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SYNTACTIC PROPERTIES OF EVACUATION AND ACCESS ROUTES IN EARTHQUAKE VULNERABLE SETTLEMENTS

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THEME: Urban Structure and Spatial Distribution

Abstract

Evaluation of natural movement in the high dense settlements becomes a crucial issue in terms of disaster management. Evacuation and access, now reveal as the two major aspects of the security of people in a disaster core. Prediction of possible disaster conditions in an urban space requires complicated calculations and varies with the characteristics of a disaster. As well, definition of cognitive properties of the urban space may help the casualty reduction. As disasters are becoming more harmful to communities day by day, Space Syntax findings may contribute to this raising issue on a constant base.

The initial casualties of earthquakes generally are caused by collapsed buildings which also significantly changes orientation patterns through the urban space. This would leave some parts of the disaster zone unreachable. People, who survive from the incident, may get trapped in the disaster core because of fires, collapsed buildings, fallen bridges, broken lifelines etc.

This research is inspired from the earthquake fact of vulnerable settlements and tends to propose an efficient model framework that provides an index of intervention to the physical structure in order to secure major evacuation and access routes first by using the natural movement evaluations and earthquake risk assessments.

In order to achieve this, two major aspects are involved; the earthquake risk assessment and the natural movement. Using Space Syntax tools, which would help definition of the routes that people prefer to use, will help the interventions being put in an order. In other words, this would provide a guideline to local authorities wiping the vulnerable buildings which are located on the major segments embody the major framework of the roads. This will eventually allow the post earthquake services to be provided more easily, and allow much more people to be evacuated from the danger zone.

In Turkey, massive urban aggloremations like İstanbul, İzmit are located very close to the earthquake faultlines and highly populated fragments of the region require urgent interventions in terms of re-building and retrofitting. The model is applied on Zeytinburnu and Avcilar districts in İstanbul, which have been impacted from the Izmit earthquke in 1999. The outputs of the proposal are compared with the anticipated evacuation plans, initially prepared by the local municipalities.

The key findings are showing that the approach can contribute to planning process as a layer with its applicable structure while it offers speeding up the mitigation process against the earthquakes.

1. INTRODUCTION

The earthquakes bring on two types of casualties. Initial casualties are generally due to the collapsed buildings, shaking of the ground and damage on the urban land. Secondary casualties, on the other hand, are generally related with the physical conditions of durability of the urban structure. These also can reach to huge numbers especially for the poor settlements with vulnerable physical conditions. People, who survive from the incident, may get trapped in the disaster core because of fires, collapsed buildings, fallen bridges, broken lifelines etc. Then, accessibility between the disaster site and outside world gets on a poor level. Roads to dispatch rescue personnel from outside to disaster area and to transfer victims from disaster area to outside cannot be accessed due to debris obstacles.

In the response phase of any disaster, especially for the vulnerable settlements, evacuation and access facilities become dependent to physical durability of the disaster core. This means, in addition to initial casualties, weaknesses of physical structure may dramatically increase these figures.

It has been assumed that the mitigation of the secondary risks of the earthquakes need to be managed well and any intervention measurement should be done in most sufficient way since the vulnerable settlements in poor communities need urgent retrofitting/ rebuilding works with very limited economic resources.

The issue of amplification of casualties due to the vulnerability of physical structure has been successfully avoided in developed countries. Even in most devastating earthquake scenario in California, the minimum expected casualties don’t get higher than 200 people while this number is 73,000 in İstanbul according to JICA report – Earthquake Model A. According to the casualties from the earthquakes, the higher numbers take place generally in poor countries(JICA, 2002).

