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Strategic Management of Municipal Debris aftermath of an earthquake

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ABSTRACT: Earthquakes in urban areas leave behind a considerable amount of debris, which delays the relief services and the reconstruction activities. The relief work would be impossible without the removal of debris from the main access roads to the devastated areas. The proper implementation of this endeavor requires a long-term management of debris. This article discusses development of strategic management for earthquake debris in the city of Tehran. Thus, the pertinent strengths, weaknesses, opportunities and challenges are identified in order to assess the actual and potential debris management capacity of Tehran. The Personal judgments are used in a Quantitative Strategic Planning Matrix (QSPM) in order to prioritize the strategies. The results of this research show that the sum of attractiveness numbers for the Internal Factors Evaluation (IFE) matrix is 2.3, which is less than 2.5. It indicates that weaknesses are more dominant than the strengths. Moreover, the sum of attractiveness numbers for External Factors Evaluation (EFE) matrix is 3.3, which indicates more potential opportunities than potential challenges. The analysis of results points out that the most important strategies in regard to the development of debris management plan are the accurate estimation of volume, weight and type of earthquake debris; reinforcement of the present structures; proper design of structures under construction; utilization of experiences from other earthquake prone countries; recycling and reuse of debris and construction wastes; and identification of the temporary debris depot sites within Tehran.

Key words: City, Management, Strategic, Debris, Natural Disasters, Environment

INTRODUCTION

The natural disasters are the types of accidents caused by natural phenomena or anthropogenic activities that could occur suddenly or gradually with considerable economic damages, human losses and psychological disorders (Khaledi, 2001). Mankind throughout the history has confronted with natural forces and disasters and has incurred substantial damages and losses. In face of all the scientific achievements, lack of adequate knowledge and sufficient resources has hampered the efforts to successfully prevent and control the natural disasters (Abdullahi, 2003). These types of natural phenomena not only have caused direct human and economic losses, but also have left behind significant amount of debris instigating environmental pollution and obstructing of relief services in devastated areas (Baycan and Petersen, 2002). On the other hand, the primary objective of debris removal is the clean up of main roads, highways and waterways at the least amount of time with the minimum resources (FEMA, 1994). Therefore, the debris removal activities should immediately commence in the

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designated areas after the occurrence of natural incidents to ensure health and safety of the local residents (Reinhart and Mecreanor, 1999).

The success of a debris removal operation depends on the allocation of the required equipment and resources in the devastated areas as well as the prompt and coordinated response by the human resources and work-force (Solis, *et al,* 1996). After the completion of the debris removal operation, the most important step is its prompt disposal. The disposal of debris is one of the main challenges in the debris management during a natural disaster. Its importance is not only due to the shear volume of the debris, but also its potential negative impact on the environment (Solis et al, 1996). Thus, environmental concerns are of a top priority in the debris disposal management, in which, environmental issues and pertinent rules and regulations are to be taken into account (Rafee, 2007).

Meanwhile, environmental management of debris through recycling, incineration, grinding and sanitary landfill could mitigate the adverse effects of the debris and reduce its final disposal volume in the landfill sites (Trankler et al, 1996). The recent studies conducted by ESCAP indicate that Asia and Australia are the most susceptible areas in the world to natural disasters and usually encounter a wide range of natural threats like earthquake, flood, storm, etc. (ESCAP, 1995). Five out of ten most severe natural disasters in 2004 has occurred in Asia and Australia causing about 55 billion Dollars in damages. Thus, the ensuing losses due to natural incidents are quite significant in Asia and Australia with devastating effects on their resources (Disaster Database, 2005). During the last decade, over 200 million people suffered economic losses or bodily injuries as a result of natural phenomena, which is seven times more than the people enduring wars and local conflicts. Several factors like inappropriate land-use, unsuitable design and construction of buildings as well as improper metropolitan infrastructures have increased the potential risks of human habitations (Habitat, 2003).

Due to the location of Iran in one of the most earthquake prone areas of the world, it is only logical to find practical and comprehensive means to combat earthquake and minimize its catastrophic consequences (Zebardast and Mohammadi, 2005). In this regard, the aftermath of any natural incident in Tehran as an earthquake prone mega city in Iran could have profound consequences on the wellbeing of the entire country (The Islamic Council of Teheran, 2005).

