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RESPONSE TIME PARAMETERS ANALYSIS OF FIRE SERVICE IN SURAT CITY: AN APPLICATION OF AHP

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Abstract : Rapid urbanisation has became common in India in recent years. As a result of this increasing urbanisation, emergency response services such as fire fighting must be planned in advance to minimise loss of life, property loss, and damage. Better coverage is achieved by proper planning or optimization of fire stations. Surat is India's fastest-growing smart city. Surat's fast development necessitates the use of response time-based fire station planning. The primary goal of this study is to apply the AHP method for parameter weighting in relation to the response time base. This research was carried out in Surat's East Zone. This study demonstrates which parameters help to improve to reduce response time.

IndexTerms - Emergency Response Service (ERS) , AHP method, Response time

I. INTRODUCTION

Fire is one of the most common hazards experienced in all aspects of life all around the world. It can happen in a business park, a residential neighbourhood, a public gathering venue, and so on. The primary causes of fires in urban areas are faulty electric wiring, short circuits, equipment failure, leakage in hazardous material supply lines, overheating electric appliances, and other factors. Fire, heat, and hot substances killed an average of 2.2 persons in India and 1.5 people worldwide (Global Burden of Disease Collaborative Network, Global Burden of Disease Study 2017 (GBD 2017), United States: Institute for Health Metrics and Evaluation (IHME), 2018). During the year 2020, 9110 citizens in India died in fire accidents. The National Crime Records Bureau (NCRB) is a government agency that keeps track of records. Emergency Response Services in urban area majorly important service for citizen safety .Every emergency services efficiency depends on its response time. Fast responding services efficiency is too effective and late responding services are less effective service.

In India, the fire department is part of the local government. The Indian government has set standards for fire safety infrastructure. According to government guidelines, the overall response time of fire services in urban centers is 5 minutes, while in rural areas it is 20 minutes. That provision is found in the SFAC and URDPFI guidelines.

The main goal of this article is to use the AHP approach to determine which criteria have the most impact on fire service response times in urban areas.

1.1 Indian Guideline for fire services based on response time

URDPFI (Urban and Regional Development Plans Formulation and Implementation) guideline :-

Fire stations, in particular, should be built on corner plots with convenient access to secondary roads. Fire stations should be located so that fire tenders can reach any disaster site within 3 to 5 minutes. Sub fire stations or fire posts should be provided within 3-4 km radius, fire stations should be provided for 2 lakh population or 5-7 km radius, and fire stations should be located so that fire tenders can reach any disaster site within 3 to 5 minutes.

SFAC (Standing Fire Advisory Committee) guideline :-

All high-hazard and densely populated regions should have a reaction time of no more than 3 minutes, while all other areas should have a response time nor more more than 5 minutes (this does not include rural areas). During peak hours, fire appliances should be used to establish the approximate locations of fire stations from which the area assigned to them may be covered within the time limit. Time to respond (3 to 5 minutes in cities, 20 minutes in rural areas) One fire station every ten square kilometres of urban area; one fire station per fifty square kilometres of rural area

1.2 Methodology of work

Select the research area based on discussions with fire officers, site visits, previous fire accidents, traffic conditions, and demographic conditions. This project was completed in two stages. The problem identification and research are chosen in phase one based on a literature review and a review by fire fighters. Data collection and analysis using the AHP approach are covered in phase two.

II. Study area

Surat is located in Gujarat's southern region and in India's western region. It is India's fastest-growing smart city. It is located on the banks of the Tapti River and has an Arabian Sea shoreline on the west side. Surat is a city with a population of 4.6 million people and a land area of 462.149 square kilometres (census 2011). Surat's population density is 10052 people per square kilometre. The city is organised into nine zones, with two planning authorities (SUDA and SMC) in charge of city planning. A total of 17 fire stations served the entire population and worked throughout the city. Surat's economy is primarily supported by two big industries: diamonds and textiles.

