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Research Article

Spatial Strategies for Crowd Management in Haridwar, India

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Abstract Crowd-related hazards are prevalent in densely populated countries like India where there is increase in the number of visitors to religious gatherings (NDMA, 2014) and the major task of authorities lies in reducing the risk of crowd disasters. The purpose of this work is to spatially analyze the crowd management and emergency preparedness strategies formulated by authorizes for the safe conduction of the *Ardh Kumbh* Mela, 2016 in Haridwar with the help of tools and technologies. In this paper, we examine the potential of using technologies like Remote Sensing and Geographical Information System (GIS) for evaluating and recommending guidelines for crowd management and emergency response. The study was largely dependent on field visits during the 2016 *Ardh Kumbh* Mela and it attempted to capture the merits and demerits of the proposed crowd management strategies such as the major crowd flow routes, infrastructure facilities, critical crowd management and emergency routes to hospitals. Various analyses like crowd capacity analysis, infrastructure scoring, and crowd flow analysis helped to recommend guidelines for Crowd Control Management.
Keywords *Mass gathering; Crowd management; Crowd flow; Kumbh Mela; Emergency response*

1. Introduction

India with its increasing population (Census, 2011) attracts a large number of people to gatherings and pilgrimages such as *Kumbh Melas, Rath Yatra, Thrissur Pooram, Ramzan* and *Durga Puja*. Over the years, several tragedies in mass gatherings caused fatalities and the greatest task lies with effectively managing the crowd and prevent the loss of control over mass (Hanna, 1994). Lack of information about the expected number of people visiting makes it difficult to successfully plan the event and effectively manage the crowd. World Health Organization (2008) defined Mass gatherings as 'more than a specified number of persons (may be as few as 1000, although the available literature refers to gatherings exceeding 25,000 persons) at a specific location for a specific purpose for a defined period of time'.

Haridwar, prominent spiritual and religious city in the state of Uttarakhand, is known for its temples and bathing Ghats. *Ghat* refers to a series of steps leading to a holy body of water, in this case, the river Ganges, which is considered sacred in the Hindu tradition. Pilgrims come from all over the world to take a holy dip in the Ganga at the most revered location of Haridwar, *Har-ki-paudi*. Haridwar is one

of the four venues in the country to host *Kumbh Mela* and *Ardh Kumbh Mela*, once every 12 years and 6 years respectively (Mehrotra, 2015). Mela refers to a cultural or religious fair or a festival and *Kumbh* is 'repetitively described as microcosm of India' (Maclean, 1968). The *Kumbh Mela* is held for about one and a half month with people participating from all over the world and there is no precise method to determine the number of people taking holy dip on an auspicious day. Haridwar is home to various fairs and gatherings throughout the year which makes it vulnerable to crowd-related hazards including but not limited to stampedes, fire, and epidemics (Mohd Arif Shuib, 2013).

Mehrotra (2015) with a team from Harvard University has investigated and documented the large-scale Allahabad *Kumbh Mela* of 2013 with the participation of approximately 34 million, monitored from its preparation stage to the actual celebrations. He spoke about the construction activities carried out in the city in terms of its scale and complexity and documented the most interesting elements of the process such as the functionary temporary structures and bridges, housing, transport, and emergency services. Alongside addressing the complex construction and destruction of the city given the scale of the city and compressed timeframes the team also identified and addressed many complex issues related to but not limited to crowd and resource management.

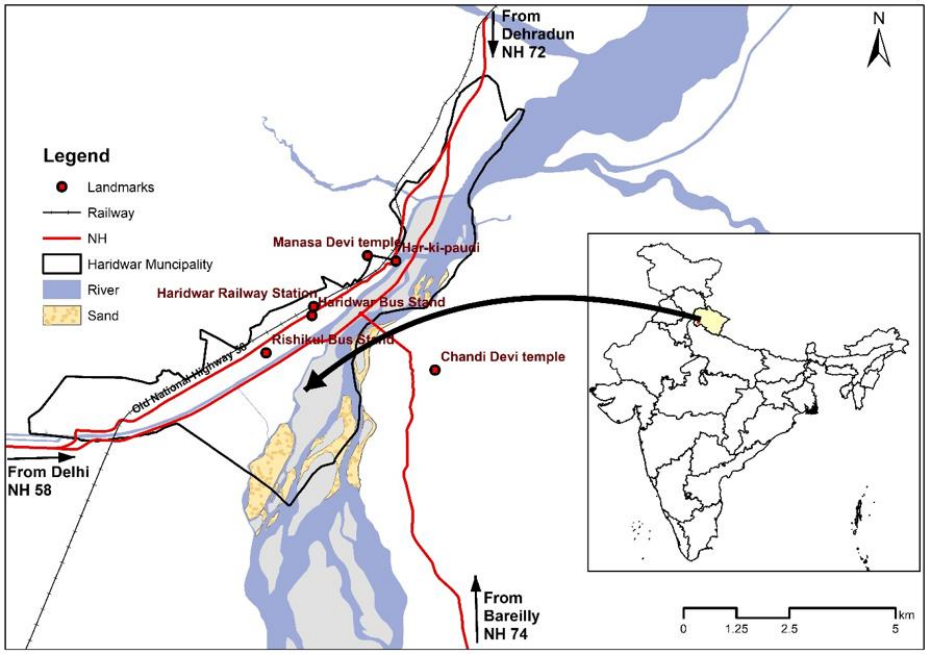

Figure 1: *Study area map*

Bihar State Disaster Management Authority (2013) studied the details of operational planning of Allahabad *Kumbh Mela* and captured the best practices that could be adopted by other states and countries all over the world for planning any mass gatherings. National Remote Sensing Centre (ISRO) & Uttarakhand Space Application Centre (2011) combinedly developed a methodology for estimating pilgrims present in *Kumbh* area on an auspicious day in 2010 Haridwar *Kumbh Mela*. The integrated data from space-based remote sensing technology and ground-based data for estimating the number of pilgrims. Various works (Mehrotra, 2015; NDMA, 2014; Sindhuja, 2015; Jeffrey Tubbs, 2007; Rani, 2017; Sultan, 2015; M Devi Anju, 2016; Hanna, 1994; BSDMA, 2013) abetted to understand the management of mass gatherings and derived useful recommendations for event organizing and safe crowd management.