It has been interpreted that a sufficient risk assessment and natural movement studies such as Space Syntax approaches can produce a guideline for disaster intervention process. The challenging questions considered in this study are:

- *Can rapid avoidance from the secondary effects of the earthquakes be achievable with poor qualities of the urban space and economic insufficiencies?*
- *Is there any possible way to organize or sort the actions should be taken regarding the people under risk?*
- *Is it possible to evaluate the natural movement patterns in the aim of evacuation designs?*

2. AIM

This study is prepared in the aim of giving the priority to the buildings which are seismically vulnerable and with high probability of blocking roads after collapsing during the rebuilding/ retrofitting process. This will eventually allow the post earthquake services to be provided more easily, and allow much more people to be evacuated from the danger zone.

Moreover, highly populated fragments with vulnerable buildings will suffer with road blockages due to building collapses. These road blockages may change the orientation of people and act as obstacles for the emergency tools such as ambulance and fire brigade.

In the light of the research questions, aim for the study is proposed as creating a model that provides an index of intervention to;

Save maximum life,
Within shortest term,
With limited economic resources in the case of an earthquake.

The model proposal evaluated two highly vulnerable settlements in İstanbul/Turkey in order to investigate that whether this assumption can be achieved and successful intervention guidance can be provided to local authorities.

A simple model that provides an index of intervention for representing the priority of the roads in terms of minimizing the human casualties after the earthquake would help these issues.

3. METHOD

Model, is aimed to be act as a layer and depiction tool for total risk assessment and process planning. While the earthquake reality makes the communities prepare disaster management programs and plans, helping professionals on this crucial issue is targeted in the first phase.

The study has two major and joint aspects; the risk assessment and the natural movement. These aspects should be considered together in such studies as the proper combination of these is supposed to give valuable output for disaster management planning process. Risk assessment, including all physical analyses about the urban settlements, would be deficient on defining the social interactions taking place in these settlements.

For such reasons, seismic vulnerability studies, physical characteristics and social interactions are compiled in order to provide a successful output, consistent with the aim of the study.

For seismic vulnerability studies for buildings, the technique used in EMPI is adopted in the intermediate level. Originally it includes three stages, each requiring more detailed works after the previous stage. The first stage inspection/evaluation works are also referred as “street survey” and correspond to preliminary assessment(IMM,2003). In this study, the seismic vulnerability evaluation is be used in this level.

Also, population, as the main driver is added to the model framework to achieve better understanding the proportion of the actual risk as it is directly related with the casualties.

For orientation of people and natural movement patterns, integration and choice values of the theory of Space Syntax.

The essential outputs of the study are lines, representing the road connections in the urban environment, as they are defining most immediate response axes to save maximum life within shortest term and limited economic resources. They also propose the areas where the vulnerable buildings must be removed and infrastructure must be secured first.

In the first phase of the model, definition of the vulnerability and calculations of the number and locations of people insecure are provided. Evaluation of the blockage risks of the roads within a network due to the collapsed buildings is the second phase of the process. After, predictions of the major routes that people use frequently to reach the city main road network and major destinations in the urban configuration will be estimated with the help of the theory Space Syntax and its techniques are indicated. In addition, some physical characteristics of the urban space such as incline are also evaluated through the model. After the combination of all these inputs, determination of the roads to be intervened first is predicted in order to secure provision of post-earthquake activities to be carried out.

The outputs of this model proposal can be used as guides for intervention actions in the urban transformation process. The beginning of the process requires good and appropriate data collection phase. The variables will be used in the model as follows;

- Vulnerable Buildings (20% of lowest scored in the cluster.). For risk assessment studies for buildings, the technique used in EMPI(Earthquake Mitigation Plan for İstanbul) is adopted in the intermediate level.

-Population and number of people living in a vulnerable buildings.

-Estimated blockage risks: Main factors amplifying the road blockage risks are defined as the vulnerability of the buildings on the street, road radius, function of the street, junction qualities and population dependent to the road.

$$B = \frac{meanF}{R} \times \mathrm{Pr}$$

B → Blockage Risk F →Mean number of floors

R → Minmium Radius of the road *Pr → Number of people living in a seismically vulnerable buildings.*

-Integration: People will be using the specific roads for evacuation during the earthquake. Integration value is added to the model for the definition of permeable roads, main destinations, which will be one of the most important argument in this phase.

