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Effectiveness of social and governance strategies on improving urban resilience against earthquake

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اثربخشی استراتژی‌های اجتماعی و حاکمیتی در بهبود تاب‌آوری شهری در برابر زلزله

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Abstract
The study of the resilience of the cities against earthquake is one of the necessities for the reduction of losses and death toll of the earthquakes. Resilience has various definitions and there is not a unique comprehensive model for its quantitative assessment. Therefore, the aim of this paper is to provide a comprehensive quantitative indicator for resilience and to study the efficacy of social and governance strategies in improvement of urban resilience against earthquake. To achieve this aim, first effective dimensions and indices of resilience of urban areas were explored and extracted by reviewing available research studies and experts elicitation method. Then based on experts' opinions and pairwise comparison the model was justified and the relative weights for dimensions and indices were obtained and a comprehensive overall resilience index was introduced. Using the proposed index, the efficacy of different social and governance strategies were compared considering three different earthquake scenarios of North-Tehran, Ray fault and floating faults. The comparisons were based on three metrics i.e. absolute value of resilience increase, distance from the origin of the Pareto chart considering implementation duration time and costs, and the ratio of cost to resilience increase. In this regard, strategy S3 (90 percent increase of social resilience), strategy S1 (10 percent increase of social resilience) and the strategy S3 were the optimal ones based on the first, second and third metric, respectively. On the whole, the social strategies had better efficiency than the governance ones, but it seems in practice the social and governance strategy categories must be implemented in an integrated manner which could be considered as a future research proposal.

Keywords: Strategy Efficiency, Social Dimension, Governance Dimension, Urban Resilience, Earthquake.

چکیده
مطالعهٔ تاب‌آوری شـهرها در مقابل زلزله از الزامات برنامه‌ریزی کاهش خسـارات جانی و مالی زلزله در شهرهاست. تاب‌آوری دارای تعاریف گوناگونی بوده و مدل جامع به‌منظور محا سبه کمّی آن وجود ندارد. لذا هدف این مقاله ارائه شاخ صی کمّی برای تاب‌آوری و برر سی اثربخ شی ا ستراتژی‌های اجتماعی و حاکمیتی در بهبود تاب‌آوری شـــهری در برابر زلزله اســـت. بدین منظور ابتدا با اســـتفاده از مطالعات کتابخانه‌ای و اخذ نظر خبرگان ابعاد و شـــاخص‌های مؤثر در تاب‌آوری شهرها در مقابل زلزله ا ستخراج شد. سپس با ا ستفاده از نظر خبرگان و روش مقایسه زوجی، وزن هر یک از ابعاد و شاخص‌ها معین گردید و شاخص تاب‌آوری معرفی شد. با ا ستفاده از این شاخص و در نظر گرفتن سه سناریو لرزه‌ای گسل شمال تهران، گ سل ری و گ سل شناور، اثربخ شی ا ستراتژی‌های اجتماعی و حاکمیتی در بهبود تاب‌آوری با یکدیگر توســـط میزان افزایش مقدار مطلق تاب‌آوری، فاصله از مبدأ با در نظر گرفتن زمان و هزینه اجرا در منحنی‌های پارتو و نهایتاً مقدار نسبی هزینه به افزایش تاب‌آوری مقایسه گردیده‌اند. بر این اساس با روش اول اســتراتژی S3 (۹۰ درصــد بهبود تاب‌آوری اجتماعی)، با روش دوم اســتراتژی S1 (بهبود ۱۰ درصــدی تاب‌آوری اجتماعی) و با روش ســوم همان ا ستراتژی S3 بهینه می‌باشد. درمجموع ا ستراتژی‌های اجتماعی عملکرد بهتری نسبت به استراتژی‌های حاکمیتی داشتند. بااین‌حال به نظر می‌رسد در عمل باید هر دو گروه استراتژی به‌صورت یکپارچه در نظر گرفته شود که به‌عنوان موضوع تحقیقات آتی پیشنهاد می‌شود.

