كلية الهندسة بشبرا
FACULTY OF ENGINEERING AT SHOUBRA
ERJ
PRINT ISSN 3009-6049
ONLINE ISSN 3009-6022

ENGINEERING RESEARCH JOURNAL (ERJ)
Volume (53),Issue (4)
October 2024, pp:172-178
https://erjsh.journals.ekb.eg

Assessment of Project's Environmental Impacts in Construction Phase

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Abstract: Environmental impact of construction projects represents challenges for the civil engineers in Egypt. This paper presents a list of environmental impact indicators in the construction phase. A preliminary list of environmental impact indicators has been collected from literature. The environmental impact indicators are divided into four groups, Ecological indicators; resources indicators, social indicators, and construction indicators. The ecological indicators are: Dust generation, Noise, Air quality, water quality, vibration, and erosion. The resource indicators are: Materials consumption, Energy consumption (fuel), Water consumption, Power consumption (electricity). The social indicators are: Social disruption, Social health, and social safety. The construction indicators are: De-watering work sites, Road cleaning, solid waste, Nearest Utilities, Storage of chemicals and fuel, and Traffic disruption. Structured and unstructured interviews have been conducted with senior engineers work in the field of Construction projects. The main purpose of these interviews were to collect data belong to the environmental impact indicators. The experts were asked to rank the indicators according to their impacts on the environment. Statistical analysis has been conducted to calculate the relative weight of these indicators. It was found that the nearest utilities, the social health, and the traffic disruption are the greatest environmental impact in Egypt. The results of this research are useful for construction engineers in construction sites to become aware of construction processes impacts on the environment.

Keywords: Environmental impact; indicators; construction phase; construction projects; assessment processes; water pollution; energy consumption.

1. Introduction

Environmental impact of construction projects represents challenges for the civil engineers in Egypt. The environment is threatened severely by so many problems, some of which are caused by the activities of construction projects. Ijigah et al., presented a list of environmental impact indicators for building construction projects [1]. Dutta and SEngupta presented an article to review the various steps involved in EIA, environmental effects of construction industry and EIA with relation to construction industry [2]. Akanni et al., introduced twenty – nine variables were identified as factors having an impact on building project performances [3]. Rizqa and Abusharar presented a study to assess the most common impacts of construction projects on the environment in Gaza Strip [4]. Marzouk et al., presented a building information modeling (BIM) – based methodology for the assessment of environmental impacts in road construction projects [5]. Shamseldin proposed an approach for considering the effects of variables when assessing item requirement [6]. Construction practices that fail to control pollution can cause damage to waterways and wetlands, kill fish, upset aquatic ecological systems and wildlife communities, and results in contamination of land and ground water [7]. Zolfagharian et al., found that the transportation resources, noise pollution, and dust generation with construction machinery are the greatest environmental impacts in Malaysia respectively [8]. Selvakumar and Jekumar found that if in the early planning before the start of the project as well as through all phases of the project's development, if environmental concerns are considered simultaneously with other technical and economic criteria, it may be possible to develop the housing projects with the protection of natural resources of that area [9]. Emami et al., presented a study bout the environmental impacts of different plans for domestic production or import of construction materials to Iceland [10]. Environmental impact of reservoir construction offers a new perspective for development, and opportunities for the implementation of restoration economy and restorative development in the watersheds [11]. Bribian et al., presented a study to deepen the knowledge of energy and environmental specifications of building materials, analyzing their possibilities for improvement and providing guidelines for materials selection in the eco-design of new buildings and rehabilitation of existing buildings [12]. Mwemezi and Luvara presented a study to identify the environmental impacts due to mining and construction activities in Kennyia [13]. Sharad et al., used an input-output-based life cycle assessment model to create a more comprehensive estimate of the environmental effects of construction processes [14]. Hamoda presented a study to measure the noise levels generated at different construction sites [15].

2. Research Procedures

Past researches in the field of Environmental impact of construction projects have been reviewed to gather a list of environmental impact indicators of the construction projects in the construction phase [1-15]. Preliminary list of environmental impact indicators was gathered. Unstructured interviews with senior engineers in the field of construction projects have been conducted to review the gathered indicators. A list of nineteen indicators has been chosen from the gathered indicators. The indicators were classified into

four groups: ecological indicators, resources indicators, Social indicators, and construction indicators. The ecological indicators include: dust generation, noise, air quality, water quality, vibration, and erosion. The resources indicators include: material consumption, energy consumption water consumption, and power consumption. The social indicators include: social disruption, social health, and social safety. The construction indicators include: Dewatering work site, road cleaning, solid waste, nearest utilities, storages of chemical and fuel, and traffic disruption. Structured interviews with seven senior engineers in the field of construction projects have been conducted. The main purpose of the structured interviews was to collect data belong to the relative weight of the chosen indicators. The senior engineers were asked to rank the indicators according to their relative importance in each group. They also, asked to rank the groups at the same manner. Statistical analysis has been conducted to calculate the relative weight of the indicators in each group. The relative weight of each group has been calculated in the same manner. The global weight of each indicator has been conducted by multiplying the relative weight of the indicator by the relative weight of the group that involves this indicator. Finally, a list of weighted environmental impact indicators has been established. These indicators represent the environmental impact of the construction projects in the construction phase in Egypt. The established list aims the civil engineers in the construction sites to become aware of the construction process impacts on the environment.

3. Indicators Identification

Table 1 shows a list of environmental impact indicators of construction projects in the construction phase. The indicators divided into four groups: 1) Ecological indicators; 2) Resources indicators; 3) Social indicators; and 4) Construction indicators. The ecological indicators group includes: Dust generation; 2) Noise; 3) Air quality; 4) Water quality; 5) Vibration; 6) Erosion. The Resources group includes: 1) Materials consumption; 2) Energy consumption; 3) Water consumption; and 4) Power consumption. The social group includes: 1) social disruption; 2) Social health; and 3) Social safety. The construction group includes: 1) De-watering work site; 2) Road cleaning; 3) Solid waste; 4) nearest utilities; 5) Storage of chemicals and fuel; and 6) Traffic disruption. The last column of Table 1 demonstrates the description of each indicator. Table 2 shows the responds (S1, S2, S3, S4, S5, S6, and S7) of seven senior engineer work in the field of construction projects. The senior engineers were asked to rank the indicators in each group in ascending order from the lowest environmental impact indicator to the most environmental impact one. The groups were ranked in the same manner. Statistical analysis has been made to calculate the average of each indicator and each group. The average = (S1+S2+S3+S4+S5+S6+S7)/7. The indicators were ranked in ascending order according to their average value in the last column. The groups have been ranked at the same manner. Table 3 shows the calculations of the relative normalized weight of the indicators. Column one of Table 3 contains the indicators or the sub-group of indicators, and the main group. Column two contains the number of indicators in each sub-group and the total group. Column three contains the rank of indicators, sub-group of indicators, and the main groups. Column four contains the non-normalized weights. Column five contains the normalized weights. The indicator's normalized weight equals the divide of the indicator non-normalized weight by the total non-normalized weight of the indicators in the same group. The global relative weight of the indicator has been calculated by multiplying the total normalized weight of the group by the total normalized weight of the indicator. The global relative normalized weight of the indicator is the environmental impact of the indicator.

Table1. Environmental impact indicators of construction projects

Groups	Indicators	Description
Ecological indicators (A)	1- Dust generation.	Impact of dust generation
	2- Noise.	Impact of noise
	3- Air Quality.	Impact on air quality
	4- Water quality.	Impact on water quality
	5- Vibration.	The vibration impact.
	6-Erosion.	Erosion of soil
. Resource indicators(B)	1- Materials consumption.	Material consumption of the project.
	2- Energy consumption (fuel)	Energy consumption of the project.
	3- Water consumption.	Water consumption of the project.
	4-Power consumption.(electricity)	Power consumption of the project.
Social indicators (C)	1- Social disruption.	The disruption impact on social.
	2- Social health.	The impact on social health.
	3- Social safety.	The impact on social safety.
Construction indicators (D)	1- De-watering work sites.	The de-watering impact of work sites.
	2- Road cleaning.	The impact on road cleaning.
	3- Solid waste.	The solid waste impact.
	4- Nearest Utilities.	The impact on nearest utilities.
	5- Storage of chemicals and fuel.	The impact of the storage of chemicals and fuel.
	6-Traffic disruption.	The impact on traffic.

Table 2. senior engineers' responds

Criteria	Indicators	S1	S2	S3	S4	S5	S6	S7	average	Rank
Ecological indicators (A)	1- Dust generation(EPA)	3	6	6	5	4	3	2	4.14	5
	2- Noise.(EPA-Egyptian code)	2	5	4	6	3	5	2	3.86	4
	3- Air Quality. .(EPA-Egyptian guide)	1	4	6	1	6	6	1	3.57	3
	4- Water quality. .(EPA-Egyptian guide)	4	3	6	2	5	4	1	3.57	3
	5- Vibration.(EPA)	5	2	4	3	2	2	4	3.14	2
	6-Erosion.(EPA)	6	1	4	4	1	1	3	2.6	1
. Resource indicators(B)	1- Materials consumption.(EPA)	3	4	4	3	4	1	1	2.86	3
	2- Energy consumption (Fuel).(EPA)	2	1	2	1	3	2	1	1.71	1
	3- Water consumption.(EPA)	1	3	4	2	2	4	2	2.57	2
	4-Power consumption (Electricity)(EPA)	4	2	2	4	1	3	2	2.57	2
Social indicators (C)	1- Social disruption.(EPA)	3	1	1	2	1	3	2	1.86	2
	2- Social health.(EPA)	2	2	3	1	3	2	1	2	3
	3- Social safety.(EPA)	1	3	2	3	2	1	1	1.71	1
Construction indicators (D)	1- De-watering work sites(EPA)	6	1	4	4	2	1	4	3.14	2
	2- Road cleaning.(EPA)	2	4	6	5	3	2	3	3.57	3
	3- Solid waste.(EPA)	3	3	5	1	4	5	1	3.14	2
	4- Nearest Utilities (EPA)	5	5	5	6	5	3	4	4.71	5
	5- Storage of chemicals and fuel.(EPA)	4	2	4	2	1	4	3	2.86	1
	6-Traffic disruption.(EPA)	1	6	6	3	6	6	2	4.29	4
Criteria	1-Ecological indicators (A)	1	4	4	1	4	1	1	2.29	1
	2-Resource indicators (B).	3	2	3	2	3	2	1	2.29	1
	3-Social indicators(C).	2	1	2	3	2	4	2	2.29	1
	4-Construction indicators (D).	4	3	1	4	1	3	3	2.71	2

Table 3. Calculation of Environmental impact indicators' global weight.

Indicators/sub-group of indicators/main groups	No. of indicators	rank	Non-normalized weight	Normalized weight	Total normalized weight	Global weight= (group's total normalized weight * indicator's total normalized weight)
1- Dust generation.	1	5	5	(5/18)*100=27.78	27.78	(0.2*27.78)=5.56
2- Noise.	1	4	4	(4/18)*100=22.22	22.22	(0.2*22.22)=4.44
3- Air Quality.	1	3	3	(3/18)*100=16.67	16.67	(0.2*16.67)=3.33
4- Water quality.	1	3	3	(3/18)*100=16.67	16.67	(0.2*16.67)=3.33
5- Vibration.	1	2	2	(2/18)*100=11.11	11.11	(0.2*11.11)=2.22
6-Erosion.	1	1	1	(1/18)*100=5.55	5.55	(0.2*5.55)=1.11
Sum	6	18			100	
1- Materials consumption.	1	3	3	(3/8)*100=37.5	37.5	(0.2*37.5)=7.5
2- Energy consumption (Fuel).	1	1	1	(1/8)*100=12.5	12.5	(0.2*12.5)=2.5
3- Water consumption.	1	2	2	(2/8)*100=25	25	(0.2*25)=5
4-Power consumption (Electricity)	1	2	2	(2/8)*100=25	25	(0.2*25)=5
Sum	4	8			100	
1- Social disruption.	1	2	2	(2/6)*100=33.33	33.33	(0.2*33.33)=6.67
2- Social health.	1	3	3	(3/6)*100=50	50	(0.2*50)=10
3- Social safety.	1	1	1	(1/6)*100=16.67	16.67	(0.2*16.67)=3.33
Sum	3	6			100	
1- De-watering work sites.	1	2	2	(2/17)*100=11.77	11.77	(0.4*11.77)=4.71
2- Road cleaning.	1	3	3	(3/17)*100=17.65	17.65	(0.4*17.65)=6.66
3- Solid waste.	1	2	2	(2/17)*100=11.77	11.77	(0.4*11.77)=4.71
4- Nearest Utilities.	1	5	5	(5/17)*100=29.41	29.41	(0.4*29.41)=11.76
5- Storage of chemicals and fuel.	1	1	1	(1/17)*100=5.88	5.88	(0.4*5.88)=2.35
6-Traffic disruption.	1	4	4	(4/17)*100=23.53	23.53	(0.4*23.53)=9.41
Sum	6	17			100.01	

1-Ecological indicators (A)	1	1	1	(1/5)*100=20	20	
2-Resource indicators (B).	1	1	1	(1/5)*100 = 20	20	
3-Social indicators(C).	1	1	1	(1/5)*100=20	20	
4-Construction indicators (D).	1	2	2	(2/5)*100=40	40	
Sum	4	5			100	

Table 4. Indicators' weight and ranking

Groups	Indicators	Weight	Rank in group	Rank in total
Ecological indicators (A)	1- Dust generation.	5.56	1	7
	2- Noise.	4.44	2	10
	3- Air Quality.	3.33	3	11
	4- Water quality.	3.33	3	11
	5- Vibration.	2.22	4	14
	6-Erosion.	1.11	5	15
. Resource indicators(B)	1- Materials consumption.	7.5	1	4
	2- Energy consumption (fuel)	2.5	3	12
	3- Water consumption.	5	2	8
	4-Power consumption.(electricity)	5	2	8
Social indicators (C)	1- Social disruption.	6.67	2	5
	2- Social health.	10	1	2
	3- Social safety.	3.33	3	11
Construction indicators (D)	1- De-watering work sites.	4.71	4	9
	2- Road cleaning.	6.66	3	6
	3- Solid waste.	4.71	4	9
	4- Nearest Utilities.	11.76	1	1
	5- Storage of chemicals and fuel.	2.35	5	13
	6-Traffic disruption.	9.41	2	3

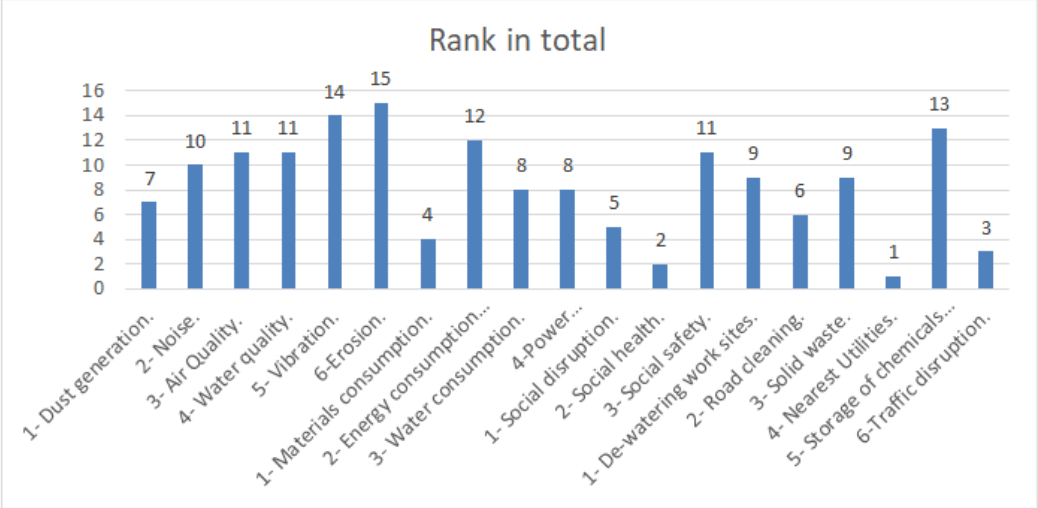

Figure1. Ranking of Indicators

4. Results and discussion

Table 4 shows the indicators' weights and ranking. The nearest utilities indicator is the most environmental impact indicator. The indicator has a relative weight equals 11.76. Rizqa and Abusharar [4] conducted their research in Gaza strip, and found that "Breakage of underground pipes (electric power cables, telephone lines, water pipes,..etc)" is ranked in the 11th position. In Egypt, the impact of construction projects on the nearest utilities is because of the absence of clear maps of the underground utilities. The second indictor in this study is the social health indicator. The indicator has a relative weight equals 10. Rizqa and Abusharar [4] conducted their research in Gaza strip, and found that "public health effect" is ranked in the 14th position. The third ranked indicator is the traffic disruption indicator. The indicator has a relative weight 9.41. Rizqa and Abusharar [4] conducted their research in Gaza strip, and found that "Increase in external road traffic due to construction site transport" is ranked in the 8th position. The

fourth ranked indicator is the material consumption. The indicator has a relative weight equals 7.5. Rizqa and Abusharar [4] found that "Raw materials consumption" is ranked 7th position. The fifth indicator is the social disruption indicator. The indicator has relative weight equals 6.67. Rizqa and Abusharar [4] conducted their research in Gaza strip, and found that "Social disruption" is ranked in the 5th position. The sixth indicator is the road cleaning indicator. The indicator has relative weight equals 6.66. The seventh indicator is the dust generation indicator. The indicator has a relative weight equals 5.56. Ijigah et al, [1], conducted their reaserch and found that, the "Dust" is ranked in the 11th position. Rizqa and Abusharar [4] conducted their research in Gaza strip, and found that "dust generation" is ranked in the 1th position. The eighth ranked indicators are the water consumption and the power consumption indicators. The two indicators have a relative weight equals 5. Rizqa and Abusharar [4] conducted their research in Gaza strip, and found that "use of water resources" is ranked in the 20th position. Rizqa and Abusharar [4] conducted their research in Gaza strip, and found that "Electricity consumption" is ranked in the 23th position. The ninth ranked indicators are de-watering indicator and the solid waste indicator. Each indicator has a relative weight equals 4.71. The tenth indicator is the noise indicator. The indicator has a relative weight equals 4.44. . Ijigah et al, [1], conducted their reaserch and found that, the "Noise from construction operation" is ranked in the 6th position. Rizqa and Abusharar [4] conducted their research in Gaza strip, and found that "Noise pollution" is ranked in the 2th position. The eleventh ranked indicators are the air quality, the water quality, and social safety, where, each indicator has a relative weight equals 3.33. Ijigah et al, [1], conducted their reaserch and found that, the "air pollution and water pollution" are ranked in the12th and 9th position respectively. Rizqa and Abusharar [4] conducted their research in Gaza strip, and found that "Air pollution, water pollution, and public safety" are 4, 12, and 22 ranked in the 4th, 12th , and 22 respectively. The twelfth ranked indicator is the energy indicator. The indicator has a relative weight equals 2.5. Rizqa and Abusharar [4] conducted their research in Gaza strip, and found that "Energy consumption" is ranked in the 13th position. The thirteenth ranked indicator is the storage of chemicals and fuel indicator. The indicator has a relative weight equals 2.35. The fourteenth ranked indicator is the vibration indicator. The indicator has a relative weight equals 2.22. The fifteenth ranked indicator is the erosion indicator. The indicator has a relative weight equals 1.11. Ijigah et al, [1], conducted their research and found that, the "soil erosion" is ranked in the 4th position. The construction indicator group has the most environmental impact of the construction projects in the construction phase in Egypt. The construction group has a total normalized weight equals 40. The ecological group, the resources indicator group, and the social indicator group, have the same total normalized weight equals 20.

Table 5 shows the result of proposed solution to face the adverse impacts of construction projects on the environment. As shown in Table 5, "search about alternative sources of energy to mitigate the adverse impacts of construction projects on the environment is ranked in the first position. The proposed solution "search about alternative construction technologies" is ranked in the second position. The proposed solution "search about alternative raw materials" is ranked in the third position. The results show the massive need of search about alternative sources of energy, search about alternative construction technologies, and search about alternative raw materials, to mitigate the adverse impacts of construction projects on the environment.

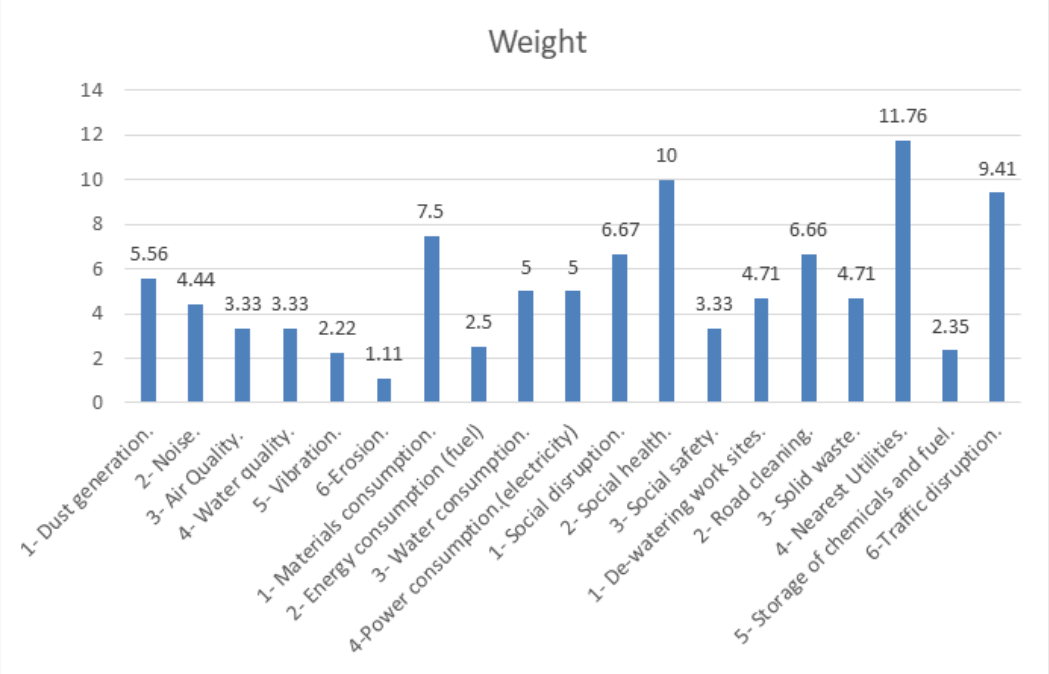

Figure2. Weigh of Indicators

Table 5 Proposed solutions to face the adverse impacts of construction projects on the environment.

Proposed solution	Q1	Q2	Q3	Q4	Q5	Q6	Average	Rank
Search about alternative construction technologies to mitigate the adverse impacts of construction projects on the environment.	3	1	1	3	3	3	2.33	2
Search about alternative sources of energy to mitigate the adverse impacts of construction projects on the environment.	2	3	3	2	3	2	2.50	1
Search about alternative raw materials to mitigate the adverse impacts of construction projects on the environment.	1	3	2	1	1	1	1.5	3

