Evaluation of final disposal sites for construction and demolition waste in Mexico City

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Abstract

In this work a multi-criterion evaluation methodology was applied to find a suitable location of a final disposal site of Construction and Demolition Waste (C&DW), in Mexico City, which guarantees to society that the proposed infrastructure will seek environmental preservation and efficiency in its operation. 12 sites were evaluated in two zones of Mexico City (south and east) under three general criteria (environmental, socioeconomic and technical). Considering specific criteria to evaluate the sites, according to the primary results obtained, a second evaluation was done to find the suitable site of final disposal of construction and demolition wastes.

Introduction

The construction industry is a relevant sector of the world economy, because the urban constructions built are sources of production and employment. In Mexico, it is estimated that this sector generates 5,6 million jobs and impacts 63 of the 73 productive branches of the country; In addition, in 2011, it contributed 6,7% to the Gross Domestic Product [1]. As other economic activity that uses inputs or raw materials, it generates solid waste, specifically Construction and Demolition Wastes (C&DW), made up of demolition debris, earth materials excavated, concrete, among others. In February 2013, a Mexican law, NOM-161-SEMARNAT-2011 [2] came into force, which establishes as an obligation for builders that generate more than 80 m^3 of C&DW in their works, the formulation and development of a management plan. However, nowadays there are few entities in the country that have fulfilled this obligation, since there is not the infrastructure to make an adequate final disposition of them. Under the previous context, this paper applies a methodology to evaluate the suitable location of a final disposal site of C&DW in Mexico City, which guarantees to society that the proposed infrastructure, will seek environmental preservation and high efficiency in its operation.

Materials and methods

In this work, due to the difficulty to locate final disposal sites for C&DW within the Conservation Soil (CS) of Mexico City a spatial analysis was initially carried out, with the purpose of delimiting the suitable areas of location for this infrastructure, particularly in the boundary between CS and Urban Soil (US). Through this analysis, 12 possible sites that meet location criteria were identified, see Figure 1. These sites were named: Camino al Ajusco, Cerro de la Estrella, Milpa Alta 2, Tláhuac 1, Tláhuac 2, Tlalpan 1, Tlalpan 2, Xico 0, Xico 1, Xico 2, Xico 2', and Xico 3.

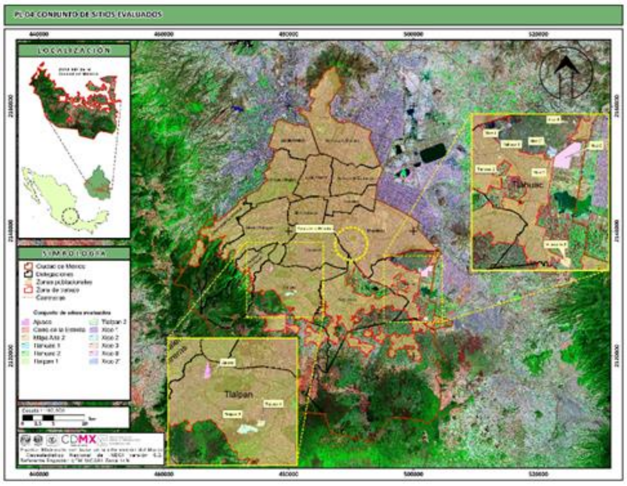

Figure 1. Preliminary delimitation of dumping sites

Multi-Criteria Evaluation (MCE) techniques were used to evaluate the viability of the potential disposal of sites of C&DW. According to Gómez and Barredo [3], such techniques are a set of operations in the decision-making processes, considering several criteria or conditions at the same time a Hierarchical Analysis Process (AHP) was applied.

Satty [4] states that the AHP criteria, is to divide a problem or a complex situation into its parts or variables that make it up, making an arrangement in hierarchical order, and then assign numerical values to subjective judgments about the relative importance of each part or variable, in order to synthesize them to determine which have the highest priority. It should be emphasized that, by dividing the situation or problem into parts or variables, the person who evaluates can focus on smaller sets of decisions. The hierarchical scheme of this technique consists of these basic levels: final goal, decision criteria (usually accompanied by sub-criteria). When analyzing the conditions to place infrastructure of any kind, environmental criteria are usually the first condition of restriction, mainly due to the existence of legal regulations and laws in different countries, which demand environmental compliance, and that take into account the possible consequences for failures in those infrastructures [5]. The technical criteria, on the other hand, are directly related to the construction and operation of the installation, and not to the possible environmental consequences that these could generate. Finally, the main objective of socio-economic criteria is to reduce the negative effects on people, as well as the cost of building.

The general function is represented in Equation 1.

$$V(A_i) = \sum_{k=1}^{n} w_l w_{k(l)} v(a_{ik}) \qquad \textbf{(1)}$$

Where $v(a_{ik})$ is the value function, w_l is the weight associated with the lth objective (l = 1, 2 ..., p), and w_k (l) is the weight assigned to the kth attribute associated with the lth objective.

The steps involved in the evaluation using the MCE-AHP technique are the following:

1. Identification of relevant criteria and / or sub-criteria.
2. Construction of a model of the hierarchical analytical process.
3. Performing pairwise comparisons of the elements on the same level with respect to the elements.
4. Calculation of the weights derived from the paired comparisons, generating the corresponding matrices.
5. Consistency test of the generated matrices, by calculating the consistency ratio.
6. Repeat steps 3, 4 and 5 for all elements at all hierarchical levels.
7. Synthesis of all weights for the elements in each level.
8. Evaluation of total consistency.

In order to use the technique MCE, there were use all variables and criteria which have an important impact on the host or reception capacity of the territory. These variables arose from the discussion with the specialized staff who collaborated during the visits, and they were accommodated according to a hierarchical scheme.

The first level in the hierarchical scheme, is the goal that is intended to reach. The second level was called general criteria (GC), and was divided into 3 areas: "environmental, socio-economic and technical”. The third level corresponds to the variables employed; This level was called specific criteria (SC), accommodated in two aspects: "factors and limitations"; the "factors" are the kind of variable that must have more than two categories or levels, while the "limiting" can only have maximum two. The hierarchical scheme can be seen in Figure 2.

