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Route Map Analysis for Fire Evacuation Planning of the Slum Community in Bangkok

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Abstract:
Fire is a major problem that causes loss of life and property. Fire incidents eventually occur with the old community neighborhoods that have landmarks within. Small communities and slums in the inner area of Bangkok, Thailand, are risk because, in many cases, they are also historical art and cultural sites. In some cases, important government agencies that driving the development of Bangkok were also built in such area. However, most Bangkok slums still lack measure or guideline for managing the accessibility and fire safety. To prevent fire damage as well as redundant accidents that may occur from fires, we need a specific study. This research has three objectives including 1) to find the potential traffic and access into Devarajkunchorn Temple Community, the case study area 2) to find the relationship between 'space syntax model' and the levels of space usage in the area and 3) to create fire-evacuation route map so that future victims can leave the area safely. The research findings are useful for security planning agencies, fire mitigation agencies, local people as well as the public. It would help reduce loss of life and property of people in slum communities with similar characters and, therefore, increase public safety. This research concludes that the Space syntax models highlighted the streets that are suitable for evacuating fire victims particularly by small vehicles. Finally, recommendations for physical and environmental adaptations are proposed

Keywords:*Fire Evacuation Route Map; Fire Incident; Slum community; Space Syntax.*

I. INTRODUCTION

Fire is a major problem causing loss of life and property. According to fire statistics from 1989-1995, there were 50,413 fires reported in Thailand with estimated total damage of over 30,000 million bahts(Disaster Prevention and Mitigation Center, 2011). In addition, according to cumulative statistics of the fire reported in Bangkok during 2016, there were 4,707 fire incidents (Disaster Prevention and Mitigation Operations Command, 2016). Most fire sites are housing, densely populated communities, tall buildings, industrial plants, shopping centers and theaters(Bureau of DisasterPrevention and Mitigation, 2017).

Currently, many agencies have paid more attention to the fire problem. Bangkok, especially had issued the Bangkok Ordinance on Building Control B.E.2544 (A.D.2001) signed the Bangkok Bylaws Building Controls 2001 (Bangkok Ordinance, 2001)which concerns fire protection, installation of fire extinguishers, building and materials specifications, etc. In addition, the Bureau of Disaster Prevention and Mitigation has purposely created the Bangkok Fire Prevention and Mitigation Action Plan 2017 (Bureau of Disaster Prevention and Mitigation,2017) as a guideline and preparation for integrated operations in case of fire incident. This includes 1) preparation of resources, system of operation for both the main responding unit and the support unit so that they can quickly and effectively respond, prevent, and mitigate the fire in a timely manner 2) establish an implementation framework to facilitate relevant operational agencies so that they can systematically coordinate and carry out the fire prevention and mitigation and 3) prevent and mitigate any possible impact on people's life and property due to fire. However, Bangkok fire prevention authority still lack knowledge on traffic potential in correlation with area accessibility of people, small vehicles and large vehicles. In case of fire, a collaborative operation of fire

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fighters' team, resource, and spatial management is necessary. To rescue victims during the fire, the intelligent escaping route map must be used to migrate them to the assembly point and lead them out of the area as quickly as possible.

This research aims to study spatial morphology of a small community, to provide route map analysis and to plan for fire evacuation. Finding traffic potential focuses primarily on the mobility of human, small vehicles, and large vehicles. It supports the 12th National Economic and Social Development, B.E. 2560-2564 (2017-2021); Section 4: National Development Strategy 4: Environmentally Friendly Growth for Sustainable Development; Goal 5: Enhance the effectiveness of management to reduce the risk of life-threatening disasters and property damage caused by natural disasters(Thai Government Gazette, 2016).

The researchers chose the study area from the criteria of density. Besides its high density, Dusit district, an inner urban area, also has historically valued art and culture with religious sites. It is an important cultural attraction of Bangkok. Many important government agencies, driving the development of Bangkok, are also in this district. However, it stills lack measure or guideline for managing fire risk.