Surat is India's fastest-growing smart city, yet fire calls are on the rise for a variety of reasons. The following chart depicts the total number of fire calls in Surat. This demonstrates that the number of fire incidents in Surat city is increasing each year.

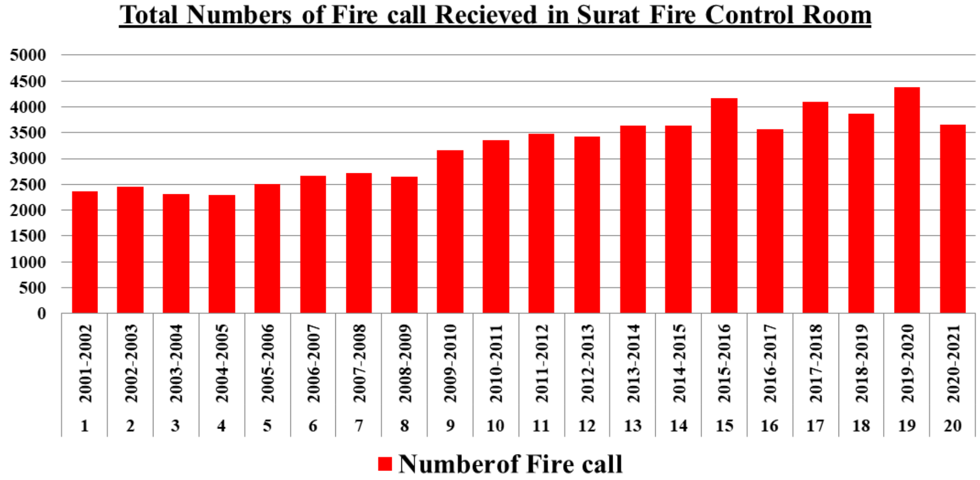

Figure 1 Fire call in Surat city during year 2001 to 2020

The reason for the increase in fire calls in Surat is that the city's population is fast growing, as are a number of industries. In Surat, more people are driving their own cars, which has resulted in traffic congestion, causing emergency services to respond late in this case. Another challenge is how to plan a fire station based on reaction time so that fires may be responded to quickly, limiting property loss and life loss.

III. Literature review

Various studies have been conducted to determine the parameter based on field conditions. The Kathmandu metropolitan area was the subject of one study (Chaudhary et al., 2016). The author used the AHP approach to calculate four parameters: distance from road, land cover, river distance, and population density. For pairwise comparison, this study used eight expert assessments. Another study was undertaken for China (Chen et al., 2020). The author of this study created a three-layer structure. The first layer, known as the goal layer, contains the aim, while the second and third layers, known as the criterion and sub criteria layers, contain 5 and 25 index, respectively. Weighting is determined for each index, and the evaluation is carried out using the Fuzzy comprehensive evaluation approach. The Analytical Hierarchy Process method is used to create a weightage index system.

Authors (Nyimbili & Erden, 2020) conducted research in Turkey. Consider six criteria based on the location of the fire station in this study. High population density; 2) closeness to main road; 3) distance from current fire station; 4) density of hazardous material facilities; 5) wooden building density; and 6) distance from earthquake-prone area were among the six criteria highlighted. The fuzzy AHP technique was used to calculate the weightage of these criteria. Take into account nineteen expert judgments when evaluating the criteria. (Erden & Coşkun, 2010) conducted another study in Turkey. High population density, distance from current fire station, proximity to main road, wooden building density, distance from seismic risk prone area, and Distance from hazardous material facilities are the six factors used in the analysis.

AHP approach developed by Satty.*(Saaty, 1987)* The Analytical Hierarchy Process (AHP) is a process that uses quantitative and qualitative characteristics to examine the priorities of a decision-making group or individual. Through the AHP approach, a comparison of two parameters is made to see which one is better than the other. calculating the weighted average of each parameter (Lin & Jian, 2010).