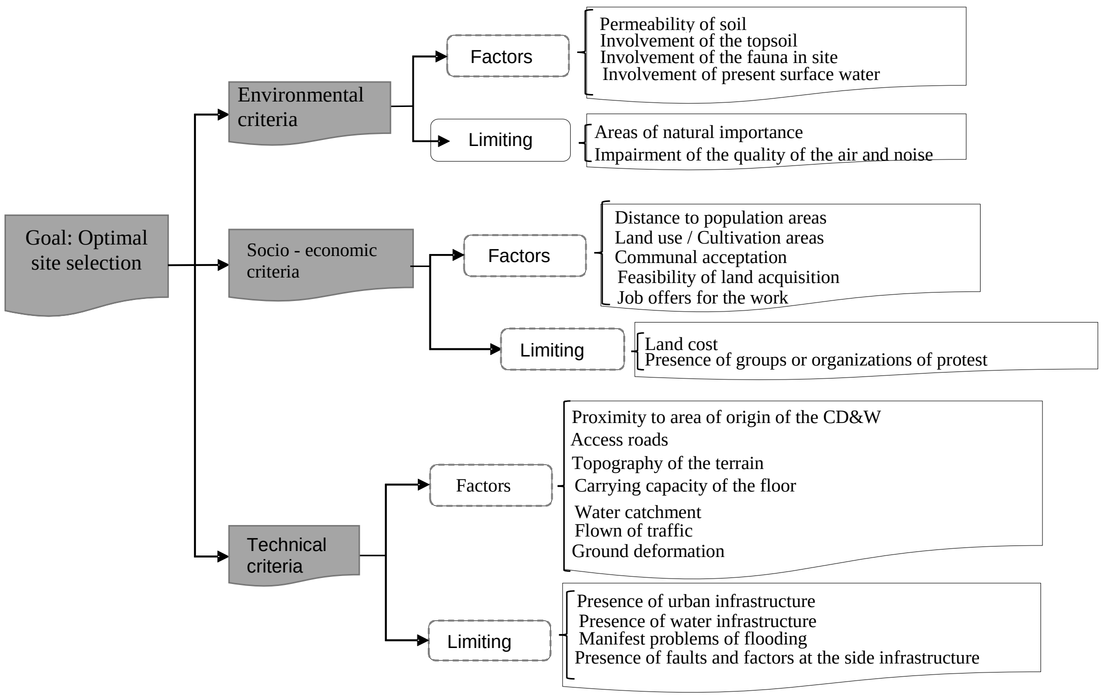

Figure 2: Hierarchical scheme used in the EMC

To carry out the weighting of the GC and SE, the comparison is used by Sally pairs (1980), that is based on a system of qualification by importance. Tables 1 to 4 present the weighting matrices, with their corresponding value or consistency ratio (CR) for each of them.

To normalize levels or categories of each variable or SC, applied a simple appraisal of values ranging from 1 to 3 for the factors, and 0 or 3 to the constraints; in this assessment, the smaller values correspond to the most unfavorable or restrictive condition, while the highest values are equivalent to the favorable condition.

Information to detail of the values adopted in the normalization of levels shown in table 5.

Table 1. Paired comparison for the general criteria

GC	**Weighing calculation**			**Sum**	**Weighing**
	Socio-economic	**Technical**	**Environmental**		
Socio-economic	1.00	4.00	6.00	11.00	0.6911
Technical	0.25	1.00	2.00	3.25	0.2042
Ambiental	0.17	0.50	1.00	1.67	0.1047
Total	**1.42**	**5.50**	**9.00**	**15.9**	**1.0000**
λ max = 3.04, **CI** = 0.022, **RI**= 0.520 and **CR** = 0.043<0.1					

Table 2. Paired comparison for the environmental criteria

	SC		**i.1**	**i.2**	**i.3**	**i.4**	**i.5**	**i.6**	**Sum**	**Weighing**
Ambiental	**i.1**	Areas of natural importance	1.00	2.00	3.00	3.00	4.00	5.00	18.00	0.34
	i.2	Affectation the existing vegetal layer	0.50	1.00	2.00	2.00	3.00	3.00	11.50	0.22
	i.3	Soil permeability	0.33	0.50	1.00	2.00	2.00	3.00	8.83	0.17
	i.4	Affectation of surface water present	0.33	0.50	0.50	1.00	2.00	3.00	7.33	0.14
	i.5	Affectation to fauna present on the side	0.25	0.33	0.50	0.50	1.00	2.00	4.58	0.09
	i.6	Impact on air quality and noise	0.20	0.33	0.33	0.33	0.50	1.00	2.70	0.05
		Total	2.62	4.67	7.33	8.83	12.50	17.00	52.95	1.00
λ max = 6.30, **CI** = 0.060, **RI**= 1.250 and **CR** = 0.048<0.1										

Table 3. Paired comparison for the socio-economic criteria

	SC		**j.1**	**j.2**	**j.3**	**j.4**	**j.5**	**j.6**	**j.7**	**Sum**	**Weighing**
Socio-económico	**j.1**	Purchase feasibility	1.00	3.00	4.00	4.00	5.00	5.00	6.00	28.00	0.35
	j.2	Community acceptance	0.33	1.00	2.00	2.00	3.00	3.00	4.00	15.33	0.19
	j.3	Use of soil/growing areas	0.25	0.50	1.00	1.00	2.00	3.00	3.00	10.75	0.14
	j.4	Distance to popular areas	0.25	0.50	1.00	1.00	2.00	2.00	3.00	9.75	0.12
	j.5	Cost of the land	0.20	0.33	0.50	0.50	1.00	2.00	3.00	7.53	0.10
	j.6	Presence of protest groups	0.20	0.33	0.33	0.50	0.50	1.00	2.00	4.87	0.06
	j.7	Job offer	0.17	0.25	0.33	0.33	0.33	0.50	1.00	2.92	0.04
		Total		5.92	9.17	9.33	13.83	16.50	22.00	79.15	1.00
λmax = 7.53, **CI** = 0.089, **RI**= 1.350 and **CR** = 0.066<0.1											

