ISSN: 2008-5079 / EISSN: 2538-2365
DOI: 10.22034/AAUD.2021.244923.2303

Using a New Method of Collecting Construction Waste Tolls in Line with Management and Reduction of Construction Waste*

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Received 24 August 2020; Revised 13 May 2021; Accepted 15 May 2021; Available Online 21 June 2022

ABSTRACT

About 50 thousand tons of construction waste is produced in Tehran daily, about seven times the household waste. This results in the movement of more than 4500 trucks during the day inside the city. Without having smart and integrated management, these movements increase the traffic and pollute the city air and impose other problems such as illegal waste disposal in passages upon urban management. Hence, by smartification of the construction waste transport system, illegal disposal of this debris can be prevented, but also by reducing the truck traffic or their path length, huge positive steps are taken toward reducing overall traffic and air pollution. Via a proper organization of construction waste and sustaining the natural resources and environment, it can provide monetization and job makings. In this research, the best "buildings' demolition" management method in Tehran is examined based on the analytical hierarchy process (AHP) regarding sustainable urban development. Then, the subsidy and penalty approach are suggested for paying the tolls of the construction waste resulting from various building demolition methods. As a consequence of executing this plan, constructors will be more inclined to demolition methods with less construction waste due to exemptions and fewer waste charges and avoid demolition methods with enormous construction waste due to higher penalties and waste tolls. The results of this study have shown that the weight values of economic, environmental, and socio-cultural criteria were 0.528, 0.333, and 0.140, respectively. The high economic criterion weight value indicates its importance among constructors. This option is used to manage and reduce construction and demolition waste. Using practical and scientific experiences and results obtained in other countries, the suggested subsidy and penalty method is selected.

Keywords: Construction Waste Tolls, Analytical Hierarchy Process, Sustainable Urban Development.

* The paper is based on the experiences of the first author during more than 20 years of activity in Tehran Municipality. Some parts of the paper have been used to fulfill the requirements of the first author's doctoral dissertation entitled "Pure management of demolition of buildings with demolition and renovation licenses." The study of the municipality of Tehran Region 2 has been used with the guidance and advice of the second author in the Azad University of South Tehran in 2020.

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1. INTRODUCTION

Every day, about 50,000 tons of construction waste is produced in Tehran, which is about seven times more than household waste, leading to more than 4,500 trucks in the city 24 hours a day. Thus, given the inattention of builders to recycling and reuse of building materials due to the destruction of buildings, Tehran loses a significant amount of cost as construction and demolition waste. However, with the proper management of building demolition, not only 70% of this waste construction and demolition becomes usable and recyclable, but it also reduces urban traffic, air pollution, environmental pollution, increases life and financial security, conserves natural resources, employment, income generation, increases citizen satisfaction and thus promotes sustainable urban development.

According to scientific and practical results in other countries, the amount of construction waste tolls, supervision intensity, transportation costs and disposal of construction waste and fines are the main elements that affect the behavior of builders in selecting the method of demolition and production of construction waste and demolition; therefore, managing the collection of construction waste tolls is an effective and new approach in reducing construction waste that minimizes the amount of waste.

Experiences in other countries indicate that implementing subsidies and penalties for the collection of construction waste tolls is the best way to manage and reduce construction waste and demolition. Moreover, with the implementation of this plan, builders become interested in methods of destruction with less construction debris because of exemptions and fewer waste tolls and avoid methods of destruction with more construction debris due to more fines and waste tolls. It has to be noted that implementing this plan will not be effective without effective and accurate supervision at the appropriate level and not considering penalties and compensation for offending manufacturers.