-Choice: Through movement potential of a space also helps to define evacuation corridors in disaster planning process.

-Topography (% incline of the roads): The incline of the land effects the orientation in the urban space. The greater a grade, the more power a person or a machine requires climbing it; therefore routes with lower grades are preferred, so long as they do not have other disadvantages, such as causing significantly increased overall travel distance.

In other words, it is a general assumption that people change or lengthen their routes when their direct passage to destination has a significant incline.

The model principally is proposed with two outputs: Road risk value and Index of Intervention values. Each value is proposing distinct outcomes providing information for total risk assessment and intervention priorities against the earthquake risk.

Road Risk Value: Basically superposition of the outcomes of risk assessment, space syntax outputs and additional data involving the physical characteristics of an area like incline%, provide the road risk value.

These values will be collected for each road and appended to a table. Also within a range, each value will have clusters from better to worse.

Table 3.1: Road Risk Value, variables table.

INTEGRATION		CONNECTIVITY		VULNERABLE BUILDINGS		POPULATION		POPULATION IN VULNERABLE		INCLINE		ROAD BLOCKAGE RISK	
Coefficient	Range	Coefficient	Range	Coefficient	Range	Coefficient	Range	Coefficient	Range	Coefficient	Range(%)	Coefficient	Range
1	2,050	0,2	1,0000	1	1,0000	1	9,21	1	5,12	1	14	1	17,74
0,8	1,580	0,4	0,0500	0,8	0,0466	0,8	5,37	0,8	2,19	0,8	12	0,8	5,40
0,6	1,441	0,6	0,0384	0,6	0,0320	0,6	4,39	0,6	1,52	0,6	9	0,6	3,60
0,4	1,331	0,8	0,0334	0,4	0,0220	0,4	3,71	0,4	0,97	0,4	6	0,4	2,15
0,2	1,210	1	0,0256	0,2	0,0096	0,2	2,82	0,2	0,38	0,2	4	0,2	0,60

Calculation of the road risk value is applied with the assistance of the sampling table (Table 3.1) including ranges of equal intervals (20% each) for each variable and assigned coefficients for these variables. Multiplication of all coefficients for a line gives the risk value as the output.

<u>Index of Intervention Value:</u> Definition of risk value helps to depict the risk assessment spatially. Also it would be used as a layer through the land use planning exercises in such areas. But given the limited time consideration in these types of extremely vulnerable settlements, sorting the risk intervention areas due to the efficiency of the process is crucial. In that sense, index of intervention value is proposed to provide this sorting in an appropriate way. With the help of this value, securing the highest number of people within a short time and can be provided. Index of intervention value is simply calculated with multiplying the risk value by the normalized choice value.

IIn. = Risk Value * (Log(Ch+2))