واژه‌های کلیدی: اثربخشی استراتژی، بعد اجتماعی، بعد حاکمیتی، تاب‌آوری شهری، زلزله.

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1. Introduction

Disasters have caused considerable losses and impacts on humans and societies from the beginning of the creation and decision makers have tried to minimize the exposure, mitigate the negative consequences and prepare measures to analyze hazards and related primary effects. The study of the resilience of cities is one of the necessities of disasters risk reduction programs. The occurrence of natural disasters has a cyclic pattern and disasters occurred frequently during human history and they will surely occur in future. Floods, earthquakes and tornadoes have often resulted immense damage on human settlements and high tolls of mortality rates. Nearly all the sites selected for settlement and work are located in disaster prone areas and despite the improvements in technologies and knowledge, disaster losses and damages have increased in a timely manner. Almost many of cities and rural areas are located across rivers or coastal lines which are in danger of flood or are placed at the seismic zones and earthquake may be a primary threat for those settled there (Smith and Petley, 2008; Kraas, 2008; Van Westen, 2013). Herman has defined natural disaster as a crisis having three dimensions of serious threat, limited time for decision making and response, and surprise element (Herman, 1972).

Crisis in international business is shown to be dependent to some factors such as event characteristics, importance of the event for the US and foreign governments, effects on the other enterprises and industries, number of people to be informed or helped and its urgency to act rapidly and the availability of these people, the number of people to whom the event must be explained, how they have access and interact to/with media, what is confirmed by media, how many people have proper response capability, the speed needed for reaction, and the probability that a crisis may lead to panic, threat, anxiety or shock (Darling, 1994). One of the first definitions of resilience was introduce by Holling (1973) at the system level as "a measure of the persistence of systems and of their abilities to absorb change and disturbance and still maintain the same relationships between populations or state variables".

The prevalence of the use of resilience terminology in the context of disaster is the birth of a new culture in disaster management issues. The outputs of the 2005 world conference on disaster reduction (WCDR) confirm that resilience concept, both in theory and application, is gradually bolded in a wide range of disaster risk reduction problems and participation issues so that it is considered as a new approach and pattern by some experts (McEntire et al., 2002).

Some definitions of resilience are reviewed in IFRC (2004) and the focus of this report was on community resilience. Norris and his colleagues concluded that the importance of resilience concept lies on the ability to bring into action the effective interventions and policies to enhance adaptive capacities and increase the possibility of adaptation against disturbances as a result (Norris et al., 2008). The definition by UNISDR is one of the accepted definitions of resilience. It mentions that the capacity of a system, community or society under the threat of a hazard is the ability to withstand, absorb, adapt, or change itself to reach to an accepted level of activity, structure or status. This subject is defined so that the social system must reach to the self-organization ability to increase its capacity, learn from the past experienced disasters, have better security and safety measures and improve the assessment capabilities of risk reduction (UNISDR, 2005; UNISDR, 2009).

Bruneau and his colleagues introduced a framework to quantitatively assess and enhance the seismic resilience of communities. They used technical, organizational, social and economic dimensions as four dimensions of community resilience and robustness, rapidity, resourcefulness and redundancy were considered as quantitative measures of redundancy (Bruneau et al., 2003). Godschalk discussed the problem of creating resilient cities and its importance. He reviewed the mitigation practices to be applied as resilience principals to physical and social elements of cities (Godschalk, 2003). Cutter proposed a place-based model for community resilience to natural disasters. She considered ecological, social, economic, institutional, infrastructure and community competence dimensions in her disaster resilience of place (DROP) model along with candidate common indicators for each dimension (Cutter, 2008). Pelling

discussed the vulnerability of cities against natural disasters in developing countries and bolded the role of social resilience in this regard and claimed that the sociopolitical, financial, and physical structures of a society have critical roles in human vulnerability and it is necessary to investigate the effects of political, governance and legislation items on risk conditions. He suggests three major interventions that should be done to improve social resilience against disasters (Pelling, 2003). Burton developed some of metrics for community resilience to natural disasters based on environmental, social, economic, institutional, infrastructural, and community-based dimensions (Burton, 2012).