This article is an attempt to evaluate the crowd control and management strategies, and emergency response strategies formulated by authorities during a mass gathering in Haridwar. With the help of

field observations, GIS and Remote Sensing technologies we have spatially analyzed the strategies laid by government authorizes during 2016 *Ardh Kumbh Mela*. Documentation and evaluation of strategies implemented during any gathering will help the authorities to learn from the past and effectively plan the upcoming gatherings. Various analyses like the crowd capacity analysis and crowd flow analysis were conducted and the suggestions were used in formulating the preparedness measures. The paper aimed at constructing certain guidelines for better crowd control and management in the case of Haridwar.

Study Area

The study area, Haridwar municipality (**Error! Reference source not found.**), lies between 78°50'E - 78°11'E longitude and 29°54'N - 29°59'N longitude encompassing a geographical area of 23.7 km^2. The *Kumbh Mela* area outspreads the municipality to an approximate area of 130 km^2. Haridwar with a current population of 0.2 million and mean floating population of 0.16 million attracts an annual average of 8 million tourists (Appraisal of City Development Plan, Haridwar, 2007). The growth rate of the floating population was estimated to be 2.5% per annum which is slightly above the national average of 2% per annum. The city which is home to spiritual societies and ashrams is attracting a large number of people with its industrial development as well. The unparalleled influx of visitors during *Kumbh Mela* creates tremendous pressure on the infrastructure facilities and natural resources.

Indian National Trust for Art and Cultural Heritage (INTACH) undertook 'Cultural Resource Mapping of Haridwar District' and listed 164 cultural resources in Haridwar which included temples, ashrams, Ghats, sacred waterbodies, rituals and other. *Har-ki-paudi* is one of the holiest places on earth for Hindus, the ancient ghat is of prime importance and a registered society carries out its maintenance activities and *Ganga Aarti* in the evenings. Notable Ghats in Haridwar besides *Har-ki-paudi* are *Gau ghat, Astipravah ghat,* Malviyadweep, Subash ghat, and *VIP ghat*, which are only a few in many.

The city has restricted physical expansion due to hills and reserved forests to the North-west and south-east, and the river which flows from North-east to the south (City Development Plan: Haridwar. Revised Under Jawaharlal Nehru National Urban Renewal Mission (JNNURM), 2007). The development is linear along the main corridor of the city confining within the municipal boundary. The old areas witness high-density unplanned development without proper infrastructure and road hierarchy. Lack of sufficient parking areas, narrow roads, unplanned commercial establishments in ghat areas, traffic junctions etc. are causing severe traffic problems and danger to pedestrian movement.

Whole new temporary city mushrooms along the river bed during *Kumbh Mela* to facilitate the tourists coming from all over India and other parts of the world. The authorities are often challenged to provide basic facilities for the tourists including but not limited to shelter, roads, electricity, sanitation, and hospitals, thus establishing a "temporary city". The Mela area extends from Haridwar to Rishikesh and has been divided into 31 sectors and those in and around Haridwar are shown in **Error! Reference source not found.**. Most of the sector areas are on the floodplains while a few are in the open lands of the industrial and residential neighbourhood. The residential tents will be provided to the pilgrims in the sector areas, but the availability and accessibility of these amenities are often questionable.

The most important and busy route of Haridwar is the Haridwar main road (old NH) which goes through the municipal area connecting principal areas like Railway station and bus stand. From the main road the traffic flows to *Har-ki-paudi* through *Upper-road* and *Lower-road*. In Haridwar the primary bus terminal which is located opposite to the railway station will be closed during mela periods as the surrounding areas will be pedestrianized. Instead of that, the *Rishkul ground* which is closer to

the national highway will be used as an alternative bus terminal to cater the increasing demand. A new transportation plan will be executed during mass gatherings, often developed by city police under the supervision of the commissioner.

