# 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.
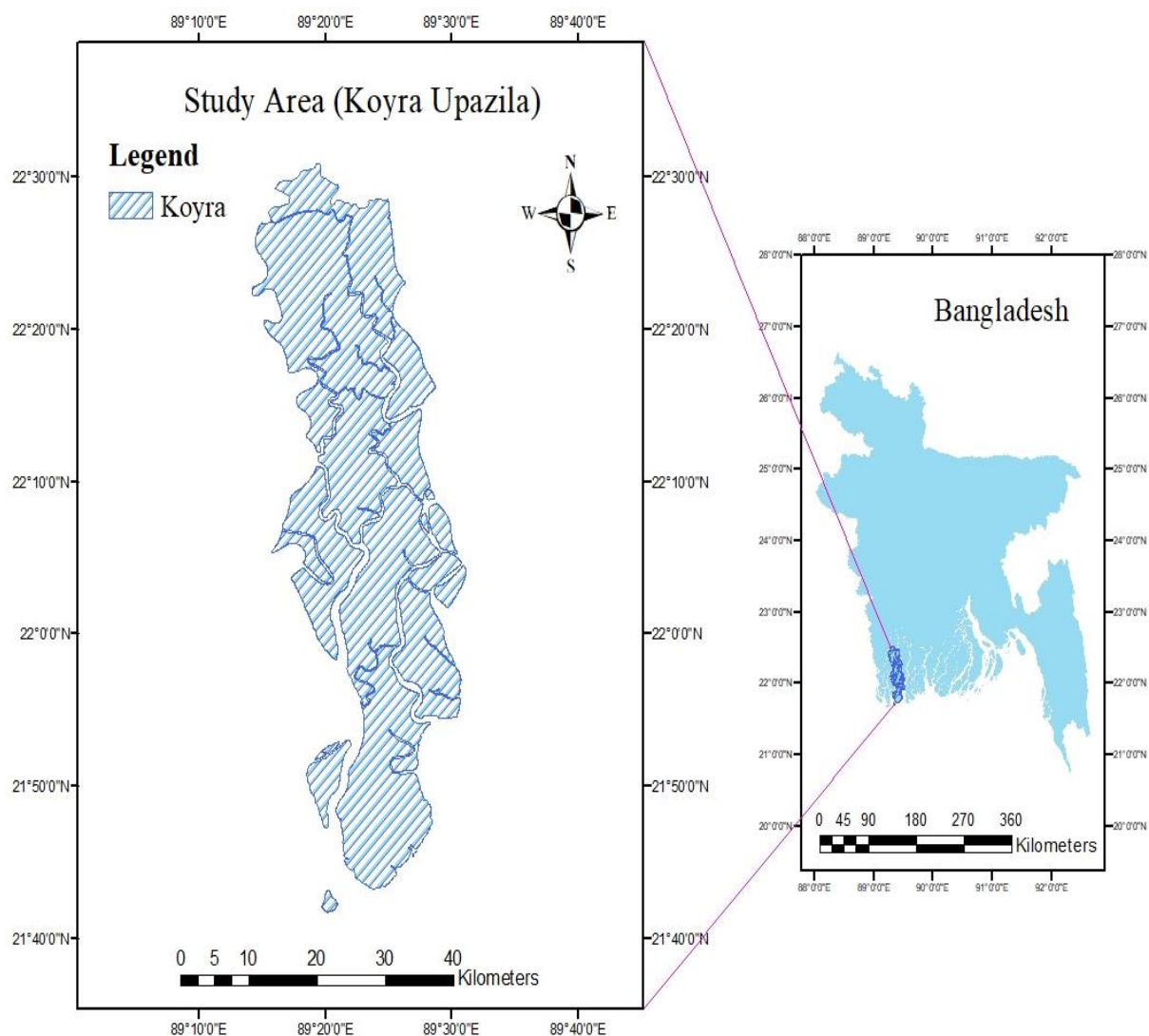
Figure 2.1 Study Area Koyra Upazila

## 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 Capcity | 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.
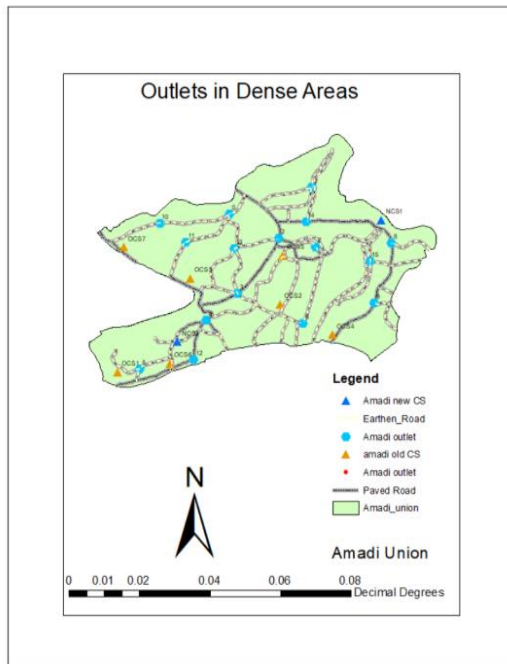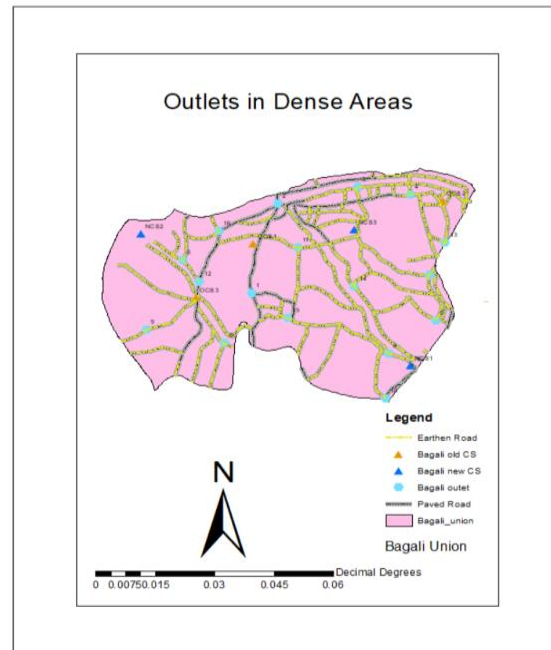


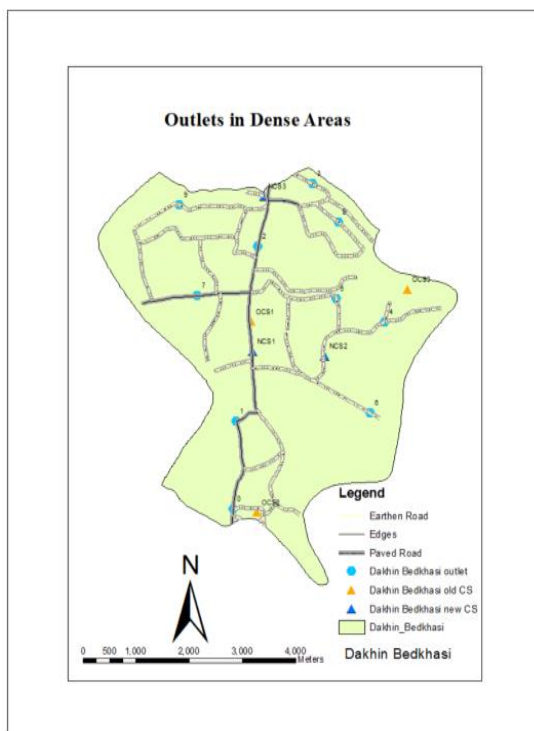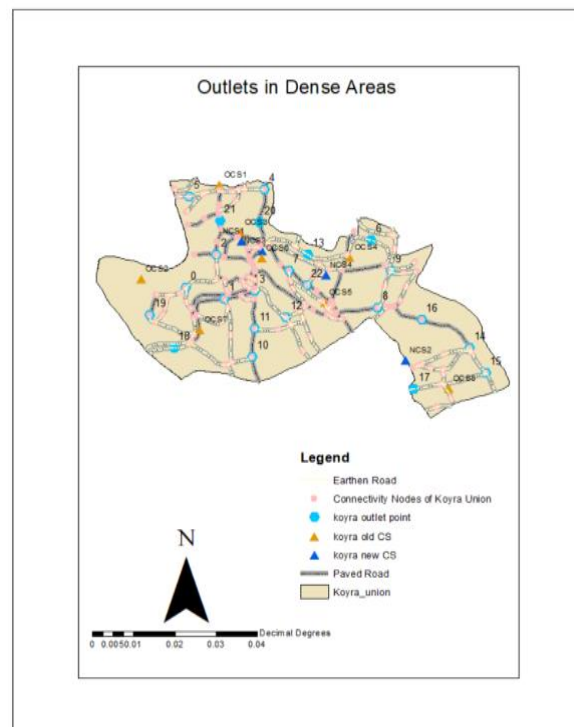(a)                                    (b)

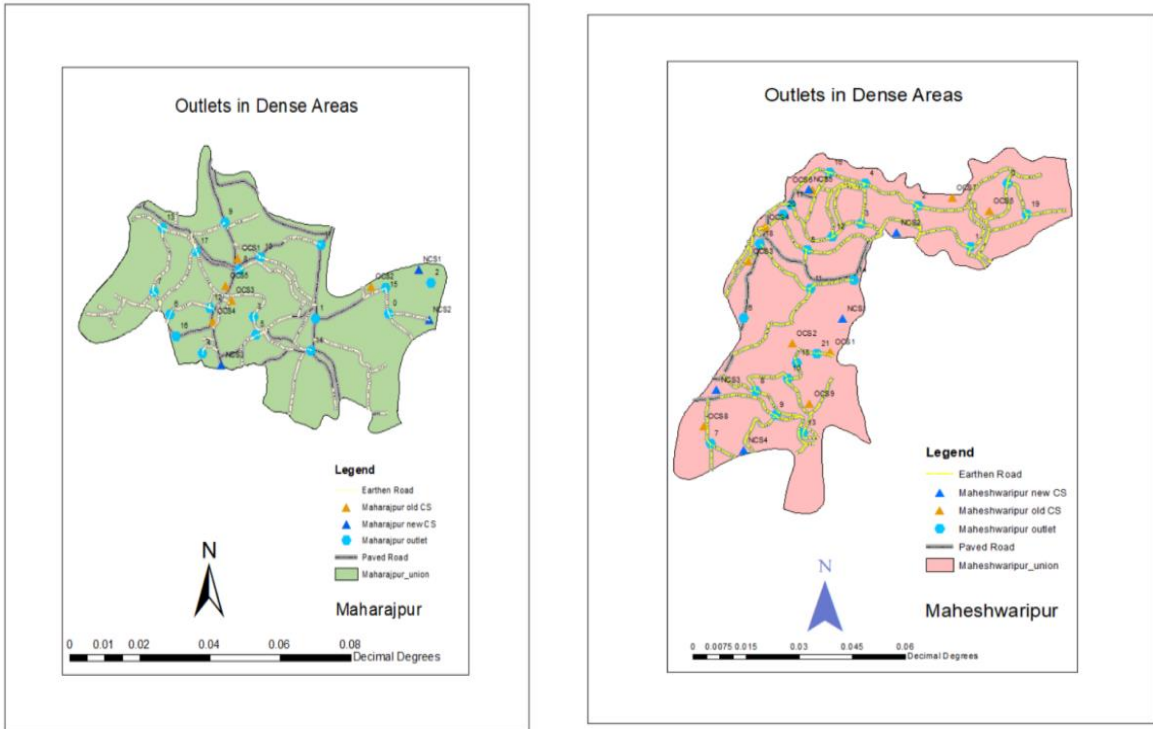Figure 3.1: (a) Outlets and Inlets in Amadi Union (b) Outlets and Inlets in Bagali Union



(a)                                    (b)

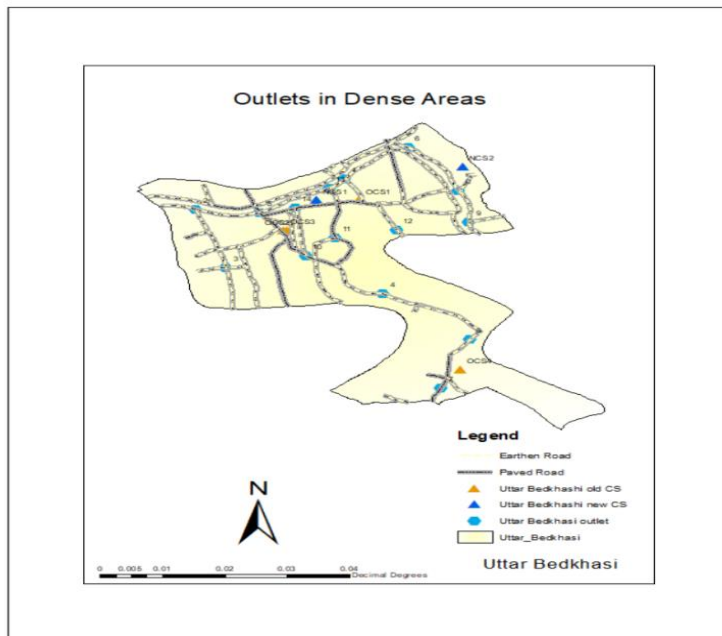Figure 3.2: (a) Outlets and Inlets in Dakhin-Bedkashi union (b) Outlets and Inlets in Koyra union

(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

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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.
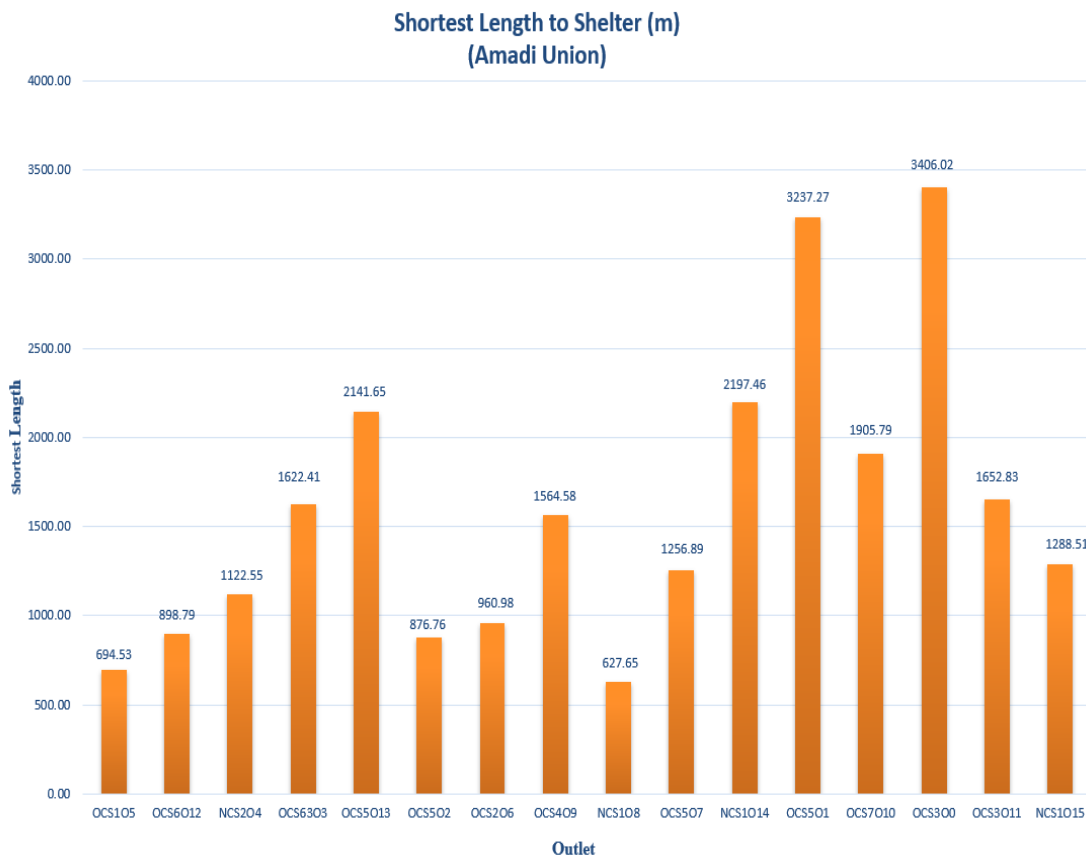


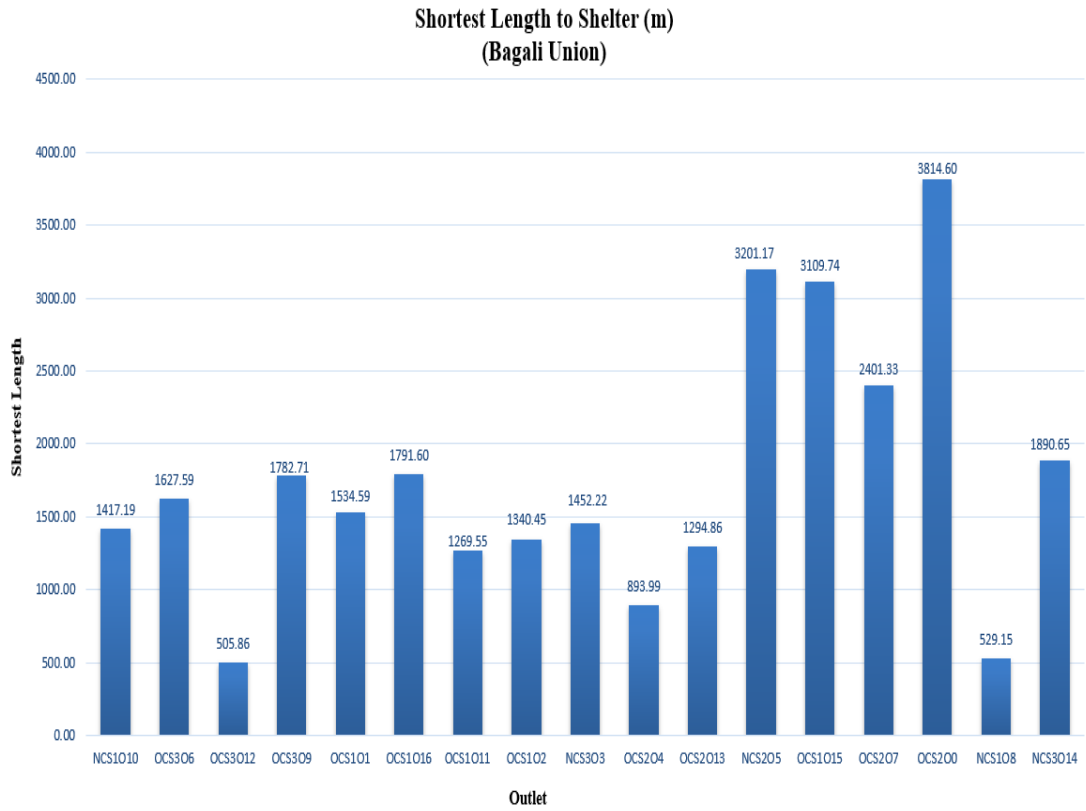Figure 3.5: Shortest length to Shelters (Amadi Union)

**Shortest Length to Shelter (m)**
**(Bagali Union)**

Figure 3.6**:** Shortest length to Shelters (Bagali Union)