Moreover, any precautionary measure against earthquakes is welcomed and could prevent huge economic and human losses (Alidousti, 1991). Therefore, development of pre-emptive plans for mitigation of earthquake impacts is highly important. One of these plans is the strategic management of earthquake debris. In a strategic management plan, all the organizations analyze their internal and external environments and identify strategic paths to realize their goals (Ghasemi, 2003).

The benefits of a strategic management include: 1) establishment of a precautionary management instead of a reactionary management 2) Providing a logical structure for allocation of resources and a regulated system for reallocation of existing resources for the new plans 3) Creation of a reliable foundation for long-term decision-making 4) Facilitating the participation of technical employees in long-term planning and 5) Establishment of a solid organizational structure for long-term planning instead of short-term decision-making (Galloway, 1990).

The primary goal of this research is to evaluate the current earthquake debris management in Tehran through the utilization of a strategic management plan. The envisioned strategic management procedure has three phases. In the first phase, the required input data and information for the development of the strategy are identified, which includes evaluation matrices for internal and external factors. During the second phase, the potential strategies are compared with each other through the usage of a matrix indicating the strengths, weaknesses, opportunities and threats (SWOT) as well as the Strategic Position and Action Evaluation (SPACE) matrix. The third phase is the decision-making phase. All the feasible strategies identified in the second phase are scientifically assessed and prioritized without personal judgments. This phase encompasses a Quantitative Strategic Planning Matrix (QSPM) (Parsian and Arabi, 2000).

MATERIALS & METHODS

In this article, the strategic management method is used for the development of appropriate earthquake debris management strategies for the city of Tehran. A list of internal factors (strengths, weaknesses) and external factors (opportunities, threats) were prepared. The identified strengths and weaknesses were weighed through the usage of Internal Factors Evaluation (IFE) matrix. The total weights of these factors were assumed to be equal to one. In the Internal Factors Evaluation (IFE) matrix, the strengths and weaknesses were given a grade of 1 to 4 depending on the type of reaction shown to their input. Thus, the grades of 4, 3, 2 and 1 indicate very good, above-average, average and weak responses, respectively. Then, the coefficient of each factor is multiplied with the above-mentioned grade to obtain the final score. Afterwards, the sum of these scores is calculated in order to determine the total score of the organization. If the total score is more than 2.5, then the strengths surpass the weaknesses and if the number is less than 2.5, the weaknesses dominate the strengths.

External Factors Evaluation (EFE) matrix is used to weigh the external factors (opportunities and threats). The process for development of this matrix is identical to the Internal Factors Evaluation (IFE) matrix. The Strengths, Weaknesses, Opportunities and Threats (SWOT) Matrix was utilized to develop four strategies of WT, ST, WO and SO. The analysis of SWOT is a strategic tool for determining the conformity of the internal factors (strengths and weaknesses) of the organization with its external factors (opportunities and threats). The SWOT analysis provides a systematic examination of the mentioned factors and selects the most suitable strategies (Woods, 1997). Strategic Position and Action Evaluation (SPACE) matrix has 4 grids, which are called Aggressive Strategy, Conservative Strategy, Defensive Strategy and Competitive Strategy. The SPACE matrix indicates two internal criteria (Financial Strength and Competitive Advantage) and two external criteria (Environmental Stability and Industrial Strength). In the SPACE matrix, four variables are selected to represent Financial Strength (FS), Competitive Advantage (CA), Environmental Stability (ES) and Industrial Strength (IS). Each of the variables are given grades of +1 (worst) to +6 (best) for the FS and IS and the variables for ES and CA are identified with the grades of -1 (best) to -6 (worst). Then the grades of the variables for each grid are added together and divided by the number of variables. Thus, the average value of FS, IS, CA and ES are obtained. Afterwards, the average values are plotted on the x-y axis and all the values on each axis are summed up. Then, the two final values are plotted and connected to each other. Finally, from the origin of the x-y axis a line is drawn to the plotted point. This line indicates the suitable strategy for the organization as to be either aggressive, competitive, defensive or conservative.