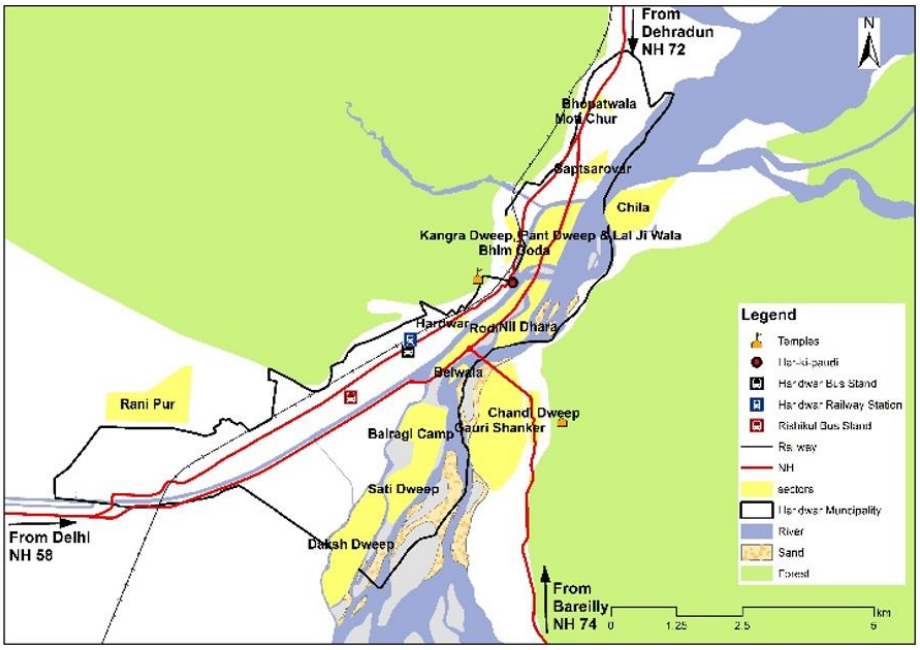

Figure 2: *Kumbh mela sector map*

2. Methodology

The study comprises two main components, field study and spatial analysis in the digital environment. Most of the primary data collection was carried out during the Haridwar *Ardh Kumbh Mela*, 2016. The primary data was collected through field visits, reconnaissance survey, questionnaire, interviews, photographs, and satellite imagery. Interviews were conducted with Mela officials and other prominent people for understanding the measures taken during the event. An observational study was undertaken to identify the existing infrastructure facilities which include structural, transport, security & information and amenities & utilities. The checklist further extends to understand the movement of the crowd and its behavior by identifying crowd triggers and interrupters in an area. Infrastructure scoring was carried out to understand the positive and negative influence of infrastructure facilities on crowd movement.

The secondary data includes information from *Ardh Kumbh mela* (2016) media Centre, user manuals, books, and newspapers. Scanned map of the municipal boundary was obtained from City Development Plan (CDP), which was georeferenced and digitized in GIS to produce the vector boundary of the study area Attribute data collection was conducted through extracting information from various sources such as google maps, field surveys, and CDP. Multispectral Sentinal Satellite images of the 10-meter resolution obtained from USGS for the year 2016 were found to be useful in the preparation of GIS base layers due to its medium resolution. Adequate help was taken from Google Satellite images and ArcGIS Online imagery since both are very high-resolution imagery. Various thematic layers such as Waterbody, Forest, Bridges, Roads, Parking areas and flood plains are digitized from Satellite imagery. Google Imagery and ArcGIS imagery helped in identifying and correcting the missing features in the maps and Web Mapping Services (WMS) like Google Maps, Wikimapia and Bhuvan helped in identifying the landmarks including but not limited to Major Temples, Ghats, Hospitals and Fire stations. The locations of landmarks obtained from online sources are

converted into GIS points and stored as layers in the GIS database which are later verified during filed visits. Thematic maps such as sector map, Parking map, and crowd flow map are prepared with the help of field data, satellite images and city development plan (CDP).

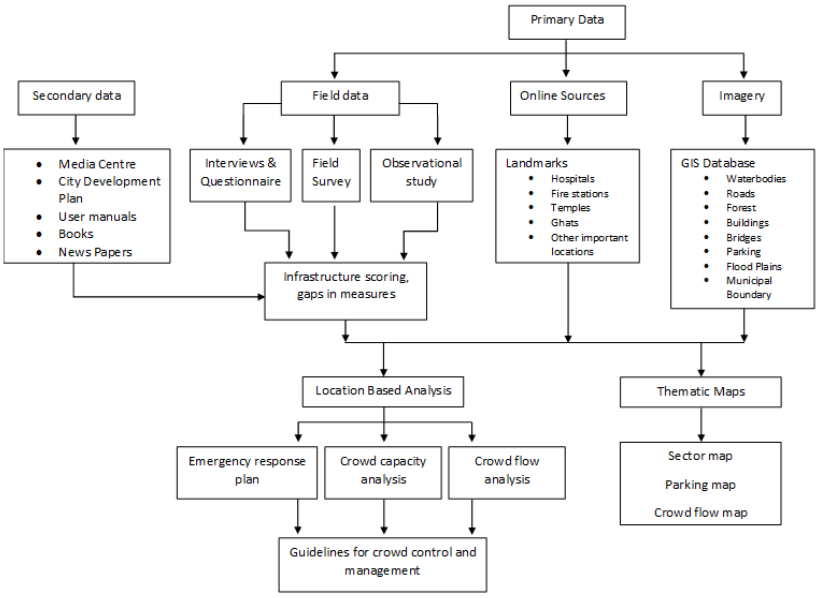

Figure 3: *Methodology flow chart*

Spatial analysis of the data was carried out to analyse the strategies laid by authorities and to eventually derive certain guidelines for crowd control and management. The crowd flow in and out of the city was studied in detail and areas with critical crowd movement were identified. The crowd capacity analysis carried out in *Har-ki-paudi* area can act as a major preparedness measure for crowd control. The crowd carrying area of *Har-ki-paudi* was calculated using GIS to compute maximum crowd capacity of the area. After spatially representing the emergency response plan laid out by authorities in *Ardh Kumbh* 2016, the appropriateness of the emergency response strategies was checked and emergency response routes to hospitals and fire stations were identified. Based on the analyses we have framed the lessons learned from the *Ardh Kumbh Mela* 2016 and the guidelines for crowd control and management are proposed.

3. Results and Discussion

Even though the 2016 *Ardh Kumbh mela* is a success in any measure, the city of Haridwar can further improve in view of upcoming *Kumbh melas* and other gatherings. Adequate field studies during *Ardh Kumbh mela* combined with GIS spatial analysis provided a sight of the issues faced during mass-gatherings in Haridwar. The findings of the study are organized into 4 key segments for further discussion: inferences from field observations, infrastructure scoring, crowd flow analysis, crowd capacity analysis, and emergency response plan.