**Shortest Length to Shelters (m)**
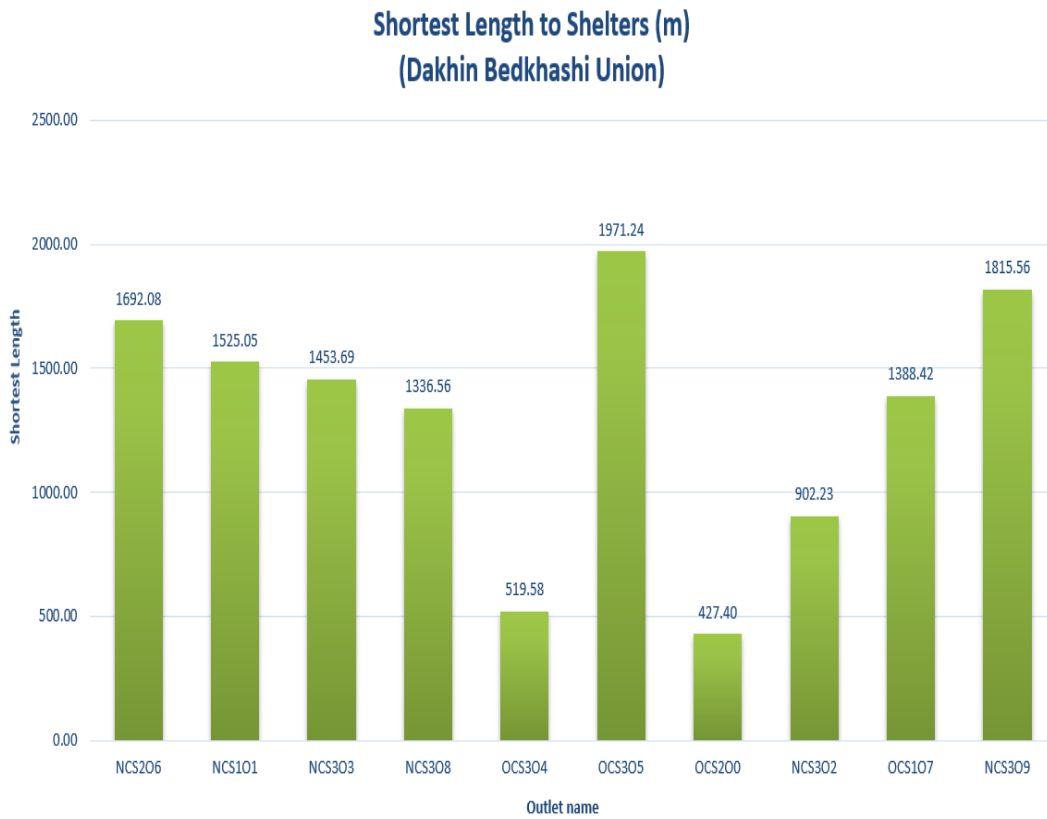**(Dakhin Bedkhashi Union)**

Figure 3.7**:** Shortest length to Shelters (Dakhin-Bedkashi Union)
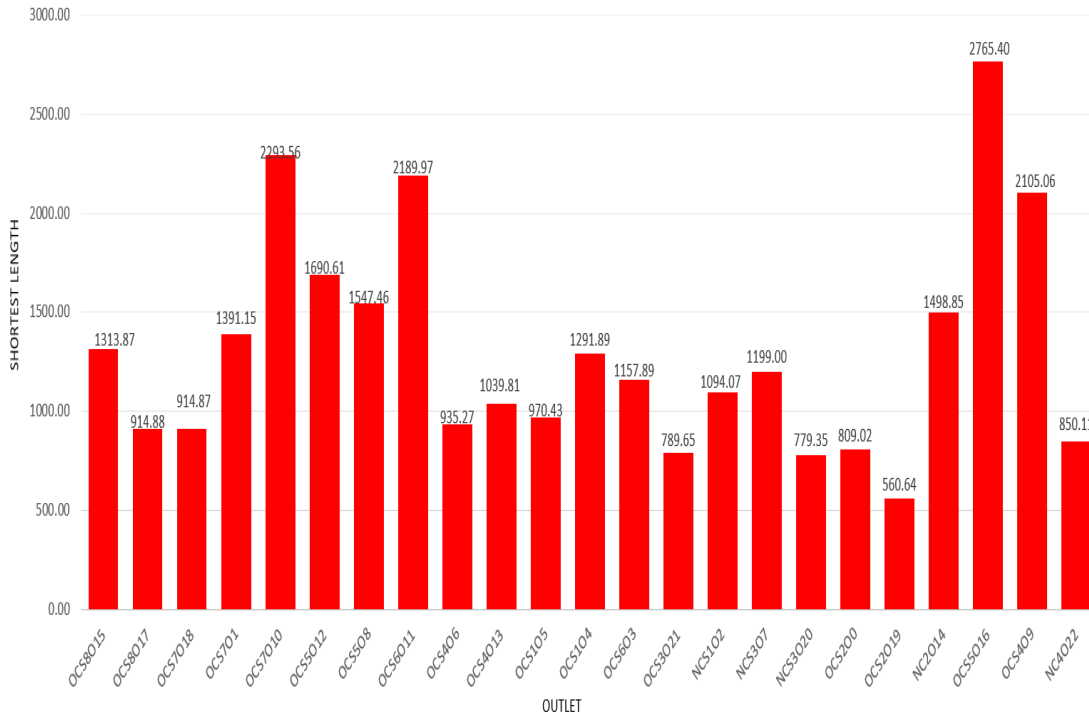
SHORTEST LENGTH TO SHELTER (M)
(KOYRA UNION)

Figure 3.8: Shortest length to Shelters (Koyra Union)



SHORTEST LENGTH TO SHELTERS (M)
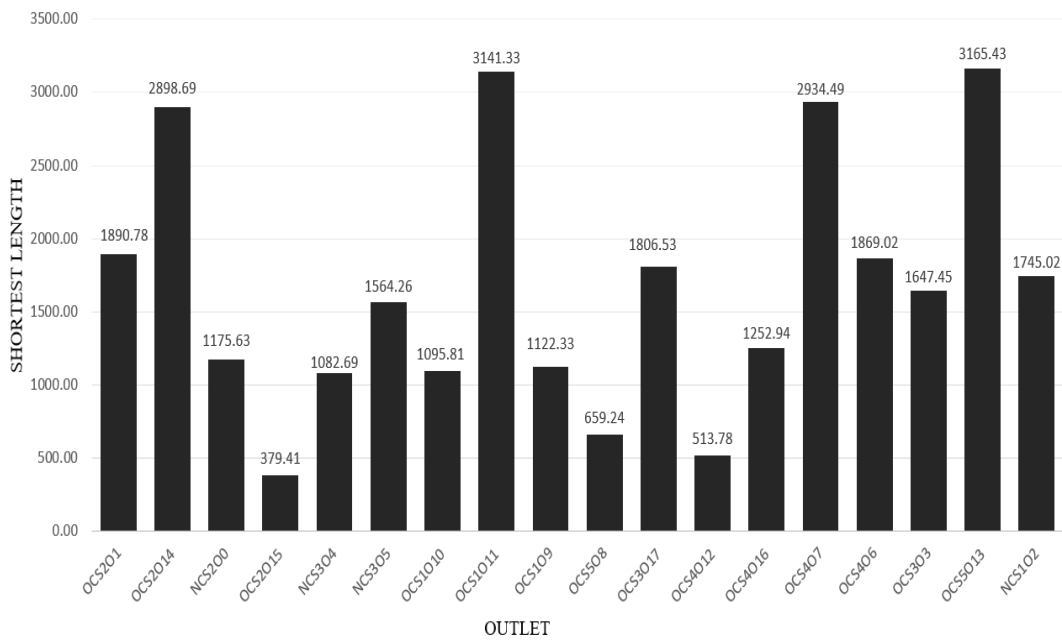(MAHARAJPUR UNION)

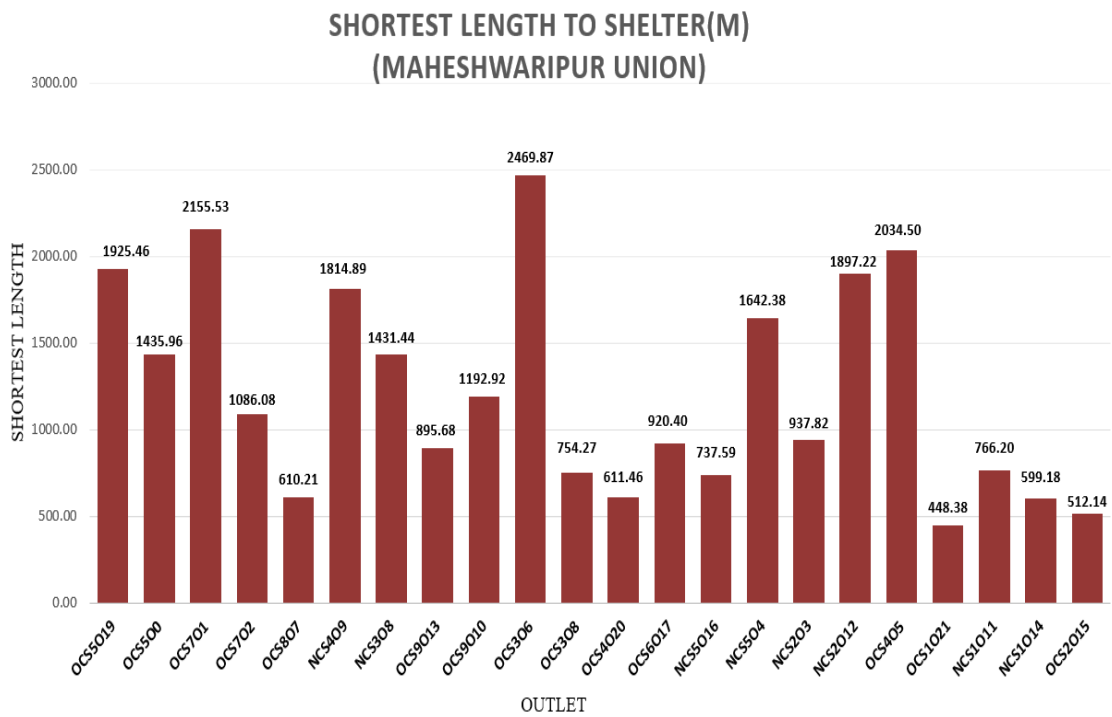Figure 3.9: Shortest length to Shelters (Maharajpur Union)

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.
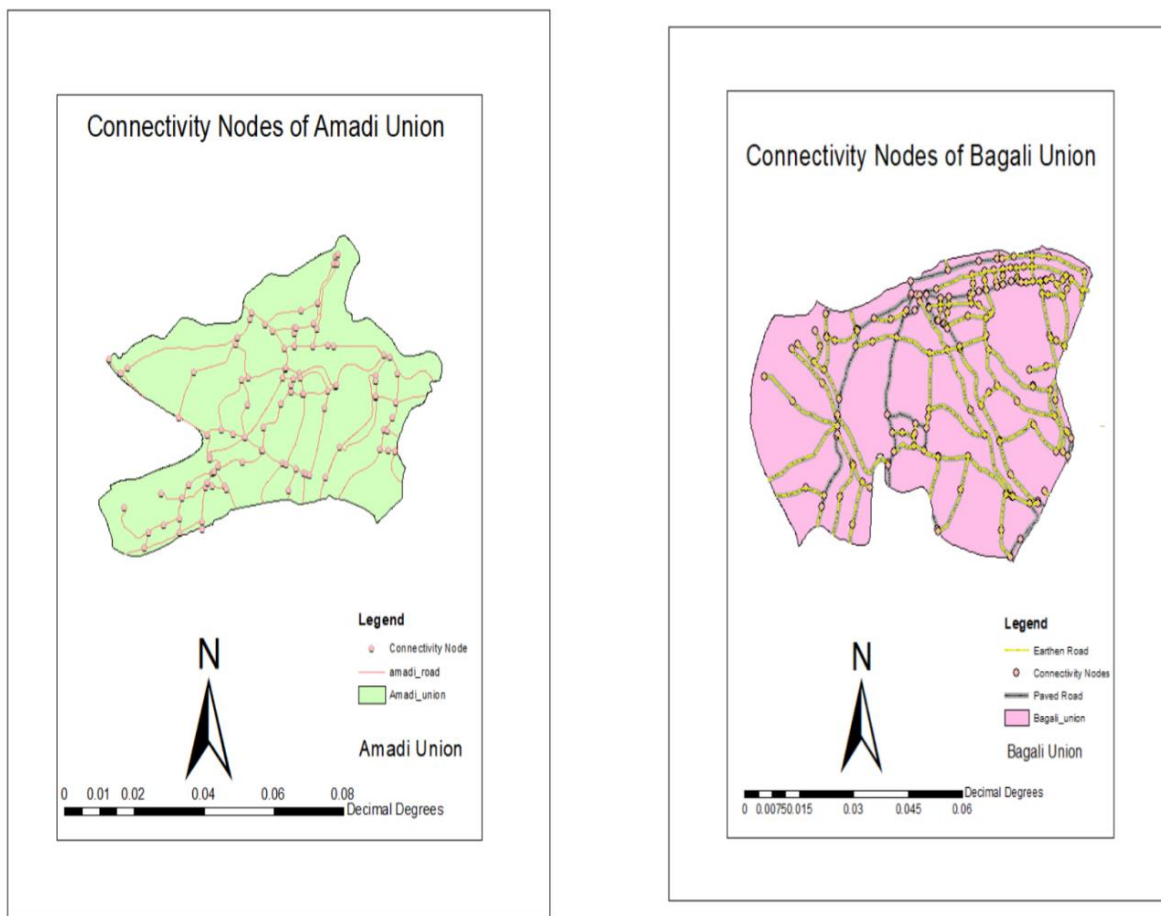