The Quantitative Strategic Planning Matrix (QSPM) identifies the relative attractiveness of the strategies developed in the previous phases. In the implementation of the QSPM matrix, the analysis of the first phase and the comparison of internal and external factors of the second phase are taken into account. In this manner, the major external opportunities and threats as well as the internal weaknesses and strengths are inserted into the right column of the QSPM matrix and each of the internal and external factors are given a weight or coefficient. These coefficients are written in one column and are similar to the ones used in the Internal and External Factors Evaluation matrices. Then, the strategies developed by the SWOT matrix will be inserted into the top row of the QSPM matrix and each strategy is designated with an attractiveness grade of 1 to 4. The 1, 2, 3 and 4 grades represent unacceptable, possibly acceptable, acceptable and highly acceptable selections, respectively. Finally, the sum of the attractiveness grades is calculated, which indicates the strategy with the most attractiveness.

RESULTS & DISCUSSION

The (SWOT) matrix for the strategic management of earthquake debris in the city of Tehran is shown in Table 1. For each of the Strengths, Weaknesses, Opportunities and Threats, several factors are identified, where the threats have the most and weaknesses have the least number of influencing factors. In the Internal Factors Evaluation (IFE) matrix (Table 2), the strengths and weaknesses were assessed quantitatively and the strengths received grades of 3 or 4 and the weaknesses were given grades of 1 and 2. In the External Factors Evaluation (EFE) matrix (Table 3), the opportunities and the threats were also assessed quantitatively and the opportunities received grades of 1, 2 or 4 and the threats were given grades of 2, 3 or 4. The grades for variables FS, CA, ES and IS are shown in Table 4. The subsequent 14 strategies obtained from the SWOT matrix were prioritized in QSPM matrix as indicated in Table 5.

Table 1. SWOT Matrix for Strategic Management of Debris aftermath of an earthquake

Strengths	**Weaknesses**
1- Available guidelines for clean up of debris and construction wastes after natural disasters 2- Presence of municipalities and organizations responsible for crisis affairs 3- Regulation # 2800 (Regulation for Design of Buildings against Earthquake) 4- Available contractors with heavy equipment and machinery 5- Identification of suitable sites for temporary depot of debris and construction wastes throughout the city by the municipality 6- Availability of earthquake and urban waste management experts	1- Lack of executive regulations on clean up and recycling of debris and construction wastes in the aftermath of disasters 2- Lack of accurate estimate of the volume, weight and type of debris after earthquake 3- Lack of debris and construction waste management plan for post earthquake period 4- Violation of urban development regulations 5- Lack of adequate budget for the purchase of construction waste collection and recycling machinery 6- Inadequate training and inappropriate work-force for collection and loading of debris and construction wastes 7- Violation of Regulation # 2800 in the construction of building structures 8- Inadequate sites for the temporary depot of construction wastes throughout the city
Opportunities	**Threats**
1- Presence of expressways and wide avenues in Tehran 2- Utilization of the past experiences in disaster prone countries during their earthquake crisis 3- Potential to recycle and reuse the debris and construction wastes 4- potential for public participation in recycling and reuse of debris and construction wastes 5- Potential for reinforcement of present structures and appropriate design of structures under construction 6- Potential to utilize compaction and recycling machinery for construction wastes 7- Establishment of a market for recycled products and quality assurance of recycled materials by official and certified organizations 8- Potential for technology transfer in the field of debris and construction waste recycling	1- Narrow streets and alleys and the relative height of the buildings in comparison to the width of the passages in Tehran 2- Construction of high-rises at inappropriate locations in terms of topography, access and public services 3- Lack of compatibility between structural designs of the buildings and the high risk of earthquake in Tehran, as well as high population density and high concentration of constructions in the city 4- Presence of earthquake prone faults and construction of residential buildings within the limits of the faults 5- Old bridges with weak structures 6- High volume and the considerable weight of the debris and the construction wastes 7- Heavy investment required for the transfer of technology in the filed of construction waste recycling 8- Potential for contamination of debris and construction wastes with dangerous materials 9- The heavy congestion of personal vehicles

Table 2. Internal Factors Evaluation Matrix for Strategic Management Debris aftermath of an earthquake in the City of Tehran