3.1. Inferences from Field Observations

Field studies showed the lack of awareness regarding the main procession routes and alternative routes and hence causing irregular movement of people in all directions in the surrounding roads. The people coming from *Rishkul* Bus stand and Railway station areas were supposed to take a turn and walk through the Rodi Belwala sectors to eventually reach *Har-ki-paudi*; instead, many people took

the upper road and lower road to reach *Har-ki-paudi* which was solely for the people coming back from *Har-ki-paudi.*

The absence of adequate parking areas which led to unplanned on-street parking along the main road hindered the movement of crowd and vehicles. The road outside the railway station got congested because of the on-road parking of rickshaws and taxis. Due to improper execution of guidelines vehicles are parked even near railway station which should be vehicle free during *mela* days. Pedestrianized upper and lower roads faced encroachment by street hawkers, one of the main causes of crowd congestion. During normal days, the mixture of pedestrian and vehicular traffic along the Ghats due to lack of proper regulations creates safety issues for the people. The absence of designated parking areas near the Ghats results in hectic parking and obstructs the pedestrian flow.

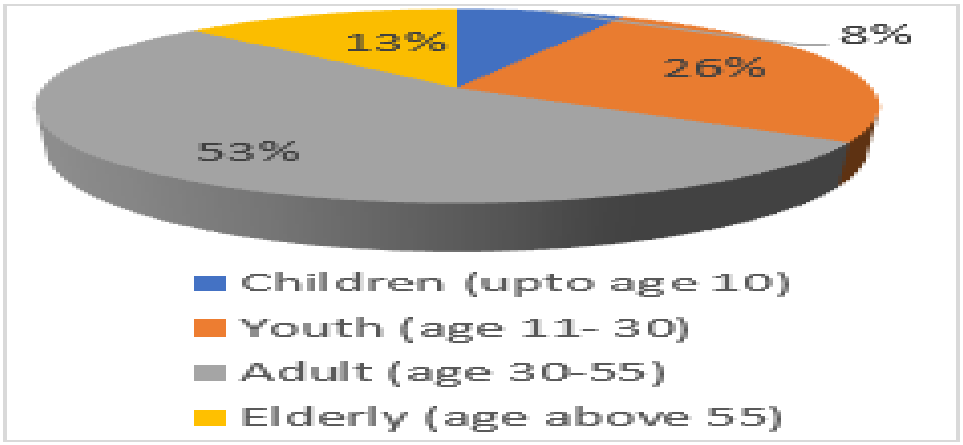

Figure 4: *Age profile of the visitors (Raheja, 2015)*

	Structural	Transport	Information and Security	Amenities and Utilities	Crowd Triggers	Crowd Interuptions
Bus Stand	0.6	-0.2	1	0.67	-0.5	-0.67
Railway Station	0.7	-0.29	1	0.89	-0.67	-0.67
Shiv-murthi Junction	0.5	-0.75	1	0.87	-1	-0.83
Mela Office	0.83	1	0.9	0.7	-0.83	-0.33
Kangra Dweep	1	0	1	1	-0.16	-0.33
Rodi Belwala	0.7	-0.29	1	0.89	-0.67	-0.67

Figure 5: *Infrastructure scoring*

Diversity in visitor's age, gender, abilities and group size in combination with their movement pose unique issues. The ghat areas are not easily accessible by elderly and persons with disabilities. The demographic profile of the pilgrims visiting the Ghats over a year reflects a higher percentage of elderly with a good number of children and women in **Error! Reference source not found.**. Nearly 50% of the tourists are women and 21% of the total visitors constitute children (up to age 10) and elderly (Raheja, 2015). The ghat of *Har-ki-paudi* was observed to be at an elevation difference of 6-9 meters which is accessible by stairs and there is no provision of ramps or elevators for the elderly.

3.2. Infrastructure Scoring

Infrastructure scoring is given for selected nodal points by using infrastructure checklist which broadly has been categorized into structural, transport, security & information and amenities & utilities. The observational study conducted identified the strengths and weakness of the existing infrastructure facilities. The checklist further extents to understand the movement of the crowd and its behavior by identifying the crowd triggers and interrupters in the area. The study nodes are identified based on the complex crowd flow patterns and congregations. The observational survey required for the infrastructure checklist was carried out during *Ardh Kumbh Mela*, 2016 with the purpose of including the temporary amenities and structures in the checklist. The categories and subcategories in the checklist are defined based on the Causes and Triggers for Crowd Disasters listed by NDMA in the National Guide on Crowd Management (NDMA, 2014). For example, railings, barricades, lighting, temporary structures, staircases, and ramps come under the category of structural. Based on the existence or non-existence of an infrastructure element and its positive or negative influence on the crowd movement, the scores are given (Table 1).

Table 1: *Criteria for the provision of scores for elements in infrastructure scoring*

Criteria	Provision Score
Existence of an infrastructure element (positive influence)	1
Existence of an infrastructure element (Negative influence)	-1
Non-existence of an infrastructure element (positive influence)	-1
Non-existence of an infrastructure element (negative influence)	1
Non-relevant infrastructure for the location	0