By considering physical characteristics that can represent the slum communities under the ownership of government agencies, the area of Devarajkunchorn Temple Community is selected. Land ownership is that of the Religious Department and the density is 88 houses per rai.

Figure 1: Physical Characteristics of Devarajkunchorn Temple Community

Figure 2: Devarajkunchorn Temple Community

II. Research Objectives

To find the potential of accessibility within the slum area.

To find the relationship between 'space syntax model' and the pedestrian movement rates within the selected area.

To plan for the fire-evacuation route to evacuate victims from the area in case of fire incident.

III. Definition of Operations

"Space syntax" is a theory, a research methodology and a set of computer programs for analyzing the relationship between spatial morphology and real-situation spatial use patterns. By this, it is a research tool for the social, economic or cultural impacts of spatial and architectural morphology. In another word, space syntax specifically studies spatial relationship among spaces to clearly understand the morphology of cities and buildings(Paksukcharern, 2005).

"Walkway" means a path through which people can walk, either in normal or emergency condition such as in case of fire. Walkway is necessary to transport the victims out of the area and to access into the area for helping people and disaster relief.

"Small vehicle access" means a route that small vehicles, i.e. bicycle, motorcycle, small cart, small rickshaw, etc., can pass into and out of the area, either in normal or emergency condition such as in case of fire. Small vehicle access is necessary to bring the victims out of the area.

"Large vehicle access" means a route that large vehicles, i.e. fire trucks, ambulances and all types of cars, can pass into and out of the area, either in normal or emergency condition such as in case of fire. Large vehicle access is necessary both to transport the victims out of the area and to provide disaster relief.

IV. Theoretical Concepts and Related Research

The Building Control Act (1979) gives priority to fire protection for the purposes of community stability, safety, fire protection, public health, environmental quality preservation, urban planning, architecture, and traffic facilitation (Building Control Act, 1979). There are 16 items issued. Five of these are related to this study.

The items include:

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(1) Type, trait, pattern, shape, size, proportion, area, and location of the building

(7) Elevation, area of empty space outside or around the building

(8) Distance or level between buildings or land territory of others or between buildings and streets, alleys, sidewalks, roads, or public places

(9) Space or facilities built for vehicle parking, entrance, and exit for some types of building as well as characteristics and size of the built space

(10) Areas forbidden for construction, modification, demolishment, mobilization are used or change the building type

Nowadays, Bangkok Metropolitan has implemented the Bangkok Fire Prevention and Mitigation Action Plan Year 2017(Office of Disaster Prevention and Mitigation,2017). Following the operational guidelines, three activities consist of before the accident, preparedness and after the accident which is in line with disaster risk management (Ministry of Interior, 2013).

Analysis of the potential movement and access for risk management of slums' fire incidents in Bangkok required a geographic information system (GIS) to analyze traffic mobility potential and area accessibility. GIS is a system that can accurately and precisely select and analyze the geographic information. In addition to spatial analysis, it can also refer to earth coordinates usage requires planning and setup in terms of quality and characteristics of the data for the analysis. For instance, data scale can be specified, and data can always be updated. Moreover, multiple sets of data can be integrated or merged(Esri,2012). This study will write the Axial line using ArcGIS program since it can import the current roadmap data for analysis which can be used to support Axial line drawing and analyze together with the natural movement as exhibited in Figure 3: Drawing the Axial line, Dusit District, Bangkok on ArcGIS program.

Figure 3: Drawing the Axial line, Dusit District, Bangkok on ArcGIS program.

Theory of Natural Movement (Hillier, 1993) studied a set of computer theories and techniques that can demonstrate the relationship between "Space Syntax" and "the nature and level of popularity of space usage". Space Syntax is a specific analytical technique of architecture and city(Hillier & Hanson, 1984). In a sense, it is the science of architecture's and city planning's morphology that focuses on physical and spatial studies(Paksukcharern, 2005). By analyzing the natural movement, the calculated relational values are expressed in numbers and lines' colors. If a line is highly associated with other lines, then its 'integration value' is also high and the line appears in hot color. Therefore, the highest value is red. The lines with lower relation to all the other lines, in the same Axial Map, are in orange, yellow, and decreasing to cool color tone from green to the least related line in deep blue, respectively (Figure 4). In short, Axial map represents the connection of the traffic network and it will show which roads are likely to be the center of that area. In figure 4 (Hillier B., 1996, 2007), the central lines are in red color.

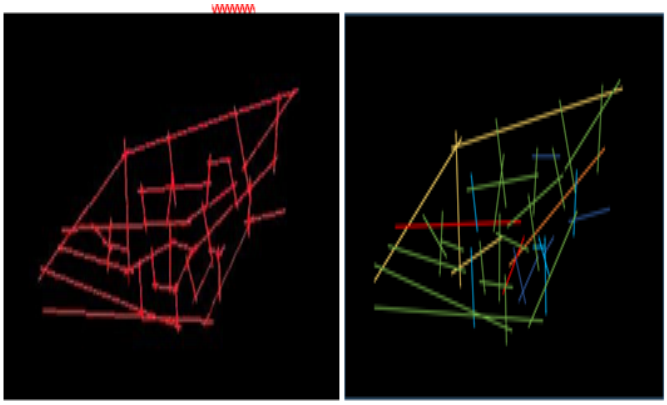

Figure 4: The Axial Lines of Gassin

Former research gives little knowledge about traffic potential and access to the areas. The physical environment is necessary to be studied with operational planning in terms of human management, resource management and spatial management. Such knowledge will help the implementation of fire prevention and mitigation (Office of Disaster Prevention and Mitigation,2017). The management of fire risks associated with road network systems, at the community and district levels, can specify spatial planning of this community.

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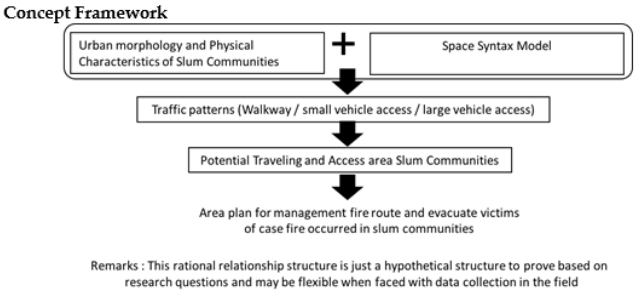

Figure 5: Concept Framework

V. Materials and Methods

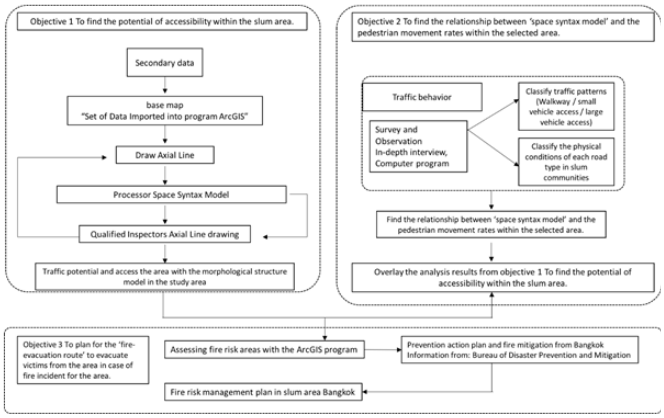

Figure 6: Research process framework

Research Methodology is divided into two main processes as follows:

Process 1 Method of research according to research questions 1 and 2

From the research question 1: What are traffic potential and accessibility into the slum?

From the research question 2: What are the morphological structures and walking behavior within this slum areas?

1) Collect data

2) Communicate with communities and all stakeholders, Organize a meeting to work together with all stakeholders, Explore the area together with the community

3) Analyze physical characteristics with secondary data about building utilization, land use, building shapes, traffic routes and locations which contains information in the form of GIS in conjunction with observations

4) Study the traveling behavior of people in slum communities from the depth-map software and field observation

5) Analyze traffic and accessibility using Space Syntax models

6) Collect traffic data from observations in the research area

7) Analyze spatial and statistical data

Process 2 Method of research according to research question 3

From the research question 3: What the guidelines to evacuate the victims in the fire event of this slum should be?