	Internal Factors	Weight of the Coefficient	Grade	Score
Strengths	Available guidelines for clean up of debris and construction wastes after natural disasters	0.1	4	0.4
	Presence of municipalities and organizations responsible for crisis affairs	0.1	3	0.3
	Regulation # 2800 (Regulation for Design of Buildings against Earthquake)	0.1	4	0.4
	Available contractors with heavy equipment and machinery	0.05	3	0.15
	Identification of suitable sites for temporary depot of debris and construction wastes throughout the city by the municipality	0.05	3	0.15
	Availability of earthquake and urban waste management experts	0.03	3	0.09
Weaknesses	Lack of executive regulations on clean up and recycling of debris and construction wastes in the aftermath of disasters	0.1	1	0.1
	Lack of accurate estimate of the volume, weight and type of debris after earthquake	0.1	1	0.1
	Lack of debris and construction waste management plan for post earthquake period	0.09	1	0.09
	Violation of urban development regulations	0.07	1	0.07
	Lack of adequate budget for the purchase of construction waste collection and recycling machinery	0.07	2	0.14
	Inadequate training and inappropriate work-force for collection and loading of debris and building wastes	0.01	1	0.01
	Violation of Regulation # 2800 in construction of building structures	0.1	1	0.1
	Inadequate sites for temporary depot of construction wastes throughout the city	0.03	1	0.03
	Total	1		2.13

Table 3. External Factors Evaluation Matrix for Strategic Management Debris aftermath of an earthquake in the City of Tehran

	External Factors	Weight of the Coefficient	Grade	Score
Opportunities	Presence of expressways and wide avenues in Tehran	0.07	4	0.28
	Utilization of the past experiences in disaster prone countries during their earthquake crisis	0.04	1	0.04
	Potential to recycle and reuse the debris and construction wastes	0.05	2	0.1
	potential for public participation in recycling and reuse of debris and construction wastes	0.03	2	0.06
	Potential for reinforcement of present structures and appropriate design of structures under construction	0.14	4	0.56
	Establishment of a market for recycled products and quality assurance of recycled materials by official and certified organizations	0.02	2	0.04
	Potential to utilize compaction and recycling machinery for construction wastes	0.02	2	0.04
	Potential for technology transfer in the field of debris and construction waste recycling	0.03	2	0.06
Threats	Narrow streets and alleys and the relative height of the buildings in comparison to the width of the passages in Tehran	0.06	4	0.24
	Construction of high-rises at inappropriate locations in terms of topography, access and public services	0.1	3	0.3
	Lack of compatibility between structural designs of the buildings and the high risk of earthquake in Tehran, as well as high population density and high concentration of constructions in the city	0.1	4	0.4
	Presence of earthquake prone faults and construction of residential buildings within the limits of the faults	0.22	4	0.88
	Old bridges with weak structures	0.02	2	0.04
	High volume and the considerable weight of the debris and the construction wastes	0.04	3	0.12
	Heavy investment required for the transfer of technology in the filed of construction waste recycling	0.01	2	0.02
	Potential for contamination of debris and construction wastes with dangerous materials	0.03	2	0.06
	The heavy congestion of personal vehicles	0.02	3	0.06
	Total	1		3.3

Table 4. Strategic Position and Action Evaluation (SPACE) Matrix for Tehran aftermath of an earthquake

Financial Strength (FS)	Score
The budget to income ratio of the Municipality for the purchase of recycling machinery is negative	3
The financial balance for the transfer of technology in the field of debris and construction waste recycling is negative	2
The current budget of the Municipality for the purchase of debris collection and transport machinery is negligible	1
Total	**6**
Industrial Strength (IS)	
Regulation # 2800 is considered as the capacity of the construction activities in the city according to the present rules and regulations	5
The productivity in recycling and reuse of debris and construction wastes is high	1
The availability of the debris clean up guidelines is a good step towards the development of the executive regulation for clean up of debris and construction wastes	3
Utilization of experts	2
Total	**11**
Environmental Stability (ES)	
Violation of urban development regulations has resulted in lack of coordination and safety during an earthquake incident in the city of Tehran	-4
Violation of the present regulations on construction of building structures would result in destruction of many structures during an earthquake	-4
The high risk of earthquake occurrence in Tehran	-6
Total	**-14**
Competitive Advantage (CA)	
Presence of various organizations responsible for crisis management has created duplication and parallel activities	-5
Usage of contractors for the clean up activities during a crisis has created competition between the private sector and the Municipality	-1
Total	**-6**
Average values are: IS = +2.75; ES = -4.66; FS = +2.00; CA = -3.00	
The points on the x-axis and y-axis are 0.25 and -2.66, respectively.	