2. LITERATURE REVIEW

Rosado examined the life cycle of construction waste in the Brazilian state of Sao Paulo (Rosado, Vitale, Penteado, & Arena, 2019, p. 477). Wang indicated that the cost of construction waste management is an effective approach in reducing the production of construction waste (Wang et al., 2019, p. 1004). Chen showed that the supervision intensity, supervision costs, fines, and waste disposal costs are the main elements that affect the decision-making behavior of contractors (Chen, Hua, & Liu, 2019, p. 190). Blaisi considered the attention to economic, legislation, and technical factors as the solution to solve construction waste management (Blaisi, 2019, p. 167). Galvaz-Martos examined Europe's best performance in managing construction waste (Galvaz-Martos, Styles, Schoenberger, and Zeschmar-Lahl, 2018, p. 166). Borghi revealed the environmental aspects of recycling construction waste in the Lombardy region of Italy (Borghi, Pantini, & Rigamonti, 2018, p. 815). Menegaki examined the obstacles and incentives affecting the production and management of construction waste (Manghaki and Damigos, 2018, p. 8). Polat stated that the main causes of construction waste in Turkey are “continuous changes in the design and architecture of buildings”, “designing errors”, and “lack or error in construction details” (Polat et al., 2017, p. 948). Esa showed that construction and civil waste management starts from the planning and design stage to reduce the volume of waste generated during the construction period (Esa Halog, & Rigamonti, 2017, p. 219). Wu showed that the most important factor determining the behavior of contractors in the management of construction waste in mainland China is economic life (Wu, Yu, & Shen, 2017, p. 290). Given the growing amount of construction waste in Europe, Dahlbo showed the need to revise the EU Waste Framework Directive (Dahlbo et al., 2015, p. 333). Ruoyo indicated that the major problem of the construction cycle of construction and recycling waste in China is the lack of customer demand for recycling this waste (Ruoyo et al., 2017, p. 86). Chen identified the factors influencing the production of construction waste in Hong Kong (Chen, & Lu, 2017, p. 799). Melo examines the management of demolition and renovation of the Lisbon metro ar1ea in Lisbon, Portugal (Melo, Gonçalves, & Martins, 2011, p. 1252). Rodriguez assessed the management of construction waste in Spain (Rodriguez et al., 2015, p. 16). Thongkamsuk examined the construction and civil waste generated in tall buildings (Thongkamsuk, Sudasna, & Tondee, 2017, p. 411). Kleemann validated demolition statistics (number and volume of demolition of buildings) in Vienna, Austria (Kleemann et al., 2017, p. 37). By examining the management of construction and civil waste in the Hanoi region of Vietnam, Lockrey stated that the creation of policies and business strategy opportunities in the development of the construction and civil waste recycling industry was a step to enhance social, economic, and environmental outcomes (Lockrey et al., 2016, p. 757). Jia studied the problems related to construction and civil waste management in China (Jia, Yan, Shen, & Zheng, 2017, p. 531). Zheng presented a new method for measuring construction waste in China (Zheng et al., 2017, p. 405). Won determined the potential opportunities in demolishing existing buildings and using destructive materials to minimize waste disposal (Won & Zheng, 2017, p. 3). Chisellini considered the circular economy as a suitable solution for managing construction and civil waste and controlling environmental impacts (Chisellini, Ripa, & Olgiati, 2017, pp. 1 and 2). Abdelhamid studied the most prominent building ranking system in Egypt called the "Green Pyramid Ranking System" to manage construction waste (Abdelhamid, 2014, p. 317). Yuan examined the obstacles and challenges regarding the causes of inefficient construction and development waste management in the Shenzhen region of southern China (Yuan, 2017, p. 84). Saez introduced the most effective methods in the management of construction and civil waste "use of industrial systems" and "integrated management of construction and civil waste collection" (Saez et al., 2013, p. 52). Yang emphasized implementing four R policies (reduction, reuse, recycling, and recovery) extensively and efficiently to prevent slips associated with construction waste (Yang et al., 2017, p. 393).

3. METHODOLOGY

The study was of the descriptive-applied type and descriptive survey in terms of data collection in 2018 and 2019 in Tehran. Common options for demolishing buildings were first identified based on material recycling.

Option A: Instantaneous destruction with disposable materials

Option B: Semi-recycled demolition (use only more valuable materials such as steel reinforcement, aluminum, bricks, and so on).

Option C: Complete recycling destruction (maximum reuse of recycled materials or recycling).

Then based on Table 1, the decision-making criteria in the study were introduced in three general categories of environmental criteria, socio-cultural criteria, and economic criteria along with their sub-criteria based on the evaluation of sustainable urban development.