IV. Evaluation of parameter

Following a thorough assessment of the literature, fourteen parameters were identified. Road conditions, traffic conditions, land use, population density, building density, types of industries, hazardous material facilities, fire station coverage, number of fire

accidents, number of fire engines, emergency rescue equipment, adequate staffing, equipment cost, and maintenance cost are all parameters to consider.
For this fourteen parameter, a suitability survey was undertaken. Nineteen decisions were taken from the city's fire and emergency services department. Based on the results, four parameters were chosen as the most and moderately suited for the study region. Road condition, land use, traffic condition, and population density are the four parameters that have been finalized.

4.1 AHP method

The AHP technique evaluates four variables, one of which is the fire department's response time. The parameter was evaluated using a first-order hierarchy. The questionnaire form was created using pairwise individual judgement (Lin & Jian, 2010). For knowing how many pair making for questionnaires there are one equation for it. *(Teknomo, 2016)*

$$\mathbf{N = n*(n-1/2)}$$

Table 1 Number of Comparison

No. of Parameters	1	2	3	4	5	6	7	n
No. of pair wise comparison	0	1	3	6	10	15	21	n*(n-1/2)

When pairwise judgments were collected as individual judgments rather than group judgments, a geometric mean of judgments was calculated (Forman & Peniwati, 1998). Calculation of the AHP technique based on (D, 2012) and (Teknomo, 2016). The AHP technique was calculated using Microsoft Excel software.
Step-1 :- To begin, create a 4*4 matrix and calculate the geometric mean of the judgments. Put the real judgments value on the left side of 1, and the reciprocal value on the right side of 1.

$$C = \begin{array}{lcccc} & \text{Road condition} & \text{Traffic condition} & \text{Population density} & \text{Landuse} \\ \text{Road condition} & 1.000 & 0.353 & 2.702 & 3.589 \\ \text{Traffic condition} & 2.833 & 1.000 & 3.057 & 3.890 \\ \text{Population density} & 0.370 & 0.327 & 1.000 & 3.696 \\ \text{Land use} & 0.279 & 0.257 & 0.271 & 1.000 \end{array}$$

Step-2 :- Sum the value in each column of the pair-wise matrix.

$$C_{ij} = \sum_{i=1}^{n} C_{ij}$$

Step-3 :- To create a normalized pair-wise matrix, divide each member in the matrix by its column total.

$$X_{ij} = \frac{C_{ij}}{\sum_{i=1}^{n} C_{ij}} \begin{matrix} 1.000 & 0.353 & 2.702 & 3.589 \\ 2.833 & 1.000 & 3.057 & 3.890 \\ 0.370 & 0.327 & 1.000 & 3.696 \\ 0.279 & 0.257 & 0.271 & 1.000 \end{matrix}$$

Step-4 :- To construct a weighted matrix, multiply the sum of the normalized column of the matrix by the number of criteria utilized (n).

$$W_{ij} = \frac{\sum_{j=1}^{n} X_{ij}}{n}$$

The proportion of each parameter weightage is calculated after the weighted matrix is calculated. The parameter's final weightage is, **Road condition** – 27.42% , **Traffic condition** – 48.57% , **Population density** – 16.49% , **Land use** – 7.52% .

Step -5 :- Consistency vector is calculated by multiplying the pair wise matrix by the weights vector.

$$\begin{matrix} 1.000 & 0.353 & 2.702 & 3.589 \\ 2.833 & 1.000 & 3.057 & 3.890 \\ 0.370 & 0.327 & 1.000 & 3.696 \\ 0.279 & 0.257 & 0.271 & 1.000 \end{matrix} * \begin{matrix} 0.274 \\ 0.485 \\ 0.165 \\ 0.072 \end{matrix} = \begin{matrix} Cv11 \\ Cv21 \\ Cv31 \\ Cv41 \end{matrix}$$

