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Analysis on Main Parameters of Fire Service Deployment of 119 Recue Center Using Spatial Information

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Abstract
Fire service is one of the essential public services to protect the people's lives and property from various dangers. As the urban structures have recently become more complicated and dense, the efficient placement and operation of fire service force is getting more important. In this respect, the present study developed a methodology to evaluate the performance of the key factors of fire service force quantitatively.
This study proposes spatial information-based methodology that can be used as actual local evaluation indicator for the accessibility, the number of residents per fire service officer, buildings under the jurisdiction of a certain fire service organization, which are the key variables of evaluation service. When applying this research methodology to an real city in size of a district, this study found out that there was a wide deviation in fire service force. Particularly, the deviation turned out greater as fire service force was placed in lower urban hierarchy.
To tackle this problem, it was found more effective to design a plan to place fire service force to narrow urban hierarchy first and then wide urban hierarchy in terms of correcting the unbalanced fire service force. Until now, studies have been carried out on the criteria to measure fire service force with, but no specific methodology to apply has been developed.
In this, this study finds itself significance that proposing and applying a specific methodology will contribute to later evaluating and improving local fire service force.

Keywords: Fire Service Deployment, GIS, Accessibility Analysis, 119 Rescue Center, Number of Residents Per Fire Service Officer

Introduction

A city is more complicated and scaled up in volume and height in structure. Accordingly, more electricity, oil, gas and chemical substances are used in a city. Besides, natural disaster happens more often and larger in scale due to climate change, which means also the increasing risk potential fire accident and disaster. Therefore, there is no doubt that enough fire service force and reasonable placement of it should be studied continually to cope with quick response to a disaster.
However, the current placement of fire service force in the Republic of Korea is organized in a conventional manner in accordance with administrative district system for convenience's sake, like from gu(district), gun(county) and to dong (village). This administrative district-based placement of fire service force can have a problem in its efficient operation[1]. Particularly, Lee, Hae-pyong[2] concluded that the current placement system of fire service force is not based on the number of firemen, the size of jurisdiction and so on. That is to say, the current placement of fire service force by administrative district unit system of the Republic of Korea does not reflect such factors as the population composition of a city, the size of jurisdiction and area density.
A number of previous studies[3-5] have already derived the factors to be reflected on the placement and improvement of fire service force and verified those factors. The absence of spatial data or the difficulty of building data to assess the weakness of fire service force have limited the attempt to demonstrate the weakness of a local area in fire service force by applying the factors to real cities. Reviewing the relevant studies[4-10] to the objective of this study, it is known that most of them confined a focus on finding areas whose accessibility is weak in terms of distance through accessibility analysis and failed in reflecting the demand of population for fire service and local density and other factors.
Therefore, this study developed a method to apply spatial data by which we can evaluate the weakness of a research area by reflecting urban physical variables to it. Last, this study applied the developed methodology to the research area of this study in an effort to verify it and find the weaknesses of the spatial composition and placement of the current fire service force.

Firefighting Resources Deployment Criteria & Organization

In general, the fire service organizations of the Republic of Korea are hierarchically structured with fire department responsible for an area in the size of a city; fire station for a district; and 119 safety center for town-sized jurisdiction.
Looking into more microscopically, fire station is supposed to set up according to the hierarchical order of city, country and district in accordance with 'Framework Act on Fire Services' of the Republic of Korea and, if necessary, it can be established at the level of local unit covering neighboring areas.
In addition, 119 safety center is specified to set up in accordance with the standard (Table 1).

Table 1: Deployment standard of 119 safety center in Korea

Division	Metropolitan city	Metropolitan city(or over 5hundred thousand)	Over 1hundred thousand under 5hundred thousand	Over fifty thousand under 1hundred thousand	Under 1hundred thousand
Population	Over fifty thousand	Over thirty thousand	Over twenty thousand	Over fifteen thousand	Over ten thousand
Area	Over 2㎢	Over 5㎢	Over 10㎢	Over 15㎢	Over 20㎢

The number of population per fire service officer is the most important indicator for the analysis of fire service force and many countries build statistics dB of this and use it as an indicator for the safety evaluation of a city.