Table 1. Decision Criteria in Demolition of Buildings

Row	Criteria	Symbol	Sub-criteria	Symbol
1	Economical	E	Demolition cost	E1
			Cost of transporting construction waste	E2
			Cost of land occupation and waste disposal	E3
			Reusing or selling destructive materials	E4
			Making new recycled materials	E5
			Demolition speed	E6
2	Sociocultural	S	Employment	S1
			Demolition security	S2
			Acceptability and level of manufacturers' knowledge	S3
			Community acceptance	S4
			Supporting related organizations	S5
			Distorting the city appearance	S6
3	Environmental	Z	Air pollution	Z1
			Soil pollution	Z2
			Groundwater pollution	Z3
			Noise and noise pollution	Z4
			Increased greenhouse gases	Z5
			Loss of natural resources	Z6

AHP was one of the most popular multi-purpose decision-making techniques since the study examined decision-making with three competing options. According to Figure 1, a hierarchical tree structure was drawn from the perspective of sustainable urban development.

Armanshahr Architecture & Urban Development
Volume 15, Issue 38, Spring 2022

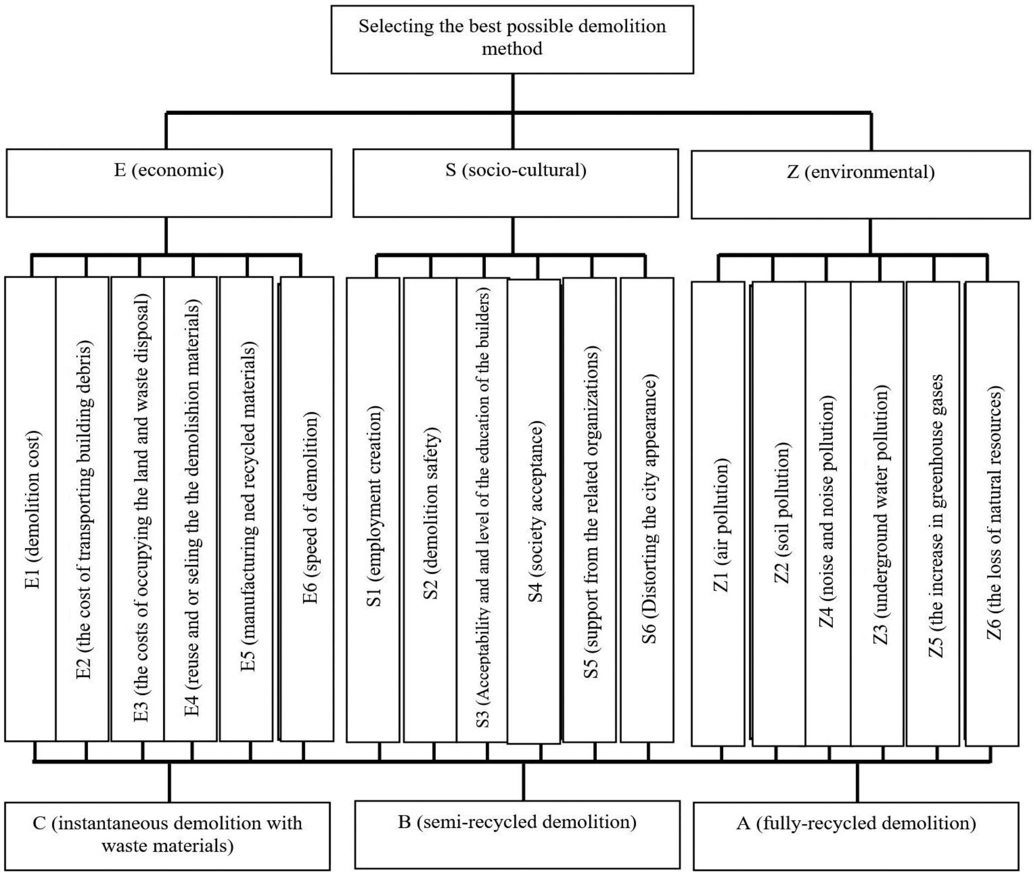

Fig. 1. A Hierarchical Tree Structure with a Sustainable Urban Development Perspective

4. CASE STUDY

The population was all the buildings being demolished in the municipality of District 2 of Tehran. As 110 buildings were in the process of demolition at the study time, some of the builders of the buildings stated did not have full and necessary cooperation with the study group. Thus, part of the population, 86 buildings, was selected as the sample using the Krejcie and Morgan table (Momeni, 2006, p. 53).

