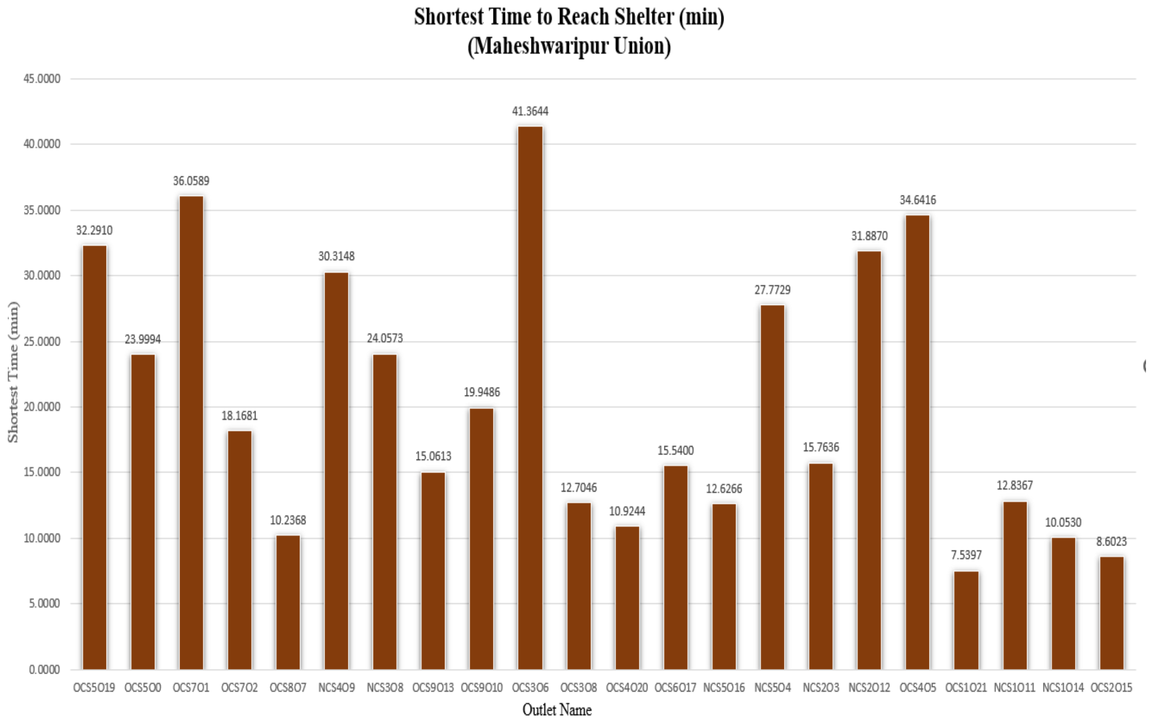


Figure 3.21: Shortest Time (minutes) from each Outlet (Maheshpur Union)