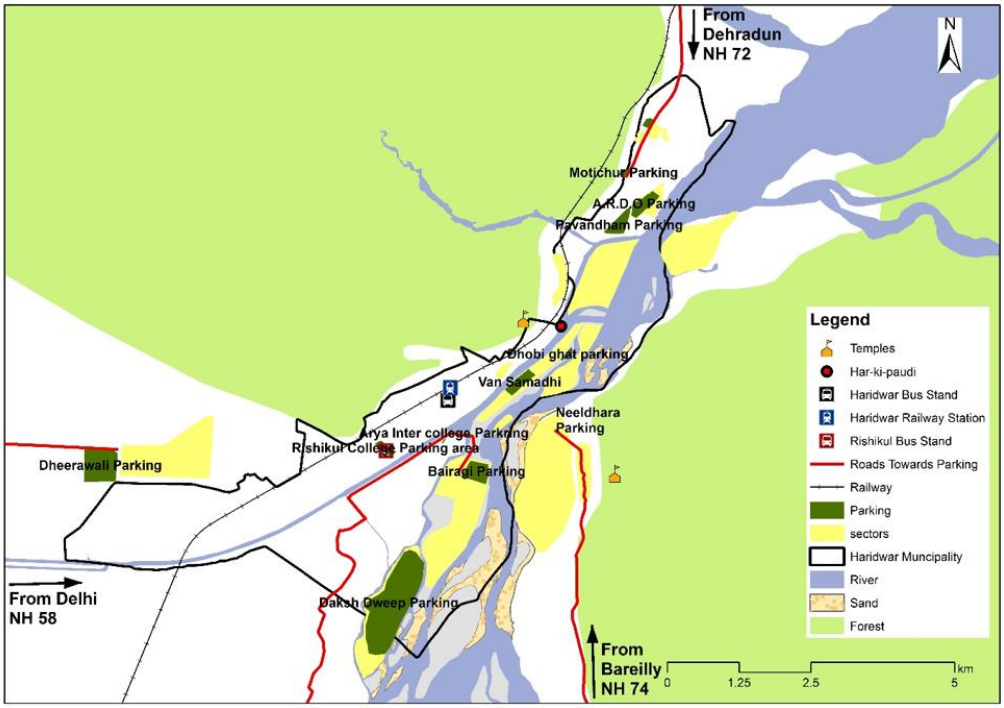

Figure 6: *Major parking areas*

For example, lighting is needed for proper crowd movement and the absence of the same can hinder crowd flow and trigger a crowd disaster. Therefore, under the criteria ‘existence of an infrastructure

element (positive influence) the score will become '1' and for the absence of lighting the score will be given as '-1' under criteria 'Non-existence of an infrastructure element (positive influence)'.
The scores of all elements/ subcategories are averaged to get the overall score of each category (**Error! Reference source not found.**). The analysis carried out in excel identified the strengths and weaknesses of infrastructure at various locations. Based on the analysis, most of the places have excellent structural facilities with *Mela* office (0.83) in the top and Shivmurthi junction (0.5) at the bottom. Likewise, the other elements- information & security and amenities & utilities also showed positive results. Transport showed negative results due to the presence of on-street parking and encroachments on footpaths. The categories- crowd disaster triggers and Crowd movement interrupters, showed negative values which showed the magnitude of triggers and interrupters in those areas. The Focus should be laid on reducing the triggers and interrupters for safe crowd management in a mass gathering.

3.3. Crowd Flow Analysis

The mapping of people's primary activities in *ghat* combined with their secondary activities such as vending, and parking helped in defining crowd flow patterns. This section discusses crowd flow pattern at the city level and crowd flow in *Har-ki-paudi* area at a detailed level.

The proportions of the traffic flow into the city of Haridwar as given by the authorities are 55% from NH 58 (from *Delhi, Meerut, and Muzaffarnagar*), 25% from NH 74 (*Saharanpur* direction) and 15% from NH 72 (*Dehradun* direction). The major parking areas that are used to accommodate the traffic flow during the *mela* days for both government and private vehicles are shown in **Error! Reference source not found.** along with major routes that carry traffic into the city. The major parking areas even though located far away from the *Har-ki-paudi* area are very easily accessible from residential sectors.

The major crowd flow routes during mass gatherings in Haridwar were identified and represented in **Error! Reference source not found.**. The crowd flow in and out of *Har-ki-paudi* during *Kumbh Mela* days is majorly through three directions: through *Rodi Belwala*, through *Neeldhara*, and through *Kangradweep*. People coming from Jwalapur-commercial area, Khankal-old town area and old National Highway go to *Har-ki-paudi* through *Rodi Belwala* sector direction. The crowd from NH72 pass through *Kangradweep* to reach *Har-ki-paudi*. All the crowd coming from *Neeldhara* and *Rodi Belwala* directions reach *Har-ki-paudi* traveling through the temporary bridges. Four new temporary bridges are constructed during every mass gathering as an alternative to the narrow roads to *Har-ki-paudi.*