Table 2. Krejcie and Morgan Table

S	N	S	N	S	N	S	N	S	N
338	2800	260	800	162	280	80	100	10	10
341	3000	265	850	165	290	86	110	14	15
346	3500	269	900	169	300	92	120	19	20
351	4000	274	950	175	320	97	130	24	25
351	4500	278	1000	181	340	103	140	28	30
357	5000	285	1100	186	360	108	150	32	35
361	6000	291	1200	191	380	113	160	36	40
364	7000	297	1300	196	400	118	170	40	45
367	8000	302	1400	201	420	123	180	44	50
368	9000	306	1500	205	440	127	190	48	55
373	10000	310	1600	210	460	132	200	52	60
375	15000	313	1700	214	480	136	210	56	65
377	20000	317	1800	217	500	140	220	59	70
379	30000	320	1900	225	550	144	230	63	75
380	40000	322	2000	234	600	148	240	66	80

S	N	S	N	S	N	S	N	S	N
381	50000	327	2200	242	650	152	250	70	85
382	75000	331	2400	248	700	155	260	73	90
384	100000	335	2600	256	750	159	270	76	95

The required samples were examined with Cochran's formula for more control, and 86 samples were confirmed.

$$S = \frac{Nt^2pq}{Nd^2 + t^2pq} \quad \text{(Formula 1)}$$

In the formula above, S is the number of samples, N the total population, t the reliability coefficient, p the population ratio with a certain attribute, q the ratio of the population without a certain attribute, and d is the sampling accuracy.

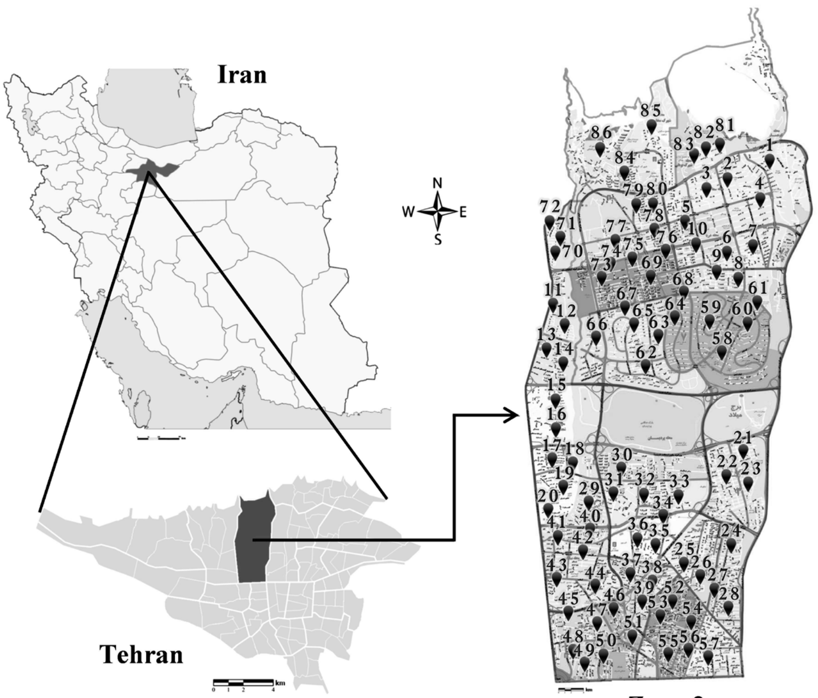

Fig. 2. The Position of the Samples in the Area Examined

5. ANALYSIS METHOD

The questionnaires were prepared using the Delphi method, and analysis was carried out using the AHP approach in Expert choice 11 software. The software is a powerful tool for performing AHP process and pairwise comparisons and is used in decision making and decision making in most sciences, including management science. Thomas L was used to determine the significance and preference in pairwise comparisons. Tomas L Satty, in the form of Table 3, was used (Abdollahi, 2015, pp. 253-268).