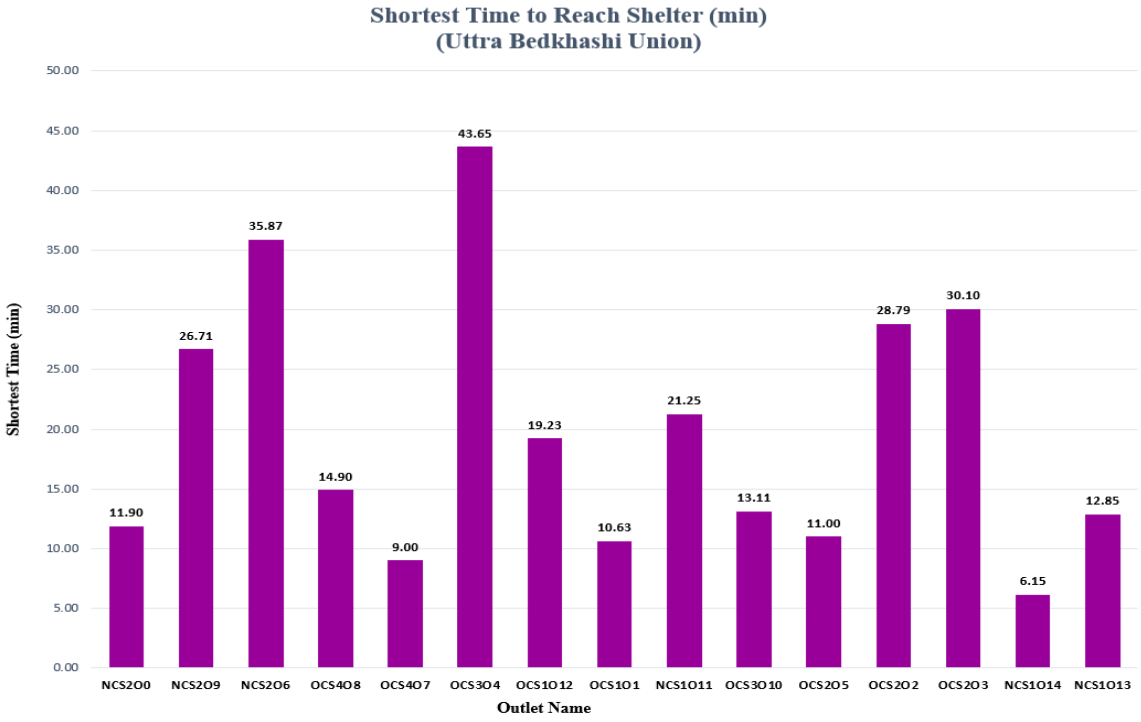


Figure 3.22: Shortest Time (minutes) from each Outlet (Uttar-Bedkashi)

Figure (3.23 to 3.29) shows Population from outlets that cover Cyclone Shelter. In figure 3.23 shows that, OCS1O5 is 825 people can able to shelter and 1923 people are remaining. similarly, OCS6O12 is 825 people can able to shelter and 238 people are remaining

