Integrated Solid Waste Management and Development of Analytical Hierarchy Process (AHP) method for Collection and Transportation In Kandahar city, Afghanistan

Fida Mohammad Sahil

Abstract- This paper assessed current situation of solid waste management system in Kandahar city, Afghanistan which is one of the south Asian developing countries, whose economic growth and changing life style have increased in recent years, so these changes have significantly increased the quantity of municipal solid waste (MSW), which can causes air, surface and ground water pollution. AHP model was applied to compare different alternatives base on collection and transportation methods, of the waste generation per capita per day. Kandahar city population generate 937 tonnen of solid wastes every day, on an average 59% of the waste is collected and transfer to open dump disposal site. The remaining waste go through open ignore therefore, the (AHP) model will provide a sustainable collection and transportation services, safe and healthy environment with increased quantity of municipal solid waste (MSW). The numbering issue is that all types of municipal solid waste are dumped in one landfill that is located 8 km far away from the city center, in Haji-Amirlalai villages, but it is operated as a dump site.

Index Terms— Municipal Solid Waste (MSW) • Municipal Solid Waste Management (MSWM) • Analytical Hierarchy Process (AHP) • Collection and Transportation, Kandahar City.

1 INTRODUCTION

Since the early 1970s, Solid Waste Management (SWM) in developing countries has received increasing attention from researchers and policy makers concerned to establish a sustainable solid waste management system (Gerlagh et al. 1999). Solid Waste management is an important facet and complicated process which could do with many technologies and methods. In any developing country, the threats posed by improper handling and disposed of solid wastes (though often ignored) contribute to the high level of mortality and morbidity (Medina et al. 2002). Regardless, to protect public health, environment and aesthetics with the economical acceptance, there is need to integrate all procedure into environmental guidelines and standard.

The most important barriers were the solid waste personnel education, waste collection & segregation and government finances. Furthermore, the relationship between the factors was dependent of the stakeholder involvement and collaboration between different sectors (Troschinetz & Mihelcic. 2009). The increasing scale of economic activity, industrialization, urbanization, rising standards of living and population growth, has led to an increase in the quantity of waste generated. According to the first economic development and population growth, the crucial role in protecting the environmental aspect and the public health, performing efficient solid waste management should be a priority for a city in developing countries (Jafari et al. 2010).

Lack of proper collection and transportation facilities, limited community participation and monitory resources, at times, results in improper or no transportation vehicle forwaste disposal adding another dimension to the ever rising cycle of problems (Zerboc et al. 2003). Environmental sound of solid waste management must go beyond the mere safe disposal. It should include minimization actions, reuse and recycling activities, proper treatment and finally safe disposal (Stockholm et al. 2003).

The original purpose of ISWM was to help decision makers select an optimum waste management system to meet specific waste management objectives (Janet et al. 2011). The optimal concentration of the waste management system for a particular community, ISWM consider: stakeholder needs, community context including characteristic of waste and distances to resource recovery markets and the various available methods of a waste prevention, resource recovery and disposal (Kollikkathara et al. 2009). Worldwide, Municipal Solid Waste (MSW) has increased and with it, higher pressure has been placed on solid waste management system. This is due to the overall growing population best categorized as a “construction-oriented society”, with less conscientious consumption patterns and with higher living standards.

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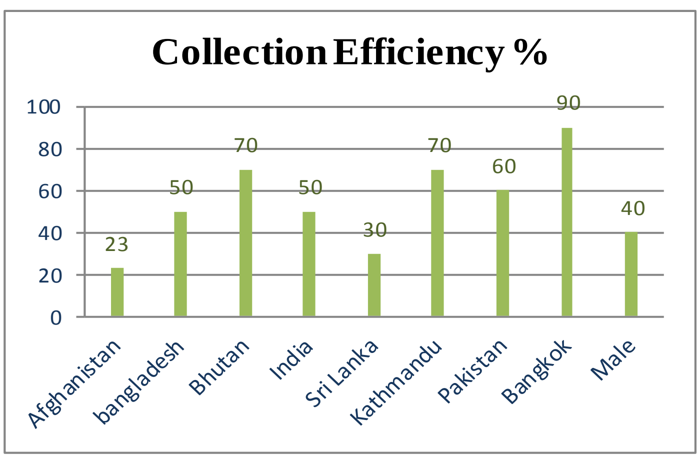
2 LITERATURE REVIEW

Municipal Solid Waste (MSW) refers to all materials generated from human, animal, economic and industrial activity that is normally solid and discarded as worthless or not needed. The discarded waste is comprised of non-hazardous domestic, street sweeping, drainage cleaning, construction and demolition waste, and industrial (office and warehousing operation) sources (Filemon and Uriarte, 2008). The MSW collection service, provided by either the private or public sector, includes many activities and requires numerous collectors and equipment (Garcia-Sanchez et al. 2008).

MSW quantity, type of the equipment, and the distance MSW transported and labor requirement are the key factors with a significant impact on the collection of MSWM. Inefficient MSW collection can rapidly deplete resources and energy (Alam et al. 2008). MSW collection efficiency has thus attracted increasing attention and is also a major concern among many local environmental authorities worldwide. Collection must also serve all collection points to achieve public satisfaction (Sharholy et al. 2007). If collection is not regular and thorough, waste will build up at collection points and overflow from containers making those sites unpleasant and hazardous to health, which discourage their use. The collection frequency is vary from place to place, it is depend on central, commercial and residential area which collection are done daily two time and three time per week respectively. (Fig 1) shows the collection efficiency of least developed countries in Asia (Glawe et al., 2007). Refuse collection involves the collection of waste from the point of generation to disposal sites by the using of collection vehicles. The collection period in time that vehicle arrives at the garbage area until the



completion of the routine.

Figure 1 Comparisons of collection efficiency of least developed countries in Asia (Glawe et al. 2007).

The frequency of collection can be twice a week, three times a week, daily, every other day, twice a day normally, depending on the size of the bins and waste generation rate. Additionally, the efficiency of household waste collection depends on the area size, length of route, the number of residences, set out rate, traffic situation and household behavior.

Additionally the most important concentration of the paper is to achieve convincible collection and transportation services for Kandahar city population, base on expert's opinion. Therefore, by using mathematical Analytical Hierarchy Process (AHP) methods we can also select the best approach, between the different alternatives which will be essentially convincible to researcher and must ensure that the instrument chosen is valid, reliable and likely gives the expected result. This was developed by Thomas L. Seety, (1980).

3 MATERIAL AND METHOD

Gathering information through the direct field observation of the study site, main means of the observation has been used as a way to examine the problem on the current operation on collection and transportation process, many collection points, waste containers and disposal sites, different waste transportation equipments and methods have been visited. Simultaneously this has contributed widely to grasp and understand more the state of the waste collection problem in Kandahar Municipality. When addressing the waste collection and transportation operating issues on a municipal level, vast number of the factor influence the waste collection and transportation management, however it is necessary to explore the way of the public engagement, with appropriately handling waste and relationship with local government, with regards to solid waste management.

Questionnaires were administrated together with managements of the solid waste collection department of Kandahar Municipality in existing 15 administrative districts expert's with personal interview. Additionally, to decide the purpose of the study based on its outcome. The purpose of the study can be classified as a basic, applied and practical the level of collection source of the allocated funds, state of the logistic and the problems confronting their operation.

Analytic Hierarchy Structure Model (AHSM) was developed in sustainable solid waste collection and transportation problem, and consists of objectives, criteria, sub-criteria and alternatives, based on distributed questionnaires and textual source of Kandahar municipality solid waste deportment and Environmental protection deportment. Fig 2 show hierarchy structure for AHSM that cover one objective (sustainable solid waste collection and transportation in the study area), five criteria (Environment aspect, Social aspect, Economical aspect, Technical aspect and Administrative aspect) and 20 sub-criteria, and 4 alternatives.

Distribution of questionnaire survey to Kandahar municipality solid waste expert's government and nongovernment policy makers, community and district authorities, academician and researchers, consist in Kandahar city to marks Saaty scale ratio between (1-9) numerical value is used as a relative intensity, to evaluate criteria, sub-criteria and alternatives for Analytic Hierarchy Structure Model

(AHSM). Pire-wise comparison are fundamental building blocks of the AHP, based on an expert's opinion and experience gained from the observation and continuous learning of system behavior. The next step is, after identifying the target/objective, criteria, sub-criteria, and alternatives, the respective levels can go through the pair-wise comparison matrix to get the weight for all the comparisons. This process is continuing until the accurate and effective collection and transportation technology is identified. Table 2 shows the process for the pair-wise comparison example.

Weight of each criterion with respect to the objective, weight of each sub-criterion with respect to criteria and weight of each alternative with respect to sub-criteria are calculated. According to equation (1), where Xi is the data point "i" and "n" are the weights of data point.

$$w_i = \sum \left[\frac{x_i}{\sum_n^i x} \right] \quad \text{…. (1)}$$

The validity of pair-wise comparisons outcome is obtained by checking consistency ratio CR. After considering the weights of sub-criteria in each alternatives, the weight of each alternatives are calculated, and finally, all alternatives would be ranked. The pair-wise comparison value according to Saaty scale ratio between (1-9) is used. Including this, to test the performance of pair-wise comparison, calculation 2 was used as a governance Equation 2 to find the maximum value of Eigen vector, consistency index CI, consistency ratio CR, and normalized value for each criteria and sub-criteria as follow:

$$\lambda \max = \frac{1}{n} \sum_{i=1}^{n} \left\{ \frac{\sum_{j=1}^{n} aij \times wj}{wt} \right\} \quad \text{…. (2)}$$

Hence (λ max) is the maximum and principal Eigen value, (n) is the size of matrix, (aij) is elements of pair-wise comparison matrix, (wj) and (wt) is Eigen value for (J) and (i) element value respectively.

$$CI = \frac{\lambda \max - n}{n-1} \quad \text{…. (3)}$$

$$CR = \frac{CI}{RI} \quad \text{…. (4)}$$

< or =10% Acceptable

> 10% Not Acceptable

Table 2 Value matrix for pair-wise comparison of criteria.

Table 1 Scale of preference

Verbal judgment of importance	Numerical rating
Equal importance	**1**
Equal to moderate importance	**2**
Moderate importance	**3**
Moderate to strong importance	**4**
Strong importance	**5**
Strong to very strong importance	**6**
Very strong importance	**7**
Very strong to extremely strong importance	**8**
Extreme importance	**9**

Generally if the consistency ratio (CR) is equal or less than 10% percent, the consistency is acceptable, if the CR is greater than 10% percent we need to revise the subjective judgment.

The final scores of AHP have been calculated by summing the multiplication of weight of specific alternative that related sub criteria weighting scores that would be the final results of the AHP modeling. According to equation (5), the AHP score has been calculated:

$$AHP_w = \sum_i^1 w_{sui} \times w_{sc} \quad \text{… (5)}$$

Where "W sui" is the final weight of sub-criteria "i" and "W sc" is the weight of alternative.

4 Result and Discussion

With an increasing population and urbanization, contributes to the increase of SW volume and type. This situation has become a major challenge for the solid waste management in Kandahar city. Most of countable municipal solid waste comes

Objective	[illegible]	cial	Economic	Technical	Administrative	Weight
Environment	1	X	X	X	X	A1
Social	1/X	1	X	X	X	B1
Economic	1/X	1/X	1	X	X	C1
Technical	1/X	1/X	1/X	1	X	D1
Administrative	1/X	1/X	1/X	1/X	1	E1

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from residential areas, commercial, institution area, cleaning of street, drainage and canal cleaning. Description of source and type of SW in Kandahar city is shown in Table 3.

The municipal solid waste collection and transportation services area of Kandahar city has a 240 Km2 square kilometer and divided in 3 region, which are sub-divided in 450 metal bin, 150 concrete bin and open dump collection point especially in lower residential area.

1. Remote service area: government offices and crowded commercial area, every day or twice a day.
2. Normal service area: institutional, commercial and high and middle residential income areas, from 8:00 am to 2:00 pm and (3:30 - 6:30) pm every, or one after another day.
3. Base on phone call service area: The community leader call to authorized person to collect and transport the solid waste from selected collection point, especially in lower residential income areas.

Source	Type of waste generation	Type of solid waste
Domestics	Single household	Food scraps, glass, metal, ashes, dust, send and domestics hazardous waste
Commercial areas	Shopping centers, markets, restaurants, office	Food scraps, glass, metal, dust, send, paper and hazardous waste
Institutional areas	Schools, government offices and center	Food scraps, glass, metal, dust, send, paper, hazardous waste and commercial areas
Public facilities	Drainage and canal cleaning, street sweeping and parks	Street cleanings, drainage and canal …..and general waste from recreational areas

Table 3 Source and type of MSW in Kandahar city

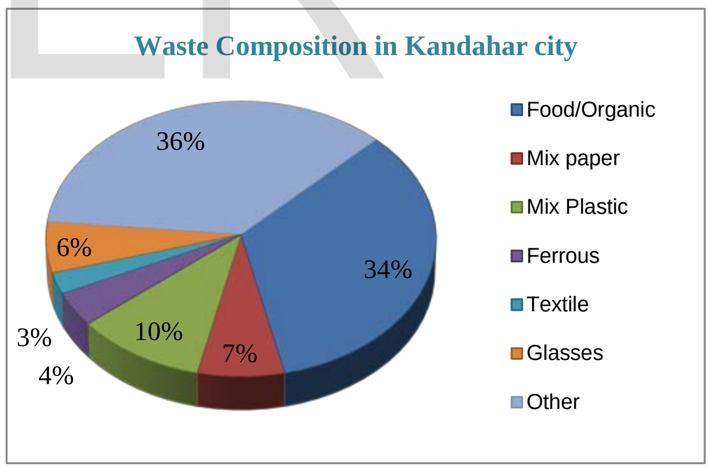
5 Study Area

Kandahar city is the capital of Kandahar province and the second large city in Afghanistan Kandahar municipality consists 15 administrative districts, Kandahar municipality solid waste collection and transportation deportment is responsible for the service of commercial, residential, institutional area and cleaning of street, drainage and canal. Public and private hospital, industrial waste, construction and demolition waste are not included in municipal solid waste collection and no private partnership in Kandahar municipality sector. The collection system is still one bin in the city, where agriculture waste is separated at source place and use us fuel in households.

Composition of MSW has to important consequences for planning and management. First the high organic content, accompanied by the hot and dry climate, result in the need for recurrent collection and the appropriate design from storage containers or bins to overcome the unpleasant smell, rodents and insects (Fig 2) shows average composition percentage of MSW in Kandahar city Afghanistan.

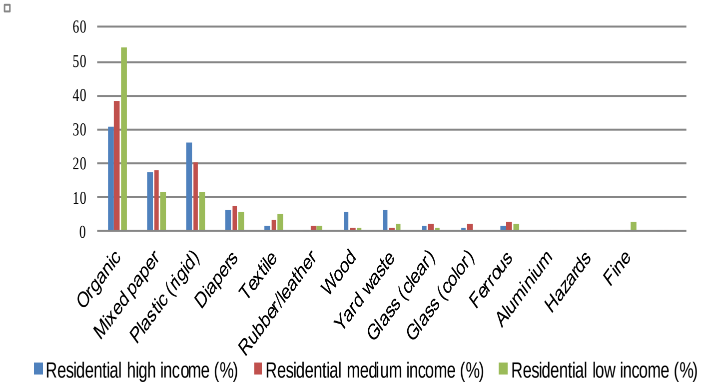
High population density, narrow of streets, luck of community participation and in adequate of right of ways challenges to improving the city's drainage. Diseases such as malaria, typhoid and Cholera are widespread. The situation of Kandahar city is getting worse due to population growth, urbanization and increased the amount of the solid waste.

Fig 2 Waste composition in Kandahar city



The waste generated by the different household for high, medium and low income economic, commercial and institutional categories are shown in (Fig 3) and the quantities of wastes are related to the economic conditions of the area. The average waste generation rate is 0.35 kg per capita per day, respectively. The city has experienced population fluctuation due to influxes of displaced persons and refugees caused by war and drought. Kandahar city population generate 937 tonnes cubic of solid wastes every day, on an average 59% of the waste is collected, transfer and disposed in the open dump site by municipality.

Fig 3 High, medium and low income composition categories percentage of MSW in Kandahar city.



6 AHP METHOD RESULT

Step 1: Analytic Hierarchy Structure Model (AHSM) was developed for sustainable solid waste collection and transportation. (Fig 4) shows hierarchy structure for AHSM that cover 1 objective, 5 main criteria, 20 sub-criteria, and 4 alternatives, according to the six experts' participant opinion.

Step 2: pair-wise comparisons of criteria, with respect to objective, pair-wise comparison of sub-criteria with respect to criteria, pair-wise comparison of alternatives with respect to each sub-criterion. The pair-wise comparison is based on questionnaire marks from six expert participants' opinion and there experience.

a) Pair-wise comparison of criteria, with respect to objective according to the six experts' participant consolidated opinion. Table 4 shows Pair-wise comparison matrix of criteria, with respect to the objective

b) Pair-wise comparison of sub-criteria, with respect to main criteria according to the six experts' participant consolidated opinion. Table 5 shows example of one Pair-wise comparison matrix of sub-criteria, with respect to environment main criteria

c) Pair-wise comparison of Alternatives, with respect to each sub-criteria Table 6 shows example of one Pair-wise comparison matrix of alternatives, with respect to resource conservation sub-criteria

Fig 4 shows hierarchy structure for AHSM

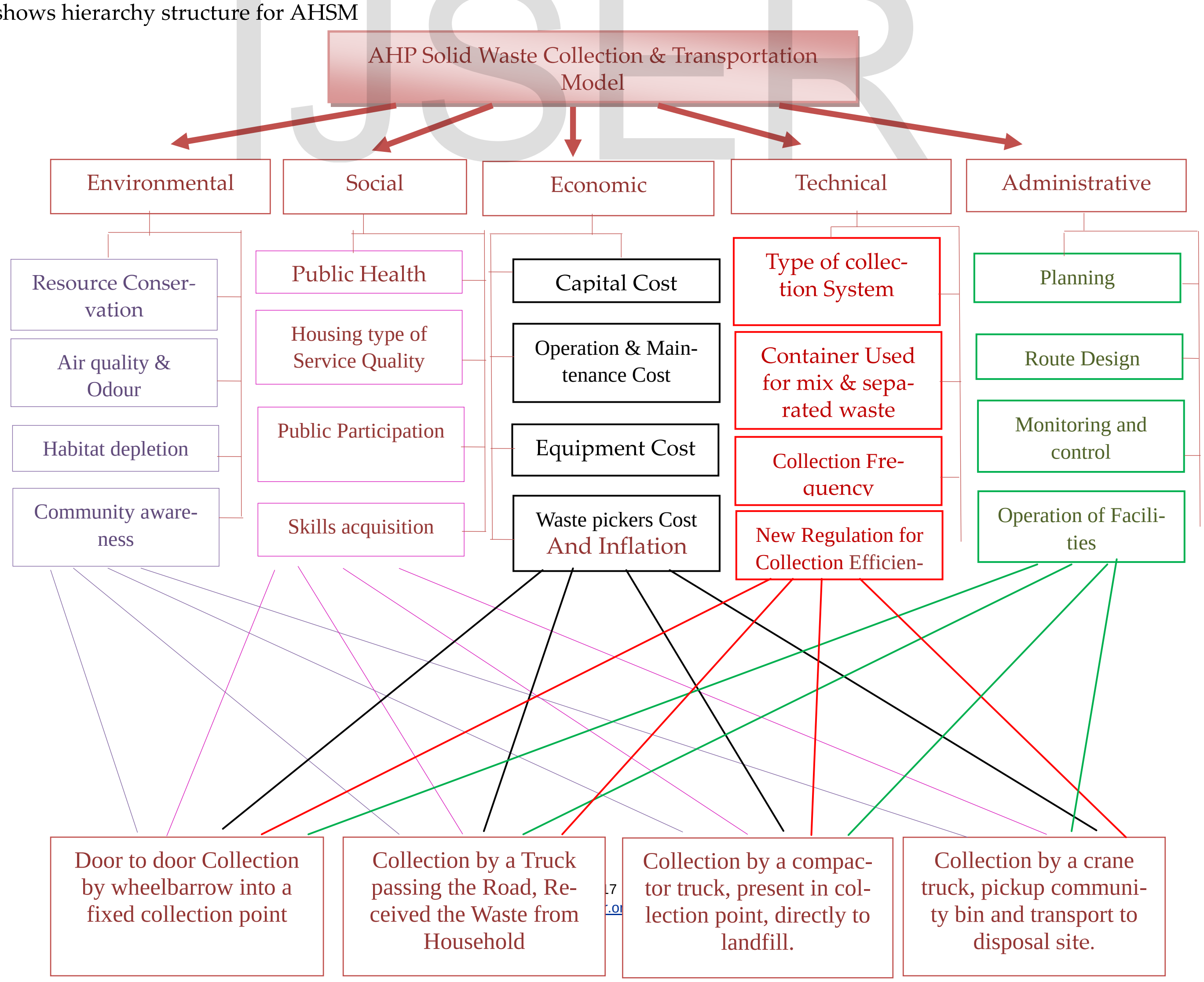


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Table 4 Pair-wise comparison matrix of criteria, with respect to the objective

	1	2	3	4	5	Criterion	Weights
1	1	2.69	0.58	1.83	1.24	Environment	30.5%
2	0.37	1	0.83	2.05	2.37	Social	9.8%
3	1.71	1.2	1	1.2	1.25	Economic	23.7%
4	0.55	0.49	0.83	1	1.31	Technical	22.6%
5	0.81	0.42	0.8	0.76	1	Administrative	13.4%

Table 5 Pair-wise comparison matrix of sub-criteria, with respect to environment

	1	2	3	4	Sub-Criteria	Weight
1	1	2.14	0.71	0.68	Resource Conservation	32.5%
2	0.47	1	3.94	0.53	Air quality & Odour	24.3%
3	1.4	0.25	1	2.63	Habitat depletion	21.2%
4	1.48	1.9	0.38	1	Community awareness	22.0%

Table 6 Pair-wise comparison matrix of alternatives, with respect to resource conservation

	1	2	3	4	Alternatives	Weights
1	1.00	1.57	0.34	0.47	Door to door collection by wheelbarrow into a fixed collection point	15.3%
2	0.64	1.00	1.81	0.89	Collection by truck passing the road, received the waste from household	22.1%
3	2.96	0.55	1.00	1.66	Collection by a compactor truck, present in the collection point, transport the waste directly to landfill	38.5%
4	2.15	1.13	0.604	1.00	Collection by Crane truck pickup community bin and transport to disposal site	24.1%

Step 3: The calculation of the final weight of each sub-criterion, weights of each sub-criterion are multiplied under the weight of main criteria. Table 7 shows calculation of final weight of each sub-criterion.

Table 7 Calculation of final weight of each sub-criterion

Main Criteria	Weight of Main Criteria	Sub- Criteria	Weight of Sub Criterion in %	Total Weight of Sub-Criterion
Environment Aspect	30.5%	Resource Conservation	32.5%	0.099
		Air quality & Odour	24.3%	0.074
		Habitat depletion	12.2%	0.037
		Community awareness	22%	0.067
Social Aspect	9.8%	Public Health Safety	17%	0.016
		Housing type of Service Quality	34.8%	0.034
		Public Participation	31.1%	0.03
		Skills acquisition	17%	0.017
Economic Aspect	23.7%	Capital Cost	38.9%	0.092
		Operation & Maintenance Cost	10.1%	0.024
		Equipment Cost	34.1%	0.081
		Waste pickers Cost And Inflation	16.9%	0.04
Technical Aspect	22.6%	Type of collection System	38%	0.086
		Container Used for mix & separated waste	14.1%	0.032
		Collection Frequency	24.7%	0.056
		New Regulation for Collection Efficiency	23.2%	0.052
Administrative Aspect	13.4%	Planning	15.5%	0.021
		Route Design	34.7%	0.047
		Monitoring and control	12.1%	0.016
		Operation of	37.7%	0.051

Facilities

Step 4: AHP scores and ranking for each alternative have been calculated by summing the multiplication weight of alternative that related to sub-criteria weight. Table 8 shows calculation of AHP scores of alternatives.