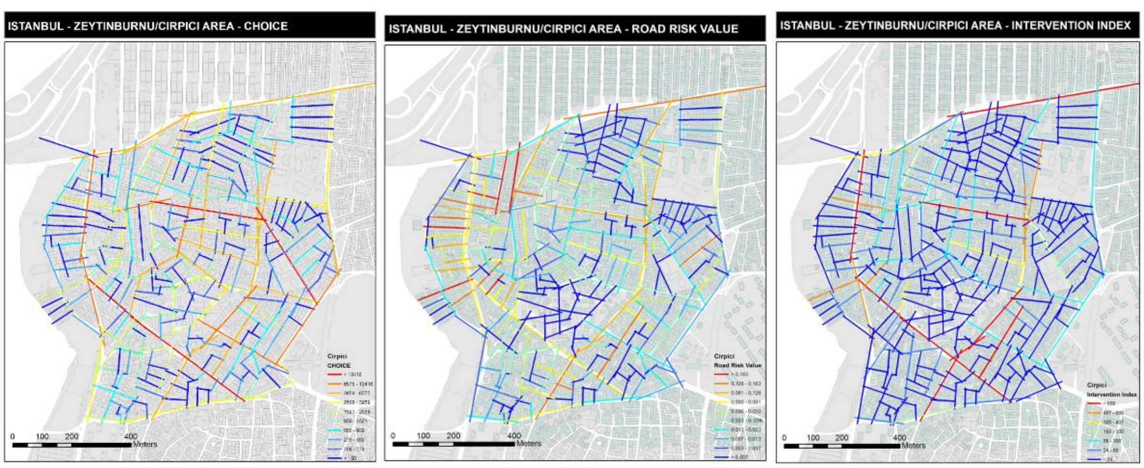

Figure 3.1: Choice, Road risk value and Index of intervention in Zeytinburnu

Demonstration of this model framework takes place in two distinctive areas as case studies. Avcılar and Zeytinburnu areas are recently announced as transformation areas due to high vulnerability and dense population in Istanbul, Turkey. Since there are a number of transformation projects regarding the earthquake issue in these areas, model outputs are tested with the final intentions and next steps of these articulated studies.

4. STUDY AREAS

Given the earthquake risk almost compasses the densely populated areas of İstanbul, an efficient intervention plan is needed for immediate respond to that risk. The model will be used for securing as high population as possible by defining risks, evacuation possibilities, population density etc.

İstanbul provides the two areas for the case studies are already holding a significant number of people in vulnerable settlements as well as these case areas. These proposals provide a starting point of this process.

Figure 4.1: Integration map and locations of centres in İstanbul

In İstanbul case above map, main destination centre reveal at the western part of the city in European continent. The core, showed with bright colours, geographically overlap with the current central business and commercial district. Also some sub centres distinctively reveal in the evaluation.

People will be using the specific roads for evacuation during the earthquake. Integration value is added to the model for the definition of permeable roads, main destinations, which will be one of the most important argument in this phase.

The outputs of the model proposal show that there are some significant consistencies between the evacuation routes that these plans propose and the index of intervention maps for the case areas. In addition, it is observed that more efficient road schemes can be provided with the help of the model output maps.

The key findings are showing that the approach can contribute to planning process as a layer with its applicable structure while it offers speeding up the mitigation process against the earthquakes.

Avcılar and Zeytinburnu settlements are already in the agenda of Turkish government with supporting plans and action studies since these settlements hold significant proportion people under risk. These plans propose evacuation methodologies, orientation routes and capacity building programmes for securing a successful response period.

Although these areas have distinctive physical and social configurations, they have high population density and vulnerable urban spaces as most important similarities. Therefore, these two settlements have been taken as case areas for this research.

Table 4.1: Çırpıcı / Zeytinburnu and Avcılar comparison table

	Çırpıcı	Avcılar
Population	55.356	161.144
Area (sqm)	846.000	7.906.000
Density (Area per person)	15,28	49,06
Average No Of Floors	4,12	4,4
Buildings	3.177	6.977
Vulnerable Buildings	497	2.681
Population in Vulnerable Buildings	12.208 (22%)	82.479 (51%)

Index of intervention value for Zeytinburnu-Çırpıcı and Avcılar should be considered as starting point rather than another layer for disaster mitigation planning process. Although these outputs can be scattered around the examples and there would be no consistency with the actual or proposed network, these lines should also be considered one by one as they have distinct risk factors and intervention possibilities.