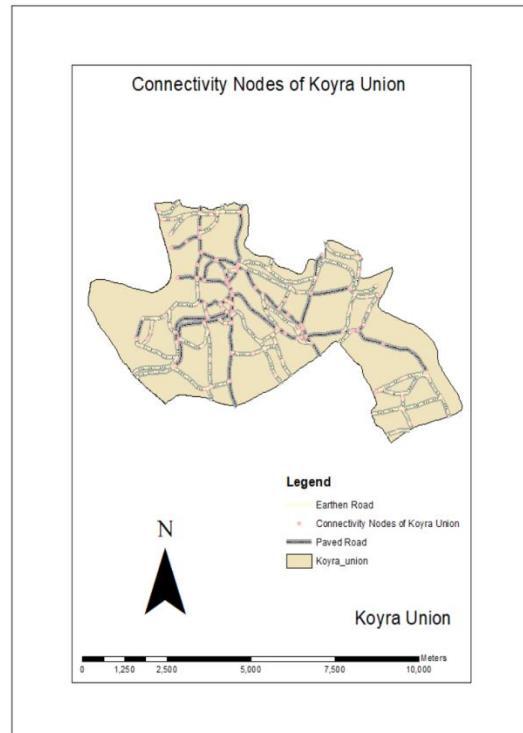(a)                                                                                          (b)

Figure 3.12: (a) Connectivity Nodes of Amadi Union (b) Connectivity Nodes of Bagali Union
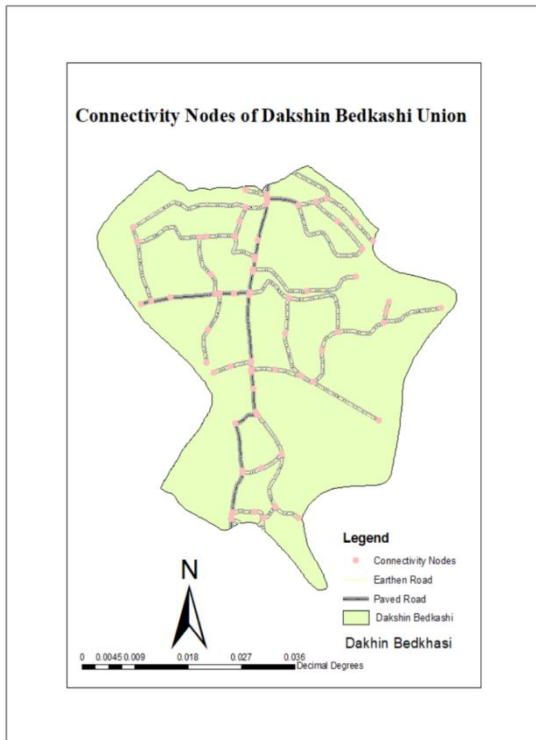
<center>(a)                                                       (b)</center>

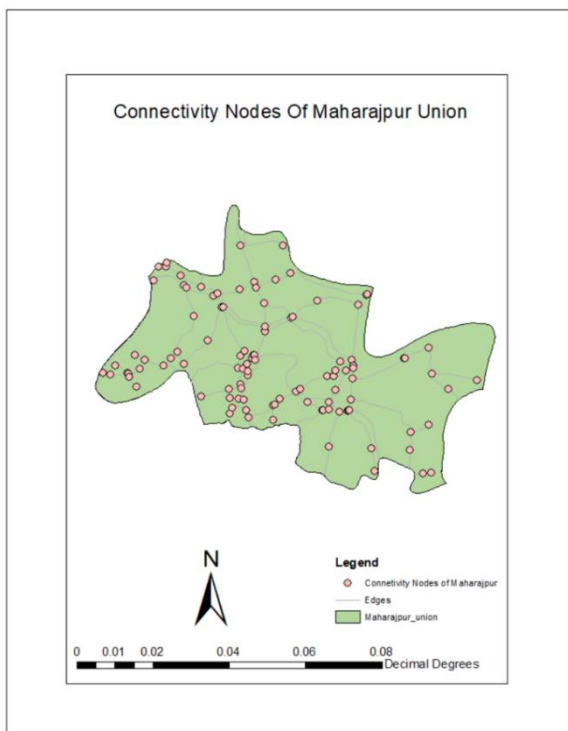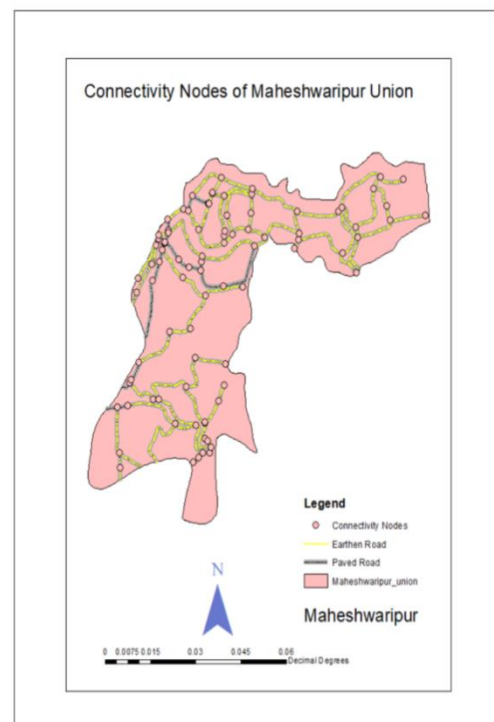Figure 3.13: (a) Connectivity Nodes of Dakhin-Bedkashi union (b) Connectivity Nodes of Koyra union.



<center>(a)                                                       (b)</center>

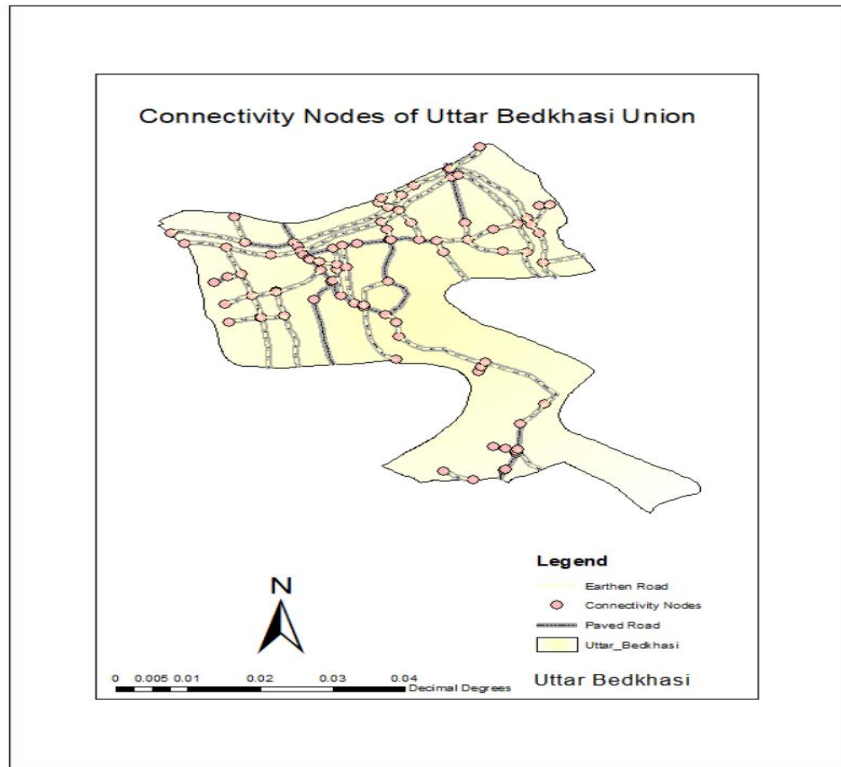Figure 3.14: (a) Connectivity Nodes of Mahrajpur union (b) Connectivity Nodes of Maheswaripur union