Table 3. Preference Values for Pairwise Comparisons

Preferences	Numerical Value
Completely reference or completely important or completely desirable	9
Preference or importance or desirability is very strong	7
Preference or importance or desirability is strong	5
A little preferred or a little more important or a little more desirable	3
The same preference or importance or desirability	1
Preferences between the above distances	8 ، 6 ، 4 ، 2

6. STRUCTURAL MODEL FITTING (VALIDATION)

For validation, first, the weight of the decision elements concerning each other and then the relative weight of the sub-criteria was calculated. To this end, each sub-criteria was compared in pairs, and the most important sub-criteria were identified. Ultimately, the correctness of the comparisons performed by the mismatch coefficient was measured and shown in Table 4.

Table 4. Inconsistency Coefficient and Weight of Criteria and Sub-criteria

Criteria	Weight Value of the Criteria	Inconsistency Coefficient of the Criteria	Sub-criteria	Weight Value of the Sub-criteria	Final Weight Value of the Sub-criteria	Inconsistency Coefficient of the Sub-criteria
(E) Economical	0.528	0.05	E1 (demolition cost)	0.416	0.219	0.07
			E2 (cost of transporting construction waste)	0.04	0.021	
			E3 (cost of land occupation and waste disposal)	0.104	0.055	
			E4 (reuse or sale of destructive materials)	0.185	0.098	
			E5 (manufacturing new recycled materials)	0.184	0.097	
			E6 (demolition rate)	0.072	0.038	
(S) Sociocultural	0.14	0.05	S1 (job creation)	0.146	0.02	0.07
			S2 (demolition security)	0.382	0.053	
			S3 (acceptability and level of knowledge of manufacturers)	0.061	0.008	
			S4 (community acceptability)	0.049	0.007	
			S5 (support for related organizations)	0.197	0.028	
			S6 (distorting cityscape)	0.166	0.023	
(Z) Environmental	0.333	0.05	Z1 (air pollution)	0.44	0.146	0.08
			Z2 (soil pollution)	0.117	0.039	
			Z3 (groundwater pollution)	0.282	0.094	
			Z4 (noise and noise pollution)	0.031	0.01	
			Z5 (increase in greenhouse gases)	0.059	0.02	
			Z6 (loss of natural resources)	0.071	0.024	

In comparing the three main criteria, the highest weight belonged to the "economic aspect" with a relative weight of 0.528 and the lowest weight to the "socio-cultural aspect" criterion with a relative weight of 0.140. "Environmental aspect" had a relative weight of 0.333.

As Table 3 shows, the highest weight was between the economic sub-criteria to "demolition cost" with a relative weight of 0.416 and the lowest weight to "cost of transportation of construction waste" with a relative weight of 0.040 in the studied area. Among the socio-cultural sub-criteria, the highest weight was for the "destruction security" sub-criterion with a relative weight of 0.382 and the lowest to "support of related organizations" sub-criterion with a relative weight of 0.049. Additionally, the highest weight among environmental sub-criteria was allocated to the "air pollution" sub-criterion with a relative weight of 0.440 and the lowest to "noise pollution" with a relative weight of 0.031.