In the Republic of Korea, one fire service officer covers 1, 316 citizens (Taiwan: 1, 858, Singapore: 1, 898; Malaysia: 2, 279). Compared with the advanced countries in disaster prevention, like USA (532) and Japan(811), one Korean fire service officer covers relative many population[11].

In the meantime, USA's RAND model, UK's Fire Service Force Response Standard, Japan's Fire Service Force Placement Standard commonly use accessibility as the base for setting the size of jurisdiction and utilize the number and size of buildings as base variables in placing fire service force. However, they apply the variables in quadrangle or radius to the models in determining the area of jurisdiction, so it is hard to use them in form of real route. Furthermore, they propose the demanding factors of fire service such as population and objects for fire service as criteria of the placement of fire service force and equipment, but practically they have never been estimated and evaluated.

For this reason, this study suggested a specific methodology that can use and apply the placement factors of fire service force such as accessibility, population of demand, and the buildings for fire service to local evaluation.

Methodology for Evaluating Parameters of Firefighting Resources based on Spatial Information

The objective of this study is to develop a methodology to apply such variables as accessibility, population in demand of fire service force, and building to evaluate the real size of jurisdiction of 119 safety center. For the purpose, this study employed Arc GIS as a tool to apply these variables to a real city and proposed a method to establish spatial data and integrate them in an effort to apply each of those variables to the research area.

To apply the first variable 'accessibility', this study conducted network analysis by using Arc GIS program and obtained the average access time from each safety center zone to the point of demand of fire service[12-14]. Since network analysis uses the graphic information of real routes and information of rotatable point of design speed, it is more suitable for evaluating the efficiency of fire service than existing accessibility analyses that uses simple radius.

In network analysis, the access distances from the point of each 119 safety center to the point of demanding within a jurisdiction are summed and averaged. To execute this analysis, the basic data consisting of network dataset, service supply point, service demand point and the boundary of analysis area as seen in Table 3 are needed.

Table 2: Base line spatial information for accessibility analysis

Classification of baseline data	Name	Data form	Attribute and details
1) Network dataset	Road route	Poly line	Length and design speed of individual route
	Node point	Point	Junctions and rotatable information
2) supply point	Safety center spatial data	Point	Location of each safety center
3) Demand point	Demand zone division data	Polygon	Census area polygon
4) Boundary of analysis area	Boundary of 119 safety center jurisdiction zones	Polygon	Polygon data of 119 safety center jurisdiction boundary

To explain Table 3 above,

1) network dataset consists of the information of routes in form of poly line shp file and the information nodes in form of point shp file. For the route information, the length and design speed of individual route. And for the information nodes, rotatable (turning to the left, turning to the right, U-turn) information should be entered.
2) Supply point means the subject to supply fire service. In this study, the location information of each of 119 safety centers was set in form of point data by using Arc GIS editor function.
3) Demand point is an object to demand fire service. In this study, information of census output area was used, which is the most detailed unit up to now. Census output area is the information of the segmentation of an area populated with 500 to 1, 000 residents by physical environment such as topography and road, which is done by Statistics Korea Office for population and housing census. In general, one district consists of more or less 1, 000 census output areas.
4) Boundary information of accessibility analysis range means the range in which the analysis of accessibility

to 119 safety centers is conducted. In this study, the boundary data of jurisdiction zones in which 119 safety center is located were used for accessibility analysis.

For the second variable 'population in demand of fire service', residential population was derived from summing, by zone, population information that contains the census output areas used in accessibility analysis. 2013 census output areas data consists of the most detailed spatial units up to now and contain accurate population statistics as attribute data. This study divided the residential population in each zone by the number of fire service officers covering a zone to eventually get the number of population per fire service officer force. And then, relative evaluation was made between areas.

The third variable is the current status of buildings in jurisdiction. To use it as the indicator for local fire service force, this study summed the number of GIS-based buildings. The existing urban physical demand estimation method uses the sum of urbanized area to evaluate fire service force. However, the present study summed the number of building by using spatial information mining method, which was attempted to demonstrate that it can be used as a more practical and quantified factor.

To verify the practical applicability of those 3 variables, this study applied them to the research area and analyzed the deviation of the variables by area and proposed a possibility of further research.

Methodology Application Results and Proposed Utilization Strategy

As the research target area to which the proposed methodology was applied, Daegu Metropolitan City was chosen out of 3 major cities of the Republic of Korea. Particularly, since this study focused on 119 safety centers, it selected 7 119 safety centers in Dalseo-gu, as spatial range of the study, where turned out to be the district whose number of population per fire service office was the highest among 7 districts in Daegu Metropolitan City.

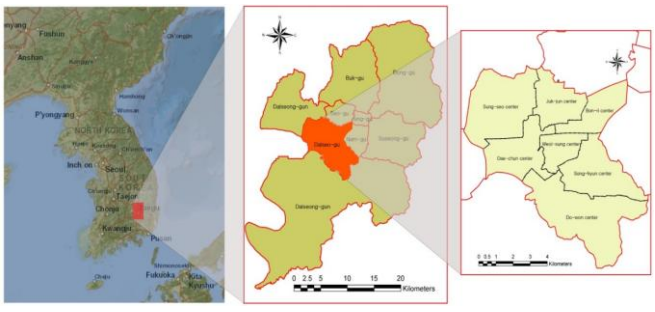

Figure 1: The location and current status of the target area

Figure 1 shows the location and current status of Dalseo-gu, which is the research area, in Daegu Metropolitan City. Dalseo-gu is the second largest population as a single district in the Republic of Korea. Its gross size is about 62.34㎢ and populated with 605, 849 residents. As seen in the right side of Figure 1, 7 119 safety centers are divided in the area.

1) Accessibility Analysis

The picture below shows the basic data list built up to conduct GIS-based accessibility analyses as described in Table 2.

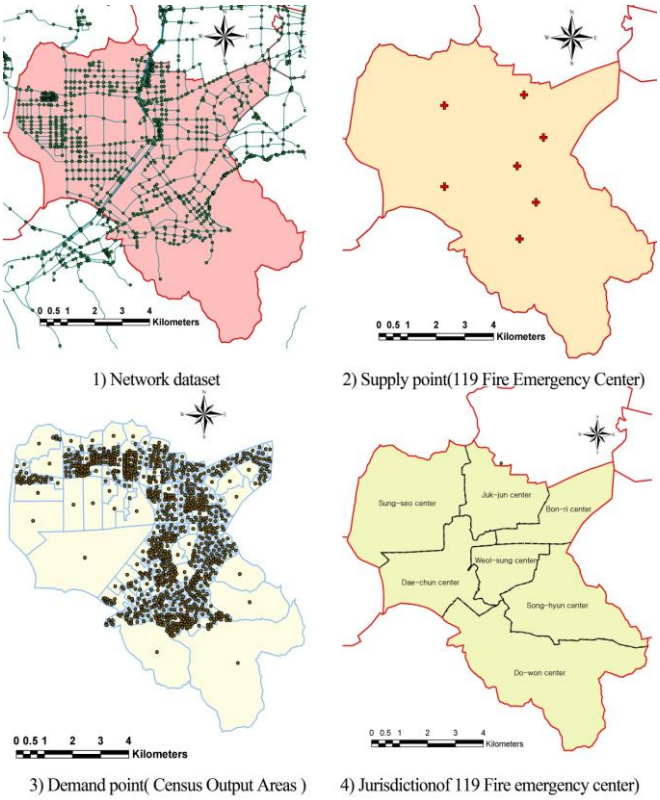

Figure 2: Built up basic data using Arc GIS

Based on the basic data below, accessibility was analyzed. To explain the analysis here, (1) including route information was used to calculate the reachable distances from each 119 safety enter (2) to each demand point (3). Since it was to determine the accessibility to the currently designated zones, each center in (2) selected a demand point in (3) within the boundary (4).

