Lowland Technology International 2016; 18 (3): 219-230
International Association of Lowland Technology (IALT): ISSN 1344-9656

Research Paper

Urban morphology and accessibility classification as supportive data for disaster mitigation in Chiang Mai, Thailand

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ARTICLE INFORMATION

Article history:

Received: 17 April, 2016
Received in revised form: 15 May, 2016
Accepted: 27 June, 2016
Publish on: 28 December, 2016

Keywords:

Urban morphology
Urban accessibility
Disaster mitigation
Space syntax
Chiang Mai

ABSTRACT

In historic town, investigation on limitations of streets to provide countermeasure during an evacuation is recently in concern. This study objective is to classify labyrinth and narrowness of urban accessibility that comprise with its urban morphology. The study area is Chiang Mai's historic town locate in northern of Thailand. To identify risk level of the street, egress point from buildings were surveyed and collected combine with street width as urban accessibility factors. Urban morphology of street network identified using space syntax integrations analysis. Additionally, Egress point locations also analysed using kernel density mapping to revealed risk level as area type and finally compared with classified streets map created by Hierarchy Cluster Analysis. The result shows classification of streets; Sub-streets were subdivided into Priorities streets determined by its level of risk. Priorities streets revealed a risk of bottlenecks caused by narrowness and high egress points ratio. Classification map shows crucial supportive data to evacuate strategies in disaster mitigation of historic town characters.

1. Introduction

1.1 Background and objective

Recently, a risk of disaster in the urban area and lack of spatial management are continuity occurring especially in developing countries (United Nations Human Settlements Programme, 2010; Christine et al., 2013; Rodwell, 2007). Aim to contribute knowledge into proper policies for spatial improvement of historic town to cope with disaster while maintain irreplaceable historic town character is considering desirable (ARUP 1995; ICOMOS, 2005), the objective of this paper is to analyze and investigate its character of urban fabric to act as evacuation routes due disaster occurs, focus on urban morphology and accessibility character.

At present-day, misguide rapid development may cause those historic towns prone to disaster risk. Meanwhile, disaster risk management trend in the 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

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Note: Discussion on this paper is open until June 2017.

management, a suitable model must be created by local context consideration, led to the differentiation of solutions in each historic town depend on its social and spatial aspects. (UNESCO, 2010) Moreover historic town has vulnerable for experiencing physical problems more than new development cities; the density of buildings, bottleneck situation in circulation within the small road, and choice of evacuation routes must be highly considered combine with its historical meaning (Mishima et al., 2013). It is an urgency to seek and investigate how the urban morphology of historic town operating in usual basis and its potential to provide evacuation. Recent studies of disaster, are, however, proposed on the shortest route to shelter provide by GIS (Wei XU, 2008; Villagra et al., 2014) therefore human behavior such spatial cognition in panic situations, may rather choose the simplest way which imprinted by spatial cognition of travelling in their urban fabric than shortest route calculated by computers(Bin et al., 1999). There have been studies on space syntax that imply selected routine travel by pedestrian in a city (Hillier et al., 1993). These studies proved a relationship between human behavior as spatial cognition and physical indicators in their studies (Kim, 1999). By analyzing Syntactic properties of urban network, it represents street usage as overall integration therefore these set of analytic tool comprise a set of GIS's spatial data may provide more appropriate evacuate route than typical shortest route method, which also relate to a spatial cognition of human(Haq, 1999).

From proven pragmatic of space syntax, it widely uses as the main analysis tool, at the early state, in 2005 Unlu et al. initiated the linkage between spatial configuration and human decision making by studying hospital and human egress in a panic situation. Afterwards, many studies highly relation in especially in emergency and panic situation (Dou et al., 2011; Choi, Kim et al., 2007). As the urban scale, recent studies (Gil et al., 2008; Fakhrurrazi et al., 2012; Sari et al., 2012; Carpenter, 2012), revealed morphological syntactic properties and socio-behavior of the human during various disaster situations had significance related. Findings suggested the urban design guideline for disaster prevention according to its syntactic properties. In 2013, Milton Castello, suggested preparedness by studying the magnitude of landslide and urban morphology in the historic town of Mexico, although the finding was revealed as socio-economic aspects. As a spatial aspect, egression from building to the morphology of street are understudying as crucial information in mitigation plan.

As Lowland historic town has many limitations as described above, moreover, in developing countries efficient earthquake evacuation route in historic town may understudy. Even though there are studies and researches concern on building stiffness or service area of emergency facilities (Hasapinyo, 2009; Thiengburanathum, 2012).

In this specific area, had some complexity issues such as; settlement belief that affected urban physical aspect, settlement choices, and/or connection between buildings and streets. To expand and provide evacuation route in historic town, dedicated survey and classification those issues as research materials and result implication for policy recommendation may need to be clarified for urban mitigation plan that highly needed in very near future (Strange, 1997; GFDRR, 2015). In this study, the result of investigating urban fabrics is obtained to understand the nature of overlaying urban settlement and its morphology.

1.2 Earthquake vulnerability in Chiang Mai, Thailand

On 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 the rural town which only one casualty was found but it raises awareness in earthquake especially northern lowland developed towns situate on the 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 (Phodeeet al., 2015; Fentonet al., 2003; Jarusiri, 2012; Songmuang et al., 2007), have high 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. As shown in **Fig. 1.**, shake map provide by USGS (United State Geological Survey) 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. The historical archive also has a record that the fault unleashed its power before leading to the fall of the great city of 'Yonok' (Jarusiri, 2012). In 1545, there also evidence of major earthquake occurred in Chiang Mai, see **Fig. 2**. 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).

Moreover, 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 historic town (Hasapinyo, 2009). This study conforms to the study of fire risk simulation in municipality area (Thiengburanathum, 2012) that showed the most vulnerable area is in the historic town according to its wooden materials and service radius of fire station.

2. Methodology

2.1 Study area

Chiang Mai, the 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 (Bangkok Bank Com, Ltd., 2008). A historic town located between Doi-Suthep Mountain and Ping River. These discreet considerations determined Chiang Mai to be the capital city, the center of Lan Na kingdom in former time (Ongsakul, 2010).

Due to fertile natural resources, Chiang Mai was the most important and influence city in that time. Since settlement period, its spatial configuration may divide by multi-spatial character of urban accessibility from a delicate shape of symmetry geometry to free-form natural pedestrian pathway follow by its functions as shown in **Fig. 3**. Due the fact that multi politic and cultures continually influence the spatial character of Chiang Mai led to deform-grid system street network. As geometric shape of the city received and intent to imitate concept of Cosmographic used by 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 street network was intentional designed, as deform-grid hierarchy of street function such as core and cross axis are comprised with sub-network of natural labyrinth street in residential area.

Since 1982 to present-day, Chiang Mai urban fabric has grown rapidly correspond with it role and determined as the important city of northern Thailand in terms of governmental, religion, cultural and economic especially in the 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

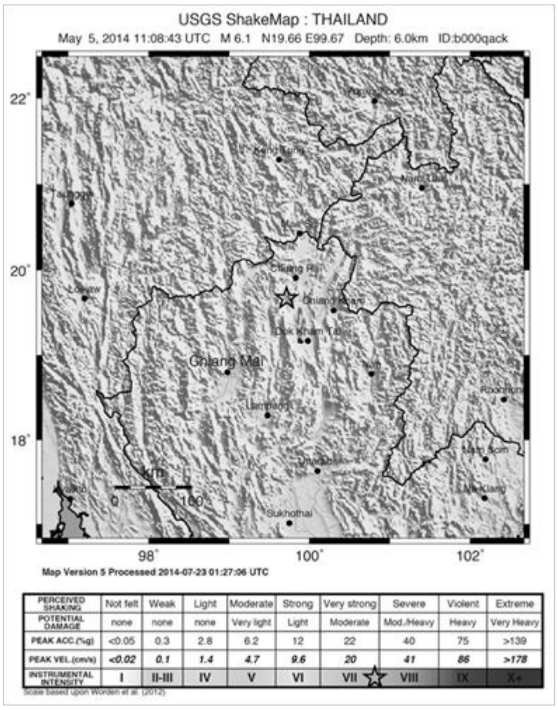

Fig. 1. Mae Chan Active fault earthquake in 2014 (USGS, 2005).

Fig. 2. Chedi-Luang; Half collapsed pagoda in Chiang Mai.

Fig. 3. Chiang Mai's Historic Town area.

of historic items is somehow, preserved the cultural landscape of Chiang Mai to represent 'Lan Na' culture, has a unique identity and contextual link to traditional activities (Chiang Mai Municipality Office, 2013; Chotesookrata, 1969). However according to evolved in a mode of transportation that overlay onto historic town, 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 character.

2.2 Research approach and conceptual framework

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 the 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 (**Fig. 4**). In this study, urban morphology divided into its spatial aspects as mentions above and combine with a function of human activities, which represent by space syntax to determine how streets were chosen to be used in normal circumstance and potential of the adaptive use of this method in an evacuation.

To analyze the 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 analysis. This measurement analyzed how many connectivity occurs when traveling inside study area. The most integrated street mean that it has minimum turning to travel to another street in the network and interpreted as the most choice of travel by pedestrians (Hillier, 2002; Hillier, 2004; Hillier, 2012; Kim et al., 2004). This method displayed as a 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 integrations consist of global and local integration (Zampieri et al., 2009; Zhang et al., 2013), through limit of angular turning as R=n and R=3, respectively. (Lee et al., 2013; Hillier, 2007; Turner et al., 2002). This set of data would be part of urban morphology factor to prioritize evacuation routes.

Secondary, in order to obtain analytic data of urban accessibility factor, Geographic Information system (GIS) toolset was used to arrange data of street width and egress point. As Street width, it comprises of geometric data of street width classified and categorized by it geometric properties to explain potential or limitation as urban accessibility factor. In this study, Egress point survey was invented to determined egress location where a building is connected to the street. This data represents a point that will use for egression from buildings by panicking evacuees when a disaster occurs (Bernardiniet al., 2014). Egress points type was divided into groups according to its function and size consist of normal, large, service, emergency exit and unused. Normal access; egress point from a building that had 1-5 meters' width. Large access; egress point that had more than 5 meters' width. Service access; egress point that origin from service access or secondary access of building. Fire-exit; egress point that determined to be emergency access. Un-use access; the unused access of buildings. Furthermore, Egress point also analysed in kernel density method using GIS Quartic (Bi-weight) kernel function to display the level of clustering in the area.

Finally, both urban morphology and accessibility will be act as classify variables using statistic hierarchy cluster analysis (HCA) to build a hierarchy of groups. In order to classification clustering, Squared Euclidean distance was used as metric to described cluster dissimilarity in this study. Dendrogram of clustered analysis will be displayed, classified group. Then, classify group will input to GIS to displayed as classification map. This method will provide both quantitative statistic data comprise with qualitative GIS mapping data. In addition, Classification map will be compared and discussed on the level of street-risk classify by this combined method.

3. Result and discussion

3.1 Syntactic properties

Syntactic properties are as follow. As for global integration value of street, it obviously showed that the most integrate axial line is the main street of city, has value of global integration (r=n) at 2.42 (A1; Ratchadamnoen), 2.113 (A2; Ratchadamnoen) other main streets are 2.213 (B1; PhraPokKlao), 2.075 (B2; PhraPokKlao) and 1.815 (C1; SamLan), 1.900 (C2; Singharat), respectively, see **Fig. 5**. Global integration also displayed discontinuous of streets in highest value of the main streets (A1 and A2; both Ratchadamnoen) which mean mostly natural movement deviate from the most integrate road (A1) to second most integrated (B1). This incident may have Affected from connectivity value of (B1), had highest connectivity value (connectivity=16). Despite discontinuity of predicted movement, syntactic graph distinctively showed important main streets role as the main network of city and thus conform to the character of the historic town that determined this road as a deform-grid system and to support major activities. However syntactic map also showed low integrate lines aggregate into clusters and distinctively designate blocks of low to integrate distribute throughout a street network. As local integration axial map, integration values were quite similar to global integration values, Main streets (Ratchadamnoen) still act as the main travel route, in addition, as shown in **Fig. 6**, city moat parameter streets, consist of Sripoom, MoonMuang, Bumrungburi, and Arak, are also chosen to be travel by residents along with the inner city, this means all level of streets were predicted to be used by local residents. Furthermore, predicted travelling choices tend to choose the eastern part of the city more than other parts especially the northern part of MoonMuang street, local integration result significantly complies to land use of Eastern part that determined and developed to be commercial district in city developing period (Tantsukanunt et al., 2013; Guntang, 1990). As for spatial integrate the value of Chiang Mai, it concluded that urban network divides into 2 types, deform-grid system act as main streets (Such as and sub-network 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 the eastern part and also consistent with settlement history that defines this eastern part as the commercial function of the city.