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 | OCS1O5 | 694.53 | 60 | 11.575 | 1 | 4 | 0.0667 | 11.642 |
| 2 | OCS6O12 | 898.79 | 60 | 14.980 | 2 | 8 | 0.1333 | 15.113 |
| 3 | NCS2O4 | 1122.55 | 60 | 18.709 | 4 | 16 | 0.2667 | 18.976 |
| 4 | OCS6O3 | 1622.41 | 60 | 27.040 | 4 | 16 | 0.2667 | 27.307 |
| 5 | OCS5O13 | 2141.65 | 60 | 35.694 | 5 | 20 | 0.3333 | 36.027 |
| 6 | OCS5O2 | 876.76 | 60 | 14.613 | 5 | 20 | 0.3333 | 14.946 |
| 7 | OCS2O6 | 960.98 | 60 | 16.016 | 9 | 36 | 0.6000 | 16.616 |
| 8 | OCS4O9 | 1564.58 | 60 | 26.076 | 1 | 4 | 0.0667 | 26.143 |
| 9 | NCS1O8 | 627.65 | 60 | 10.461 | 3 | 12 | 0.2000 | 10.661 |
| 10 | OCS5O7 | 1256.89 | 60 | 20.948 | 3 | 12 | 0.2000 | 21.148 |
| 11 | NCS1O14 | 2197.46 | 60 | 36.624 | 4 | 16 | 0.2667 | 36.891 |
| 12 | OCS5O1 | 3237.27 | 60 | 53.955 | 9 | 36 | 0.6000 | 54.555 |
| 13 | OCS7O10 | 1905.79 | 60 | 31.763 | 2 | 8 | 0.1333 | 31.896 |
| 14 | OCS3O0 | 3406.02 | 60 | 56.767 | 4 | 16 | 0.2667 | 57.034 |
| 15 | OCS3O11 | 1652.83 | 60 | 27.547 | 2 | 8 | 0.1333 | 27.681 |
| 16 | NCS1O15 | 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
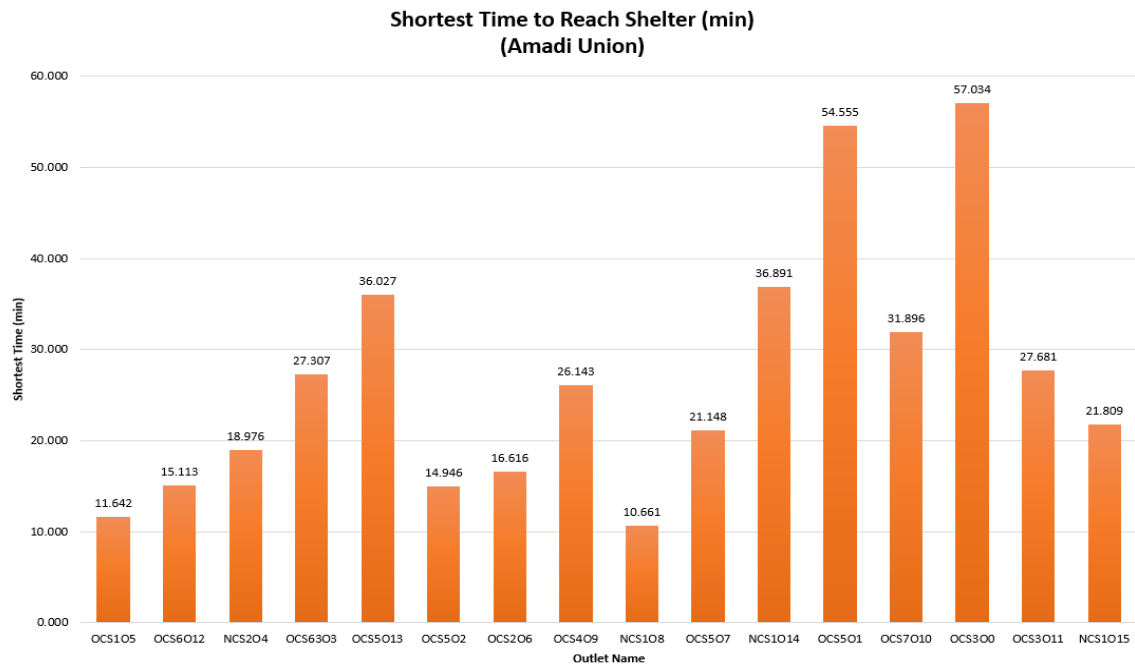


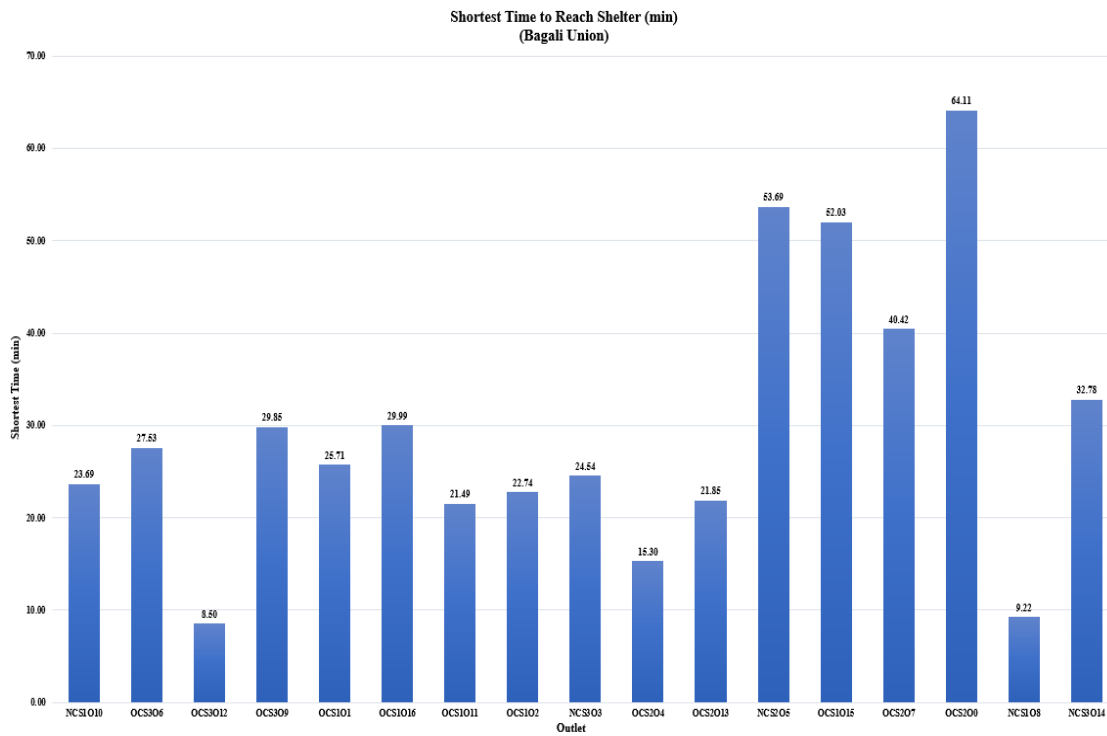Figure 3.16: Shortest Time (minutes) from each Outlet (Amadi Union)



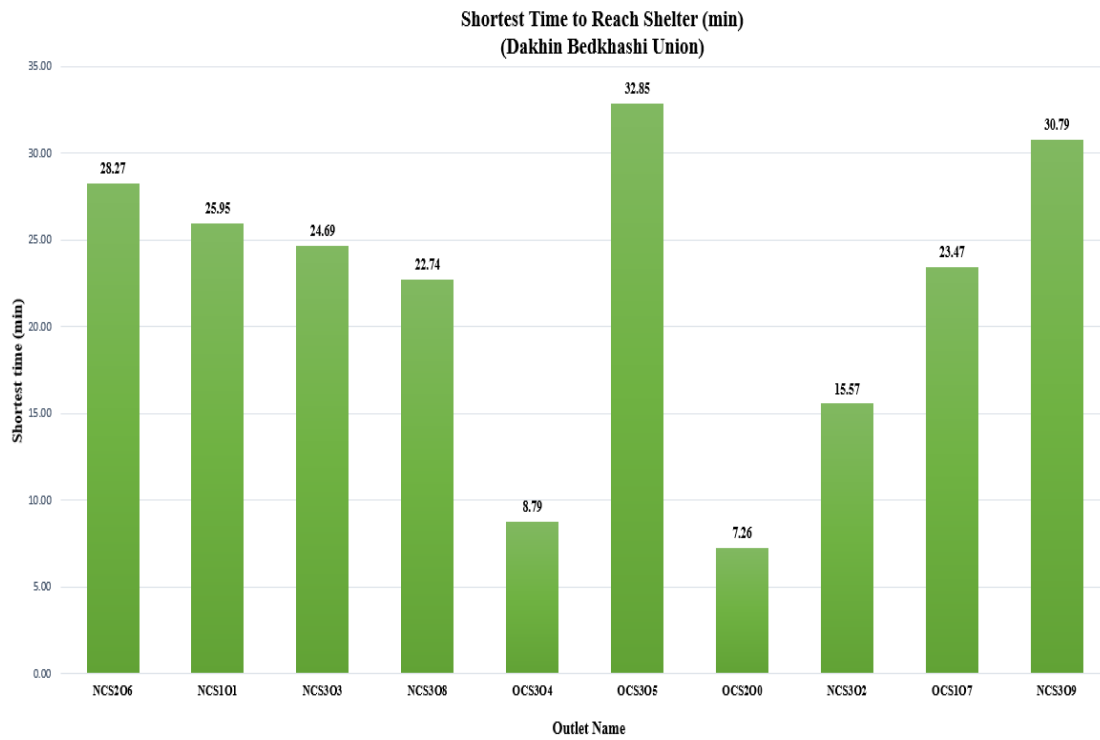Figure 3.17: Shortest Time (minutes) from each Outlet (Bagali Union)

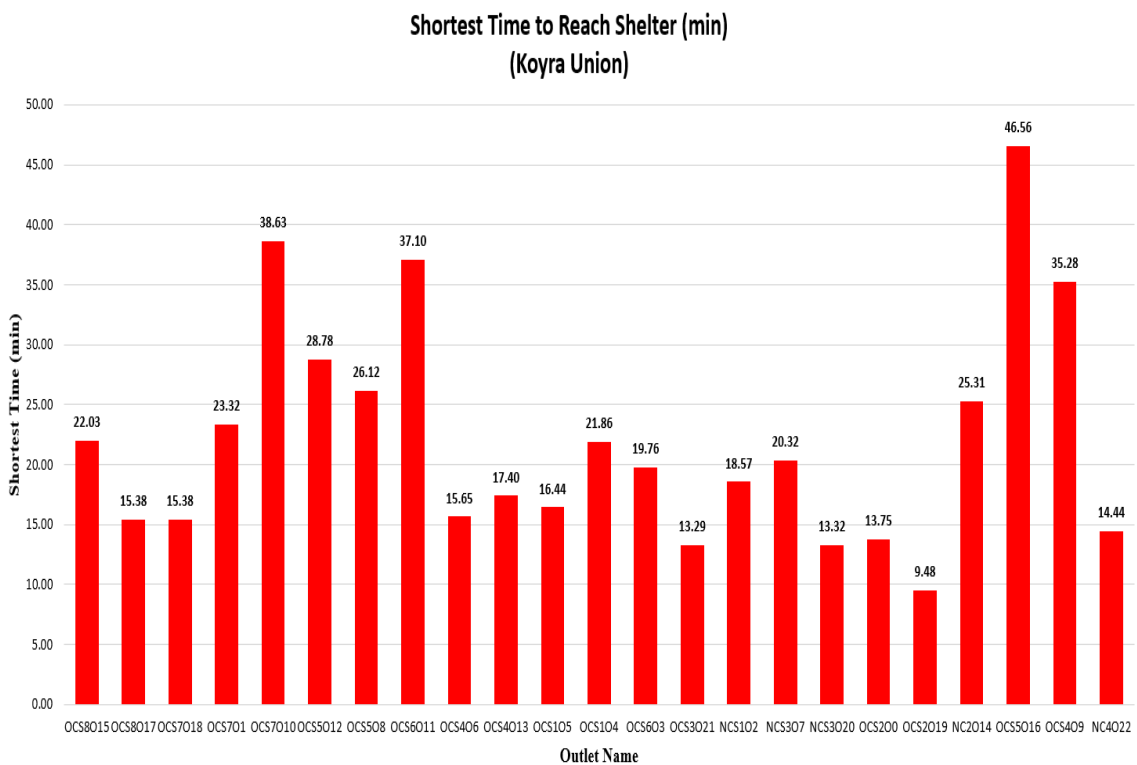Figure 3.18: Shortest Time (minutes) from each Outlet (Dakhin-Bedkashi Union)



Figure 3.19: Shortest Time (minutes) from each Outlet (Koyra Union)
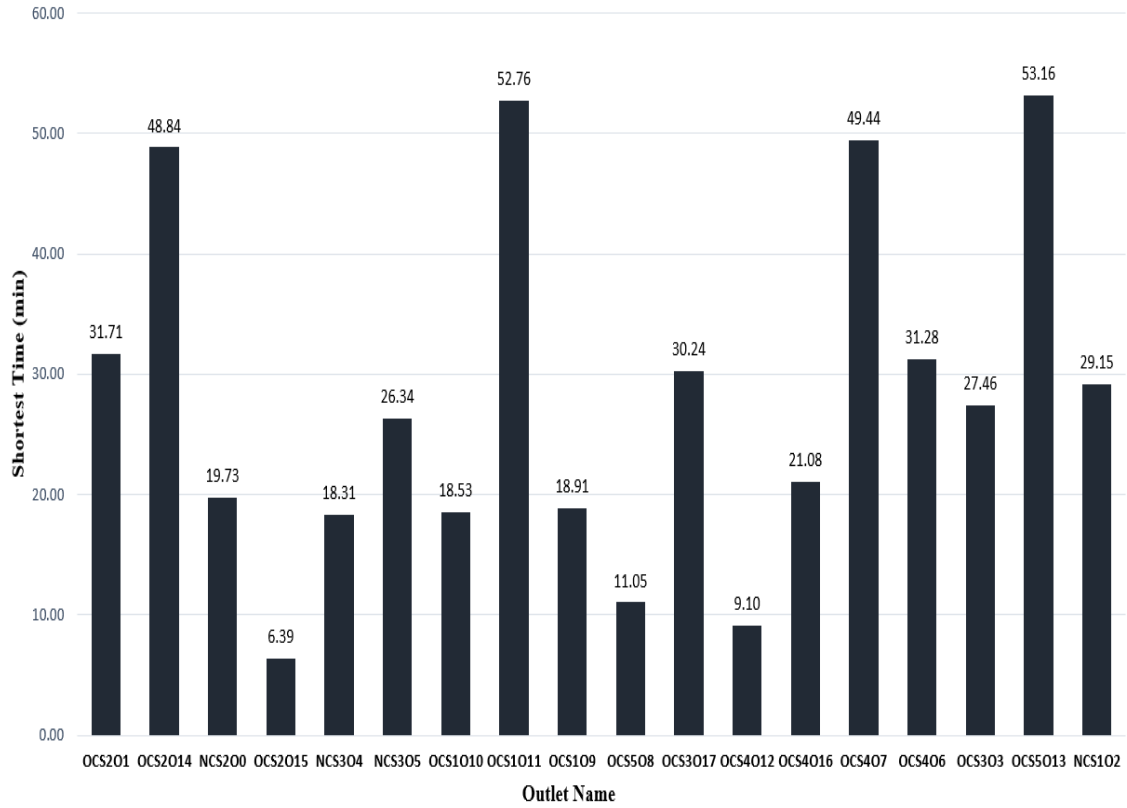
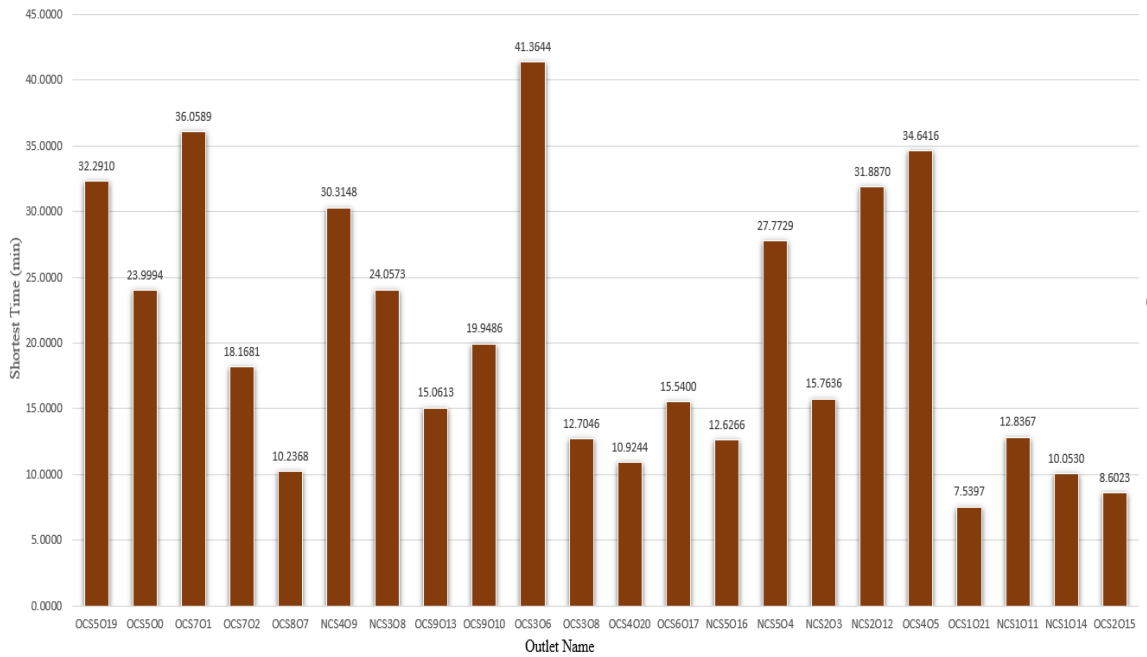Figure 3.20: Shortest Time (minutes) from each Outlet (Maharajpur Union)



Figure 3.21: Shortest Time (minutes) from each Outlet (Maheshpur Union)
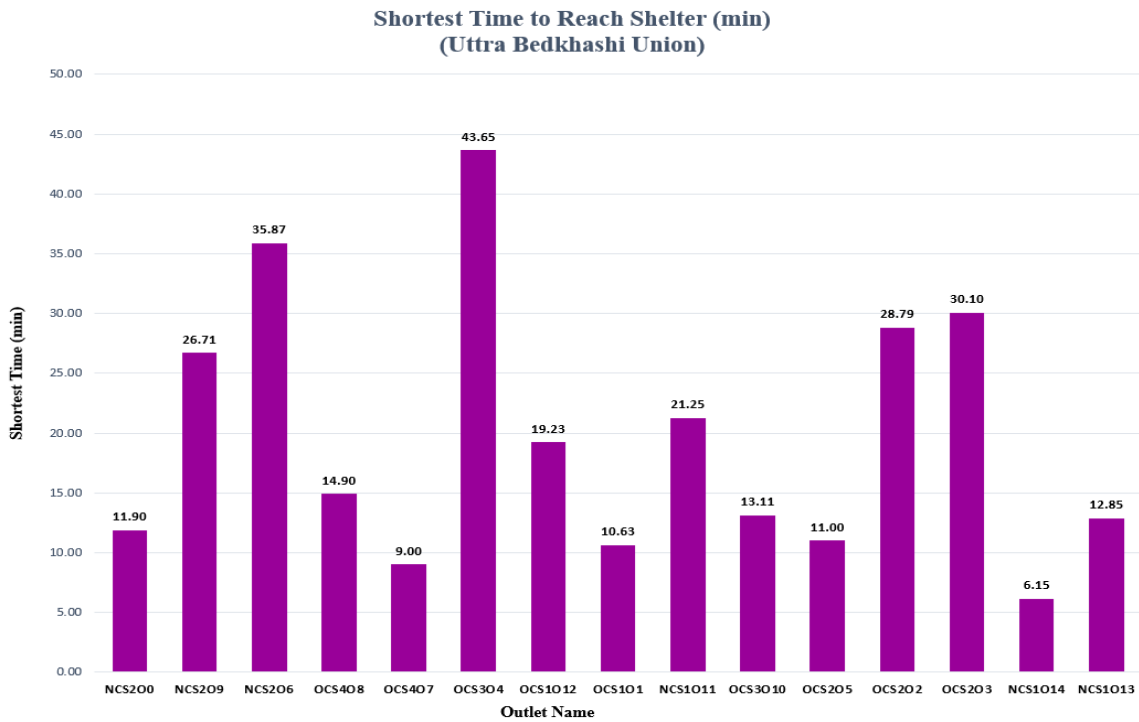
Figure 3.22: Shortest Time (minutes) from each Outlet (Uttar-Bedkashi)

