Strength, Weakness, Opportunity and Threat Analysis of Solid Waste Management at KUET Campus

By

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A thesis submitted in partial fulfillment of the requirements for the Degree of Master of Science in Civil Engineering

Khulna University of Engineering & Technology
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Declaration

This is to certify that this thesis work entitled "Strength, Weakness, Opportunity and Threat Analysis of Solid Waste Management at KUET Campus" has been carried out by Md. Razib Sarder in the Department of Civil Engineering, khulna University of Engineering & Technology, Khulna, Bangladesh. The above research or any part of this work has not been submitted anywhere for the award of any Degree or Diploma.

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Approval

This is to certify that this thesis work submitted by Md. Razib Sarder entitled "Strength, Weakness, opportunity and Threat Analysis of Solid Waste Management at KUET Campus" has been approved by the board of examiners for the partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering, Khulna University of Engineering & Technology, Khulna, Bangladesh in November 2017.

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Md. Razib Sarder

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Affectionately dedicated

To

my beloved parents

for their love, support and encouragement.

ABSTRACT

Waste management is a method used to reduce waste, mainly by means of source reduction and includes the recovery, recycling and reuse of waste products. The advantages of management are both eco-friendly and economically extensive, such as saving dumps and creating jobs. Integrated solid waste management (SWM) can be described as the selection and use of suitable engineering and management alternatives to achieve waste management goals. SWOT analysis is a great tool for this approach, which is one of various ideal planning tools for organizational management to ensure that clear goals are recognized for a project to recognize all the factors associated with positive and negative initiatives. To achieve this task, the process includes four factors namely Strengths, Weaknesses, Opportunities, and Threats which are rated using Analytical Hierarchy Process (AHP). This study explains SWM at KUET campus and may also be an innovator in solid waste management in other universities in Bangladesh.

The rate of solid waste generation has been observed as 0.099 kg/capita/day excluding construction, demolish and street sweeping waste, in which food and vegetable, paper, and plastic waste has been noticed as 52.04%, 42.01% and 3.70%, respectively. Some lemon peel, eggshells and others waste also has been produced as 0.30%, 0.20% and 1.75%, respectively. The average paper waste went into the market has been found as 63.34 kg/month which is very less compared to that of paper waste and the average plastic waste which has been given in to the market has been as 51.75 kg/month which is the 17.41% of plastic waste generated at this campus. The average monthly compost at solid waste management plant (SWMP) in KUET campus has found as 48.57 kg/month.

SWOT analysis of SWM has been performed through field level investigation, laboratory tests and questioner survey. There are nine strengths, six weaknesses, four opportunities and five threats of SWM at KUET campus have been identified. Door to door collection, Recycling, Composting, Transportation of Solid Waste, Manpower and equipment for SWM, Sorting of Solid Waste, Enforcement and Awareness for SWM, Financial support for SWM, Burning system of sanitary SW has been found as the first, second, third, fourth, fifth, sixth, seventh, eighth and ninth strength, respectively. Recycle of low density waste like paper and polythene, Burning Temperature at Burning Unit and Related Air Pollution, Training Program among Staff and awareness program among stakeholders, Roadside Construction Waste Deposition, Route Selection for Collection and Transportation of SW, Time for Decomposition of Degradable SW during Composting has been seen as the first, second, third, fourth, fifth and sixth weakness of SWM, respectively. Market Based Recycling of SW, Resource Recovery from Citrus Peel and Eggshells, and Route Selection for SW Collection and Transportation has been observed as the first, second, third and fourth opportunities in case of SWM at KUET campus. Damages of Equipment like Rickshaw-van, Damages of Roadside Waste Bins, Difficulties in Transportation of SW to the Ultimate Disposal Site, Damages of Waste Management Plant and Accidents among staff in Collecting, Transporting and Sorting of SW has been noticed as the first, second, third, fourth and fifth threats at this campus for SWM.

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Nomenclature

All the notation and symbols are defined where they first appear in the text or figures. For convenience, the more frequently used symbols and their meanings are listed below.

KUET	:	Khulna University of Engineering & Technology
SW	:	Solid Waste
SWM		Solid Waste Management
SWOT	:	Strength, Weakness, Opportunity and Threat
AHP	:	Analytical Hierarchy Process
SWMP	:	Solid Waste Management Plant
MSWM	:	Municipal Solid Waste Management
TOPSIS		Technique for Order Preference by Similarity to Ideal Situation
MSW		Municipal Solid Waste
MMTCE		Million metric tons of carbon equivalent
SO		strengths-opportunities
WO		weaknesses-opportunities
ST		strengths-threats
WT		weaknesses-threats
MCDM		Multi - Criteria Decision Making
ANP		Analytic Network Process
WM		Waste Management
ANC		Average of Normalized Column

CHAPTER I

INTRODUCTION

1.1 General

Waste management is the challenging experience in the most of the countries in the world. The difficulties varies from reducing generation of solid wastes, separating, change of habits, collection, carry, treatment, recycling and disposal of the solid waste materials. Growing environmental problems and the focus on material and energy recovery are progressively changing the orientation of solid waste control and planning. Presently, the main objective is to design maintainable and affordable solid waste control systems considering the range of management methods (Gakungu et al., 2012). Due to increasing inhabitants, modified consumption styles, financial growth, changing income, urbanization and industrialization, the creation of solid waste elements are increased (Ngoc and Schnitzer, 2009). Waste management is a technique used to accomplish waste minimization, mainly through minimization at source, but also such as recycle and reuse of elements. The advantages of waste management are both environmental and economical and wide in their protection such as the benefits of dump areas and also assemble employments (Dhande et al. 2005).

Solid waste has become one of the greatest problems and its control is one of the main issues now days. Developing countries face significant problem i.e. solid waste management in city as well as in village areas. The most apparent environmental damage triggered by solid waste is aesthetic. It is necessary to have precise information on planning a proper solid waste management. In contrast, lack of knowledge on the undesirable health resulting from solid waste has grown the incidence of contagious diseases. SWOT analysis is an excellent device to discover the chances and ways for starting and properly applying the MSWM program and by this model, proper action plans were developed for public organization to improve MSWM.

SWOT study was an outstanding device to understand more about the chances and ways for initiating and efficiently implementing the MSWM program and by this design, ideal action plans were created for public organization to enhance MSWM. The SWOT research is one of several ideal planning methods that are used for the management of a company to ensure that there is a clear purpose described for the project or venture, and that all aspects related to the effort, both good and bad, are recognized and resolved. In order to achieve this, the process includes four areas of consideration: strengths, weaknesses, opportunities, and threats of solid waste management. It should be observed that, when determining and classifying appropriate factors, the main concern is not just on inner issues, but also exterior elements that could affect the results of the project. The strengths, weaknesses, opportunities and threats can be ranked by fuzzy TOPSIS method and analytic hierarchy process (AHP).

This study concern about the Strengths, weaknesses, opportunities and threats of solid waste management adopted at KUET campus. Strengths, weaknesses, opportunities and threats of solid waste management at KUET campus has been measured through base line study, focused group discussion and laboratory analyses and has been ranked them through analytical hierarchy process (AHP).

1.2 Background of this Study

SWM is gradually becoming a major task in many places of developing countries because of fast urbanization and increase in population. This can be described by ineffective collection methods, insufficient coverage of the collection, processing system and inappropriate disposal. The question of interest is how to take care of this waste in the most efficient way and with the least adverse impacts especially in the fast urbanizing places of the developing countries, where the problems of solid waste management are becoming a serious risk to the human health and the surrounding environment. Defective SWM program is creating adverse ecological impacts like land and water pollution, responsible for contagious illnesses, obstruction of open drain and small canals and loss of bio-diversity and lack of life of landfill.

Modem urban centers consume significant amounts of resources including energy, water, food and raw materials, and they also generate bulk of waste materials. The success with which a city can manage these waste materials is one of the ability of the organizations within the town to work together to solve major town ecological issues (Middleton, 1995). There is no single best remedy to waste disposal, but a variety of possibilities exists. Solid waste is at the core of town environmental issues. The current public solid waste management practices especially collecting, processing and disposing are considered to be ineffective in the developing nations. The typical troubles are low collection coverage and irregular selection services, raw open disposal and burning without air and water quality management, the reproduction of flies and vermin; and the handling and management over informal waste picking or scavenging activities (Bartone, 1995). Generally, one third to two third of the public solid waste materials generated in the cities of the developing countries are not collected (World Resources Institution et al., 1996). Consequently, the uncollected waste, which is often also combined with individual and animal excreta, is thrown out simultaneously along the roads and in drainpipes, so leading to surging, reproduction of pest and rodent vectors and the spread of illnesses (Cointreau, 1982; UNEP-IETC, 1996; Zurbrugg, 2002). The uncontrolled and unscientific disposal of public solid waste materials has brought about an increasing number of incidents of risks to individual health; pollution of both surface and ground water which is in turn a serious individual hazard to wellness. Amazingly, the infrequent disposal of public solid waste materials in water bodies' resources and low lying areas without consideration of its effect on the environment is a common practice in many places of the developing countries (Medina, 2010; Zurbrugg, 2003; Da Zhu et al., 2008). All these waste management malpractices combined with the poor state of cleanliness make things extremely incredible to be occurring in the places of the least Developed Countries.

Pest and rodent vectors are drawn to the waste and can spread illnesses such as cholera and dengue fever. Utilizing water contaminated by MSW for showering, food irrigation and drinking water can also reveal individuals to disease microbes and other pollutants. The U.S. Public Health Service identified 22 human illnesses that are connected to inappropriate MSWM. Waste worker and pickers in developing countries are rarely protected from direct contact and injury, and the co-disposal of dangerous and medical waste materials with MSW presents serious health risk. Fatigue gases from waste collection automobiles, dust arising from disposal methods and the open burning of waste also promote our health-related issues (Singh, 2013).

In Bangladesh, due to deficiency of inspiration, attention, dedication, expertise as well as money a significant portion of waste materials, 40-60%, are not properly stored, gathered or disposed in the specific places for ultimate disposal. The efficiency of solid waste disposal relies on the selection of proper site and current global trend of waste control problems arises from unsustainable methods of waste disposal, which is ultimately a result of insufficient planning. World Health Organization (2014) classified Dhaka as one of the mostly contaminated places. Public Solid Waste is being generated at more quickly, appearing a serious control risk. Fast growth of industrial sectors, insufficiency of money, insufficient trained human resources, unsuitable technology and lack of knowledge of the community are the major restrictions of solid waste management for the fast growing city like Dhaka (Yasmin and Rahman, 2017). There is a growing amount of waste generation in Bangladesh and it is estimated to achieve 47,064 tons/day by 2025. The Waste Generation Rate (kg/cap/day) is predicted to increase to 0.6 in 2025 (Islam, 2016).

The governance of solid waste materials at most of the campuses in Bangladesh are operating through a crucial level due to the missing of appropriate services to deal with and get rid of huge quantity of SW. Indecorous disposal was accountable for increasing of health issues and insanitary problem which outcomes in ruining the beauty of the campuses. But in recent years the waste management program at KUET campus is considerably improving and till now the authority trying to level up the SWM program to achieve at meridian level to becoming a successfully healthy and eco-friendly campus. Commonly solid wastes are produced at KUET campus from human activities and the major elements of solid wastes are food wastes, paper, plastic and some special waste materials (sanitary wastes). In the recent time, due to the impressive development of features of KUET, some construction waste is also produced. For proper management over solid waste materials, several features such as waste storage, collection, transport, treatment and disposal systems are implemented by KUET administration and the sustainability of solid waste management is very much important (Sarder et al. 2015).

1.3 Objectives and Scope of this Study:

The main objective is SWOT analysis of SWM at KUET campus, which includes the analysis of strength of SWM, weakness of SWM, future possibilities or opportunities of SWM and threats associated with SWM at KUET campus. The objectives of this research are given below:

A. To assess the present scenario and strength, weakness, opportunity and threat of SWM at KUET campus and to rank them.
B. To adopt appropriate techniques to overcome the limitations associated with solid waste Management.
C. To investigate the possibility of market based solution of SWM at KUET campus.
D. To check the sustainability criteria of SWM at KUET campus.
E. To propose a sustainable and low cost SWM management system at KUET campus.

Nowadays, most country encounters challenges to manage the solid waste due to high waste generation rate, lack of landfill and lack of information and appropriate guidance. Aim of solid waste control depends on adopting a sustainable approach which includes appropriate storage space, collection, transport, treatment, resource recovery, utilization of equipment involved in waste management and human resources, finding out the strengths, weakness, opportunities, threats and encourage techniques to overcome the weakness. Presently solid waste storage space, collection, transport, treatment and disposal system at KUET campus is going through an organized way and campus becomes more aesthetically and environmentally attractive. This study delineates the appropriate solid waste management at KUET campus and it may be the innovator for solid waste management to the others university of Bangladesh.

1.4 Organization and Thesis Outline:

The organization and outline of this works as appeared in this dissertation is illustrated in figure 1.1

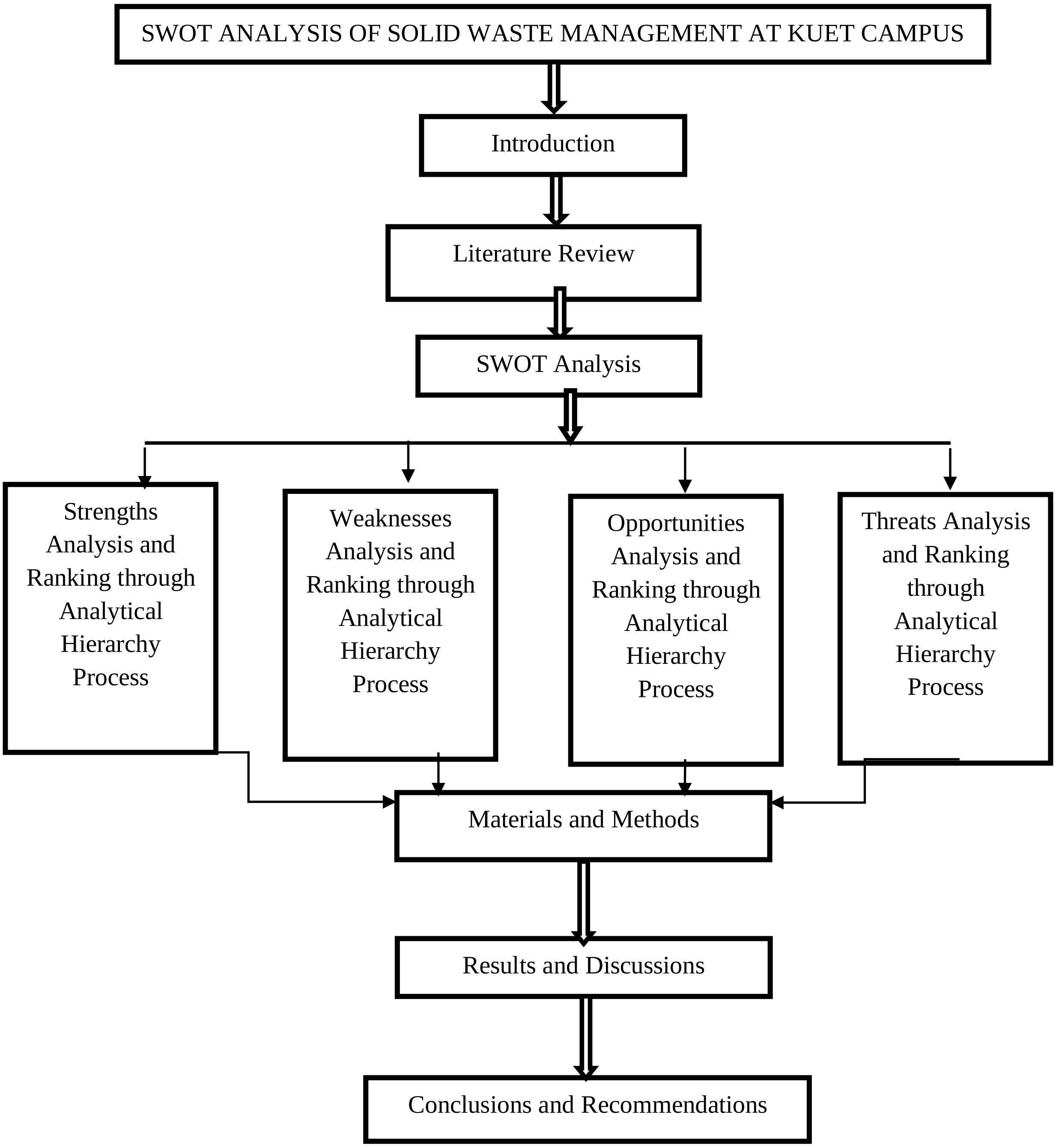


Figure 1.1 Diagram of the thesis outline

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

Urbanization and population growth are completely accountable for high rising rate of solid waste and its proper control is an issue of most of the nations. Solid waste materials are all the wastes materials coming as a result of human activities that are normally solid and are extracted as useless or undesirable. The term is comprehensive and involves the heterogeneous mass of throw away from homeowners and commercial activities, as well as the more homogeneous accumulations of a single commercial activity. Insufficient management of solid waste is accountable to growth of disease, environmental deterioration and supreme effect on livelihoods. Inappropriate management of waste presents a menace to Environment and eventually in the accomplishment of sustainable development. Waste being one of the members of greenhouse gases, impacts climate change and it is for this reason that as a country need to develop sustainable waste management systems and to overcome this growing global challenge. Solid Waste Management (SWM) is a much bigger issue of developing financial systems as compared to developed countries. The South Asian region is confronted with the task of providing scientific SWM solution to its population. The lack of knowledge and execution of current defective structure also contributes to the issue of defective SWM.

Thus, in order to provide sustainability of solid waste management at KUET campus, the KUET authority has to take some measures in the segment of waste storage, collection, transportation, sorting, waste treatment and disposal. SWOT study is an effective device for analyzing the sustainable solid waste management practices. A SWOT analysis relates to an analysis of Strengths, Weaknesses, Opportunities and Threats that are related with the solid waste management at KUET campus. Analytical Hierarchy Process (AHP) is used for ranking of different strengths, weaknesses, opportunities and threats.

2.2 Solid Waste

Waste, trash, rubbish, garbage, or junk is the name given to any ineffective or undesirable material. Although, the term "waste" is the normal used, the others are used generally as alternatives, even though they have specific definitions. Rubbish or trash is mixed of household waste, such as papers and packaging. The Americans define food waste or garbage to be table waste and kitchen waste. Junk or scrap is metallic part of the waste stream. The European Union defines waste as an object the holder discards, intends to discard or is required to discard. According to the United Kingdom's Environmental Protection Act 1990, waste includes any substance which constitutes a scrap, an effluent or other unwanted surplus arising from the application of any process or any substance or as an article which requires to be disposed off, which has been broken, worn out, contaminated, otherwise spoiled unless the contrary is proven. Solid waste means the unwanted remains, residues, removed materials or by-products which are no longer required for the initial use (Mensah et al. 2014). Solid waste is used to explain non-liquid waste elements coming up from household, trade, industrial and public services. There are eight major categories of solid waste generators: residential, commercial, industrial, institutional, development and demolition, public services, process, and farming. (Oyelola and Babatunde, 2008).

Municipal Solid Waste - commonly called junk or rubbish, includes daily items such as product packages, foods waste, papers, steel, plastic materials, ceramics, fabrics, natural leather, rubberized, bone fragments, ashes, fruit husk, used battery, paint and household items. These types of waste create health and ecological menaces when it is not properly managed. Solid waste management (SWM) may refer to the collection, transfer, treatment, recycle and disposal of solid waste. Waste management presents a great task to many countries. The problem has become so difficult to control that individual health is confronted. In addition to the effect on human health, roadsides of major towns and cities are littered while streams are blocked by generated waste. With the urbanization population densities and per capita waste generation is increased on the other hand, the availability of land for waste disposal is reduced day by day. According to the USEPA the various options of waste management are: source reduction and reuse (waste prevention), recycling, composting, waste combustion and disposal in landfills (Mensah et al. 2014).

The Global Waste Management (GWM) Market Report (2007) display that the MSW generated in the year 2006 was near to 2 billion tones with a yearly increase of 7% since 2003. It has been mentioned that the formation of MSW from 2007 to 2011 has been increased by 8% per year and nearly 37.3% in a 5 year period worldwide. According to WHO, the low income countries produce roughly 0.5 kg to 3 kg of complete medical care waste annually by an individual. Now days, E-waste is known as one of the most increasing kinds of waste with a rate of average 1% in solid waste and achieved 2% in 2010 and to be thought to increase more in the future (Assessment of Current Waste Management System, 2009). The per capita solid waste generation in developed countries like Canada, Switzerland, France, United Kingdom and USA varies between 0.9 – 2.7kg per day and in the developing countries like India, Sri Lanka and Thailand generates 0.3-0.65kg, 0.4-0.85kg and 0.5-1kg per day (Korner, 2003-2006). From the total quantity of waste generated in Canada, nearly 50% is municipal solid waste. A report from the US Environmental Protection Agency (USEPA) show that 56.9% of total waste generated in the USA is disposed of in landfills, 27% is material recycled and 16.1% is incinerated (Kuniyal, 2010)

2.3 Waste Quantity in Asian Countries

Figure 2.1 shows the solid waste quantities are estimated to increase from 26, 15, 24, 57 and 91 million tons in 2001; 32, 24, 33, 77 and 112 million tons in 2010 and 39, 40, 44, 104 and 136 million tons in 2030 in India, Nepal, Pakistan, Bangladesh and Sri Lanka respectively. The waste quantity with respect to GDP of the study countries were found in India to be 0.66 in 2001, 0.80 in 2010, 0.98 in 2030; in Nepal to be 0.27 in 2001, 0.44 in 2010, 0.72 in 2030; in Pakistan to be 0.33 in 2001, 0.44 in 2010, 0.59 in 2030; in Bangladesh to be 0.55 in 2001, 0.73 in 2010, 1.01 in 2030 and in Sri Lanka to be 0.49 in 2001, 0.60 in 2010 and 0.73 in 2030 respectively (Khajuria et al. 2008) .

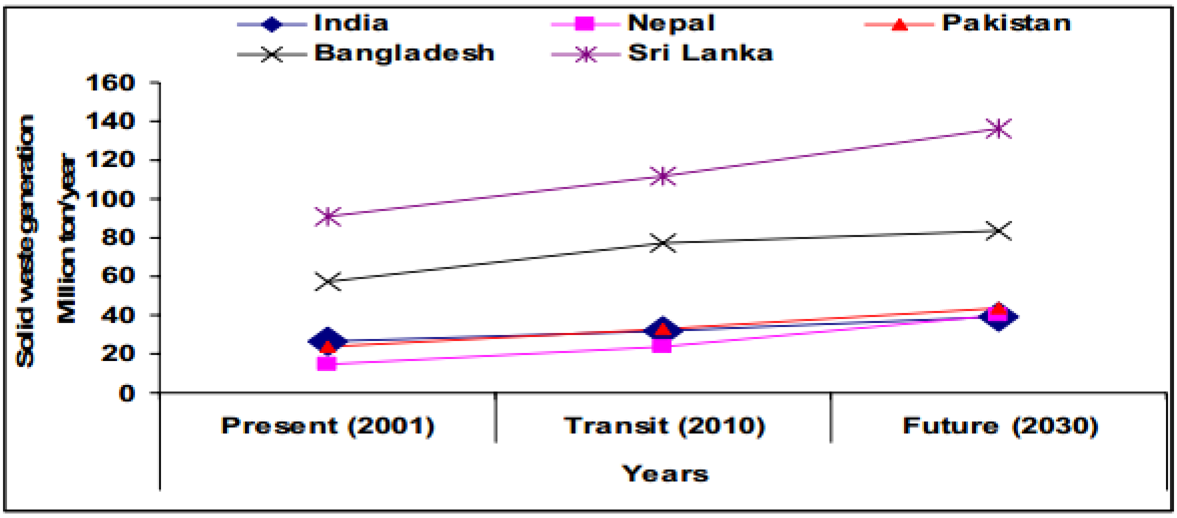


Figure 2.1: Generation of MSW (present-transit-future-phase) in developing Asian countries (Khajuria et al. 2008).

According to the World Bank report, in 1995 GDP per capita was about 490 US dollars with 27.8% city population, producing about 0.64 kg/capita/day of MSW and it further increases in 2025 to about 48.8% of city population with a high income GDP of about 1050US dollars, due to this relationship, a waste amount of about 0.6-1.0 kg/capita/day is approximated in the research of developing nations by the World Financial institution. It is expected that by 2025, about 52 % of The Asians would be living in towns resulting in an important change in the distribution of individuals as well as the development of the city boundaries. The solid waste creation is based on the dimensions of the city inhabitants, density of population, financial growth and consumption rate of industrial products. The per capita generation of solid waste in the research countries is given in figure 2.2, which indicates a range of 0.66, 0.27, 0.33, 0.55 and 0.49 kg per capita in 2001; 0.80, 0.44, 0.44, 0.73 and 0.60 kg per capita truly and 0.98, 0.72, 0.59, 1.01 and 0.73 kg per capita in 2030 respectively, due to the rise in the city inhabitants (figure 2.2), a similar study also observed by the Global and World fact sheet. Lowest waste amounts in Nepal put together to be 0.27 to 0.72 kg/capita in upcoming scenarios and the utmost waste amount was discovered to be 0.66 to 0.98 kg/capita truly to 2030 respectively (figure 2.3). This is mainly due to financial difference among the inhabitants. The city inhabitants is over 38 percent and the waste formation has been increasing over the years

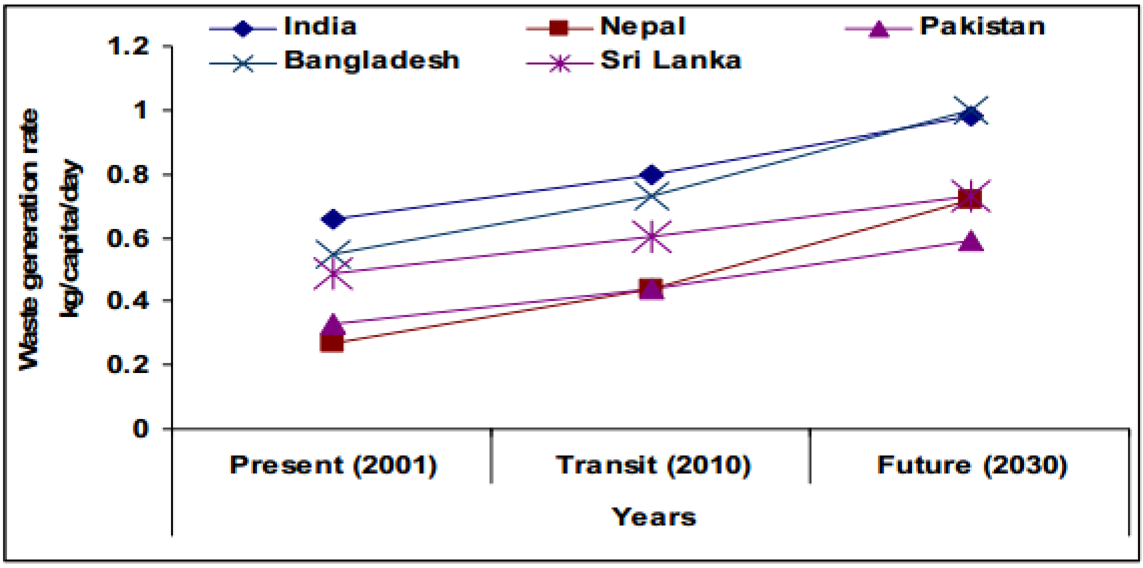


Figure 2.2: MSW generation kg/capita/day (present-transit-future phase) in developing Asian countries (Khajuria et al. 2008).

The per capita generation of solid waste in Asian cities also correlated between the ranges of 0.2 to 1.7 kg/day. This is based on the economic status and population density. The urban population is over 38 percent and the waste generation has been increasing over the years. SW generation depending on per capita generation increases with the level of income of the family or individual. Figure 2.3 indicates that as every person in a developing country increases their income, so the solid waste increases in the same ratio.

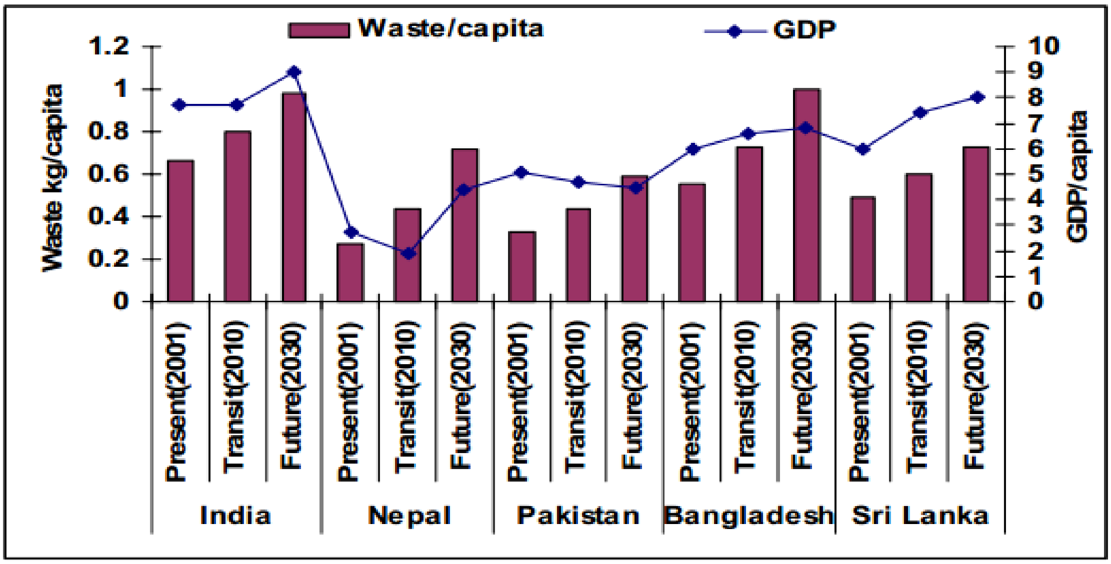


Figure 2.3: Correlation between GDP per capita and waste generation (present-transit-future phase) in Asian developing countries (Khajuria et al. 2008).

2.4 **Composition of Solid Waste Materials**

Solid waste composition studies are mainly used for constructing a well-defined waste management for several reasons which admits potential for material recovery, to find out the origin of component generation, thermal, to approximate its chemical and physical properties. Seasonal change and geographic aspect are the factors which influence waste composition study. Waste is sorted based on the waste categories for the composition. The composition of generated waste is extremely variable as a consequence of seasonal variation, lifestyle, demographic, geographic, and local legislation impacts (AbdAlqader and Hamad, 2012).

One of the most significant differences between the waste generated in developed and developing nations is in terms of its composition. The wastes generated in developed countries are mainly inorganic in nature, whereas organic contents form a large portion of waste in developing countries (Hoornweg et al. 1999, Medina 2002, Zerboc 2003, and Zurbrugg 2003). In the developing country scenario, the proportion of organic contents in waste is almost three times higher than that in developed countries (Medina 2002, Zerboc 2003). Even though the volume of waste generated in developing countries is much lower as compared to that in developed countries, the nature of waste is denser and has very high humidity content (Hoornweg et al. 1999, Medina 2002, Zerboc 2003, and Zurbrugg 2003). The nature and composition of waste is highly dependent on income and lifestyle of the population.

It is evident that the organic wastes form the largest percentage of solid wastes in developing urban centers around Asia, and research has shown that same is true for other developing nations across the world (Hoornweg et al. 1999, Medina 2002, Zerboc 2003, and Zurbrugg 2003). Being highly organic and humid in nature, solid waste management in developing countries presents both opportunities and constraints that are entirely different than the developed countries (Hoornweg et al. 1999, Zurbrugg 2003, and Inanc et al 2004).

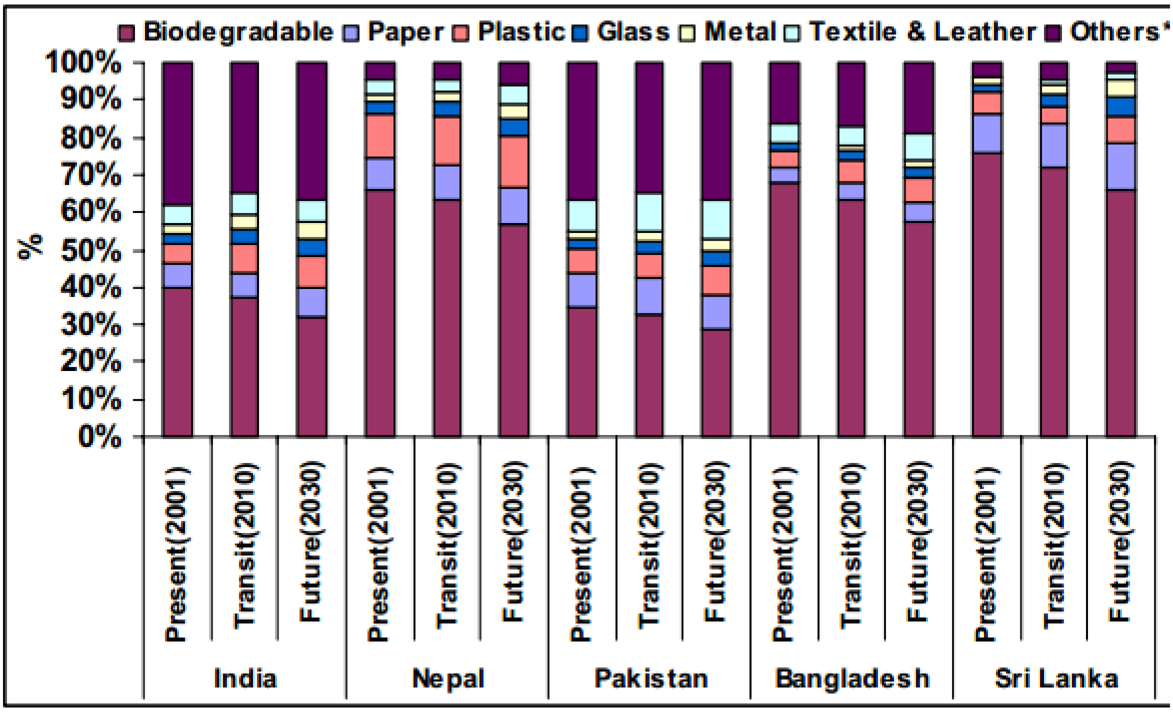


Figure 2.4: MSW composition (present-transit-future phase) in Asian developing countries (Khajuria et al. 2008).

2.5 Effect of Mismanagement of Solid Waste

2.5.1 Health Problems

Critical public health issues occur due to uncollected solid waste and waste generally leading to many contagious illnesses such as water carried diseases such as cholera and dysentery. Such occurrence of illnesses sets additional pressure on the health services available in developing nations. In 1994, pest and rodent vectors are drawn to the waste and one may recall that as many as 200,000 people had to leave after the occurrence of pneumonic problem in Surat in Western Indian. The occurrence is connected to the unmanageable fermentation of waste materials which created positive conditions for the reproduction and growth of insects or rodents and bugs that served as vectors of diseases (Venkateshwaran 1994). A comparable study by WHO (1995) seen in 1994 that 616960 cases of cholera resulting to 4389 fatalities were revealed in Angola, Malawi, Mozambique and Tanzania (UNCEA 1996) which can be connected to the fact that in North Africa as much as 20 to 80 % of city solid waste materials are thrown out in open areas (Chakrabarti and Sarkhel 2003). Pollution of soil water by disease causing creatures from water leaking through dumps is likely to contain the malware of liver disease, poliomyelitis and gastroenteritis (Medina 2002); therefore such water contamination may have long term health effects apart from dysentery and cholera.

The U.S. