Analysis of urban morphology and accessibility character to provide evacuation route in historic area

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Abstract

In historic area, investigation on limitation of streets to provide further countermeasure in time of evacuation is highly concern. This study objective is to clarify labyrinthine and narrowness of urban network. Study area is Chiang Mai’s historic area locate in northern of Thailand. Subjects of this study are egress point and accessibility of urban network, to act as evacuation network investigated by space syntax analysis combine with GIS as primary tool. Result show incompetent of narrow streets comprise with egress point that resemble integration value of streets and led to summarized of its urban morphology for evacuation plan.

Keywords: Historic area; Space syntax; Evacuation route; Urban accessibility; Egress point

1. Background and aim of this study

Cities have been and still are containing complex refuge, acting as shelter from natural disaster these leading to cluster of hotspot as spatial aspect combine with complicated layer of historic items evolve through time. (Christine, Ebba, & Claudia, 2013) (Rodwell, 2007). Recently, risk of disaster in urban area and lack of spatial management are
continuity deriving especially in developing countries (United Nations Human Settlements Programme, 2010). Aim to contribute knowledge into proper policies for spatial improvement of historic area to cope with disaster while maintain irreplaceable historic area character is considering desirable (ICOMOS, 2005), the objective of this paper is to analyse and investigate its character of urban fabric to act as evacuation route due disaster occur focus on urban morphology and accessibility character.

Recently, misguide rapid development may cause those historic areas prone to disaster risk. However, disaster risk management trend in 21st century is going to emphasize on preparedness and cycle of disaster risk more than only focus on recovery strategy (IPCC, 2012). Therefore to create efficiency risk management, suitable model must be created by local context consideration, led to differentiation of solutions in each historic area depend on its social and spatial aspects. (UNESCO, 2010) Moreover historical area has vulnerable for experiencing physical problems more than new development cities; Density of buildings, clout of circulation within the small road which is somehow one of heritage item that must be conserve to maintain its historical meaning (Mishima, Miyamoto, & Taguchi, 2013). It is urgency to seek and investigate how urban morphology of historic area operating in usual basis and its potential to provide evacuation. Recent studies of disaster, are however, proposed on shortest route to shelter provide by GIS (Wei XU, 2008) therefore human behaviour such spatial cognition in panic situations, may rather choose simplest way which imprinted by spatial cognition of travelling in their urban fabric than shortest route calculated by computer. There have been studies on space syntax that imply selected routine travel by pedestrian in city (Hillier, Penn, & Hanson, 1993). These studies also found relationship between human behaviour as spatial cognition and physical indicators in their study (Kim, 1999). By analysing Syntactic value of urban network, it represent street usage as overall integration therefore these set of analytic tool comprise with set of GIS’s spatial data may provide more appropriate evacuate route than typical shortest route method, which also relate to spatial cognition of human.

As historic area there many limitation as described above, moreover in developing countries efficient earthquake evacuation route in historic area may understudy even though there are study and research concern on building stiffness or service area of emergency facilities. (Hasapinuyo, 2009) (Thiengburanathum, 2012) In specific area, had some complexity issues such as settlement belief that affected urban physical aspect. To expand and provide evacuation route in historic area, combine and overlay those issues as research materials and result implication for policy recommendation may needed to be clarified for urban mitigation plan that highly needed in very near future. In this study, result of investigating urban fabrics is obtained to understand the nature of overlaying historical accessibility character and its morphology.

2. Methodology

2.1. Site study

Historic area, Urban items usually create vulnerability to evacuate therefore it also act as identity of its own form and characteristic. These issues caused limitation by itself due to width of street or any urban accessibility may contain historical contents. In this study, historic area site was tested to represent viable method to cope with disaster risk due to limitation of this accessibility. Chiang Mai is used as site study since it comprises with highly geometric shape and also natural preset of internal streets that need to profoundly investigate and also it is representative of typical urban morphological cities in the same period, which shared settlement belief.

Chiang Mai, previous capital of northern in Thailand settled for 720 years old, in the valley of Ping river basin. Location for settlement came from consideration of religious beliefs and respect to the natural feature as same as other cities in northern region by that time. Historic area located between Doi Suthep Mountain and Ping River. These discreet considerations determined Chiang Mai to be capital city, center of Lanna kingdom in former time (Ongsakul, 2010).
Due to fertile natural resources, Chiang Mai was the most important and influential city in that time. Since settlement period, its spatial configuration may divide by multi-spatial character of street network from delicate shape of symmetry geometry to free-form natural pedestrian pathway follow by its functions. To the fact that multi-politic and cultures continually influence spatial character of Chiang Mai led to deform-grid system road network. As geometric shape of city received and intent to imitate concept of others capital cities established during that period such as ‘Sukhothai’ (Soraya, 1999) this geometric concept applied to its perimeter shape of city wall and moat that would be useful in wartime, it created area cover 2.56 square kilometers within perfect shape of rectangular perimeter segment. Inner boundary urban network was intentional designed, as deform-grid hierarchy of street function such as core and cross axis comprise with sub network of natural labyrinth network of residential area.

Since 1982 to present-day, Chiang Mai urban fabric has grown rapidly correspond with it role and determined as important city of northern Thailand in terms of governmental, religion, cultural and economic especially in tourism sector (National Economic and Social development of Thailand, 1982). Despite rapid development, it still maintains wartime defensive elements, historic administration center, temples and large market spaces more than other provinces in the north. This trace of historic items are somehow, preserve as cultural landscape of Chiang Mai to represent ‘Lanna’ culture, has unique identity and contextual link to traditional activities. However according to evolved in mode of transportation that overlay onto historic area, vulnerable and risk from limited evacuation route may derive from its spatial configuration that only response to pedestrian movement in previous time result in narrow streets and also labyrinth alike.
2.2. Earthquake vulnerability

In May 2014, Northern part of Thailand suffered major earthquake disaster with 4-7 Richter produced more interest in earthquake disaster response/mitigation plan that may overlook. Fortunately, this severe disaster occurred in rural area which only property damage were found but raise awareness in earthquake especially provinces on active fault of Northern Thailand. Disaster vulnerability raised the awareness of earthquake disaster mitigation especially in historic cities in northern, Thailand. These cities mostly situated on active faults of seismic activities. Recently, researchers in Thailand have highly interest in the Mae Chan fault, which pass through the provinces of Chiang Rai and Chiang Mai. The fault had the most potentially destructive power in the country in the event of an earthquake. Nowadays, Mae Chan fault remains stable as stress continues to build up. Risk map shows vulnerability of northern Thailand cities rated by scale of cities and active faults in the area which Chiang Mai is the most vulnerable city in northern Thailand, see fig.2.(a). Historical archive also has a record that the fault unleashed its power before leading to the fall of the great city of ‘Y onok’ (Jarusiri, 2012). In 1545, there also evidence of major earthquake occurred in Chiang Mai. This incident caused the largest pagoda called ‘Chedi Luang’ partially collapsed and still left the evidence to be seen in present-day (Ministry of Education, 1979), see Fig.2. (b).

Chiang Mai is changing to the economic center of the northern region which concentrated with commercial district, high-rise buildings and roads which accommodating vehicular transport but the concentration of buildings usually built on narrow streets, led to difficulty of accessibility and high density residential area as well as inefficiency data for disaster mitigation. According to recent study, showed the most damage occurred in the building's collapse levels corresponding to the cluster of the buildings located in the historical area (Hasapinyo, 2009). This study conform to the study of fire risk simulation in municipality area (Thiengburanathum, 2012) that showed the most vulnerable area is in the historic area according to its wooden materials and service radius of fire station.

2.3. Method of Analysis

Urban morphology studies usually study on how city develop and transform to represent its embedded history. This study focuses on its network, however, not only movement of urban network is concerned, other urban morphology items such as building usage, egress point, and its condition are also used to exemplify tolerance of urban network to mitigate evacuation. In this study, urban morphology divided into its spatial aspects as mentions above and combine with function of human activities, which represent by space syntax to determine how network was chosen to be used in normal circumstance and potential of adaptive use of this method in evacuation.

To analyze potential of urban morphology to compensate with evacuate route. First, Syntactic properties of
Chiang Mai calculated how much integrate of each street by space syntax technique. This measurement analyzed how many connectivity occurs when travel inside study area. The most integrated street mean that it has minimum turning to travel to another streets in network and interpreted as the most choice of travel by pedestrians (Hillier, 2002) this method displayed as gradual color graph within GIS map. Graph also clarified complication in accessibility of urban networks relate to easy to access and choice in using of streets by determination in value of integration value consist of global and local integration, through limit of angular turning as R=n and R=3, respectively. (Lee & Kyung, 2013). This set of data would be important result to prioritize evacuation routes in historical area. To analyze urban network as a whole, intelligibility correlations (Hillier, 2007) was used and calculated to explain current situation its consist of 1) Intelligibility coefficient; which is regression between integration value(R=n) and its connectivity. According to Hillier, result of linear regression represents lostness or wayfinding of city (Hillier, 2004) through integration and connectivity correlation of axial line. 2) Synergy coefficient; which is regression between integration value(R=n) and integration 3 (R=3). This linear regression represent how small local network embedded to global network. For example, it show how strong of local movements are perfectly link to global or overall movement, which imply that local streets that served neighborhood are easily to connect and use by both outsider and insider (Dalton, 2010).

Secondary, in order to obtain analytic data of urban accessibility character, Geographic Information system (GIS) toolset was used to assort data of analysis as follow 1) Egress point; determined to be egress location where building entry are connected to the urban network. This data represent as point that will use for egression from buildings by panicking evacuees when disaster occurs. Egress points type was divided according to its function and size consist of normal, large, service, emergency exit and unused. 2) Street width; geometric data of urban network which is street width classified and categorized by it geometric properties to explain potential or limitation with another research material.

To evaluate potential evacuate route of urban network, combination toolset of space syntax and GIS integration was created. Syntactic properties and urban accessibility consist of egress point and street width will overlay and statistical evaluate, simultaneously. Egress point will calculate by kernel density method, Global integration syntax and street width shall be analyzed through correlation analysis to clarified spatial configuration of urban morphology and its condition to act as evacuation route when disaster occurs. Finally, this perspective and result in analysis of historic area as urban accessibility character combine with syntactic properties will be discussed.

3. Result

3.1. Syntactic properties

Syntactic analyses are as follow. A for global integration value of street, it obviously showed that the most integrate axial line is main street of city, has value of global integration (r=n) at 2.264(A1), 2.113(A2) other main streets are 2.213(B1), 2.075(B2) and 1.815(C1), 1.900(C2), respectively, see fig.3. (a). Global integration also displayed discontinuous of street in highest value of main streets (A1 and A2) which mean mostly natural movement deviate from the most integrate road (A1) to second most integrated (B1). This incident may caused by connectivity value of (B1), had highest connectivity value (connectivity=16). Despite of discontinuity of predicted movement, syntactic graph distinctively showed important main streets role as main network of city and thus conform to character of historic area that determined these road as deform-grid system and to support major activities. However syntactic map also showed lower integrate lines congregate into cluster and distinctively designate blocks of low integrate distribute among main streets. As local integration axial map, integration values were quite similar to global integration values, Main streets are still act as main travel route, in addition, city moat perimeter are also chosen to be travel by residents along with inner city, this mean all level of streets were predicted to be used by residents. Furthermore, predicted travelling choices tend to choose eastern part of city more than other parts, see fig.3. (b) especially local integration result significantly complies to land use of eastern part that determined and developed to be commercial district since settlement period (Guntang, 1990). As for spatial integrate value of Chiang Mai, it can be conclude that urban network divide into 2 types, deform-grid system act as main streets and subnetwork with labyrinth local residential streets, which showed in high integrate value and low integrate value, respectively. For overall syntactic property, integration values are aggregate in eastern part and also consistent with settlement history that defines this eastern part as commercial function of city.
Intelligibility coefficient showed that Chiang Mai has low intelligibility value ($R^2=0.3478$, Mean integrate=1.38). It could interpret that spatial configuration may cause tourists or outsiders in moderate incident of lostness (Hillier, Burdett, Peponis, & Penn, 1987)(Hillier, 2004). Primary cause of lostness also showed in syntactic map, it has complicate subnetwork. Synergy coefficient showed potential of integrated overall urban network to travel through ($R^2=0.75$) due to comprise of deform-grid and blocks of residential area. Thus coefficients could be simply explain that for outsider or tourist may be get lostness due labyrinth and incompetent grid system as a whole but for local resident it may be easily to travel inside this city due to various choice of routes derive from these blocks network.
3.2. Urban accessibility character

Egress point from buildings had been collected and categorized in 5 types consist of 1) Normal access; egress point from building that had 1-5 meters width. 2) Large access; egress point that had more than 5 meters width. 3) Service access; egress point that origin from service access or secondary access of building. 4) Fire-exit; egress point that determined to be emergency access 5) Un-use access; the unused access of buildings. Summary from field survey, A mount of egress point are as follow, Normal access found 2,793 (66.58%), Large access found 1,357 (32.35%), Service access found 23 (0.55%), Fire exit are extremely rare which found only 3 (0.07%) as well as un-use access which found 19 (0.45%). Sum of egress points categorized by GIS combine with information from building owners, showed large number of egress point clustering in eastern part of city, mostly in residential area that streets were aggregated as subnetwork, see Fig.5. (a).

Fig. 5. (a) Egress point location and street width. (b) Streets condition in Chiang Mai.

Width of street has its average at 3.82 meters. These streets are incapable for 2-way traffic, moreover, dense and labyrinth formation of subnetwork has narrowest street which only 0.82 meters wide and incapable to be evacuation route. Result of street width range is in between 0-2.9 and 3-5 meters found 41.39% and 45.58%, respectively. In addition the most number determine by GIS, mostly streets width is 3 meters, which found 31.21%. It showed significance issue in historic area, evolved from narrow streets, may incapable to support density of buildings in present-day due to street character. Moreover overall urban network may change slower and difficulty to improve more than other urban characters. Additionally, these narrow streets are mostly attached by large number of egress points led to vulnerable of residents cause by congestion when disaster occurs.
3.3. Statistic correlation

To analyze urban networks for evacuation route, clustering group of egress points were calculated by kernel density analysis method. Result displayed as raster density, significantly aggregated along eastern part of city. According with syntactic properties, overlay mapping also provide relation between kernel density result and urban morphology, see fig.6. (a). Cluster of egress points is somehow, significantly shared the same location of low integration value axial lines. It could interpret that residents may congregate dwelling along low traffic for tranquil and peaceful environment led to compact neighborhood and created specific identity in each block. In case of evacuation, these may led to vulnerability of these neighborhoods due streets narrowness. However it also conform to congregation of street syntactic property that distribute throughout each block of deform-grid and imply potential in urban management through this urban morphology analyses.

In addition, correlation between syntactic properties and its accessibility was used to explore delicate consideration such as potential and limitation of spatial configuration to act as evacuation route. Width of streets that determine capability of evacuation were resolved however Chiang Mai’s historical area relation between global integration and street width has very low ($R^2=0.1338$, see fig.6. (b)). Which mean streets that predicted to be most use by residents may incapable for traveling and may cause traffic congestion. Results pose vulnerability of historic area to cope with disaster, as evacuation routes.
4. Discussion

From this study on evacuate routes in historical area of Chiang Mai, following issues have been clarified and created essential material to verify vulnerability of urban morphology in term of evacuation routes:

1) In historic area of Chiang Mai, Integration value of urban morphology categorized streets as deform-grid represent main network and labyrinth neighborhood blocks represent organic subnetwork distribute along with main network.

2) Chiang Mai has low value of intelligibility coefficient affect lostness of city and may create difficulty for users to understand urban network of this city in term of wayfinding however synergy coefficient showed various choice of travelling route in this area.

3) Egress points of Chiang Mai are usually narrow than 3 meters with may need to improve or regulate intense control guideline to mitigate casualties from earthquake or even different kinds of disasters.

4) Egress points cluster with deviate narrow and low integrate street. It also aggregate to eastern part of city according to commercial and urban function determined since settlement.

5) Narrow Streets in historical area are mostly attached by egress point and incapable to be evacuation route that need further study to clarified limitation of streets.

6) Street widths are incompetent to integration value, which mean street width unable to comprehend highly used streets represent by its integration value and pose vulnerability of city, however narrow streets are significantly comprised to cluster of egress point density and integration in term of its aggregation to the eastern part of city.

7) Space syntax combine with GIS technique is robust tool to identify urban morphology and led to better understanding of its network to provide evacuate routes.

Additionally, study limit on fact that uncontrolled factors may affect street width such as historical meaning of streets or social factors but results displayed distinctively incompetent and limitation in historic city, also improper function of street measure by its syntactic properties and accessibility. Overlay mapping showed incompetent between global integration and width of street, need more delicate study, in this matter especially historical meaning before gradually improve to appropriate evacuation route or strengthening intensive countermeasure.

5. Conclusion

This finding shows vulnerable of historical city of Chiang Mai to major disaster such as earthquake disaster. In historic area, urban accessibility may incapable to act as evacuation routes in panic period due to cluster of egress in narrow streets, which may lead to more casualties. Space syntax combine with GIS technique led to better understanding labyrinth urban network of historic area which considered to be necessity to provide mitigation plan through it result by provide proper strategy to cope with those hazardous events. Moreover, this study clarified and reaffirms vulnerability cause by density of buildings overlay and transform onto previous formation that create more complex of urban networks and its morphology. Further studies needed to be continuity investigate in various delicate factors.

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References