Table 5. Prioritization of Feasible Strategies through the Usage of their Relative Attractiveness in the Strategic Management of Debris and Construction Wastes

No.	Strategy
SO1	Utilization of Regulation #2800 and the earthquake experts for reinforcement of the present structures and appropriate design of structures under construction as well as stronger monitoring in the future
WT3	Accurate estimation of volume, weight and type of debris in each district of Tehran for development of debris management plan, determination of number of required machinery and the location of temporary depot sites
WO2	Usage of past experiences from the disaster prone countries for the development of the debris management plan
WT1	Destruction of uncertified buildings, especially those with inadequate distance from the building in front of them
WT2	Developing criteria for prohibition of high-rise construction at inappropriate locations in Regulation #2800
ST2	Utilization of contractors possessing heavy equipment and machinery for collection and disposal of debris and construction wastes
WT4	Focusing on the management of dangerous wastes within the debris management plan
WO4	Allocation of the required budget for the purchase of recycling and compaction machinery through public participation and establishment of a market for recycled products
WO3	Usage of recycling and reuse processes for the reduction of debris at the landfill sites
SO2	Utilization of the mobile machinery for compaction and recycling of debris and construction wastes in the disaster area
ST3	Allocation of specific locations for dangerous wastes in the temporary depot sites as well as the usage of experts for the management of dangerous wastes
WO1	Emphasizing on the construction of wide expressways in the urban development plan
SO3	Establishment of a market for recycled products by the pertinent organizations and contractors as well as employing experts for quality control of recycled products
ST1	Utilization of earthquake experts for reinforcement of old bridges and other essential passages

Earthquake as a natural phenomenon has no adverse effect by itself. The lack of preparedness and prevention measures is the determining factor in the scale of earthquake's devastating consequences. As long as the vulnerability of the human lives, socio-economic structures and human habitats is not eliminated against earthquakes, the consequent damages and calamities are inevitable. The identification of these consequences on the various aspects of human wellbeing would facilitate the crisis management and mitigate the potential dangers and risks. A strong earthquake would profoundly affect local residents' livelihood and every feature of their daily lives in the devastated area and even have impacts at national or regional levels (Alidousti, 1991).

The preparedness against earthquake is the most effective tool in reduction of adverse consequences in every society. The prevention of a catastrophe is impossible; however it is quite practical to minimize its impacts. The social preparedness is an important part of damage reduction plan and is considered as one of its integral components (Abdullahi, 2003).

Therefore, due to the high risk of earthquake occurrence in the city of Tehran and the potential scale of devastation, it is quite logical to have precautionary measures to mitigate the damages. The development of earthquake debris management plan is a significant step in reduction of future damages caused by earthquake. Due to the fact that the residential buildings are the dominant type of structure in the city of Tehran and most of these buildings are not designed to withstand earthquakes, their consequent debris in the aftermath of an earthquake would be a major contributor to the blockage of access roads, slowdown of relief services and delay of reconstruction activities. As a result, the first step in development of a debris strategic management plan is to determine the volume, weight and type of debris and to designate the appropriate sites for their temporary depot in each district of the Tehran metropolitan.

The past experiences of the other countries could be a great source of information. The precise estimation of the debris caused by a natural disaster is quite an intricate and difficult process, because there are so many variables that have to be taken into consideration. Thus, the scale of debris estimation could vary from few tons to thousand of tons, depending on the considered variables. The only feasible planning measure is to estimate the real available number of relief forces and personnel as well as the level of debris management capacity prior to the occurrence of the disaster (Solis, *et al.,* 1996).

During a natural disaster, it is quite possible to designate several temporary debris depot sites, because the shear size of the resulting debris would surpass the capacity of the landfill sites and the transportation equipment and facilities. The utilization of temporary debris depot sites will reduce the clean up costs. Actually, debris would be managed twice, first at the temporary depot sites and second at the final disposal sites (Burgess and Giroux, 1997).