Different methods or frameworks are proposed by researchers to quantify or assess the resilience in complex systems such as cities. The methods could be categorized into qualitative and quantitative approaches. Carlson et al. (2012) and McManus et al. (2007) proposed a framework for resilience assessment at system and regional level based on surveys, questionnaires, and expert scoring to assess personal, business, governmental, and infrastructural aspects of resilience. Roege et al. (2014) developed a scoring matrix for system's performance assessments and resilience of energy systems. The analytic hierarchy process (AHP) as an analytical method may also be used as a versatile tool to convert the theoretical concepts into comparable indices that will make it very easy for decision makers to select the optimal strategies (Orencio & Fujii, 2013). Eshghei and Gafari (2020) evaluated the resilience situation in some districts of Tehran municipality using earthquake Multi-criteria decision-making methods including TOPSIS, VIKOR, HAW and SAW. They ranked the resilience of the studied municipally districts of Tehran from very low to high resilience against earthquakes and discussed that the authorities serious determination to reduce vulnerability of the cities are very influential to reach a resilient city. In general, qualitative resilience assessments are suitable tools for long-term decisions and policies since they provide a suitable overall view of the resilience of a system.

Considering the importance of governance, laws and governmental institutions on disaster management, improvement of urban resilience, the interactive relation between governments and societies, the paper tries to compare the effectiveness of social strategies with governance strategies in the framework of resilience improvement in urban areas.

2. Materials and Methods

2-1 Research Algorithm

The available literature and documents were investigated to obtain the dimensions and indices of urban resilience. The available research body was first categorized and then the indices were extracted. Afterwards, a questionnaire was designed to finalize the selected dimensions, components and indices. 20 experts participated in the survey. 70 percent of the experts had more than 10 years related job experience and 19 persons out of 20 had Ph.D. degree. A pairwise comparison was performed by experts to determine the effect of each one of the dimensions and indices. The mean discrepancy coefficient was calculated to be 0.075 with the maximum of 0.091. In the process of weighting of indices the elements of each row were compared with the above row in a pairwise manner and the relative weights were calculated. Then with aggregation of the relative weights the final weight for each option was calculated. Figure 1 shows the process of exploring the resilience model and the stages for selection of the robust strategy.

2-2 Introducing Strategies

Investigated strategies may vary depending on the implementation capacities of the studied country and city. Hence, it is supposed that social strategies (S) contain social and financial dimensions and governance strategies (G) include institutional and security dimensions. The present condition is also considered as the base case. Each one of the strategies were generated with 10, 50, and 90 percent improvement of the dimension with respect to the base case.

It must be noted that the selected strategies are merely for relative comparison of the effectiveness of the considered dimensions on total resilience increase in this study. These strategies are indeed representing the rate of increase of the resilience of each dimension with respect to the base case. Table 1 shows different considered strategies. In order to

compare the strategies better, the implementation cost of each one and their time duration for implementation are also estimated based on the performed conversations with each sector experts and the available documents in the institutions and organizations. The time duration for implementation for each strategy is divided into 3 categories. First category strategies need the least implementation time to be performed and to be influential. This category is called "low duration" here. The second category includes strategies with "moderate duration time" which often need some years to be done and to show their effectiveness. Finally the strategies that need a decade or more to be implemented are categorized as "long duration".

In order to consider the implementation cost of each strategy the costs are categorized into nine levels considering the indices of the strategy. These cost levels are considered only for comparison. Three main levels i.e. low, moderate and high are considered and each main level is divided to three sublevels. The number "1" indicates the low sublevel in the low cost level and number "9" indicates the high sublevel in the high cost level.

Table 1. Considered Strategies

No	Strategy Name	Dimensions considered for improvement		Improvement with respect to the current status (base case)		
				10%	50%	90%
1	Social	Social-Economic	Strategy label	S_1	S_2	S_3
			Time duration for implementation	Short	Moderate	Long
			Implementation cost	2	4	6
2	Governance	Institutional-Security	Strategy label	G_1	G_2	G_3
			Time duration for implementation	Short	Moderate	Long
			Implementation cost	3	5	7

3. Data and Results

In the proposed resilience index, the effect of each dimension, i.e. the effect of the resilience of each sector on the overall resilience of the urban area against earthquake, was estimated based on experts' opinions. Table 2 shows the resilience dimensions and their components. Table 3 shows the dimensions' weights. The resilience model includes physical, social, security, economic, institutional and technical dimensions. For more details on the resilience conceptual model which includes the dimensions and indices see Behzadfar et al. (2017) and Ghasemi et al. (2020). It is noteworthy that the analysis was performed for municipality district No. 6 of Tehran metropolitan and the seismic scenarios of JICA was considered in the study to simulate an earthquake which includes North-Tehran fault, Ray fault and a floating fault (JICA, 2000).

The overall calculated resilience indices for the three seismic scenarios, three social resilience improvement strategies and three strategies of governance resilience improvement were compared in Table 4. The ratio of the implementation cost to resilience increase (CRI) was also shown in Table 4 for each combination of scenario-strategy. Distance from the origin of Pareto chart (DFO) in Table 4 was based on a three ordinate Pareto front considering duration time as ordinate X1, implementation cost as ordinate X2 and resilience as ordinate X3. Considering DFO results enables the analyst to find the optimal strategy based on time, cost and resilience variables in the strategy selection process. The least squares method was used here.

Table 2. Resilience dimensions and their components

Dimensions	Components	Dimensions	Components
Social	Education level in the region Social capital	Economic	Employment business categories

	Past social experiences Insurance coverage Ethnicities Women participation in society Family size Age structure of the population		Livelihood scale in the region Income and equity Ownership Participation rate of women in economy
Technical	Infrastructures Transportation network Construction technology Emergency and rescue centers Past technical experiences	Institutional	Institutional relationships Rights and laws Institutional performance and efficiency Institutional context
Security	Political stability Economic security Social security Border security	Physical	Population density in residential units Number of building floors City density Structural types Area footage of worn-out urban texture Accessibility Buildings footage areas Lifespan of the buildings