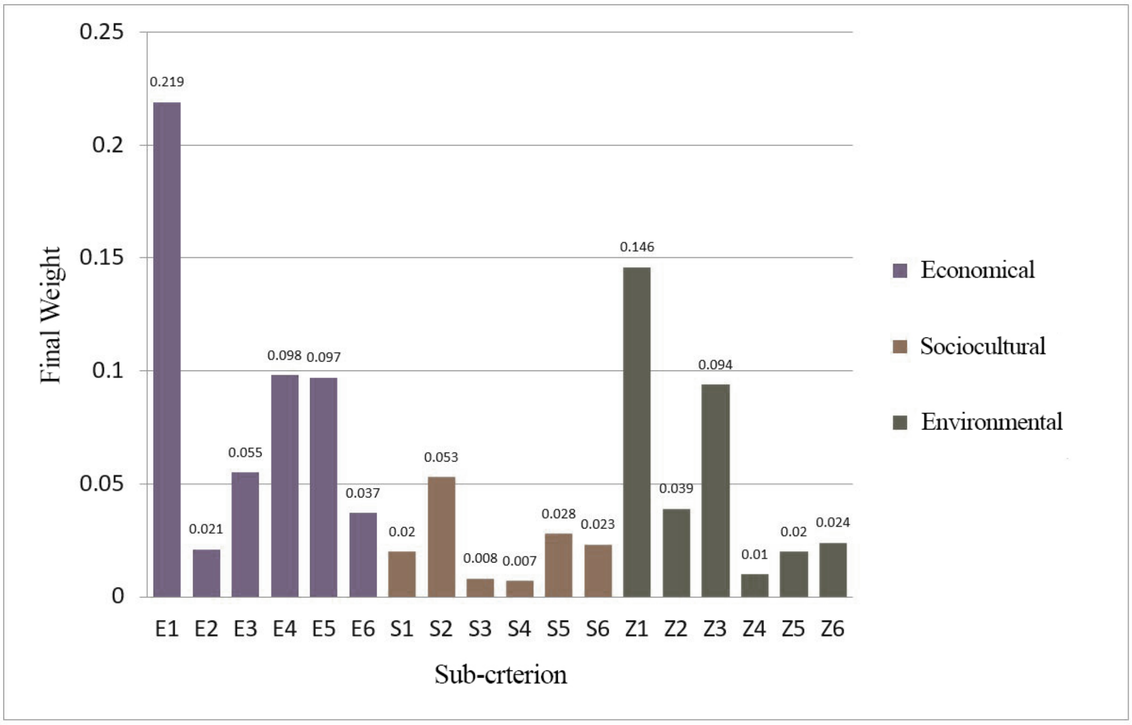

Fig. 1. The Effect of the Final Weight of Sub-criteria in Selecting the Best Method of Demolition of Buildings

7. RESULTS

The final weight of the options was calculated and prioritized and shown in Figure 2, given the effect of the weight of each criterion and sub-criterion. The table below shows option A: instantaneous demolition with disposal materials, option B: semi-recycled destruction (use only more valuable materials such as steel reinforcement, aluminum, bricks, and so on), and option C: complete recycled destruction (maximum reuse of destructive materials or their recycling).

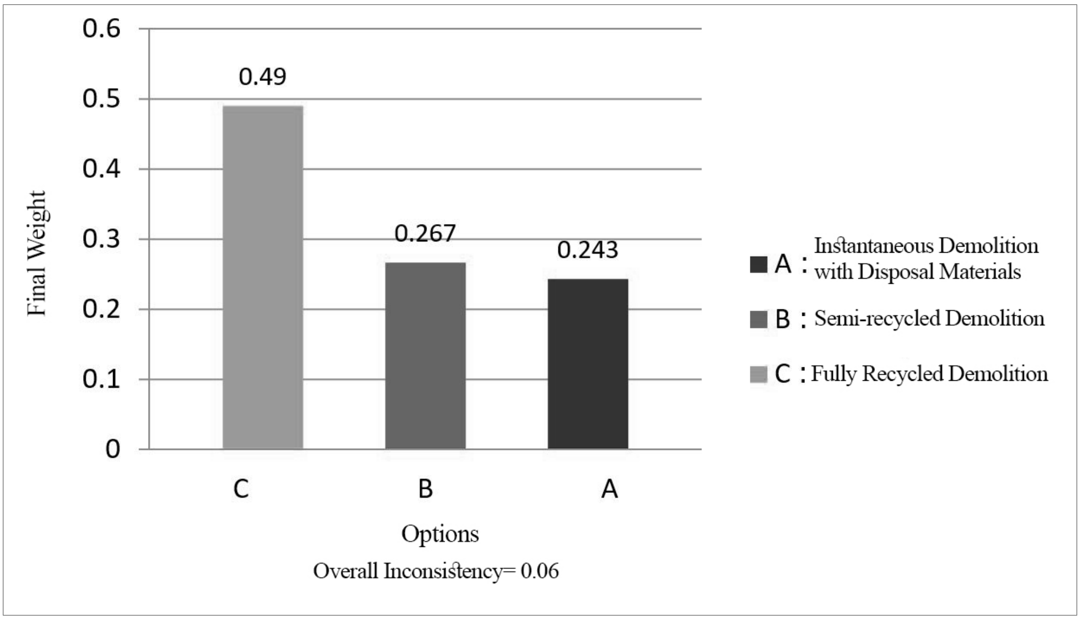

Fig. 2. Final Priority of the Options based on the Effect of all Criteria and Sub-criteria