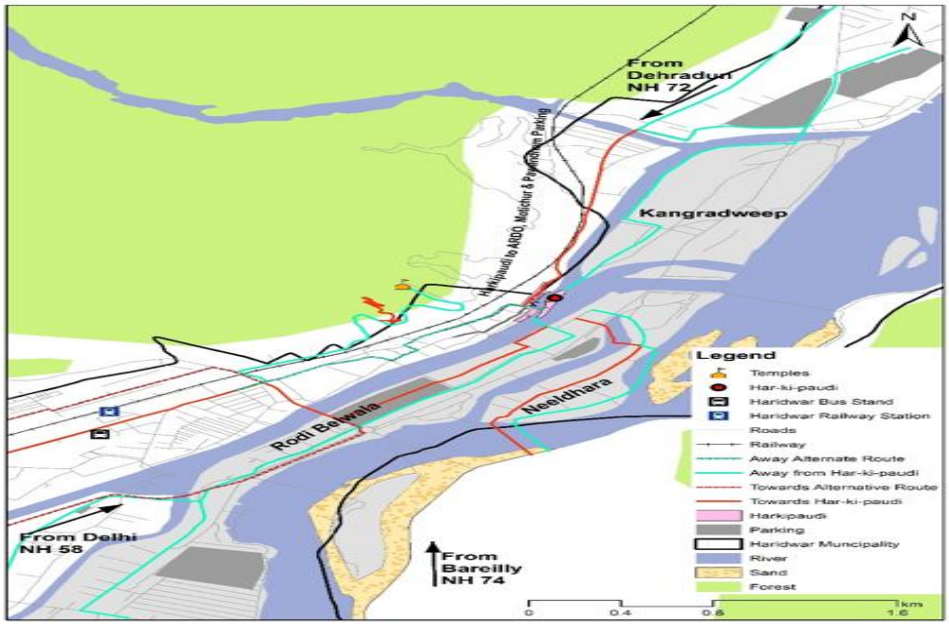

Figure 7: *Crowd flow in and around Har-ki-paudi area*

Har-ki-paudi is connected to the other side of the river with four temporary bridges besides one permanent bridge during mass gatherings and the crowd flow in *Har-ki-paudi ghat* area is shown in **Error! Reference source not found.**. Among the four temporary bridges connecting the *Har-ki-paudi* with sector areas, three carry the crowd towards *Har-ki-paudi* while the other carries the crowd outside towards *Neeldhara*. The crowd should flow out of *Har-ki-paudi* through seven exits out of which five open to upper road and one open to lower road. Crowd flow into *Har-ki-paudi* is through five ways: two permanent bridges and three temporary bridges. *Har-ki-paudi* is located at a lower elevation from the abutting road and is accessed through staircases.

The field study identified certain crowd flow issues as well as the elements acting as triggers for crowd hazards. Several puja stalls on the ghat steps which are beside the temple complex are interrupting the crowd flow and increasing the crowd density. One temporary bridge which has a direct opening to ghat steps has the possibility to exponentially increase the crowd density. Lack of emergency entries and exits from *Har-ki-paudi* is one major issue. Controlled entries and exits should be implemented to reduce the risk of crowd congestion in the area.

3.4. Crowd Capacity Analysis

Har-ki-paudi, the prominent ghat, needs to accommodate the increasing demand from pilgrims. The maximum allowable number of tourists in the *Har-ki-paudi* area is not determined specifically whereas implementation of any strategy should be based on the expected crowd size. The estimates as per *mela* authorities during the interviews about the maximum crowd capacity of *Har-ki-paudi* area was lacking authenticity and are merely rough approximations. Determining the crowd capacity of the available area helps authorities in controlling and regulating the crowd more effectively.

For crowd capacity analysis, detailed mapping of *Har-ki-paudi* area was carried out to demarcate areas with crowd movement (**Error! Reference source not found.**). By excluding immovable features such as temples, clock tower and stalls the remaining area was calculated in GIS. The probable crowd carrying area was calculated to be 15,120 m^2 of levelled ghat surface, 620 m^2 wet/slippery surface and 1159 m^2 of steps in *Har-ki-paudi* ghat.

The maximum density that can be allowed in case of rainy and slippery conditions is only 2 p/m^2 (persons per square meter) (Oberhagemann, 2012). For static (immobile) crowds, 5 p/m^2 is the maximum allowable limit and even allowing 6 p/m^2 is high risk as per Still (2014). As per a report by Oberhagemann (2012) the densities of 5-6 p/m^2 must not be exceeded for static crowds. For dynamic (moving) crowds the acceptable limit is 1.5 p/m^2 and the critical limit is reached at 2 p/m^2 (Oberhagemann, 2012).

Crowd capacity of *Har-ki-paudi* was calculated for two different scenarios using maximum allowable crowd densities. The first scenario considered the ghat area to have the static crowd, which is the case during occasions like Ganga Aarti or other special worships. The second scenario assumed typical ghat activities and considered the crowd to be dynamic. The crowd capacity gives the maximum number of persons that can be accommodated in the area at any given time.

The maximum number of individuals that can take a dip in *Har-ki-paudi* area depends on ghat length and is calculated based on the approach employed by Mehrotra (2015). The length of the ghat was calculated to be approximate 1100m. Taking 0.5m as an average width of the human body nearly 2200 individuals can line up side by side. Thus, 6600 individuals can be accommodated if people stack up in 3 layers. Taking into consideration that people take holy dips for 14 hours, i.e., from 5 a.m. to 7 p.m. and if a devotee takes an average time 5 min for a holy dip then nearly 1,108,800 individuals can take a dip in *Har-ki-paudi* area. Considering 24 hours of time, if specials arrangements are made, nearly 1,900,800 people can take holy dips in *Har-ki-paudi* area. Taking the fact that nearly 17 million (USAC & NRSC, 2011) took baths on Shani-Snan day on April 14, 2010, *Kumbh Mela*, all the tourists cannot visit and take a dip in *Har-ki-paudi* without increasing the risk of the area.