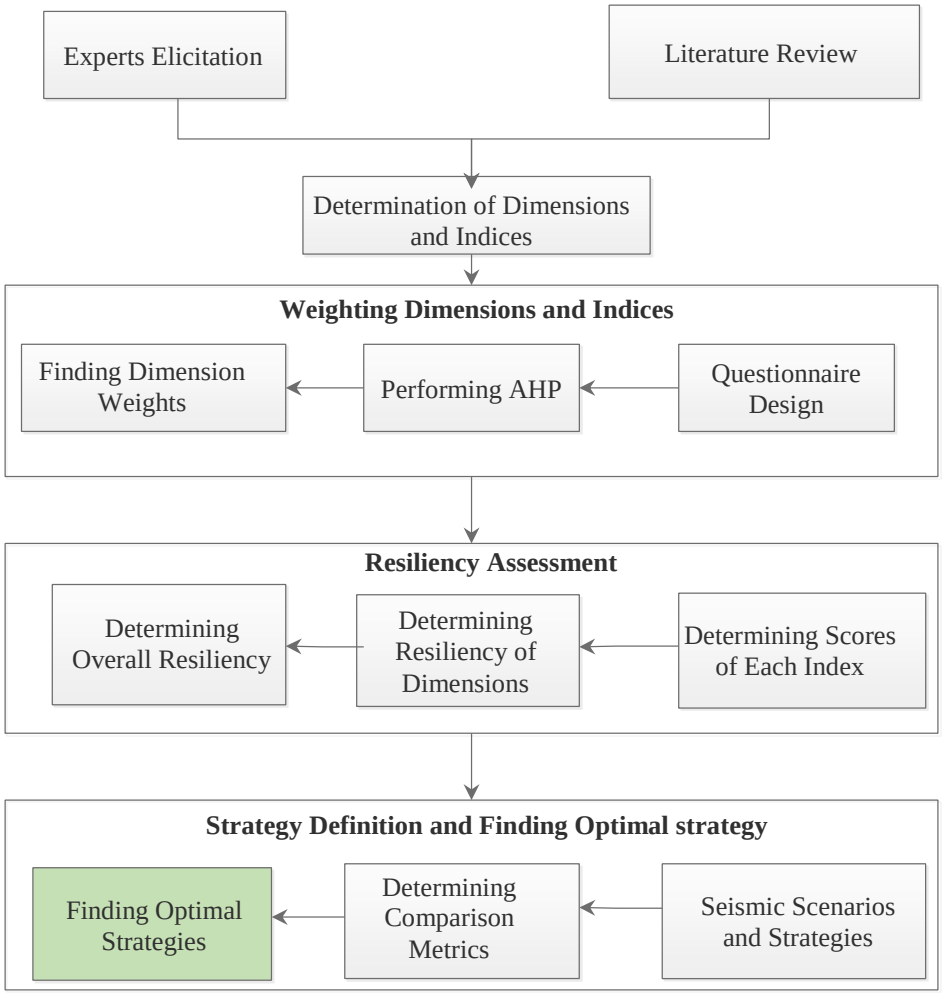

Figure 1. The process of exploring the resilience model and selection of the optimal strategies

Table 3. Urban resilience dimensions and their weights

Dimensions	Weights
Physical	0.202
Social	0.198
Security	0.159
Economic	0.153
Institutional	0.151
Technical	0.136

Table 4. Overall resilience index and Distance from Origin (DFO) and Cost to Resilience Improvement decision metrics for different scenarios and strategies

No.	Strategy		North-Tehran Fault Scenario	Ray Fault Scenario	Floating Fault Scenario
1	S_1	Resilience Index	0.476	0.471	0.473
		CIR	11.685	11.795	11.795
		DFO	2.877	2.878	2.877
2	G_1	Resilience Index	0.471	0.468	0.470
		CIR	23.950	21.185	20.862
		DFO	3.206	3.207	3.206
3	S_2	Resilience Index	0.544	0.538	0.541
		CIR	4.674	4.718	4.718
		DFO	5.021	5.021	5.021
4	G_2	Resilience Index	0.521	0.524	0.528
		CIR	7.983	7.062	6.954
		DFO	5.406	5.406	5.406
5	S_3	Resilience Index	0.612	0.606	0.608
		CIR	3.895	3.932	3.932
		DFO	6.719	6.720	6.720
6	G_3	Resilience Index	0.571	0.581	0.585
		CIR	6.209	5.492	5.409
		DFO	7.628	7.627	7.627

4. Discussion

The values of resilience indices for the present status - i.e. base case - were 0.458, 0.454 and 0.456 for the three considered seismic scenarios of North-Tehran, Ray and floating faults, respectively. The strategy G1 had the least resilience improvement (around 3 percent) and the strategy S3 results in the highest resilience increased (around 33 percent) for all the three considered seismic scenarios. It must be noted that the resilience increase within the strategies of each dimension improvement (social or governance), which considers 10, 50 and 90 percent increase with respect to the base case was not linear. It means that the overall resilience improvement did not increase as 10, 50 and 90 percent when we moved from G1 to G3, or S1 to S3. Considering the absolute overall resilience improvement as the only criteria for the strategy selection and not the other metrics, the social strategies were more effective than the governance strategies.