3.2 Accessibility character

Summary from field survey, Amount 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%). In Summary, egress points categorized by GIS combined with information from building owners, mostly, clustering in the eastern part of the city especially on the northern part of MoonMuang street. In addition, clustering of egress point, usually followed by its residential area that streets were connected as sub-network, for example, Arak 2, WiangKaew, and MoonMuang 9 in the northern part and Bumrungburi2, PhraPokKlao 4 and MoonMuang 1 in the southern part, see **Fig. 7**. Further analysis using kernel density is needed to be performed to clarify better understanding of egress point clustering which will discuss in next section with statistic HCA.

As shown in **Fig. 8**, Width of streets have its average at 3.82 meters. These streets are incapable for 2-way traffic, moreover, dense and labyrinth formation of sub-network has the narrowest street which only 0.82 meters wide and incapable of being evacuation route. The 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 town, evolved from narrow streets, may incapable of supporting density of buildings in present-day due to the street character. Moreover, the overall urban network may change slower and difficult to improve more than other urban characters. Additionally, these narrow streets are mostly attached by numbers of egress points led to vulnerable of residents cause by congestion when a disaster occurs.

3.3 Statistic hierarchy cluster analysis and kernel density map

As shown in **Fig. 9**, urban morphology and accessibility were factors in classifying streets network, consist of Global integration, Local integration, Egress points, and street width. From HCA, the result shows that when classifying into 2 group (Case 25), 1st priority sub-streets consist of 2 streets, has classified dissimilarity compare to the rest. When classifying into 4 group (Case 10), Moat streets consist of Sripoom, MoonMuang, Bumrungburi, and Arak,Primary streets consist of Ratchadamnoen, Ratchamanka, SamLan, Singharat, PhraPokKlao, and the southern part of Ratchapakinai streets emerge as group. However, the most significant result of HCA is classified into 7 group (Case 5), this level of classification could separate new groups consist of the secondary street, sub-street, 2nd priority sub-street, and 3rd priority sub-street, respectively.

For Classification result as shown in **Table. 1**, 1st priority sub-streets are displayed as highest influenced. They contain the highest ratio of Egress point and quite low in both integrations and street widths. These streets consist of private street next to Sripoom 1, and MoonMuang 5. Primary and moat streets have shared similarity on the highest width and highest integrations value. On the contrary, Primary streets have high value in Global integration, Moat street has high value in Local integration, integration results indicated dissimilarity in these streets which divide them into the different group. Secondary streets and sub-streets have shared similarity on egress points and street width but they could be separated by values of both integrations. 2nd and 3rd priority sub-streets have shared similarity on egress point only, the most significant dissimilarity is street width 2nd has narrower sub-streets than 3rd priority sub-streets at 3.38 meter, 5.18 meter), respectively. However, even both priority sub-streets and typical sub-streets shared similarity on streets width (Range from 3.03 to 5.18 meter), their significant dissimilarity are egress point value which priority street groups have higher than the rest of streets. In summary, HCA essentially classified urban street into typical streets and high priority streets. In typical streets,