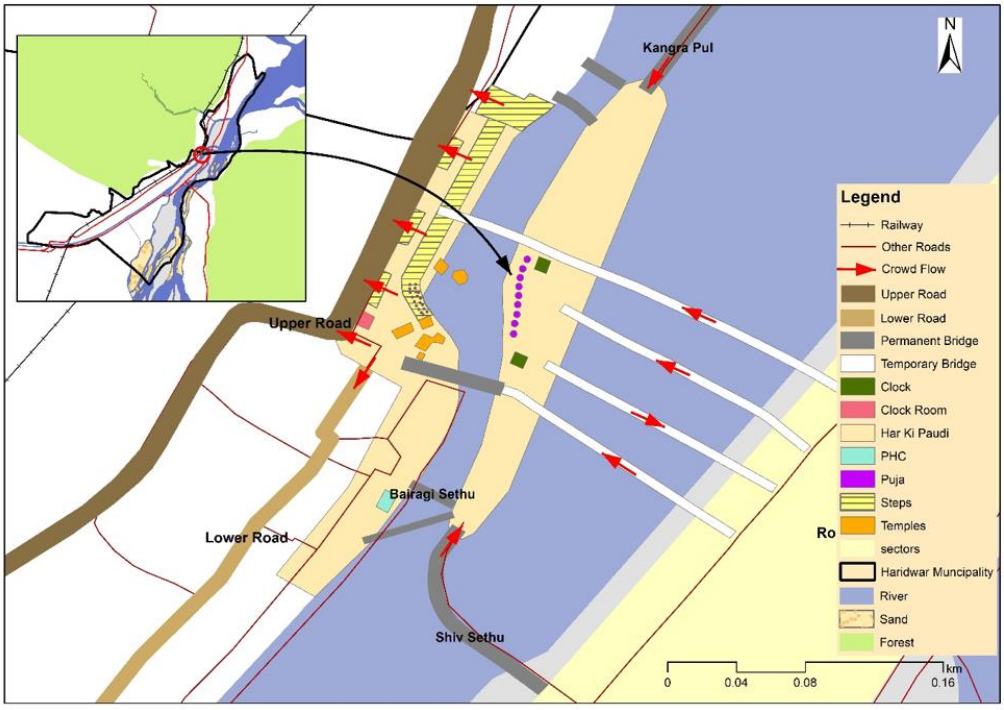

Figure 8: *Har-ki-paudi crowd flow map along with direction of crowd flow*

Table 2: *Crowd Capacity of Har-ki-paudi area*

Scenario	Crowd count in static and dynamic crowd zones (in persons)	Crowd

	Leveled ghat area- 15,120 m^2	Slippery area- 620 m^2 (Critical limit - 2 p/m^2)	Ghat steps area- 1159 m^2 (Critical limit - 2 p/m^2)	capacity (persons)
Scenario 1 (Static crowd)	15120*5=75,600 (Critical limit- 5 p/m2)	620*2=1,240	1159*2=2,318	79,158
Scenario 2 (Dynamic crowd)	15120*2=30,240 (Critical limit- 2 p/m^2)	620*2=1,240	1159*2=2,318	33,798

3.5. Emergency Response Plan

Field visits aided in the identification of certain emergency plans premeditated by the authorities that will be laid down if the inflow increases suddenly. In case of emergencies like a stampede in *Har-ki-paudi* or if the crowd capacity exceeds the limit, the crowd will be held in holding areas. As it was discussed earlier that crowd flow towards *Har-ki-paudi* in three directions, the holdings areas were concentrated in those areas (**Error! Reference source not found.**). Based on the expected crowd of an event, the authorities will modify the capacity of holding areas. Even after utilizing holding areas, if the authorities fail to control the density in *Har-ki-paudi*, then people in holding areas will be directed towards nearby Ghats but not to *Har-ki-paudi*. Besides the use of holding areas, other emergency plans include directing the crowd to take longer routes from bus stand area to reach *Har-ki-paudi* (Figure 8). The last stage of the emergency plan will be implemented when it is impossible to allow more people into Haridwar. In such case, both public and private vehicles will be stopped from entering Haridwar. The trains will be diverted to nearby railway stations avoiding people to reach Haridwar.

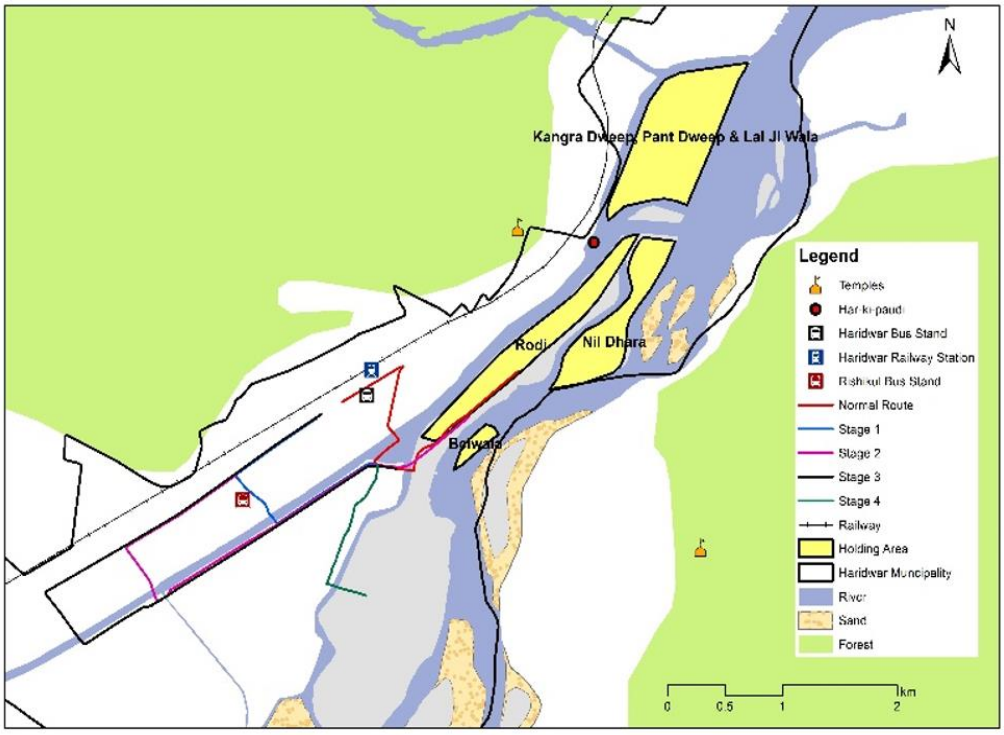

Figure 9: *Map showing Emergency plans such as holding areas and alternative routes*