Analyzed through the process above, the accessibility values of the total 7 zones in Dalseo-gu are follows. The picture above shows the results of accessibility analysis by census output area, which means each demand point. The average reachable times, which were obtained by summing them up by jurisdiction, are displayed on the right side of the picture. It turned out that the average reachable time from each 119 safety center to a demand point was 2 minutes and 01 second. The deviation of the average reachable time between jurisdiction zones was about one minute and 12 seconds. All safety centers were calculated to reach demand points within 5 minutes, but the time does not include the time period between the point of receiving a report to that of mobilization. Therefore, some zones of the areas can have room for improvement, say, Dae-chun 119 center zone.

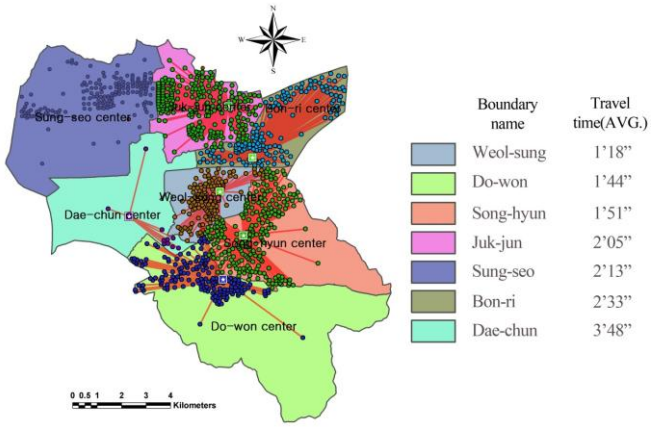

Figure 3: Result of estimated travel time by each 119 safety center

2) Analysis of the Number of Residents Per Fire Service Officer

To calculate the number of the residents per fire service officer in the research area by jurisdiction zone, the number of residential population was collected by census output area and divided by the number of full-time fire service force by center. The table below shows the number of the residents per fire service officer by jurisdiction zone, which was extracted through micro data, the number of fire service force by safety center, and the number of residents per fire service officer.

Table 3 Result of estimated population per fire officer by 119 safety center area

	Weol-sung	Song-hyun	Bon-ri	Sung-seo	Juk-jun	Dae-chun	Do-won	Total
Population (A)	65, 738	125, 642	78, 967	91, 872	130, 365	4, 956	93, 053	524, 855
Fire officer(B) [15]	49	19	19	19	19	16	17	158
Population per fire officer(A/B)	1341.6	6612.7	4156.2	4835.4	6861.3	309.8	5473.7	4227.2 (AVG)

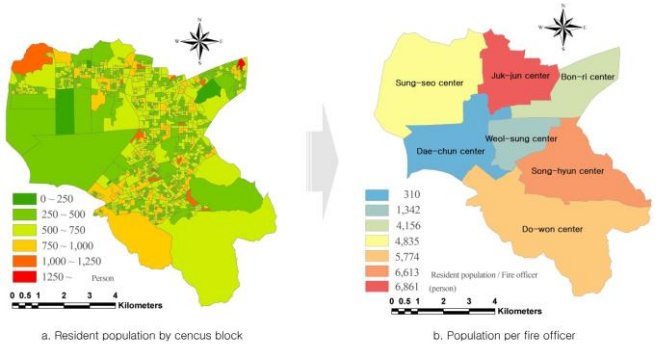

Figure 4: Result of estimated population per fire officer by 119 safety center area

When looking into the graph and the table, we can see that there is considerable difference in the number of residents per fire service officer by jurisdiction zone. Particularly, Dae-chun zone, which had the smallest number of residents per fire service officer, was different by 6, 300 from Juk-jun that had the largest number of residents per fire service officer. It indicates that the number of residents per fire service officer by jurisdiction zone can be adjusted when the proposed method in this study is applied.