1) Analyze the traveling pattern into this area to increase security for life and property

2) Analyze Space Syntax model on ArcGIS program

3) Import data, road map, building utilization, building style and morphological structure

4) Make in-depth interviews with experts

5) Create area plan for fire escaping route

6) Public hearing to get opinions from all stakeholders

VI. Data Analysis and Results

By generating a representing model of street network, the study displays the resulted accessibility of the area (Hillier, 1993). The result shows the lines parallel with the Chao Phraya River consist of Samsen Road, NakhonRatchasima Road, Pichai Road, Rama 5 Road and Nakhon Chai Si Road, totaling 5 lines. The roads that are perpendicular to the Chao Phraya River, consist of Phitsanulok Road, Sri Ayutthaya Road, Ratchawithi Road, Sukhothai Road, NakhonChaisi Road, AmnuaySongkhram Road, Thahan Road, Pradiphat Road and Pracharat Road, totaling 9 lines. These are important roads at the district level and are the main road for traffic when counting the total number of connections that have occurred in the system.

6.1 Integration analysis of the alleys' network

Global integration value, called radius n, calculated the overall networked relationship from every segment of road to all the other segments of roads within that Axial Map. The lesser the steps an axial line, that is a segment of road, use to connect to all other segments the higher the global integration value it has. Figure 7 shows that highly integrated streets in Dusit district are in gridiron street pattern. In the area considered, some blocks and buildings are gated personal or official places, whereas, the community spaces are filled with small and dead ended alleys. Therefore, the result of analysis does not show a smooth gradation of integration pattern, but the jumping values from main streets that directly connected to local small alleys in the area. In another picture, the

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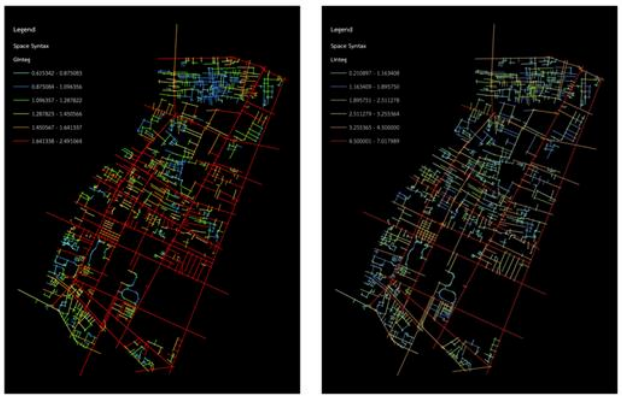
'integration radius 3' or local integration shows the value of local networking connectivity of a street segment to link with a group of segments around it. The number 3, for the name integration radius 3, is used because the local integration value calculates the 3-step relation from the concerned street segment as the first step, the directly connected segment(s) as the second step and the segment(s) connected to the second step segment(s) as the third step. Local integration value, hence, shows the local networking centrality of the street, whereas global integration shows overall networking centrality in the axial map. Findings from the analysis, show that most of the important roads in the grid system both at district and sub-district level are the same roads. There are only Pracharat Road, Phichai Road, Thahan Road and Pradiphat Road which has a reduced importance value. As shown in Figure 7, space syntax, through appropriate spatial indicators, can express the intensity and distribution of the traffic volumes in roads of a town(FrancesceLeccese, 2019).



Global Integration Local Integration

Figure 7: Analysis of independent traffic network Dusit district

6.2 Connectivity analysis of the alleys' network

When analyzing 'connectivity values', that show how many roads are directly connected to the road, the axial map within Dusit district explains that the Rama 5 road, with highest connectivity value, connected with other roads most directly (Figure 8).