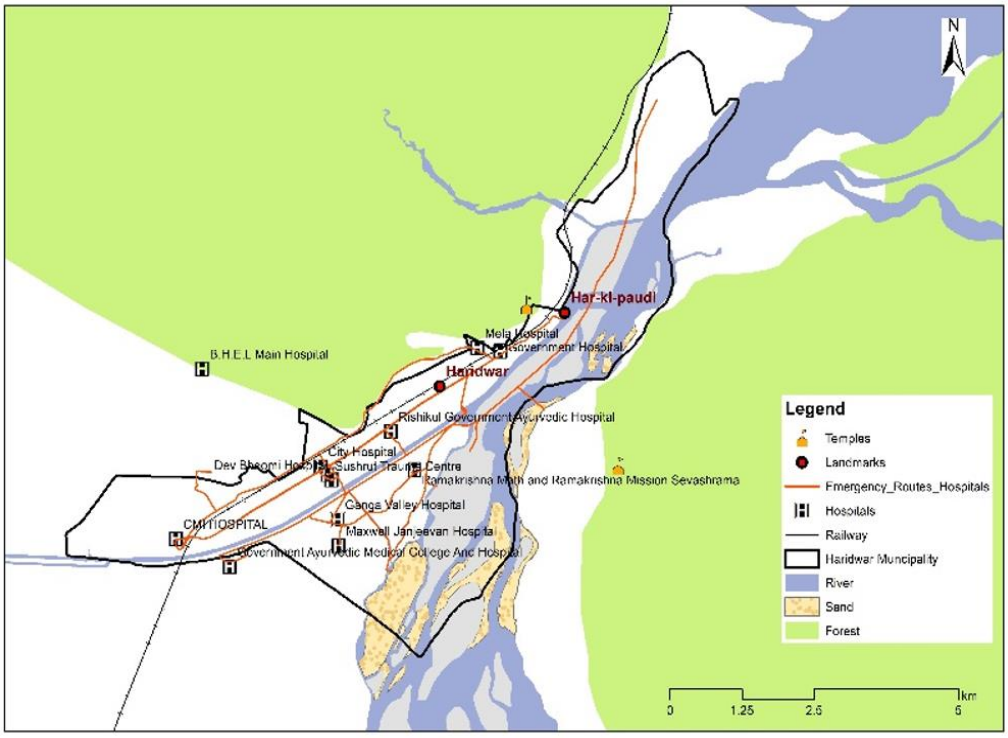

Figure 10: *Emergency routes to major hospitals*

To identify emergency vehicle routes to hospitals we have mapped major hospitals falling in the municipality area, with the help of field visits and WebGIS. Emergency routes to those hospitals from major Ghats and sector areas were identified using network analysis in GIS (**Error! Reference source not found.**). The analysis does not include the numerous first aid centers and clinics that mushroom during *Kumbh Mela* and the temporary fire stations that come up in and around the residential sectors. The proximity of Mela Hospital and Government Hospital makes them the immediate respondents for emergencies in *Har-ki-paudi*. In the worst-case scenario, waterbody (Ganga River) will act as a better alternative route to a hospital for emergency response. For effective emergency response, authorities should recognize the importance of emergency routes and provide these lanes with necessary services.

4. Conclusion and Future Scope

Mass Gatherings have the potential to create a strain on the infrastructure and living of the city. Many challenges were faced by event organizers, resource planners, emergency services and other departments to provide a safe gathering during 2016 *Ardh Kumbh*. Analysis of Crowd control and Emergency response strategies implemented during *Ardh Kumbh* indicate the need for detailed planning of evacuation procedures, dynamic crowd control, and preparedness measures. This study was intended to provide backing for authorities to efficiently organize and manage upcoming mass-gatherings.

Weaknesses of the city are determined by mapping the essential facilities and infrastructure with the help of Remote Sensing Images. Infrastructure scoring identified the strengths and weakness of existing infrastructure elements leading to the identification of crowd interrupters and triggers. Crowd flow analysis in the pilgrim zone helped to derive the possible crowd control issues which can aid the authorities to prepare better for emergencies. Crowd capacity of *Har-ki-paudi* provides authorities with crucial information regarding the maximum allowable limit to avoid disastrous events. Due to fluctuations in the expected crowd count and dynamic nature of the crowd, the task of successfully

managing the mammoth gatherings can only be achieved with constant efforts from both governments and local bodies.

Spatial analysis of the data mostly obtained from detailed field studies during *Ardh Kumbh Mela*-2016 helped in formulating guidelines for disaster risk reduction in Haridwar considering its vulnerability towards crowd disasters. Taking into consideration the massiveness and complexity of *Kumbh Mela* some guidelines are recommended apart from the above discussions:

Local bodies and the public should be educated regarding emergency routes and evacuation plans and their participation should be encouraged. Counting the number of pilgrims precisely using modern techniques such as sensors should be employed to monitor crowd count at any given point of time. This will aid in regulating the number of people and hence reducing unlikely events. Also, uncontrolled entries and exits in and around *Har-ki-paudi* area need to be strictly regulated. Another major issue which needs immediate attention is the lack of recreational and open spaces in Haridwar, which leads to increase in density of *Har-ki-paudi* and surrounding commercial areas which can be tackled by developing more recreational facilities. Construction of open-air auditorium and other recreational facilities in *Pant Dweep* which hosts cultural events during *melas*s will attract more people towards that area. Increasing tree cover and other shaded seating areas in *Har-ki-paudi* will improve the comfort of pilgrims during hot sun. Provision of temporary seating arrangements will reduce the number of people seated on the ground at random locations. Strategies should be employed to enhance the natural beauty of Rodi Belwala sector thereby stimulating the crowd to take bath in those Ghats. The *Har-ki-paudi* ghat which is at 6-9-meter elevation difference needs the provision of ramps and elevators in the view of providing Universal accessibility for elderly and differently abled. The recommendations can be considered when planning for mass gatherings events.

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