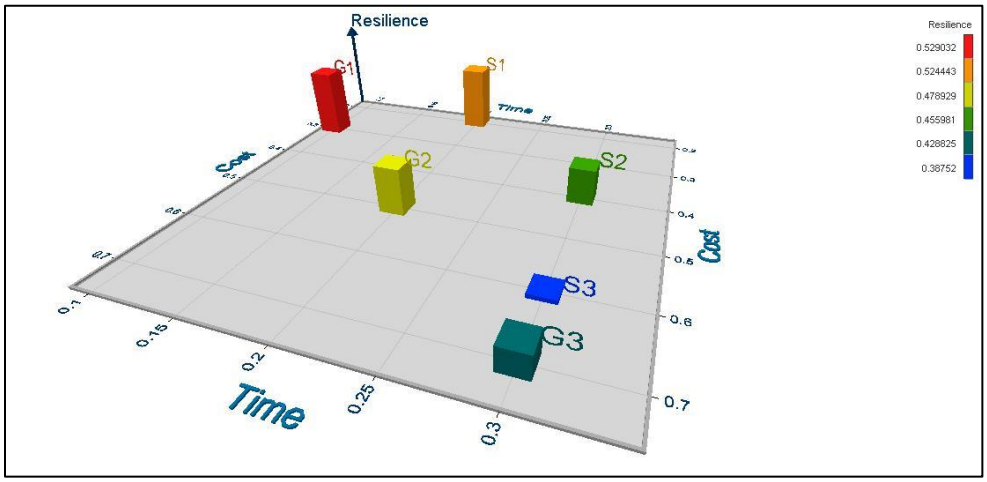

Figure 2. Distance from origin in Pareto charts for different strategies

It is worth mentioning that in the selection of an optimal strategy, the implementation cost of the strategies and their duration time for implementation were considered as important criteria and thus they must also be considered in our analyses. Accordingly as shown in Table 4, the best optimal strategy and the worst one will be S1 and G3 when the distance from the origin of the Pareto chars was considered as a decision variable i.e. the effects of the implementation cost and duration time would be included in decision process. Figure 2 shows the distance of the strategies to the origin (the base case). The governance strategy had lower efficacy than the social strategies when the Pareto distances were compared. As stated before the ratio of implementation cost to resilience increase could be considered as another decision metric. Based on this metric, the social strategies were also more effective than governance strategies in the framework of urban resilience improvement. The S3 and S2 strategies were ranked first and second based on this parameter, respectively and the G1 strategy was ranked last in this regard.

5. Conclusion

Seismic resilience studies of cities against earthquakes are aimed to reduce the mortality and financial losses caused by earthquakes in cities. One of the purposes of this paper was to provide a quantitative indicator for resilience considering that it has various definitions. Using available research studies and expert elicitation, dimensions of resilience in cities against earthquake were extracted first. Subsequently, using the method of paired comparison, the relative weights of physical, social, security, economic, institutional and technical dimensions were determined and an overall urban resilience index was introduced. Using this index and considering three seismic scenarios of North-Tehran fault, Ray fault and floating faults, the effectiveness of social and governance strategies in improving the resilience were compared with each other with three metrics i.e. increasing the total resilience, distance to the origin of Pareto charts considering time and cost, and finally, the ratio of implementation cost to resilience increment. According to the results of the study, based on the first metric, the S3 strategy (90 percent increase in social resilience) was ranked first. Strategies S1 (10 percent increase in social resilience) and S3 were ranked as optimized based on the second and third metrics, respectively.

Social resilience improvement strategies showed best performance in urban resilience improvement based on all the three considered decision metrics. Among all the considered social strategies, the strategy S3 had the best resilience improvement with respect to the cost and the strategy S1 was the best strategy when duration time was the decision parameter. Considering interrelations between different dimensions of resilience rationally, many parameters could be influential in the selection of social strategies as to be the superior strategy. Among these factors, the place of public participation in the power hierarchy, role assignment between planners and governance body, participatory planning

process, and the characteristics and goals of the beneficiaries were introduced by researchers as the core concepts of different participation ladder frameworks. However, the importance of governance dimension, the rules and laws in controlling the crises of natural disaster must not be underestimated and a proper situation based on proactive approach must be taken in place to prevent crisis to become catastrophes. Altogether, social strategies were better than the governance strategies, however, in practice, both strategies must be concurrently considered in an integrated manner. Despite comparing only social strategies (including social and economic dimensions) and governance strategies (including institutional and security dimensions) here as the discrete ones, more research studies is necessary to be done in future in which the strategies are to be integrated simultaneously alongside the other physical and technical dimensions.

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