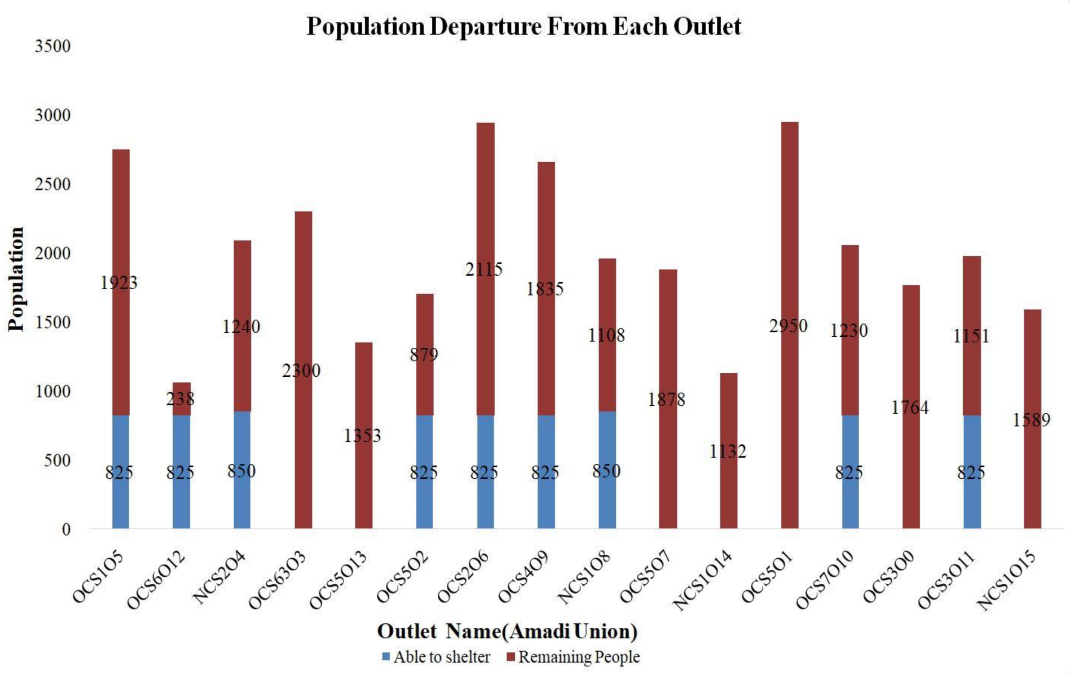


Figure 3.23: Population from outlets that cover Cyclone Shelter

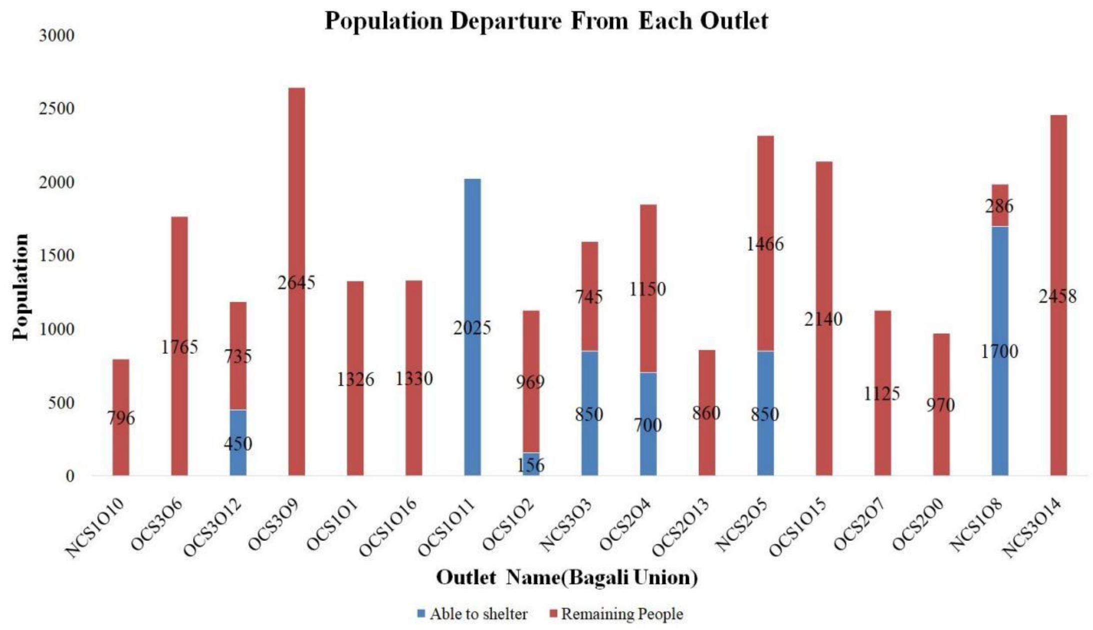


Figure 3.24: Population from outlets that cover Cyclone Shelter

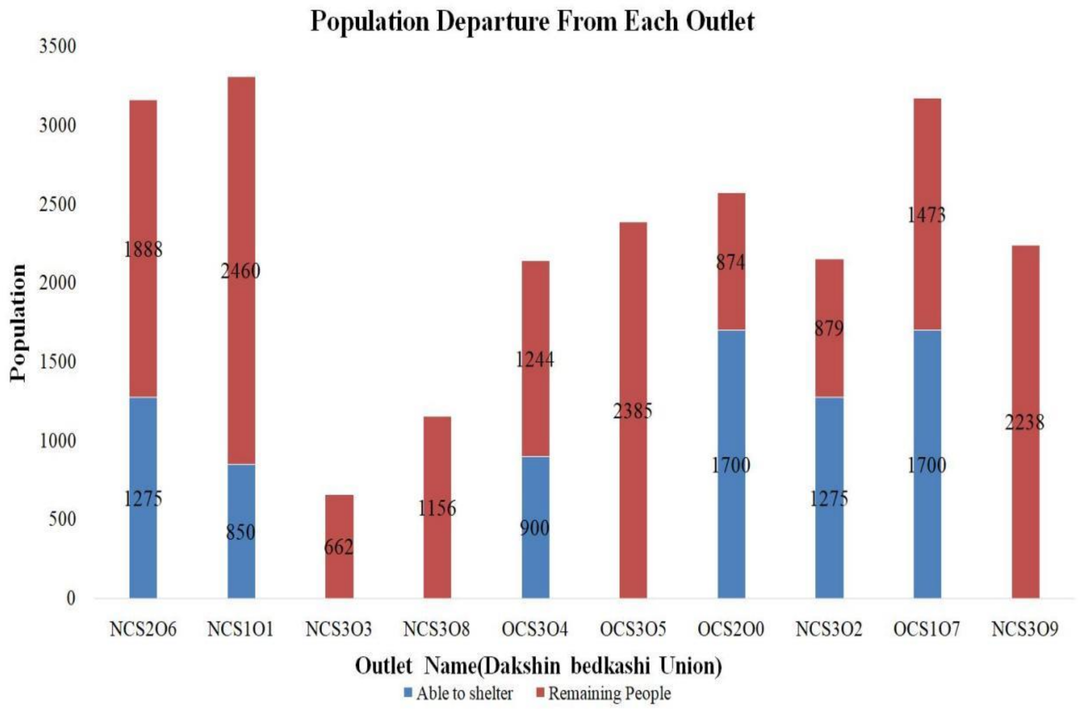