Another strategy is recycling and reuse of debris at the landfill sites, because a major portion of the debris could be recycled, if they are not contaminated by pollutants (Kartman, *et al.,* 2004). The prevalence of recycling and reuse practices would reduce the cost of debris management and protect the environment. The recycling and reuse processes separate a significant portion of debris and reduces their adverse effects. Currently, the reuse of debris and construction wastes is being implemented by advanced techniques, which could facilitate the debris management (Coke, 1995). Sometimes the recycling of construction wastes could interfere with the clean up activities. In these cases, the following strategies are to be identified in the debris access polices (Paw and Lauritzen, 1994):

1-The responsibilities of the debris management

2-The prioritization of access to debris and construction wastes, for example, the priority should be given to the owners and then to the contractors

3-Determination of the debris and construction waste ownership

One of the influential factors in development and expansion of debris and construction waste recycling is the establishment of a market for the sale of recycled materials through the pertinent organizations and contractors. The utilization of experts on quality control of the recycled products would also strengthen the market. Moreover, the usage of mobile recycling and compaction machinery could expedite the recycling process. Another valuable strategy is the reinforcement of the present structures and proper design of the structures under construction according to the Regulation # 2800 (the regulation on design of buildings against earthquakes) under the supervision of the experts. Also, the prohibition of constructing high-rises at inappropriate locations, destruction of uncertified buildings and suitable design and reinforcement of other structures like bridges and roads are highly advised.

Another important strategy is the availability of heavy machinery and equipment for the collection and disposal of debris, which would greatly facilitate the clean up process during a natural crisis. This initiative could be materialized by finalizing contracts with the contractors who possess such equipment prior to the occurrence of earthquake.

The collection and management of dangerous wastes in the debris is the other noteworthy strategy. The dangerous wastes might include pesticides, paints, chemical solvents, cleaning agents, stored fuels, chemical materials used in agricultural and industrial processes, etc., which could be leaked or discharged during incidents like earthquakes. These materials are sometimes toxic and present a serious threat to human health and the environment. Therefore, the management of dangerous maters requires prompt response and actions to identify the followings (Elkurre, 1997):

-The source of dangerous materials
-The potential risks
-The isolation and sealing off measures
-The management and disposal requirements

After the identification and collection of the dangerous wastes, specific locations at the temporary depot sites have to be allocated for them.

CONCLUSION

From the assessment of the Internal Factors Evaluation (IFE) matrix whose total attractiveness number is 2.13, it could be concluded that the weaknesses are more dominant than the strengths. In another word, the actual capacity of Tehran for debris management during an earthquake is very low. Also, the total attractiveness number obtained from the External Factors Evaluation (EFE) matrix is 3.3, which indicates the dominance of opportunities over the threats. This represents the good potential capacity in the city of Tehran for debris management during an earthquake. Moreover, the analysis of the Strategic Position and Action Evaluation (SPACE) matrix (shown in Figure 1) points out that a Defensive Strategy located at the lower left grid of the matrix is suitable. Therefore, the organization is to modify and improve the internal weaknesses and avoid external threats. Also, it has to provide the required financial needs to combat the crisis. As a result, the following strategies are recommended:

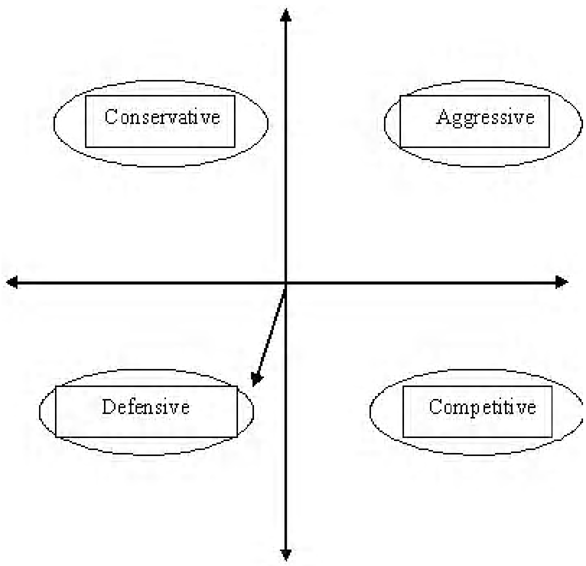

Fig. 1. Earthquake Debris Management position evaluation diagram

-Accurate estimation of the volume, weight and type of debris as well as the number of required machinery and the identification of the temporary depot sites in each district of Tehran metropolitan,
-Destruction of uncertified building units, especially those not observing the required distance from the building in front of them,
-Establishing regulations prohibiting the construction of high-rises at inappropriate locations, and
-Focusing on management of dangerous wastes within the debris management plans.

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