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
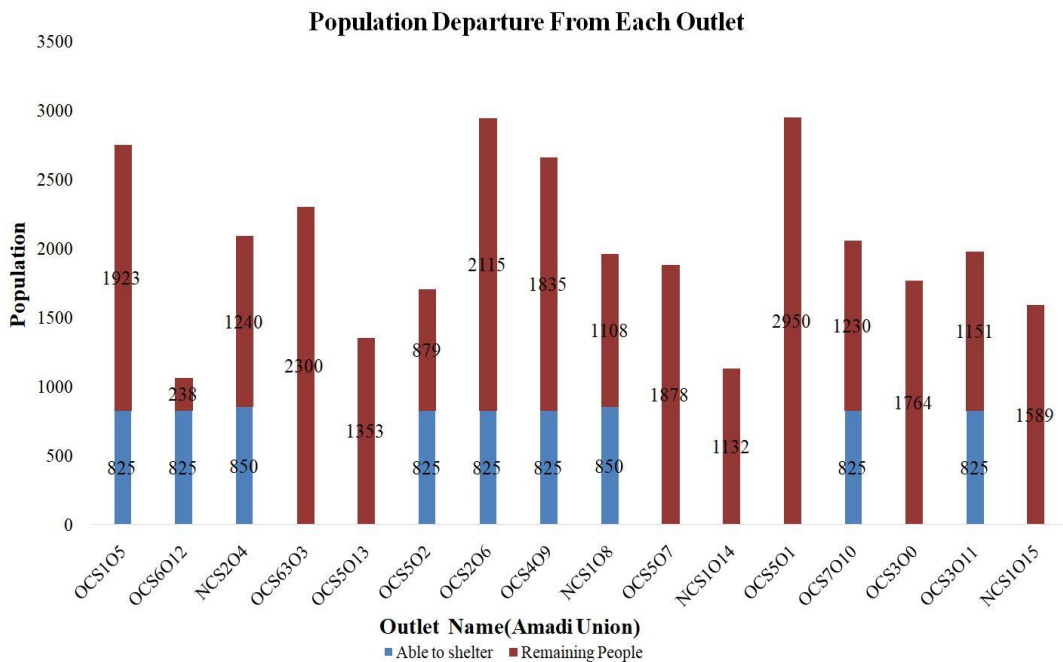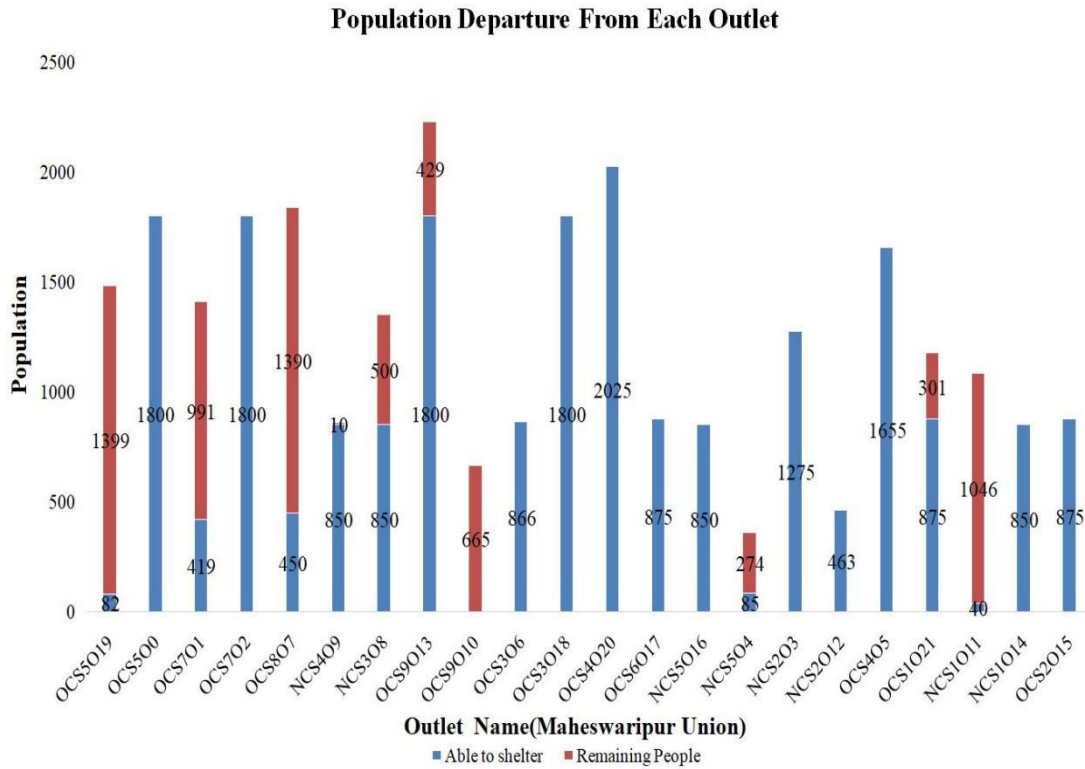


Figure 3.23: Population from outlets that cover Cyclone Shelter
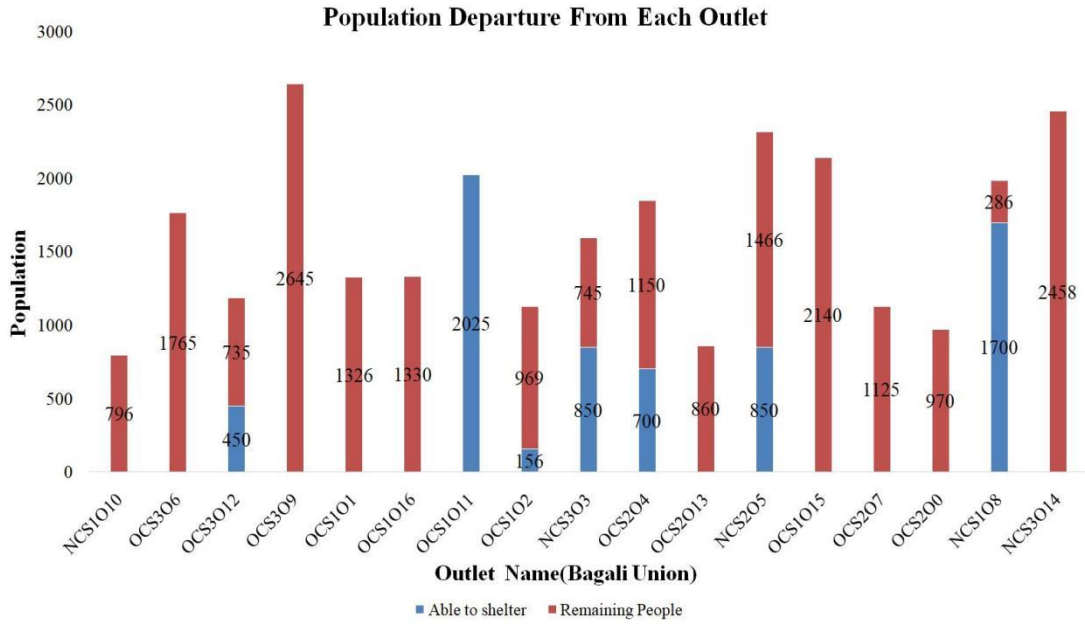
Figure 3.24: Population from outlets that cover Cyclone Shelter
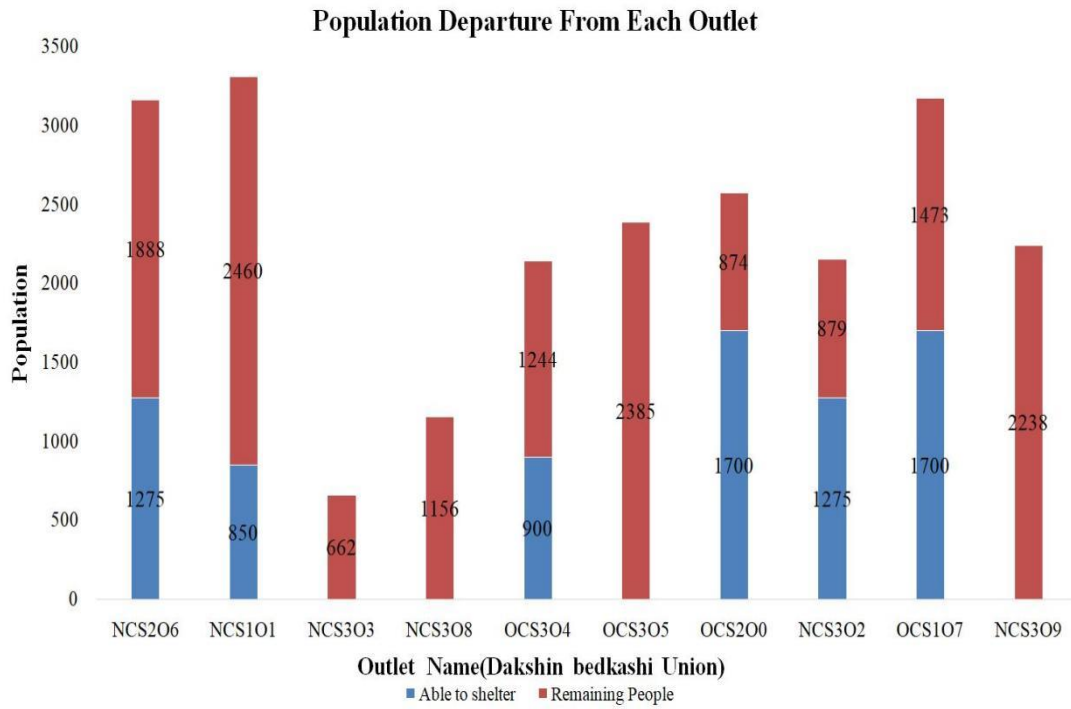