Figure 3.25: Population from outlets that cover Cyclone Shelter

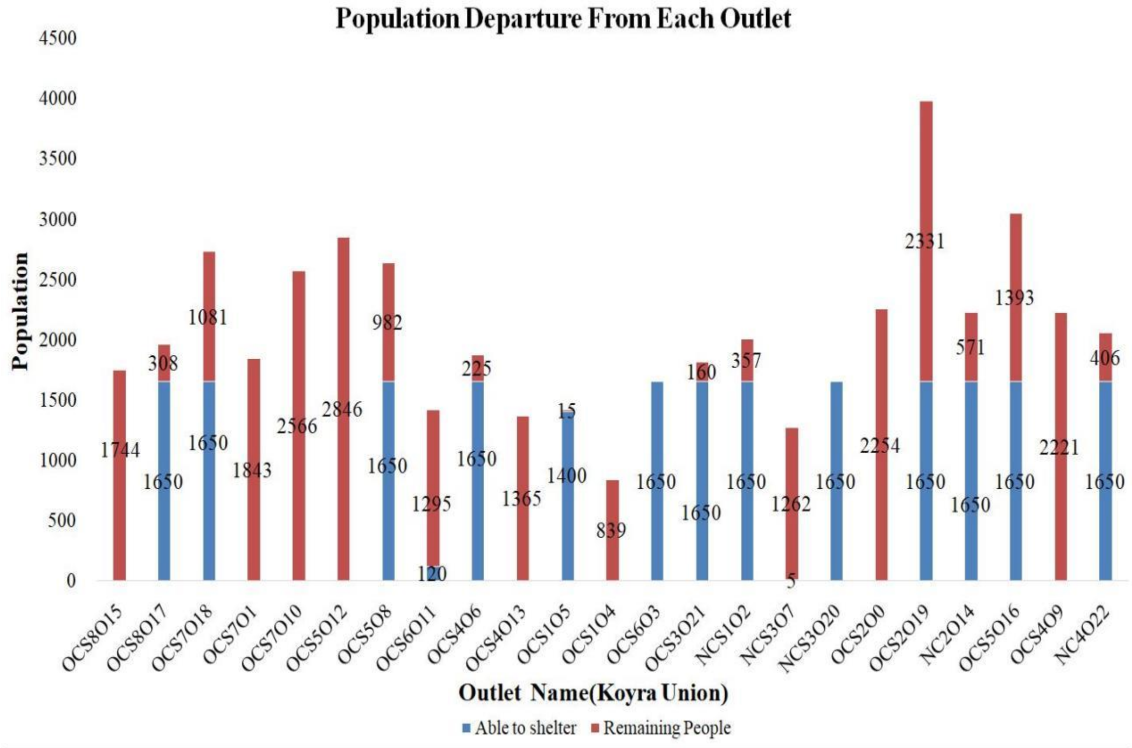


Figure 3.26: Population from outlets that cover Cyclone Shelter

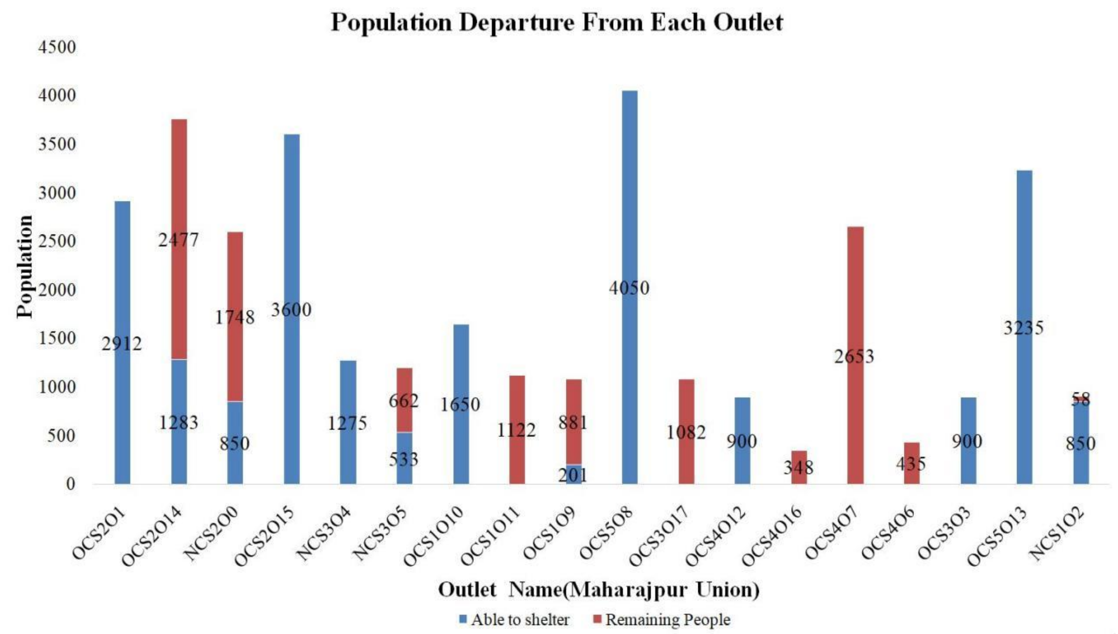