Table 4: Paired comparison for technical criteria

		SC	**k.1**	**k.2**	**k.3**	**k.4**	**k.5**	**k.6**	**k.7**	**k.8**	**k.9**	**k.10**	**k.11**	**k.12**	**Sum**	**Weighing**
Technical	**k.1**	Land area	1.00	2.00	2.00	3.00	3.00	4.00	4.00	5.00	5.00	6.00	6.00	7.00	48.00	0.19
	k.2	Distance to origin of land	0.50	1.00	1.00	2.00	2.00	3.00	3.00	4.00	5.00	5.00	6.00	6.00	38.50	0.15
	k.3	Access road	0.50	1.00	1.00	2.00	2.00	3.00	3.00	4.00	4.00	5.00	5.00	6.00	36.50	0.14
	k.4	Land topography	0.33	0.50	0.50	1.00	1.00	2.00	2.00	3.00	3.00	4.00	4.00	5.00	26.33	0.10
	k.5	Presence of hydraulic infrastructure	0.33	0.50	0.50	1.00	1.00	2.00	3.00	4.00	3.00	4.00	4.00	5.00	28.33	0.11
	k.6	Carrying capacity of the land	0.25	0.33	0.33	0.50	0.50	1.00	1.00	2.00	2.00	3.00	4.00	5.00	19.92	0.08
	k.7	Water catchment	0.25	0.33	0.33	0.50	0.33	1.00	1.00	2.00	2.00	3.00	3.00	4.00	17.75	0.07

	k.8	Presence of urban infrastructure	0.20	0.25	0.25	0.33	0.25	0.50	0.50	1.00	1.00	2.00	2.00	4.00	12.28	0.05
	k.9	Vehicular flown	0.20	0.20	0.25	0.33	0.33	0.50	0.50	1.00	1.00	2.00	2.00	3.00	11.32	0.04
	k.10	Manifest problems of flooding	0.17	0.20	0.20	0.25	0.25	0.33	0.33	0.50	0.50	1.00	1.00	2.00	6.73	0.03
	k.11	Presence of faults and fractures at the side infrastructure	0.17	0.17	0.20	0.25	0.25	0.25	0.33	0.50	0.50	1.00	1.00	2.00	6.62	0.03
	k.12	Ground deformation	0.14	0.17	0.17	0.20	0.20	0.20	0.25	0.25	0.33	0.50	0.50	1.00	3.91	0.02
		Total	4.0	6.7	6.7	11.4	11.1	17.8	18.9	27.3	27.3	36.5	38.5	50.0	256.2	1.0
$\boldsymbol{\lambda max}$ = 13.04, **CI** = 0.094, **RI**= 1.570 and **CR** = 0.060<0.1																