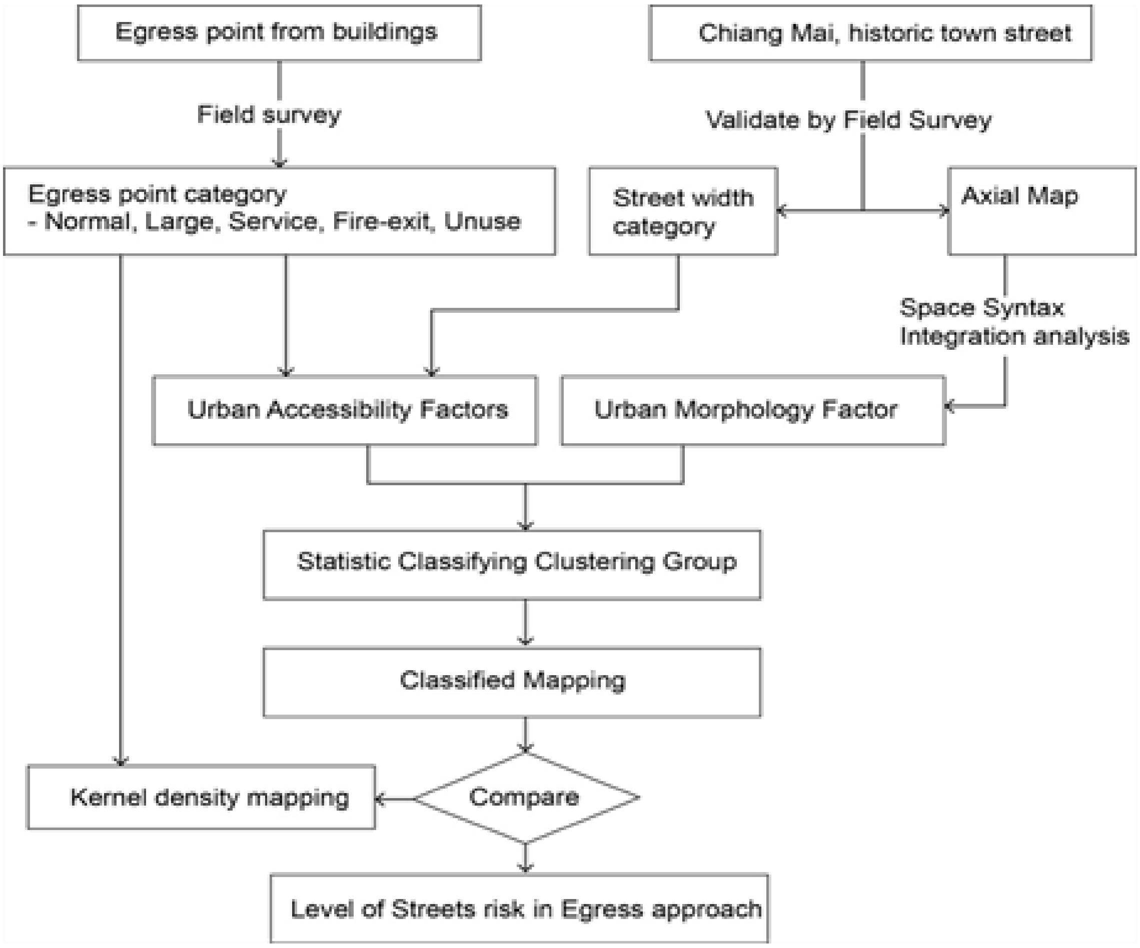

Fig. 4. Conceptual Framework.

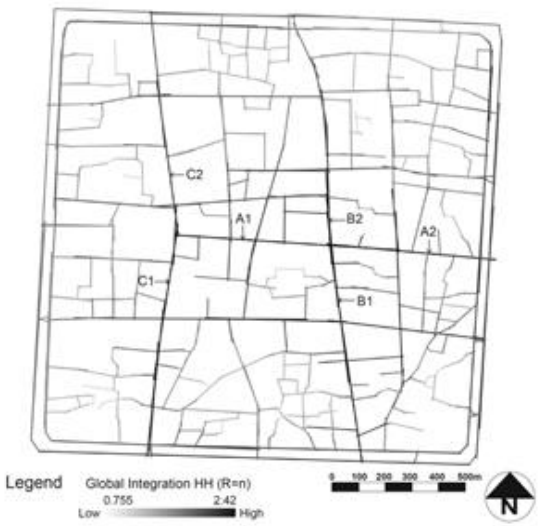

Fig. 5. Global Integration HH (R=n).

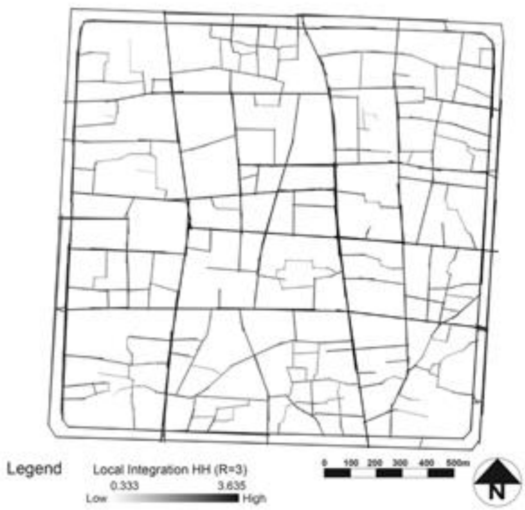

Fig. 6. Local Integration HH (R=3).

primary, secondary, sub-street, and moat streets was classified due to its street width, integrations and low egress point value. High priority streets, show a crucial result in the classifying level of accessibility risk determined by its high egress point value. This result revealed the risk of streets network that affects in disaster

Table 1. Descriptive of HCA factors.

Factor/Group		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Global Integration (R=n)	1st prior	2	1.261	.	.	.	.	1.261	1.261
	2nd prior	10	1.162	0.106	0.033	1.087	1.238	1.028	1.349
	3rd prior	10	1.567	0.093	0.029	1.501	1.634	1.381	1.738
	Moat	33	1.479	0.184	0.032	1.414	1.545	1.214	2.014
	Primary	18	2.098	0.153	0.036	2.022	2.174	1.809	2.430
	Sec	141	1.566	0.165	0.014	1.539	1.594	1.218	1.924
	Sub	191	1.151	0.155	0.011	1.128	1.173	0.804	1.537
		405	1.376	0.296	0.015	1.347	1.405	0.804	2.430
Local Integration (R=3)	1st prior	2	1.641	.	.	.	.	1.641	1.641
	2nd prior	10	1.439	0.316	0.100	1.213	1.664	0.849	1.731
	3rd prior	10	2.451	0.145	0.046	2.347	2.555	2.294	2.750
	Moat	33	2.625	0.367	0.064	2.495	2.755	1.915	3.506
	Primary	18	3.181	0.249	0.059	3.057	3.304	2.761	3.635
	Sec	141	2.360	0.271	0.023	2.315	2.405	1.689	2.998
	Sub	191	1.539	0.348	0.025	1.489	1.588	0.499	2.172
	Total	405	2.009	0.593	0.029	1.951	2.067	0.499	3.635
Egression Point (Weighted by Line length)	1st prior	2	0.408	.	.	.	.	0.408	0.408
	2nd prior	10	0.231	0.022	0.007	0.215	0.247	0.191	0.270
	3rd prior	10	0.234	0.031	0.010	0.212	0.256	0.193	0.279
	Moat	33	0.083	0.039	0.007	0.069	0.097	0.000	0.149
	Primary	18	0.151	0.023	0.006	0.139	0.163	0.099	0.193
	Sec	141	0.083	0.042	0.004	0.076	0.090	0.000	0.187
	Sub	191	0.082	0.055	0.004	0.074	0.090	0.000	0.200
	Total	405	0.094	0.061	0.003	0.088	0.100	0.000	0.408
Street width	1st prior	2	3.690	.	.	.	.	3.690	3.690
	2nd prior	10	3.383	0.540	0.171	2.996	3.770	2.750	3.930
	3rd prior	10	5.181	1.140	0.360	4.366	5.996	2.790	6.010
	Moat	33	12.020	0.000	0.000	12.020	12.020	12.020	12.020
	Pri	18	6.594	0.904	0.213	6.145	7.044	4.970	7.560
	Sec	141	4.062	1.303	0.110	3.845	4.279	1.900	8.170
	Sub	191	3.031	0.627	0.045	2.942	3.120	1.620	4.840
	Total	405	4.366	2.629	0.131	4.109	4.623	1.620	12.020

mitigation to imply measure to cope with a panic situation in historic town.

In this study, Egress point kernel density was created to reveal and validated vulnerable in a post-disaster evacuation, see **Fig. 11**. From egress point density mapping, high-density clusters are distributed throughout the urban street network. The highest clusters are located, mostly, in eastern part which conforms to local integration that located in the same area. Its distribution character also conforms to classification map of streets. Groups of priority streets shared similar location to egress clusters.

Comparing results between Classification map and Kernel density affirm the relation of egression points and High priority streets in term of its location. A Higher value of density or disadvantage in urban accessibility significance related. A Cluster of egress points also represents settlement formation of the historic town itself. Priority street such as Arak 2, WiangKaew, and MoonMuang 9 in the northern part and Bumrungburi2, PhraPokKlao 4 and MoonMuang 1 in the southern part. These reveal as distinctive vulnerable in settlement formation inside the historic town. The 1st priority streets, especially Sripoom 1, are distinctively situated on the highest cluster of Egress Point Kernel density. The 2nd and 3rd priority streets were located mostly in the eastern part of town are comprised with kernel density mapping. Although some of the priority streets have low consistent with kernel density mapping, these streets contain low width of the street more than typical streets. Moreover, typical streets are also comprised of clusters of kernel density but they contain a lower value of HCA factors which affect the street risk priority.

The result also confirms vulnerable due to clusters of egress point are located in narrow and labyrinth streets determined by both urban accessibility and urban morphology using Space syntax axial map's integrations analysis. This study revealed street vulnerable could be identified through these factors. Measurement for disaster

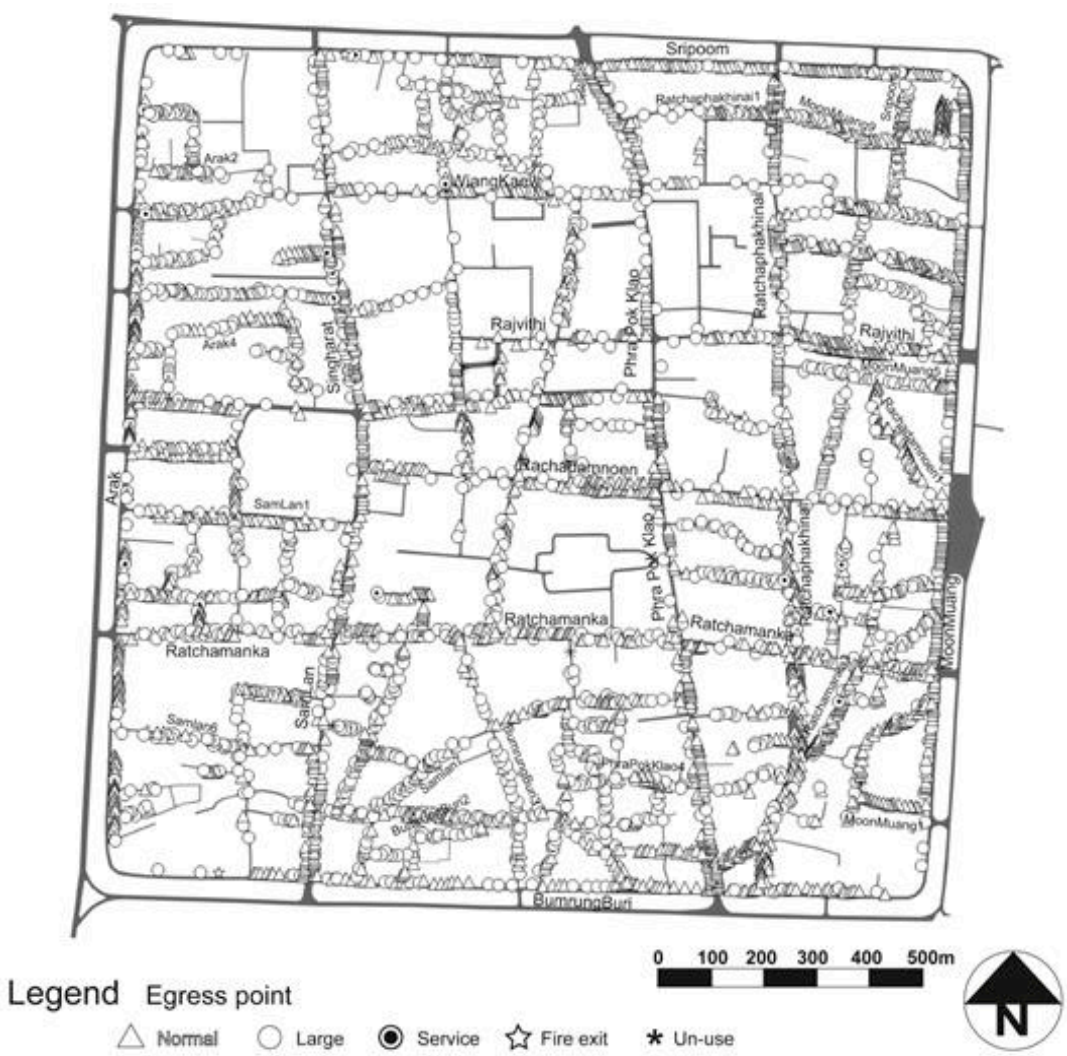

Fig. 7. Egress point location.

Fig. 8. Urban network categorized by its width.

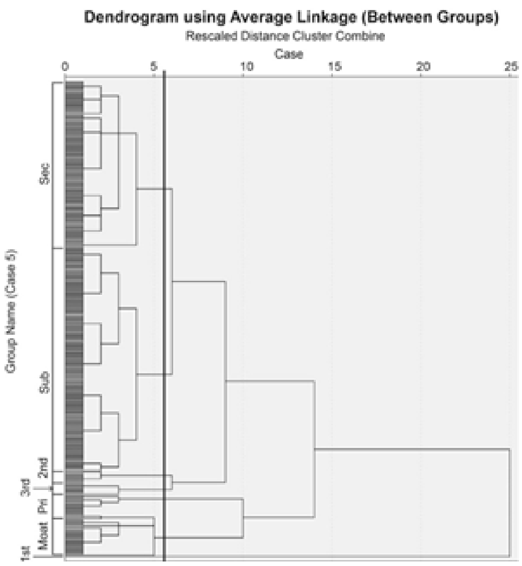

Fig. 9. Case and Classification result of HCA.

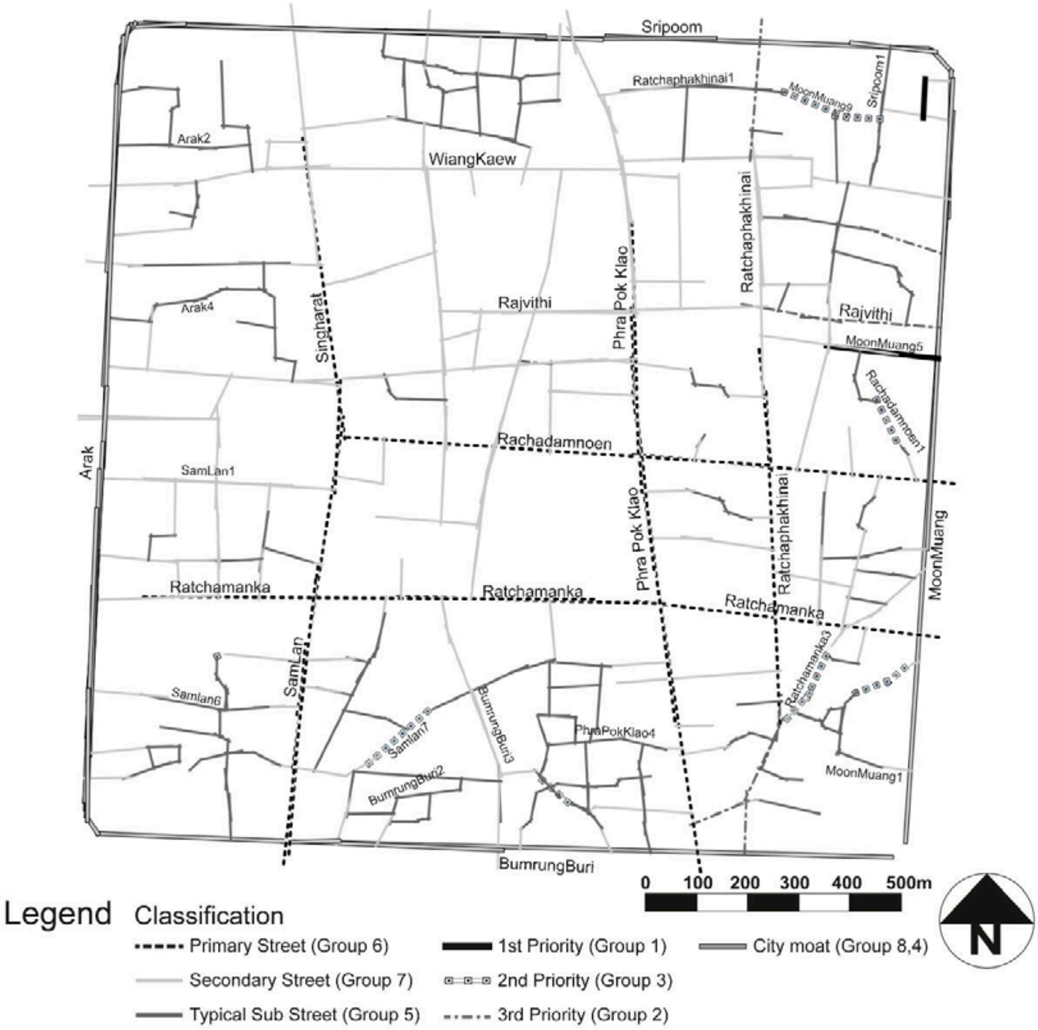

Fig. 10. Streets Classification location.

mitigation is needed, according to classification map, various level of control or manage could be applied. In this study, the priority of risk level is identified for easy transform into implementation in streets design guideline or regulation control measurement. However, historic aspect of streets must be further included as design aspect for any design guideline to maintain its noteworthy value of the historic town.

4. Conclusion and further study

From this study on evacuating routes in historic town of Chiang Mai, following issues have been clarified and created essential material to verify vulnerability of urban morphology in term of disaster mitigation:

- In the historic town of Chiang Mai, Integrations analysis of Urban morphology categorized streets as deform-grid represents main network and labyrinth

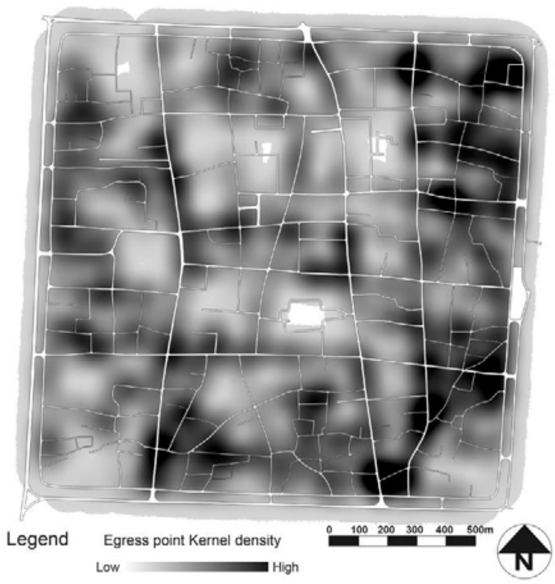

Fig. 11. Egress point Kernel density result.

neighborhood blocks represent organic sub-network distribute along with the main network.

- Egress points of Chiang Mai are, mostly, narrow than 3 meters with may need to improve or regulate intense control guideline to mitigate casualties from an earthquake or even different kinds of disasters. This measure may according to the risk level of streets that may create a bottleneck during an evacuation.
- Kernel density analysis of Egress point shows high clusters distributed throughout the urban network and in labyrinth streets.
- Egress points cluster with deviate narrow and low integrate street. It also aggregates to the eastern part of the city according to commercial and urban function determined since settlement.
- Narrow Streets in historic town are mostly attached by egress point and incapable of being evacuation route that needs to clarified limitation of streets.
- Street widths are incompetent to integration value, which means street width unable to comprehend highly used streets represent by its integration value and pose vulnerability of city, however, narrow streets are significantly comprised of a cluster of egress point density and integration in term of its aggregation to the eastern part of the city.
- Space syntax combined with GIS technique is robust tool to identify urban morphology and led to better understanding of transform its network into evacuating routes.
- HCA evaluated Chiang Mai historic town, revealed the classified level of risk in sub-streets through its priorities and conform to Egress kernel density map. It efficiently separated typical sub-streets and priority sub-street that available to implement appropriate measure especially in spatial and regulation management.
- HCA result divided function of a street into 4 categories consist of Primary, Secondary, Sub-street and priorities streets.
- HCA's prioritized streets and typical streets are highly consistent with the cluster of Egress Points' kernel density which reveals the possibility of risk management improving in some areas or streets.

Additionally, study limit on a fact that uncontrolled factors may affect street widths such as the historical meaning of streets or social factors such as demographic factor due to the complication of accurate data. Population data had been divided by inconsistent administrative districts and unable to provided accuracy survey in the boundary of a study area. Moreover, demographic data that may need to include in further study is quite dynamic because rapid gentrification and its tourism character of Chiang Mai. Results displayed distinctively incompetent and limitation in the historic town, also an improper function of street measure by its syntactic properties and accessibility. From compare mapping showed incompetent between urban morphology and width of a street that needs more delicate study, in this matter especially historical meaning before gradually improve to appropriate evacuation route or strengthening intensive countermeasure.

This finding shows vulnerable of the historical town of Chiang Mai to a major disaster such as earthquake disaster. In historic town, urban accessibility may incapable of acting as evacuation routes the in panic periods due to it bottleneck in priorities streets which may lead to more casualties. Space syntax combine with GIS technique led to better understanding labyrinth urban network of historic town which considered being the necessity to provide mitigation plan through it result by providing proper strategies to cope with those hazardous events. Moreover, this study clarified and reaffirms vulnerability cause by a density of egression that creates more difficulty by its natural of settlement and morphology. Further studies needed to be continuity investigate in various delicate factors to finally provided appropriated strategy for disaster mitigation.

Acknowledgements

This paper modified from Conference proceeding in title 'Analysis of Urban morphology and accessibility character to provide evacuation route in historic area' of 'Urban Planning and Architectural Design for Sustainable Development 2015' (UPADSD 2015), University of Salento, Lecce, Italy. Authors would like to express unfathomable gratitude to Department of Civil engineering and Architecture, Saga University for financial support in field survey in Chiang Mai, Thailand.

References

ARUP, 1995. Environmental capacity. Methodology for historic cities. London: pp 75.

Bangkok Bank Com. Ltd., 2008. LaksanaThai2: Background. Bangkok: Thaiwatanapanich: pp 447.

Bernardini, G., D'Orazio, M., Quagliarini, E. and Spalazzi, L., 2014. An Agent-based model for earthquake pedestrians' evacuation simulation in urban scenarios. Procedia Transportation Research, **2** (1): 255-263.

Bin, J., Michael, B. and Christophe, C., 1999. Geometric accessibility and geographic information: Extending desktop GIS to space syntax. Computer, Environment and Urban System: 127-146.

Carpenter, A., 2012. A safe haven from the storm? Disaster recovery and space. 8th Intl. Space Syntax Symposium. Santiago: Space Syntax Laboratory, 8174:1-15.

Castillo, M.M., 2013. Urban pattern and disaster risk: The informal city on the hills. The 9th Intl. Space Syntax Symposium. Seoul: Space Syntax Laboratory, 114:1-13.

Chiang Mai Municipality Office, 2013. Chiang Mai city policy 2013. Chiang Mai: Chiag Mai Municipality Office: pp 27.

Choi, J., Kim, M. and Choi, H., 2007. Evacuation efficiency evaluation model based on Euclidean distance with visual depth. 6th Intl. Space Syntax Symposium, Istanbul, Space Syntax Laboratory, 041: 1-16.

Chotesookrata, S., 1969. Taiyuan Konmueng. Bangkok: Odeon Store.

Christine, W., Ebba, B. and Claudia, R., 2013. Planning for climate change in urban areas: From theory to practice. Journal of Cleaner Production, **50** (1): 68-81.

Dou, K., and Zhan, Q., 2011. Accessibility analysis of urban emergency shelters: Comparing gravity model and space syntax. RSETE 2011.Nanjing, IEEE: 5681-5684.

Fakhrurrazi and Van Nes, A., 2012. Space and panic. The application of Space Syntax to understand the relationship between mortality rates and spatial configuration in Banda Aceh during tsunami 2004. 8th Intl. Space Syntax Symposium, Santiago, Space Syntax Laboratory, 8004: 1-24.

Fenton, C. H., Charusiri, P. and Wood, S. H., 2003. Recent paleoseismic investigations in Northern and Western Thailand. Annual of Geophysic, **46** (5): 957-981.

GFDRR, 2015. Bringing resilience to scale. Washington DC: Global Facility for Disaster Reduction and Recovery.

Gil, J. and Steinberg, P., 2008. From flood risk to indirect flood impact: evaluation of street network performance for effective management, response and repair. WIT Transaction on Ecology and the Environment: pp10.

Guntang, I., 1990. The study on characteristic and development of transportation network and built-up area in Chiang Mai. Bangkok, Chulalongkorn Univ.: C2-C6.

Haq, S., 1999. Expectation of exploration: Evaluation the effect of environmental variables on wayfinding. The power of imagination. 1, Florida, EDRA: 84-94.

Hasapinyo, C., 2009. Vulnerable assessment of Schools building in Chiang Mai and people awareness on seismic disaster preparedness. Chiang Mai, Chiang Mai Univ.: pp 198.

Hillier, B., 2002. A theory of the city as object: or, how spatial laws mediate the social construction of urban space. Urban Design International, **7** (3): 153-179.

Hillier, B., 2004. Can streets be made safe? Urban Design International, **9** (1): 31-45

Hillier, B., 2007. Space is the machine: A configurational theory of architecture. London, Space Syntax.

Hillier, B., 2012. Studying cities to learn about minds: some possible implication of space syntax for spatial cognition. Environment and Planning B: Planning and Design: 12-32.

Hillier, B., Penn, A. and Hanson, J., 1993. Natural movement or configuration and attraction in urban pedestrian movement. Environment and Planning B, **20** (1): 29-60.

ICOMOS, 2005. Kyoto declaration 2005 on protection of cultural properties, Historic Areas and their settings from loss in disasters. Kyoto: 1-4.

IPCC, 2012. Managing the risk of extreme event and disasters to advance climate change adaptation. New York: Cambridge Univ. Press: pp 573.

Jarusiri, P., 2012. Opinion on the likelihood of earthquakes in Thailand. ASTV Manager Daily newspaper, 2012, May 1: pp. 14.

Kim, Y.O., 1999. Spatial configuration, spatial cognition and spatial behaviour. London, University College London.

Kim, Y.O. and Alan, P., 2004. Linking the spatial Syntax of cognitive maps to the spatial syntax of the environment. Environment and behavior: 483-504.

Lee, S. and Kyung, W., 2013. Combining space syntax with GIS-based built environment measures in pedestrian walking activity. Proceeding of the Ninth International space syntax symposium. Seoul, Sejong Univ.: pp. 098.

Ministry of Education, 1979. Story of important places in Northern Thailand. Bangkok: Teacher Council: pp 124.

Mishima, N., Miyamoto, N. and Taguchi, Y., 2013. Comparative analysis of measures to secure two-way evacuation routes for vulnerable people during large disasters in a historic area. World Academy of Science, Engineering and Technology; Intl. J. Social, Human Science and Engineering, **7** (8): 125-134.

National Economic and Social development of Thailand, 1982. The fifth revision plan for socio-economic development of Thailand. Bangkok, National Economic and Social development of Thailand.

Ongsakul, S., 2010. History of Lanna. Bangkok: Ammarin.

Phodee, P., Trisirisatayawong, I. and Aobpaet, A., 2015. Coseimic and postseismic displacement of 2011 M 6.8 Tarlay Earthquake, Myanmar using InSAR techniques and Inversion analysis. Engineering Journal, **19** (2): 157-169.

Rodwell, D., 2007. Conservation and sustainability in historic cities. Oxford, Blackwell Publishing Ltd.: pp 255.

Sari, F. and Kubat, A. S., 2012. Syntactic properties of evacuation and access routes in earthquake vulnerable settlements. 8th Intl. Space Syntax Symposium. Santiago: Space Syntax Laboratory, 8038: 1-11.

Songmuang, R., Charusiri, P., Choowong, M., Won-in, K., Takashima, I. and Kosuwan, S., 2007. Detecting active faults using remote-sensing technique. Science Asia, **33** (1): 23-33.

Soraya, T., 1999. Becoming Thai. Bangkok: Chulalongkorn Univ.: pp 80.

Strange, I., 1997. Planning for change, conserving the past: Towards sustainable development policy in historic cities? Cities: 227-233.

Tantsukanunt, P. and Duangthima, W., 2013. The Multi-Layered Districts of Chiang Mai City. Chiang Mai, Puepae: pp 183.

Thiengburanathum, P., 2012. Fire disaster analysis in Chiang Mai municipality area. Chiang Mai, Chiang Mai Univ.: 1-8.

Turner, A. and Penn, A., 2002. Encoding natural movement as an agent-based system: an investigation into human pedestrian behaviour in the built environment. Environment and Planning B: Planning and Design: 473-490.

UNESCO, 2010. Managing Disaster Risks for World Heritage. Paris: UNESCO World Heritage Centre: pp 56.

UnÄu, A., Ulken, G., and EdgÄu, E., 2005. A Space Syntax Based Model in Evacuation of Hospitals. 5th International Space Syntax Symposium (p. LongpaperII). Delft, TU Delft: 161-171.

United Nations Human Settlements Programme, 2010. Land and Natural Disasters: Guidance for Practitioners. Nairobi, United Nations Human Settlements Programme (UN-HABITAT): pp 144.

USGS, 2005. Shake map. Retrieved February 23, 2016, from USGS (2005, December 8): http://earthquake.usgs.gov/earthquakes/shakemap/global/shake/b000qack/.

Villagra, P., Rojas, C., Ohno, R., Xue, M. and Gomez, K., 2014. A GIS-base exploration of the relationships between open space systems and urban form for the adaptive capacity of cities after an earthquake: The case of two Chilean cities. Applied Geography: 64-78.

Wei XU, N.O., 2008. A Model analysis approach for reassessment of the public shelter plan focusing both on accessibility and accommodation capacity for residents. J. Natural Disaster Science, **28** (2): 85-90.

Zampieri, F.L., Rigatti, D. and Ugalde, C.M., 2009. Evaluated model of pedestrian movement based on space syntax performance measures and artificial neural nets. The 7th Intl. Space Syntax Symposium Stockholm, Space Syntax Laboratory, 135: 1-8.

Zhang, L., Chiradia, A. and Zhuang, Y., 2013. In the intelligibility maze of space syntax: A Space syntax analysis of toy models, mazes and labyrinths. The 9th Intl. Space Syntax Symposium, Seoul, Space Syntax Laboratory, 082: 1-18.