Figure 3.27: Population from outlets that cover Cyclone Shelter

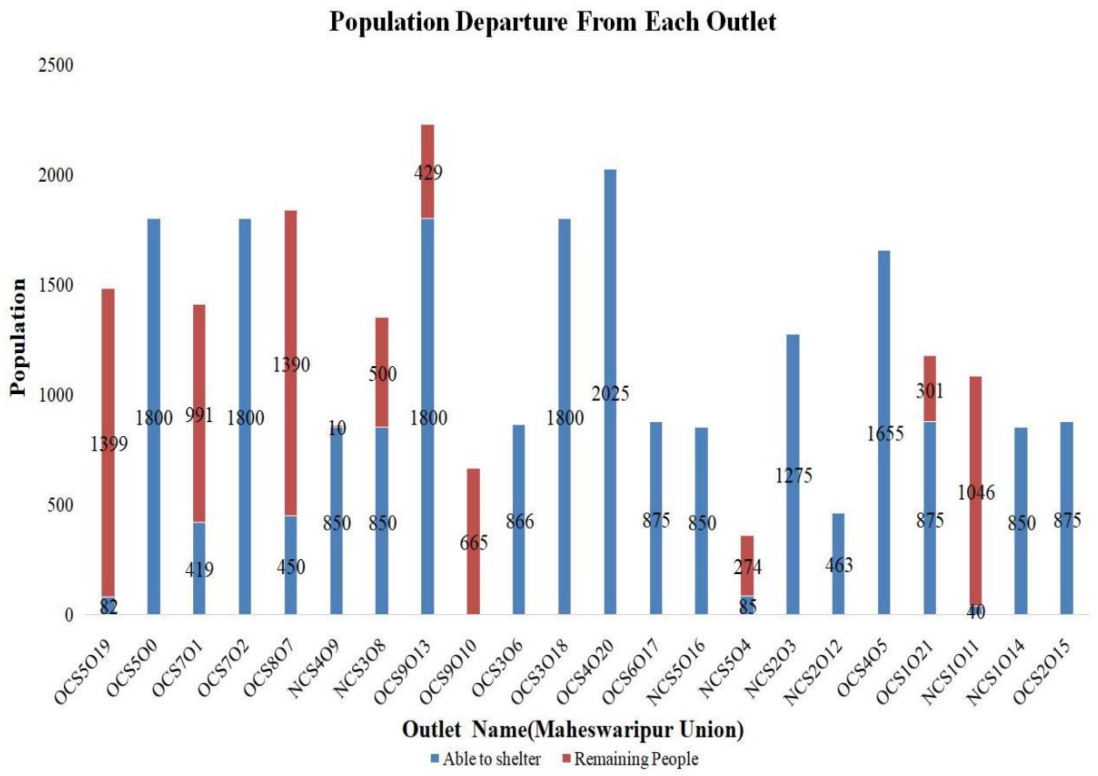


Figure 3.28: Population from outlets that cover Cyclone Shelter

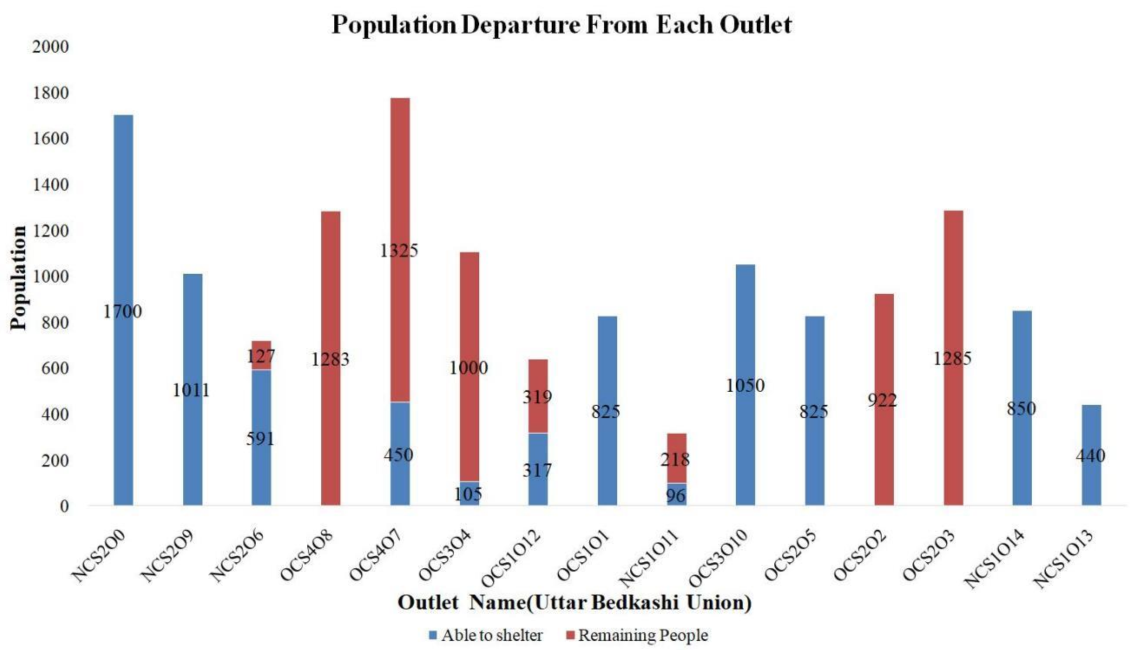


Figure 3.29: Population from outlets that cover Cyclone Shelter

Also figure 3.29 shows the number of people departing from each outlet that cover the capacity of the cyclone shelter. It is observed that 591 people can depart from outlet NCS2O6 and remaining are 127.

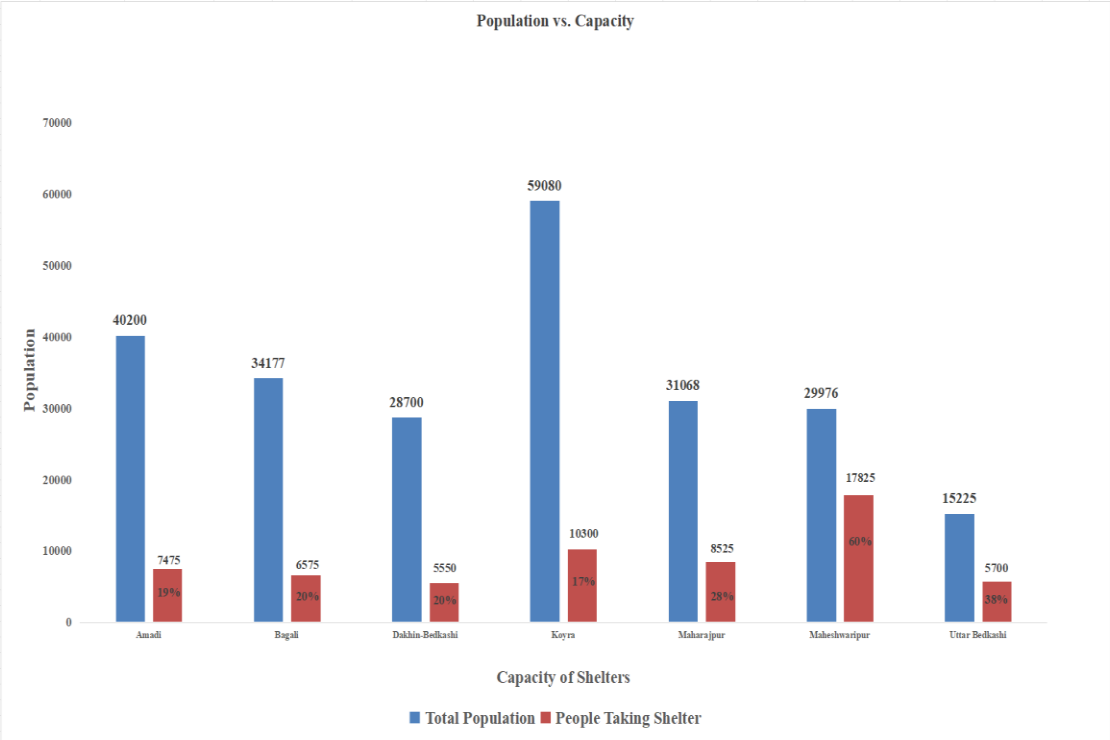


Figure 3.30: Population demand versus capacity of cyclone shelter (Each union)

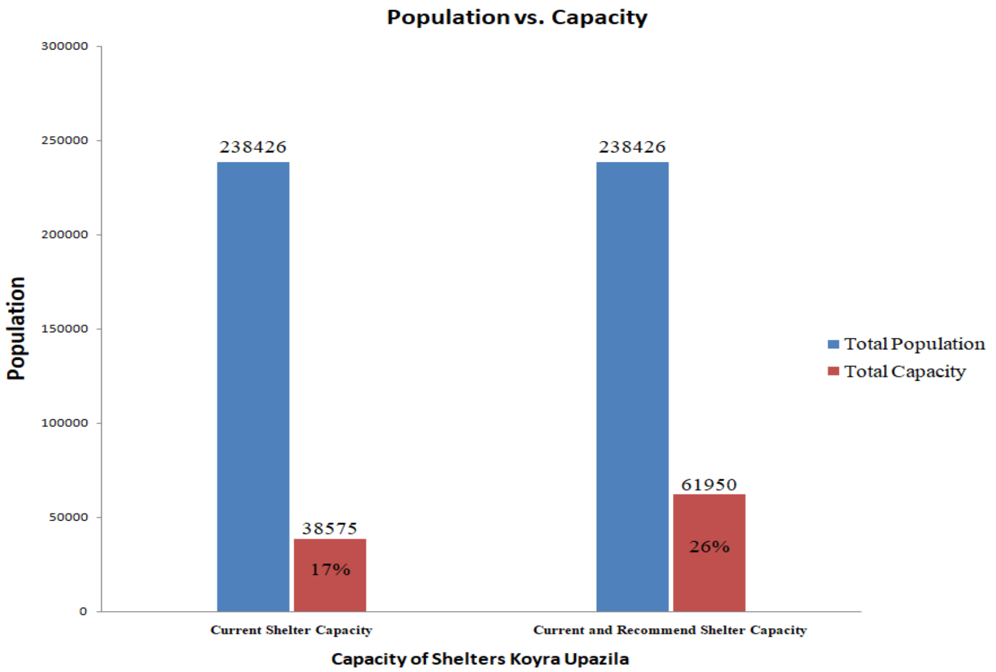


Figure 3.31: Population demand versus capacity of cyclone shelter (Koyra Upazila)