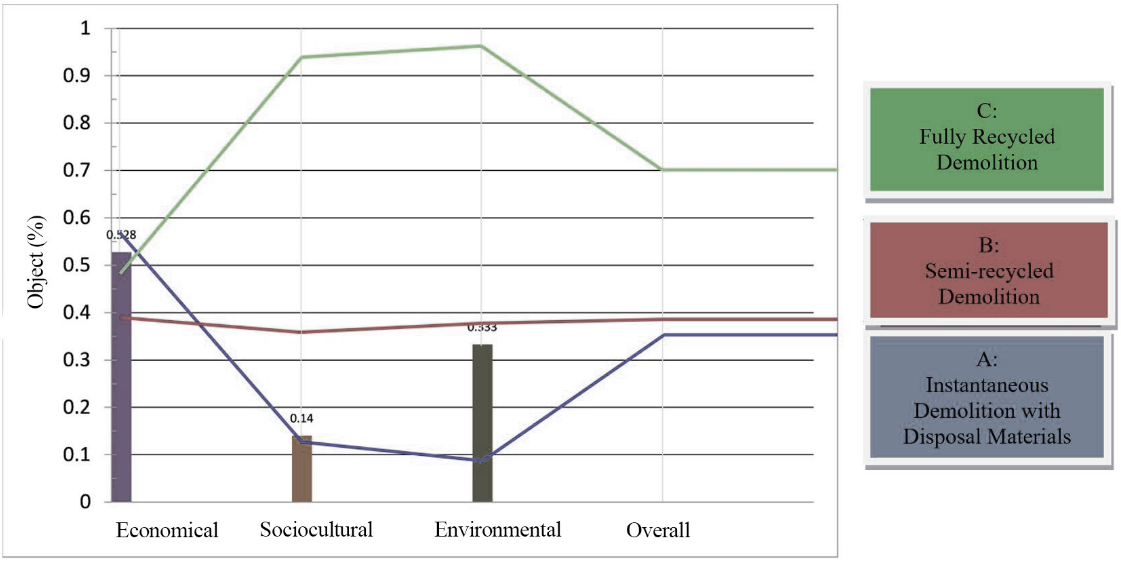

Fig. 3. Relative Significance of each Option Compared to Other Options in Terms of Main Criteria

Calculating and collecting tolls from waste caused by demolition and excavation in this new method:

In this method, to reduce the waste caused by the demolition of the existing building and encourage owners to use the methods of demolition of existing buildings with less garbage and more recycling, it is suggested that, first, the waste of one cubic meter of soil and garbage determined by the Islamic Council of Tehran for 2020, the amount of 15,000 Rials is announced. Compared to the construction cost of a building, this amount of tolls is a very small amount for builders, so the value of soil and garbage produced and related tolls are not of much financial importance in the construction process. Hence, examining and reviewing this basis for collecting construction waste tolls by the Islamic Council of the city professionally and taking all aspects of sustainable urban development into account is necessary. Second, considering subsidies and expert exemptions from construction waste tolls is the main way to use recycled demolition methods when demolishing an existing building.

The owner or lawyer applying for the demolition and renovation permit, when referring to the electronic offices of the city, at the same time as going through the steps related to obtaining the building permit, fill in the construction waste forms, and announce the demolition method envisaged for the existing building in the mentioned forms. The value and weight of construction and demolition waste are calculated based on the area of the existing building and the volume of excavation for the construction of basements based on the plans proposed by the owner by the experts of the electronic office. Waste tolls from demolition and excavation are calculated according to the value of soil and debris obtained and the demolition method announced by the owner, based on the tolls of one cubic meter of soil and debris determined by the Islamic Council of Tehran.

As the experiences gained in most countries in the semi-recycled demolition method, about 30% of more valuable materials such as steel reinforcement, aluminum, bricks, and so on are separated. The volume of construction and demolition waste is about 70% of the total volume of garbage is due to demolition, so 20% subsidy and discount is proposed to use this method, and tolls are calculated based on 50% of the weight of construction waste and demolition for the entire building. Also, for the complete recycling demolition method, which reduces the amount of construction and demolition waste to 70% by maximizing the reuse of recycled materials or their recycling, it is suggested that 30% of construction waste and non-recyclable demolition be exempted and no construction tolls should be collected from the builder's conducting demolition in a completely recycled way solely for demolition (this exemption does not apply to the soil from excavation).