Figure 3.25: Population from outlets that cover Cyclone Shelter

24
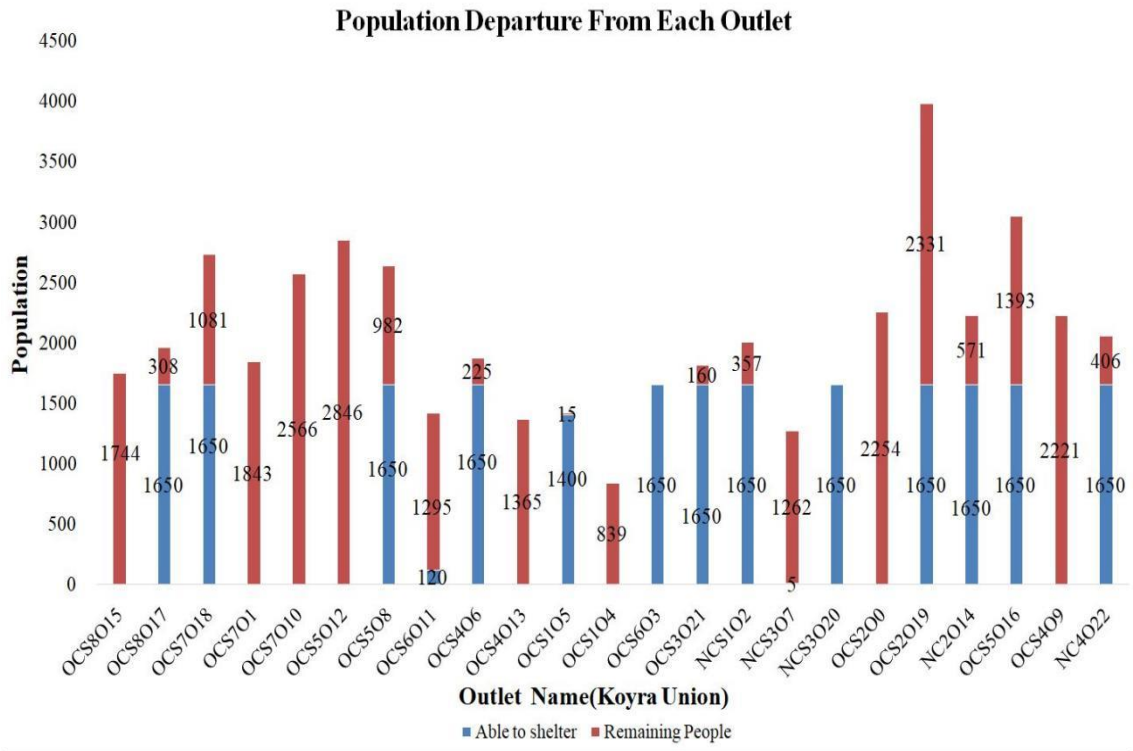
Figure 3.26: Population from outlets that cover Cyclone Shelter
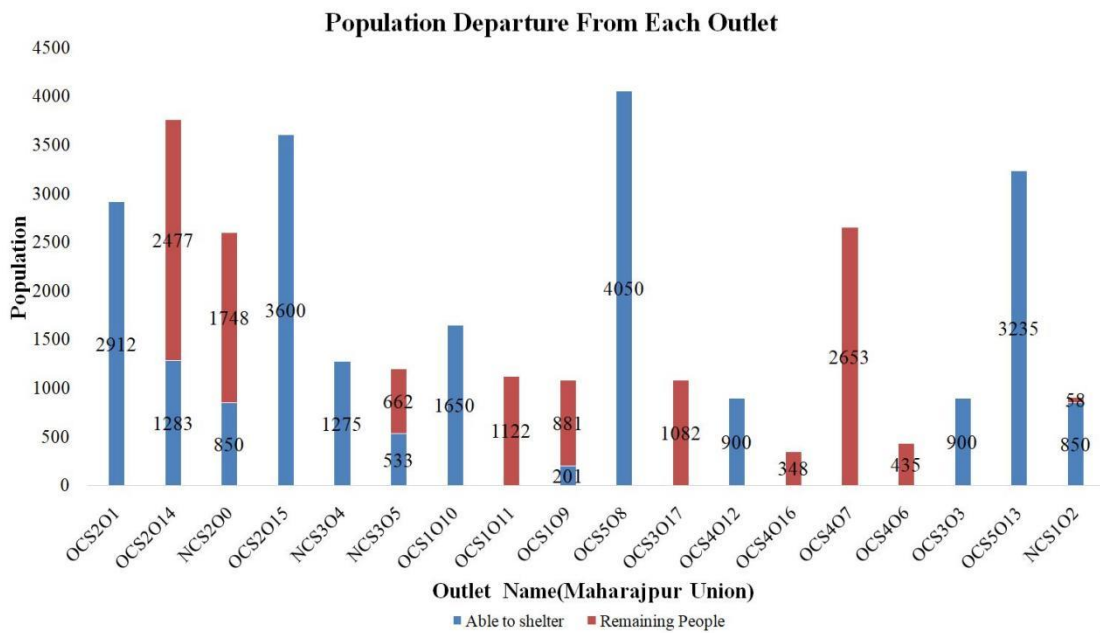


Figure 3.27: Population from outlets that cover Cyclone Shelter

25

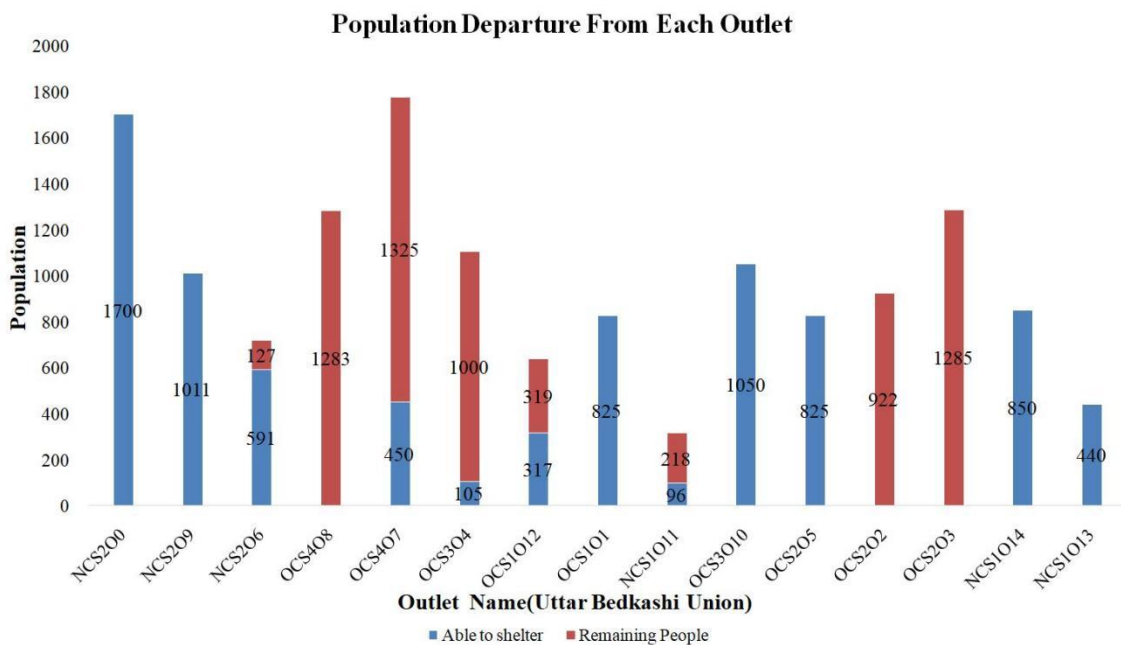Figure 3.28: Population from outlets that cover Cyclone Shelter



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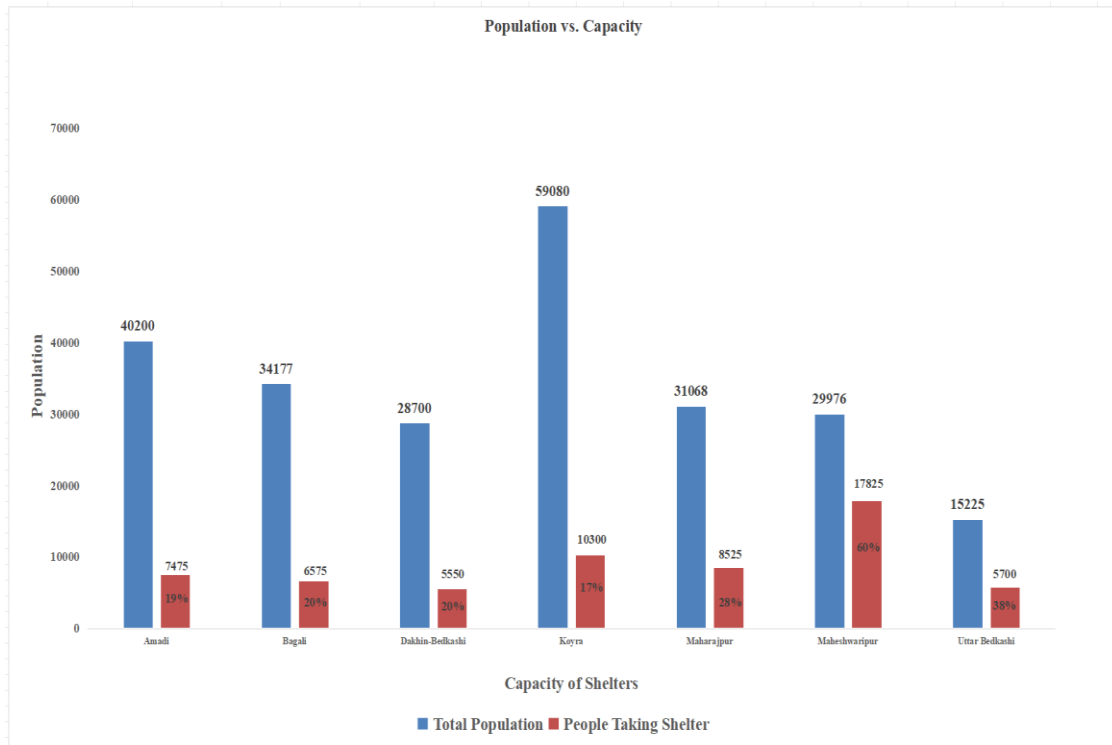
Figure 3.30: Population demand versus capacity of cyclone shelter (Each union)
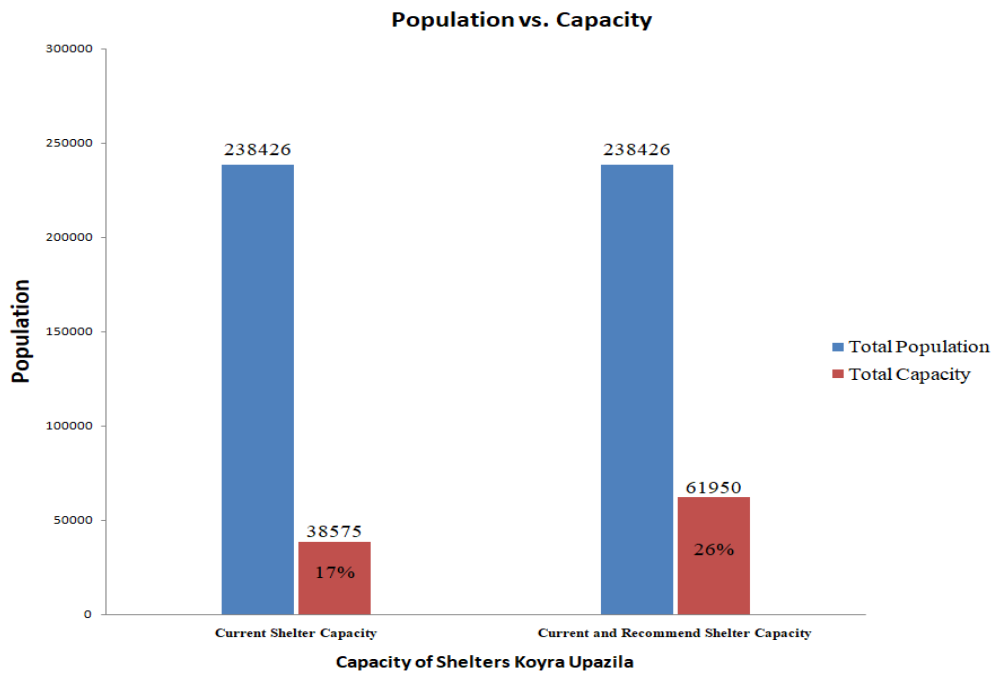


Figure 3.31: Population demand versus capacity of cyclone shelter (Koyra Upazila)

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.

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