Figure 3.30 shows that the cyclone shelters in different unions have varying capacities and their coverage of the total population. In the Amadi union, the capacity of 7475 people in cyclone shelters can only cover 19% of the total population. Similarly, in the Bagali union, the capacity of 6575 people in cyclone shelters can cover only 20% of the total population. The Dakhin-Bedkashi union has cyclone shelters with a capacity of 5550 people, covering only 20% of the total population. The Koyra union's cyclone shelters, with a capacity of 10300 people, can cover only 17% of the total population. In the Mahrajpur union, the cyclone shelters with a capacity of 8525 people cover only 28% of the total population. Additionally, the cyclone shelters in the Maheswaripur union with a capacity of 17825 people can cover 60% of the total population, and the cyclone shelters in the Uttar-Bekashi union, with a capacity of 5700 people, cover only 38% of the total population. Figure 3.31 shows that in Koyra upazila, only 17% of the total population can be accommodated by the current official shelter capacity. However, with the addition of the new (suggested) cyclone shelters, 26% of the total population can be accommodated.

4. Conclusions

In a developing country like Bangladesh, the death rate due to cyclones is decreasing. While the 2007 Cyclone SIDR was as devastating as the cyclone of 1991, the death toll has been reduced due to the proper dissemination of early warnings. This improvement indicates progress in the disaster management sector. Further reduction in the death rate could be achieved through a scientifically conducted evacuation. To ensure a proper evacuation, it is necessary to develop and follow departure routes. Different types of existing roads have been considered for the development of evacuation routes. It has been suggested to create more outlets in densely populated areas to accommodate more people in shelters. Analysis has shown that the shelter capacity of Koyra Upazila is 61950, which can only accommodate 26% of the total population. This study provides insight into managing the population and identifying suitable nearby shelters. It can serve as a role model for developing a detailed cyclone evacuation plan for coastal communities in Bangladesh.

5. Reference

Ali, A. (1996). Vulnerability of Bangladesh to Climate Change and Sea Level Rise through Tropical Cyclones and Storm Surges. *springer link* , 171–179.

Bukholm, H. N. (1999). Network analysis–raster versus vector, A comparison study. *husdal.com* , 1.

Chanda1, S. K. (2020). Cyclone Aila and Coping Strategies of the Coastal Households in Southern Bangladesh*. *Bangladesh e-Journal of Sociology* , 1.

Edris Alam, A. E. (2023). Change in cyclone disaster vulnerability and response in coastal Bangladesh. *wiley online library* .

Edris Alam, A. E. (2010). Cyclone disaster vulnerability and response experiences in coastal Bangladesh. *wiley online library* .

Hasnat, M. (2016). Optimum route modeling for emergency response during disastrous situation in densely populated urban area. *central libaray,BUET* , 31.

Irin Hossain, A. R. (2020). Cyclone and Bangladesh: A Historical and Environmental Overview from 1582 to 2020. *International Medical Journal* , Volume 25.

Md. Abdus Sattar a b, K. K. (2019). Tropical cyclone risk perception and risk reduction analysis for coastal Bangladesh: Household and expert perspectives. *science direct* , 1.

Md. Sohel Rana, K. G. (2010). APPLICATION OF REMOTE SENSING AND GIS FOR CYCLONE DISASTER. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Science* , 1.

Muhammad Al-Amin Hoque, B. P. (2021). Cyclone vulnerability assessment of the western coast of Bangladesh. *taylor and francis online* , Pages 198-221.

Sayem Ahmed, M. Z. (2019). Effect of extreme weather events on injury, disability, and death in Bangladesh. *taylor & francis online* , 306-317.

Tanveerul Islam, R. E. (2008). Climatology of landfalling tropical cyclones in Bangladesh 1877–2003. *SpringerLink* , Volume 48, pages 115–135,.