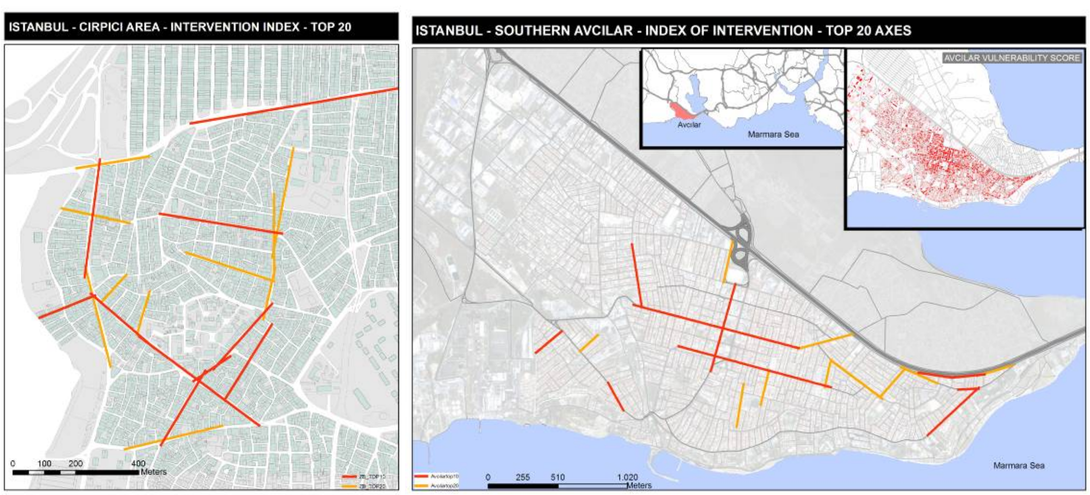

Figure 4.2: Index of intervention values (Highest 20) for Çırpıcı and Avcılar

Securing an area from a disaster requires articulated and detailed base data and constant management of the planning process. In the stage of defining risk and indexing the actions accordingly to these risks, the outputs of this study become important.

Zeytinburnu Pilot Project, which has a very detailed and sophisticated planning background and modern approaches to disaster mitigation, defines the evacuation routes for Çırpıcı area as seen in figure 4.3. Although index of intervention value outputs and these proposed evacuation axes don't overlap. While the Index of Intervention offers the streets marked with A and B, the project offers C in project map.

The main reasons for this inconsistency may be;

-The scale differences between the plan and the proposed study,

-Property availability in C zone

-Lack of information on population density and blockage assessments in the planning process

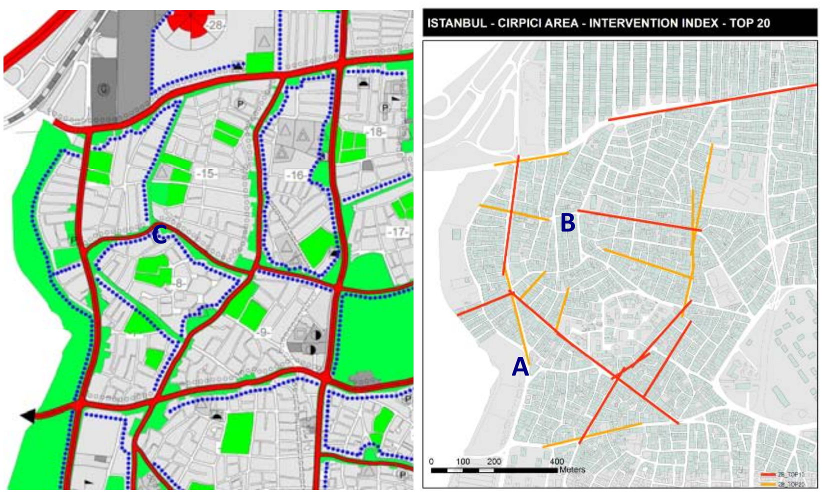

Figure 4.3: Proposed road hierarchy (Left - IMM, 2005) and Index of intervention values (Highest 20) of Çırpıcı Area, Zeytinburnu.

In Avcılar case, the proposed road network and anticipated evacuation corridors almost compasses on the lines in the index of intervention map successfully.

At this point, the important issue is understanding that the proposed network map is the future state of Avcılar. This means there will be a retrofitting process in order to secure these lines and build the proposed roads. This process needs time and money while the earthquake risk constantly remains the same.

At this point, Index of intervention value gives a chance to define priorities among these roads to be secured. The highest value means highest number of people to be secured.