3) Object Buildings for Fire Service

To calculate the number of the objects for fire service of each safety center, this study classified the entire jurisdictions in the research area (about 36, 000 buildings) and summed the buildings by jurisdiction.

The topographic information and distribution of the buildings combined in the process are displayed as in the picture below.

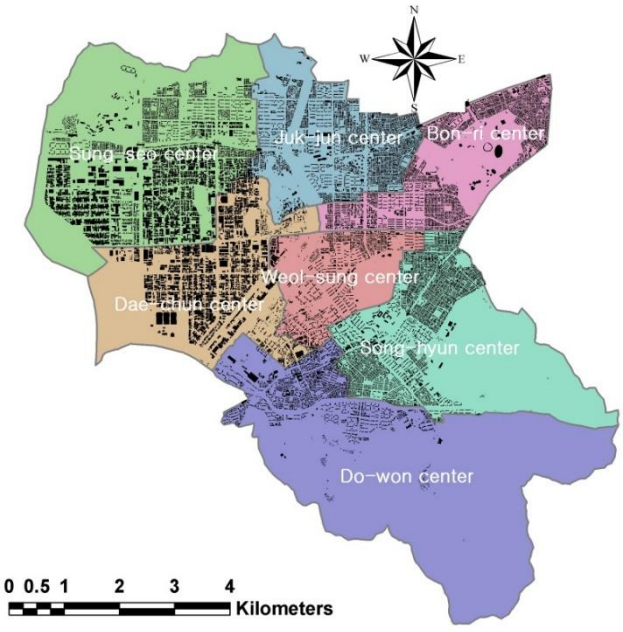

Figure 5: Analysis result of the number of the objects by 119 safety center area

Using the information, the current status of the summed objects for fire service by safety center zone is listed in the table below.

Table 4: The number of the object buildingsby 119 safety center

	Weol-sung	Song-hyun	Bon-ri	Sung-seo	Juk-jun	Dae-chun	Do-won	Total
Building number	1, 591	8, 136	8, 541	5, 587	7, 016	2, 225	2, 963	36, 059
Ratio(%)	4.41	22.56	23.69	15.49	19.46	6.17	8.22	100.00

As seen in the table above, Bon-ri 119 safety center and Song-hyun 119 safety center cover more than 20% of the buildings for fire service of the total buildings in the research area. However, Weol-sung 119 safety center covers only 4.4% despite the size of fire service force more than 2 times as many as the other zones. It demonstrates that the local unbalance of fire service force hasn't been reflected yet to the placement plan of fire service force. Therefore, it is necessary to adjust the placement.

Conclusions &Discussions

In conclusion, the table below summarized the proposed methodology using spatial information for the variable of accessibility, fire service force, and objects for fire service and the results of the application of the methodology to real cases.

Table 5: Overall analysis result of fire service by 119 safety center

	Weol-sung	Song-hyun	Bon-ri	Sung-seo	Juk-jun	Dae-chun	Do-won	Total
Travel time	1'18''	1'51''	2'33''	2'13''	2'05''	3'48''	1'44''	2'01'' (AVG)
Population per fire officer	1341.6	6612.7	4156.2	4835.4	6861.3	309.8	5473.7	4227.2 (AVG)
Building number	1, 591	8, 136	8, 541	5, 587	7, 016	2, 225	2, 963	36, 059

As seen in the table above, the zones in the research target area are very unbalanced by the evaluation factor for fire service force. However, the present study hopes that future studies need to consider the calculation of coefficients of the variables through the importance analysis in evaluating them. In addition, it is considered possible to develop the placement model of fire service force to reduce the local deviation of each variable through advanced adjustment simulation if the methodology proposed in this study.

So far, the methodology used for the placement of fire service force has employed top-down approach (from large local unit to small local unit). In this respect, the present study demonstrated that the deviation of fire service force gets bigger in lower hierarch. Therefore, bottom-up placement is suitable for relieve the unbalance of fire service force in local areas

Acknowledgments

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