Table 5: Description of criteria and normalization of levels

GC		**SC**	**Condition/situation**	**LN**
Environmental	**i.1**	Description of criteria and normalization of levels	The site is out of an important natural area	3
			The site is located within an area of natural importance	0
	i.2	Involvement of the existing topsoil	There is no topsoil; the site is located in an arid area or the topsoil has been removed by previous use	3
			Is there a topsoil of minor (grasslands), there are no endemic species on the site	2
			There are endemic plants of the region in the site/presence of dense vegetation cover	1
	i.3	Permeability of soil	Slow permeability/floors / fully clay / very deep aquifers (> 20m)	3
			Moderate permeability / Rocky soils / groundwater intermediate	2
			Rapid permeability/floors / completely Sandy / groundwater close to the surface (1-4m)	1
	i.4	Involvement of surface water	In the vicinity of the venue there are no surface waters which could be affected by the activity	3
			The adverse effect will be fairly significant on the receiving body	2
			There may be a severe impairment in surface waters in the vicinity by runoff or drag of materials or diversion of runway.	1
	i.5	Involvement of fauna in the site	There is no wildlife present on campus or that is present is not endemic and environmental importance	3
			On the campus there is fauna of medium importance / non-endemic / commercial importance	2
			On the grounds there is fauna of endemic or environmental importance	1
	i.6	Affecting the quality of air and noise	Near the venue are other activities that generate constant noise, so the generation of noise by this activity is not relevant and/or there is a locality in the vicinity could be affected.	3
			There are no other activities that generate constant noise near the venue / the presence of towns in the vicinity that may be affected	0
Socio- economic criteria	**j.1**	Feasibility of purchase	The site belongs to the municipality or other State institution, so the acquisition is easy	3
			The site belongs to a private owner only or several but with attitude positive	2
			Exists or can exist hostility to the project on the part of the owners, cannot be determined or contact all owner, there are tenders concerning property titles, they were demanding exorbitant prices or similarly unfavorable conditions	1
	j.2	Communal Acceptation	High acceptance. Other infrastructure projects that have not generated discontent in the community have been built in the vicinity.	3
			Mean acceptance. Population divided between accepting or not the construction site, due to that there have been no other type of infrastructure building in the area of location or similar.	2
			Low acceptance. The discontent of the population with the realization of works has been around the project site	1
	j.3	Use of soil/crop areas	Lands of commonly used / unused current /	3
			Land / crop	2
			Land for human settlements	1
	j.4	Distance to population areas	Populations at more than 1000 m distance	3
			Populations between 500 - 1000 m from	2
			Population less than 500 m away	1
	j.5	Cost of land	The terrain is feasible are available (cheap)	3
			It is not feasible to acquire land or hardly available (expensive and not feasible)	0

	j.6	Presence of protest groups	Near to the land, there is evidence the presence of groups or non-governmental organizations that could confront the execution of the works.	3
			Near the ground is evident the presence of groups or non-governmental organizations that could confront the execution of the works.	0
	j.7	Job offer	More than 50% of workers in infrastructure to locate belong to the area of influence or nearby communities.	3
			Between 20 and 50% of workers in infrastructure to position they belong to the area of influence or nearby communities.	2
			Less than 20% of workers in infrastructure to locate belong to the area of influence or nearby communities.	1
Technical criteria	**k.1**	Area of the property	The property has> 50 Ha.	3
			The property has an area of 25 to 50 Ha	2
			The property has < 25 Ha	1
	k.2	Suburban origin of C&DW	The Centre of gravity of the C&DW production areas are less than 10 km on the area of the construction site	3
			The Centre of gravity of the C&DW production areas are between 10 and 20 km with respect to the area of the construction site	2
			The Centre of gravity of the C&DW production areas are more than 20 km with respect to the area of the construction site	1
	k.3	Access roads	Access via paved existing up to the proposed site. It has more than 8 m wide. Further construction is not required	3
			Paved access road is a distance amp;lt; 500 m of the property under consideration. You must build the section of access	2
			Paved access road over 1 km away.	1
	k.4	Topography of the terrain	Flat areas with small undulations with slopes less than 10% or semi-planas	3
			Gentle hills with outstanding 20% maximum	2
			Very rough terrain with slopes greater than 20%	1
	k.5	Presence of water infrastructure	There is the presence of infrastructure within the premises or in the vicinity that may be affected by the work to locate	3
			There is the presence of infrastructure within the premises or in the vicinity that may be affected by the work to locate	0
	k.6	Carrying capacity of the floor	> 50 Ton/m^2 with the presence of hard soils and rock	3
			Land with capacities of between 15 and 50 Ton/m2 in intermediate soils	2
			< 15 Ton/m^2 in soft soils	1
	k.7	Water catchment	There is a collection of rainwater within the premises or in the vicinity	3
			There is a catchment minor gives rainwater	2
			There is an important collection of rainwater within the premises or in the vicinity	1
	k.8	Presence of urban infrastructure	There is the presence of infrastructure within the premises or in the vicinity that may be affected by the work to locate	3
			There is the presence of infrastructure within the premises or in the vicinity that may be affected by the work to locate	0
	k.9	Flown vehicular	In peak hours, the time of arrival to the venue are short	3
			In peak hours, the time of arrival to the venue are short	2
			In all business hour vehicular flow is heavy which lengthen the time of arrival to the venue	1
	k.10	Manifested problems of flooding	On the campus there are no problems of flooding or flood	3
			In the grounds there are manifest problems of flooding or flood	0
	k.11	Presence of faults and fractures on campus	In the location of the infrastructure area not be tectonically active with presence of faults and fractures /fractures have not been produced by desiccation of Lake area or by overexploitation of the aquifer	3
			The location of the infrastructure area is tectonically active with presence of faults and fractures / fractures have been presented by desiccation of Lake area or by overexploitation of the aquifer	0
	k.12	Ground deformation	Hard soils and rock with less than 5 cm deformations (zone I)	3
			Intermediate soils with deformations less than 15 cm (zone II)	2
			Soft floors with deformations of over 15 cm and presence of adjacent structures and 30 cm with close (zone III)	1

Ln=level normalization

Results and discussion

The results of the group of the sites obtained are presented in Figure 2. The sites: Camino al Ajusco, Xico 3 and Xico 1, obtained the highest scores, since they complied with the variables of the environmental, technical and socio-economic criteria; the latter was the most important.

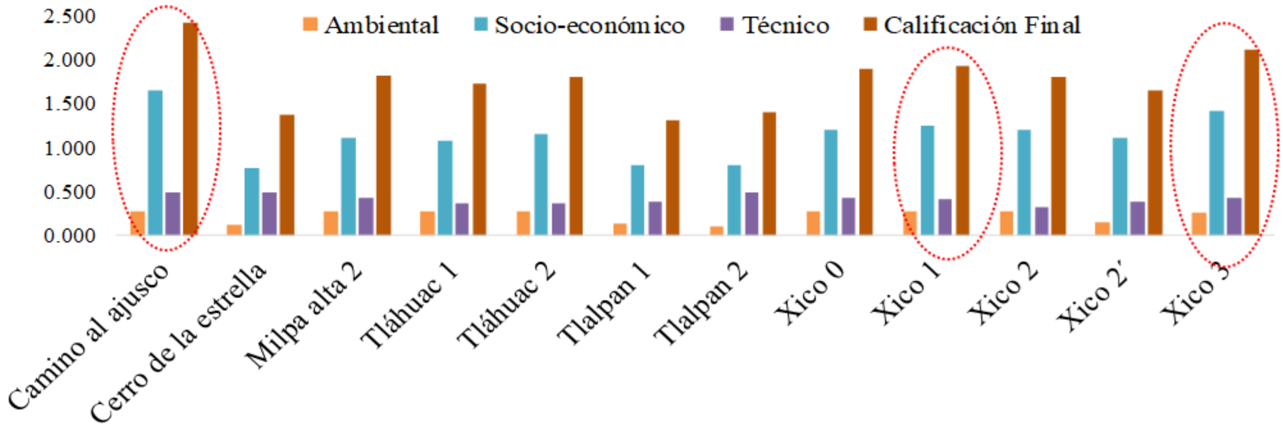

Figure 2. Results of evaluated sites with the three considered criteria

Conclusions

The methodology presented, evaluated and determined the most viable sites regarding environmental, socio-economic and technical variables. The sites that obtained the highest scores were: Camino al Ajusco, Xico 1 and Xico 3. Finally, it is important to mention that, Multi-Criteria Evaluation methodology could be applied to similar studies in different regions of Mexico.

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