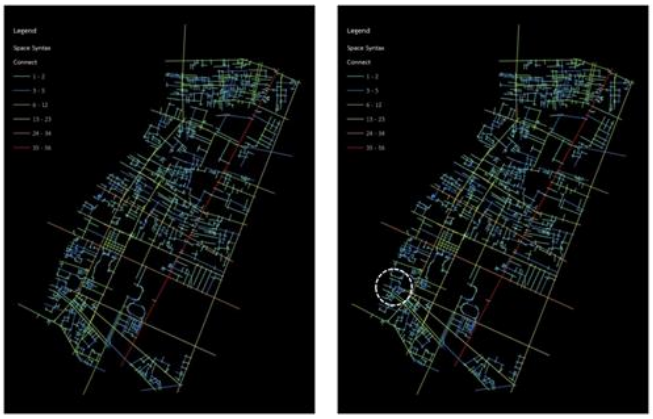


Figure 8: Connectivity Value Analysis Results

6.3 Visual analysis to improve accessibility of the community space

A study on the path dependency in southeast Asian city, Jarkata Indonesia, addresses the problem of inequality in mobility and accessibility(IstiHidayati, 2019). We find same problem that need improvement of community accessibility, particularly to prevent huge damage from fire accident. In Devarajkunchorn temple community case, this study analyzes visual connectivity of the space by applying depthmapX 0.7.0. By calculating the access of human vision, the most visible area of this small community are, first, the parking area and, second, the community entrance that leads to both Devarajkunchorn temple and the golden teak museum. Shown in Figure 2, both are important historical architecture and cultural places. Figure 9 represents both the visual, and accessibility, morphology of this community. Some alleys have limited visual access due to the physical characteristics of the area. Moreover, the complexity of traffic route includes very narrow alleys and dead ends of streets, where pedestrians cannot connect to other routes. In emergency case of fire, it may cause large damage to life and property, since there is only one way in and out. In this case, fire truck would not accessible or difficult to access. There are many obstacles to evacuate victims from the area and to get help from firefighters

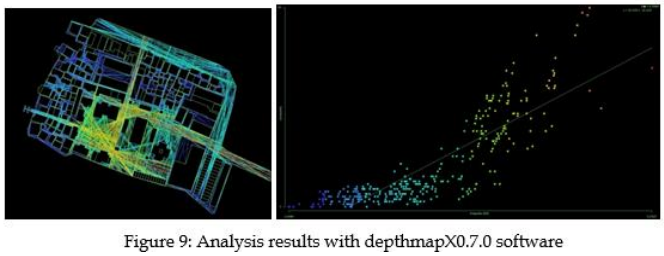


Figure 9: Analysis results with depthmapX0.7.0 software

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In addition, by using the program depthmapX 0.7.0, the researchers used the physical characteristics of the area to analyze pedestrian walking. It is found that the travelers, who are not local people or house owners in the community, tend to travel on public transport routes that are visibly accessed. Intelligibility coefficient showed that Devarajkunchorn temple community has high intelligibility value (R2 =0.73084). As shown in Figure 10, the results of the analysis are consistent with visual accessibility.

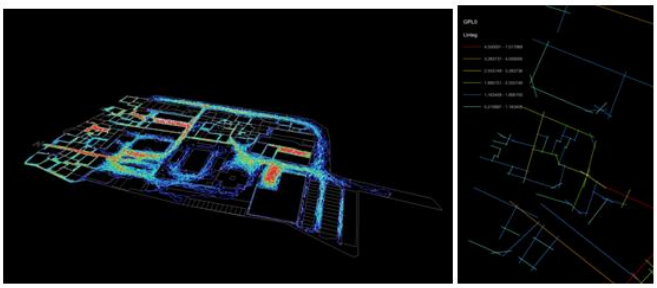

Figure 10: Foot analysis results from detphmapX 0.7.0

Moreover, we collected data of pedestrian traveling in the field by recording the rate of people traveling by within Devarajkunchorn Temple Community area. The 4 points are observed, collecting 2 time periods in the busy day when there are a lot of people outside traveling into the area on Saturday 19 October 2019. In contrast, on Friday 18 October 2019, the other data collection on less busy day was done during 8.00-8.15, 12.00-12.15 and 16.30-16.45 periods. Average numbers of traffic in each area including classification of passers in the area are shown in Figure 11.