It is necessary to specify the demolition method of the building in the demolition and renovation permit and effective and accurate monitoring of the demolition method stated in the issued permit, during the demolition of the old building, by the supervising engineers of the property and the relevant municipality. Moreover, if there is a discrepancy between the demolition method of the existing building and the demolition method stated in the issued license, payment of three times the construction waste tax approved by the Islamic Council of the city has to be provided as punishment and compensation for the total area of the existing building before demolition. By non-reporting the violation by the supervising engineer of the property and failure to be prevented by the relevant district officials, the offenders should be dealt with based on Note 7 of the Article 100 Commission.

The advantages of the new method of collecting construction waste tolls:

The following can be stated among the advantages of the new method of collecting construction waste tolls:

- Accurate calculation of the value of construction waste and demolition and excavation in the city electronic offices.
- Multiple-time increase in revenue because of the construction waste tolls collected in the municipality.
- Reduction of construction waste and demolition greatly and incomparably compared to before the project.
- Preserving the natural resources and the environment
- Reduction in soil and groundwater pollution because of the reduction of burial materials
- Reduction of greenhouse gas production because of the reduction of landfill materials
- Reduction in the cost of land occupation and waste disposal for the municipality
- Monetization because of reusing or sale of destructive materials
- Job creation because of the creation of second-hand construction materials markets
- Making it possible to build cheaper buildings with second-hand building materials by low-income groups
- Increasing the attention of supervising engineers and officials of municipal districts to the demolition method of buildings with demolition and renovation licenses.
- and so on.

8. CONCLUSION

The findings indicated that the weight value of the economic criterion was 0.528, environmental criterion 0.333, and socio-cultural criterion 0.140. The high weight value of the economic criterion showed its significance among builders and important options for managing and reducing construction and demolition waste.

Considering the findings from the AHP technique, the option of “complete recycled demolition” (maximum reuse of recycled materials or their recycling) with a weight of 0.490 is the best option for demolishing buildings. The option of “semi-recycled demolition” (mere use of more valuable materials such as iron, steel reinforcement, aluminum, bricks, and so on) with a weight of 0.267 is the second priority and “instant destruction with waste materials” with a weight of 0.243 was selected as the final option. The inconsistency coefficient of all comparisons was 0.050 and less than 0.1, indicating the judgments' consistency.

According to the scientific and practical results obtained in other countries stating that the construction waste tolls, the intensity of supervision, transportation costs and disposal of construction waste, and fines are some of the main factors affecting the behavior of builders in selecting the method of demolition and production of construction waste and demolition. Construction waste collection tolls were used as an effective and innovative approach in reducing the production of construction waste that can minimize waste. In this method, to collect construction waste tolls, subsidies and exemptions are considered to manage and reduce construction waste and demolition, and builders are interested in demolition methods with less construction debris because of fewer exemptions and tolls, and demolition methods with more construction debris are avoided because of more fines and waste.

Hence, it is recommended that the Islamic Council of Tehran first review the tolls set for construction waste in an expert manner and take into account all aspects of sustainable urban development. Second, to expand the use of recycled demolition methods when demolishing an existing building, construction waste tolls should be applied for the “complete recycled demolition” method with full exemption and for “semi-recycled demolition” with a 50% discount. For offending builders acting against the demolition method shown in the demolition and renovation license, paying three times the construction waste toll approved by the Islamic Council of the city for the total area of the existing building before demolition should be considered as punishment and compensation.

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HOW TO CITE THIS ARTICLE

Farzad, Sh., Vosughifar, H., Rabieefar, R., & Hosseini, S. M. (2022). Using a New Method of Collecting Construction Waste Tolls in Line with Management and Reduction of Construction Waste. *Armanshahr Architecture & Urban Development Journal*. 15(38), 267-277.

DOI: 10.22034/AAUD.2021.244923.2303
URL: http://www.armanshahrjournal.com/article_152347.html

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