Table 8 shows calculation of AHP scores of alternatives.

Sub- Criteria	Door to door Collection by wheelbarrow into a fixed collection point	Collection by Truck passing the Road, Received the Waste from Household	Collection by a Compactor Truck, present in the collection point, directly to landfill	Collection by Crane Truck pickup community bin and transport to disposal site
Resource Conservation	(15.3*0.099)	(22.1*0.099)	(38.5*0.099)	(24.1*0.099)
Air quality & Odour	(21.6*0.074)	(20.4*0.074)	(24.9*0.074)	(33.1*0.074)
Habitat depletion	(7.3*0.037)	(13.1*0.037)	(29.8*0.037)	(49.8*0.037)
Community awareness	(31.1*0.067)	(18.3*0.067)	(25.2*0.067)	(25.4*0.067)
Public Health Safety	(13.5*0.017)	(13.8*0.017)	(45.7*0.017)	(27.1*0.017)
Housing type of Service Quality	(48.8*0.034)	(25.5*0.034)	(12.6*0.034)	(13.1*0.034)
Public Participation	(24.8*0.031)	(22.7*0.031)	(26.4*0.031)	(26.1*0.031)
Skills acquisition	(38.7*0.017)	(19.2*0.017)	(19.1*0.017)	(23*0.017)
Capital Cost	(26.6*0.092)	(33.8*0.092)	(21*0.092)	(18.5*0.092)
Operation & Maintenance Cost	(33.7*0.024)	(21.9*0.024)	(20.8*0.024)	(23.6*0.024)
Equipment Cost	(32.4*0.081)	(16.7*0.081)	(37.4*0.081)	(13.5*0.081)
Waste pickers Cost And Inflation	(32.7*0.04)	(12.3*0.04)	(39.3*0.04)	(15.7*0.04)
Type of collection System	(27.2*0.086)	(21.4*0.086)	(30.6*0.086)	(20.8*0.086)
Container Used for mix & separated waste	(28.6*0.032)	(17*0.032)	(25.8*0.032)	(28.6*0.032)
Collection Frequency	(33.2*0.056)	(18.1*0.056)	(21.7*0.056)	(27*0.056)
New Regulation for Collection Efficiency	(30.7*0.053)	(18.6*0.053)	(28.3*0.053)	(22.4*0.053)
Planning	(21*0.021)	(39.3*0.021)	(28.1*0.021)	(11.6*0.021)
Route Design	(11.2*0.047)	(31.2*0.047)	(26.8*0.047)	(30.8*0.047)
Monitoring and control	(21.8*0.016)	(25.6*0.016)	(28.3*0.016)	(24.3*0.016)
Operation of Facilities	(24.9*0.051)	(19.1*0.051)	(34.7*0.051)	(21.3*0.051)
Total Weight	**25.30**	**21.08**	**28.07**	**23.05**
Ranking	**Second**	**Fourth**	**First**	**Third**

7 Conclusion

The current waste management system is limited to collection, transportation, disposal (open dumpsite), and is characterized by lack of strategic planning, lack of institutional arrangement, lack of operation, lack of effective financial management and lack of environmental protection and their relationships. The selection of AHP method is applied to assign priorities, best alternatives based on hierarchy structure model for solid waste collection and transportation management. This is evaluated by authorized, government and nongovernment decision makers in order to standardized defined objectives by AHP models.

In order to achieve the MSW collection and transportation system in Kandahar city, experts' opinion for comparing the best collection and transportation alternatives. The result of AHP in term of goal, criteria, sub-criteria and alternatives weight and ranking shows that, best collection and transportation alternatives is compactor truck, passing through collection point and transfer the waste directly to landfill has the highest score (28.07%) and it is the most appropriate collection system technology for Kandahar city.

The research endeavors to include a holistic view of the solid waste collection and transportation situation, with AHP using methods for the first time in Kandahar city. Previous to this study, no research had been carried out in terms of solid waste management in Kandahar city; this study has partially filled that gap.

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