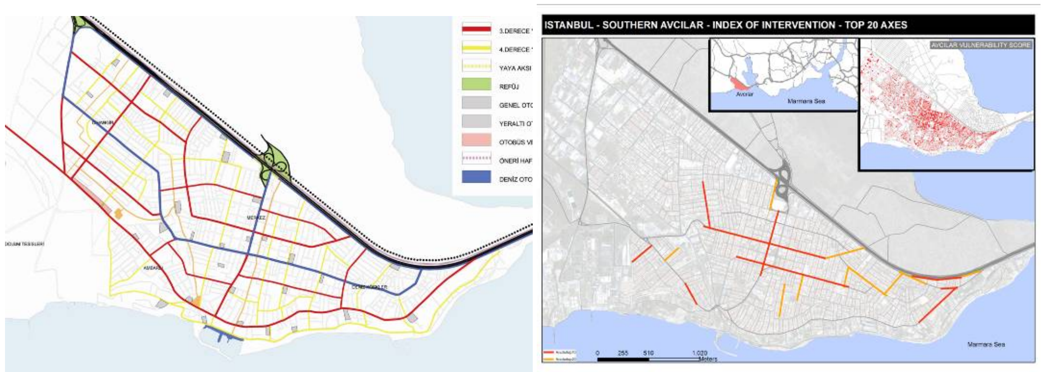

Figure 4.4: Proposed road hierarchy (Left - IMM, 2004) and Index of intervention values (Highest 20) of Avcilar.

As seen in both examples, Index of Intervention gives solid outputs, consistent with the current and proposed road scheme, and giving priority of the earthquake risk locally.

5. CONCLUSION

The rapid rehabilitation of urban areas need articulated organization and funding. Provision of cost-lowering process and efficient intervention should be the key issues for this type enhancement for cities.

Each line has an intervention degree, related with risk assessment and natural movement. Securing one the red lines in here doesn't mean only securing people living in that street, also creating a evacuation preference for other residents through the settlement.

These study outcomes are:

Contribution to planning process as a layer: The outputs mainly provide information for securing the durability of physical structure. These can be regarded as one of the layers used for superposing the facts about the settlement in the analysis phase. Planners and professionals on this process can use these to better depict the earthquake reality.

Focuses on streets as a joint media for physical and social evaluation: Model takes streets and alleys to combine the data and illustrate the risk assessment workings. This also allows the natural movement patterns to be evaluated with the same base with risk assessments, especially for the definition of evacuation corridors. With this approach, every street has its own population, building count, functional usage and blockage risk. Thus, outputs are articulated and solid as they consider both types of variables.

Fulfils the time & economy dilemma: It simply spots the most important segments in terms of earthquake security. The street which has the highest degree of index of intervention value is;

- One of the most common routes through that settlement,

- It holds the highest population under risk and

- Highest population to be secured from captivities due to the road blockages.

So, this indexation will allow taking the steps one by one which will save as much people as possible with the limited time and money.

Progressive: The study proposes an approach for disaster management process to be better executed. However, the variables used in this methodology are progressive. For example, model includes the seismic vulnerability scores of buildings calculated after the street surveys. Further evaluation of seismic safety will eventually be fruitful as those would be more precise. Also, model only includes concrete buildings as 98% of the building in case areas are concrete. The other building materials and seismic evaluation for that types of buildings needs to be added to model in order to use this on different samples.

Also, the streets can be divided into segments on each break. This will allow more information and detail about the local orientation patterns. Saving people with more "local" evacuation strategies might be possible with this approach.

However, seismic evaluation workings need to be done by the professionals and buildings must be surveyed one by one.

Recurrent: After the retrofitting progress starts, the calculation should be done recurrently. Index intervention values and maps should be created again. Because, the system would become a different cluster. For example, after securing the most important axis, second one would loose importance against other streets or alleys. For this reason, this evaluation is proposed as a recurring activity. The success of the outputs lays on the representation of actual conditions through the model.

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