Then it is accomplished by dividing the weighted sum vector with parameter weight

$$Cv_{11} = \frac{1}{W11}[C11W11 + C12W21 + C13W31]$$
$$Cv_{21} = \frac{1}{W21}[C21W11 + C22W21 + C23W31]$$
$$Cv_{31} = \frac{1}{W31}[C31W11 + C32W21 + C33W31]$$
$$Cv_{41} = \frac{1}{W41}[C41W11 + C42W21 + C43W31]$$

Step -6 :- λ is calculated by averaging the value of the consistency vector.

$$\lambda = \sum_{i=1}^{n} C\mathrm{Vij} = 4.252$$

$$CI = \frac{\lambda - n}{n-1} = \mathbf{0.0839} < \mathbf{0.1}$$ (Weightages are acceptable)

$Cr = \frac{CI}{RI} = \frac{0.0839}{0.9}$ = **0.093 < 0.1** (Weightages are acceptable)

RI is a random index**. (**Saaty ,1980) suggest RI for CR calculation .RI table shown in table number- 17. Where n = order of matrix

Table 2 Random index value

n	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0..58	0.9	1.12	1.24	1.32	1.41	1.46	1.49

Source- *(Saaty, 1987)*

V. Conclusion

After applying the AHP approach to the study area, it was discovered that road conditions (27.42%), traffic conditions (48.57%), population density (16.49%), and land use (7.52%) have an impact on firefighting response times. In future fire station planning for the study region, the government authority should take these considerations into account and aim for a 5 minute fire response time for the entire area. Because traffic congestion is a serious concern, the fire department's response time in an emergency situation is significantly delayed. Public awareness plays an important part in response time activities as well. In order to conduct a GIS-based network analysis and create an emergency response service, the four parameters must be considered.

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References

1. Chaudhary, P., Chhetri, S. K., Joshi, K. M., Shrestha, B. M., & Kayastha, P. (2016). Application of an Analytic Hierarchy Process (AHP) in the GIS interface for suitable fire site selection: A case study from Kathmandu Metropolitan City, Nepal. *Socio-Economic Planning Sciences*, *53*, 60–71. https://doi.org/10.1016/j.seps.2015.10.001
2. Chen, M., Wang, K., Dong, X., & Li, H. (2020). Emergency rescue capability evaluation on urban fire stations in China. *Process Safety and Environmental Protection*, *135*, 59–69. https://doi.org/10.1016/j.psep.2019.12.028
3. D, K. B. (2012). *How to do AHP analysis in Excel The Analytical Hierarchy Process - AHP*.
4. Erden, T., & Coşkun, M. Z. (2010). Multi-criteria site selection for fire services: The interaction with analytic hierarchy process and geographic information systems. *Natural Hazards and Earth System Science*, *10*(10), 2127–2134. https://doi.org/10.5194/nhess-10-2127-2010
5. Forman, E., & Peniwati, K. (1998). Aggregating individual judgments and priorities with the Analytic Hierarchy Process. *European Journal of Operational Research*, *108*(1), 165–169. https://doi.org/10.1016/S0377-2217(97)00244-0
6. Lin, L. K., & Jian, C. Y. (2010). Maintenance algorithm and management system of sidewalk facility. *Journal of Marine Science and Technology*, *18*(5), 723–730. https://doi.org/10.51400/2709-6998.1923
7. Nyimbili, P. H., & Erden, T. (2020). GIS-based fuzzy multi-criteria approach for optimal site selection of fire stations in Istanbul, Turkey. *Socio-Economic Planning Sciences*, *71*(July 2019), 100860. https://doi.org/10.1016/j.seps.2020.100860
8. Saaty, R. W. (1987). The analytic hierarchy process-what it is and how it is used. *Mathematical Modelling*, *9*(3–5), 161–176. https://doi.org/10.1016/0270-0255(87)90473-8
9. Teknomo, K. (2016). Analytic Hierarchy Process (AHP) Tutorial. *Applied Sciences*, *6*(5), 22.
10. URDPFI Guidelines 2014
11. SFAC meeting 1st to 38th
12. www.suratmunicipal.gov.in