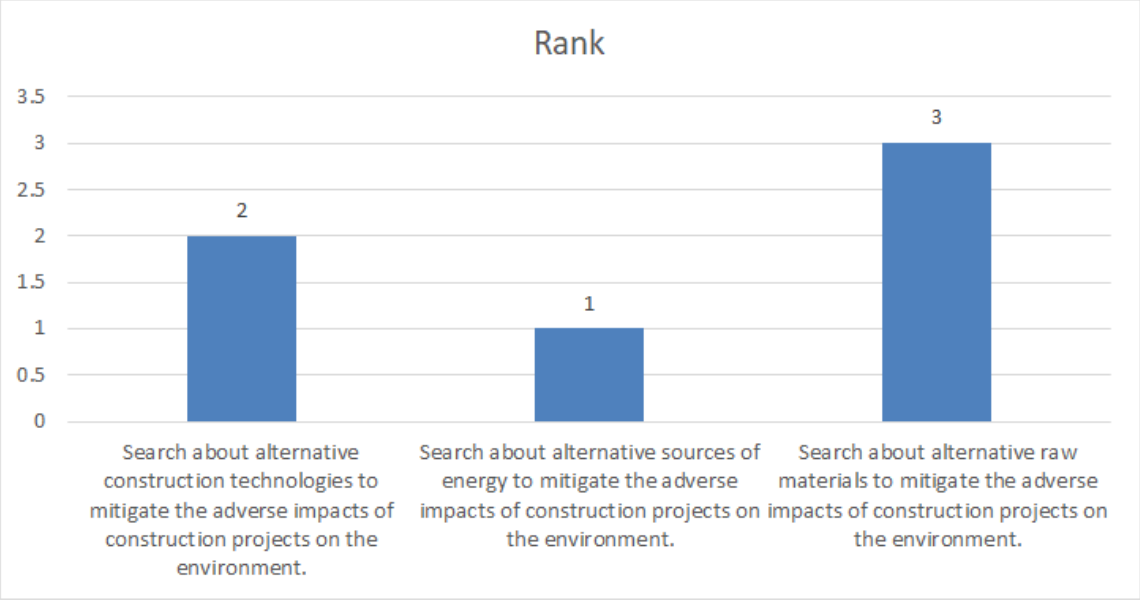

Figure 3. Ranking of proposed solutions

5. Conclusions and recommendations

Conclusions

The results showed that the construction sector has the massive direct and indirect impacts on the environment. Based on the interviews results, the following conclusions can be drawn:

1. Results showed that "nearest utilities", "social health", "traffic disruption", and "materials consumptions" have ranked in the 1st, 2nd, 3rd, and 4th positions respectively. These results reflect the severity and frequency of these impacts on environment.
2. Results showed that "Construction indicators" is the most important criteria that affect the environment in Egypt in the construction phase of the construction project.
3. Results showed that the dust generation, the noise, the air quality, and the water quality have massive effect on the ecological environment.
4. Results showed that "material consumption", "Energy consumption", "water consumption" , and "power consumption" are considered the most important indicators that shows the massive effect on the construction on the world resources.
5. Results showed that "social health", "social disruption", and "social safety" represents the massive effect of the construction projects in the construction phase on the environment.
6. 6. Results showed that "nearest utilities", "traffic disruption", and "road cleaning" are the most important indicators in the construction criteria. Nearest utilities in Egypt severs form the absence of clear maps that may explain the different utilities about the project site.
7. The results of this study can be very useful to enhance the awareness regarding the environmental impacts of the construction projects in the construction phase. The results of this study can help in making environmentally friendly construction plans in the early stage of construction project. Moreover, the results of this study will be useful to architects, designers and builders in order to carefully design buildings and other infrastructure that are environmentally friendly and sustainable.

8. The results of this study can be used to develop an environmental impact assessment model. The model can be used to evaluate the construction projects in the construction phase.

Recommendations

The results of this study reveal that the following recommendations should be considered:

1. The environmental impact of the construction projects needs more efforts of the governments and people whom working in the field of construction industry.
2. Researches in the field of the environmental impact should be developed.
3. Researcher should be look for alternative technologies to mitigate the effect of construction projects on the environment.
4. Researchers should be look for alternative sources of energy and power to decrease the dependency on the natural energy and power sources.
5. Researchers should be look for alternative materials to decrease the dependency on the natural materials.
6. The governments should obligate the contractors in the field of construction to apply the instructions of the environmental laws and rules.

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