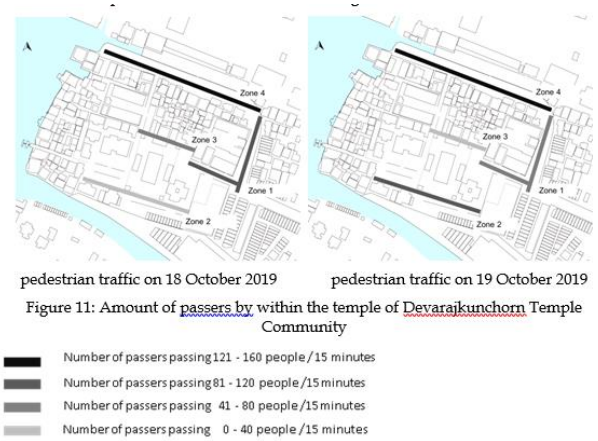

Figure 11: Amount of passers by within the temple of Devarajkunchorn Temple Community

In addition, the research surveys the pattern of buildings' entrances. The gates of houses, temples, and buildings used as entrances to connect with the community are drawn in figure 12. The entrance gates were crucial to the accessibility of each space(RungpansaNoichan, 2018). The pattern shows the hierarchy of physical accessibility into buildings within the community. From analysis, there are many routes to enter and exit the community; narrow alleys and many cul-alleys. This analysis differentiates that the routes that people within the community use more are the routes that have direct access to their residences. In contrast, the routes that people from outside of the area particularly use for traveling are the routes that have good visibility. As shown in figure 13, the internal routes are related to the results of the analysis from depthmapX0.7.0 (figures 9 and 10).

Figure 12: Gate Layout of Devarajkunchorn Temple Community

Figure 13: The popularity routes within the Devarajkunchorn Temple community

VII. Research Results

From overlaid information, we found that the roads with yellow values in Space syntax model are suitable to evacuate victims by small vehicle. That roads are connection points between the main exit and many buildings. Roads with these characteristics can reach the victims and quickly bring victims out of this area. Therefore, we should avoid placing obstacles in the area of the yellow axial line shown in space syntax model. (figures 14)

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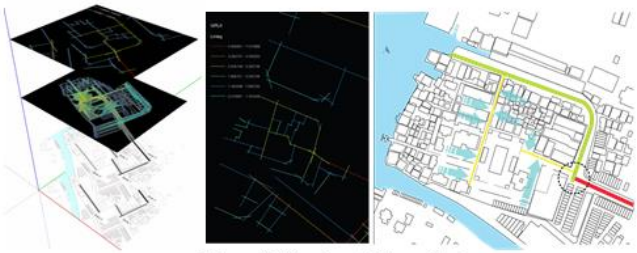

Figure 14. Overlay of data analysis

7.1 Potential of accessibility within the slum area.

The potential of access into Devarajkunchorn Temple Community is not arranged in good order from main roads to secondary roads and to alleys. Main roads connect directly to the alleys within the community. There are a lot of narrow alleys that can be used for traveling in and out by pedestrians and motorcycles. Cars, however, can reach only the main routes either in the temple's vehicle parking lot or at the north side of the community.

7.2 Relationship between space syntax model and the pedestrian movement rates within the selected area.

The relationship between space syntax model and the pedestrian movement rates within the community shows a stronger relation in terms of 'visual connectivity' (figure 9, 10 & 11), rather than a strong relation between integration values (figure 7) and walking pattern (figure 11). It was found that people in the community use short-distance connections to their residences, whereas people from outside select to travel on the main routes that being visible from outside. The analysis results are consistent with visual accessibility and related to the results of depthmap analysis.

7.3 Plan for the fire-evacuation route to evacuate victims from the area in case of fire incident.

Area planning to cease fire and evacuate victims from the area in the event of a fire is necessary for the Devarajkunchorn Temple Community. Because of complex traffic routes including many alleys and cul de sac, fire may cause vast damages to life and property since there is only one narrow way in and out of this area. The fire truck is virtually not accessible. As Xiaorui Zhang (2019) studied, the accessibility measurement will play a more scientific guiding role in the planning and construction of urban traffic networks. From the results in 7.1 and 7.2, this research provides a planning of fire evacuation routes as shown in Figure 15.

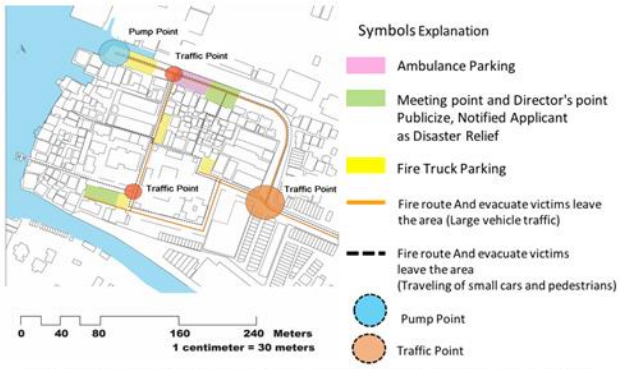

Figure 15. Route Map Plan for fire routes and evacuate victims from the area

VIII. Summary

From the above findings, Devarajkunchorn Temple Community should be planned for the fire routes. Firefighting routes and victim evacuation routes could be analyzed by using space syntax together with ground observation. Recommendations for improving this community in terms of firefighting and victims evacuation are as follows:

1) Set the water pumping station for firefighting at the 'north dead-end alley' of the community next to Chao Phraya River, so that, in the case of fire, the firefighters can pump water from the river to cease fire. The alley's width is accessible for fire truck. Moreover, it is connected to high-integration street and being visible from the main street.

2) Set the specific fire trucks' parking lots including 4 places, colored yellow in figure 15; 1) the street near the water pumping station 2) the car parking in front of Devarajkunchorn School 3) the car parking in front of the museum and 4) the community's entrance area.

3) According to visual analysis (figure 9), there are two places with 'good visibility' and 'high passing rates of pedestrians and vehicles' (zone 2 and 4 in figure 11) including, the first, the car parking in front of the museum and, the second, the entering corner of the wide north alley, where fire truck could access, that to be planned as assembling places, directing and information centers that would help the fire victims.

4) With the obstructed character of this community's

street plan, filled with tiny alleys, cul-alleys and cul de sac, the new traffic enabling points should be placed at the entrance to the community and the other two junctions as shown in red circles (figure 15).

5) The community entrance and walkways within the community should be obstruction-free. In a fire accident, such clear alleys will make the conveyors quickly evacuating people out of the area and open up the access for fire fighters to access in a timely manner. In addition, there should be a map indicating both the location of this community's fire extinguisher and the telephone numbers of the responsible persons.

6) For the riskier groups of people, such as the elderly, the disable persons, home-based severe patients and small kids there should have special stickers or symbols attached in front of their houses. They should be evacuated with first in a fire case. For the tiny alleys, particularly where vehicle cannot entry, the pavement should be very convenient for people both for daily walk and for emergency case of fire.

7) An ambulance should be prepared at car parking spot.

In conclusion, the results of this research provide analysis and planning for the fire evacuation route map of Devarajkunchorn temple community. Stakeholders should improve physical and environmental conditions of the area. The research result is useful not only for this community, but also for other slum communities in Bangkok.

Future research should cover few other studies; for examples, analysis of statistic correlation between the values from Space syntax model and pedestrian movement rates, three-dimensional design of streets and urban environment for the fire evacuation situation and community's involvement and action that would suitable with fire evacuation

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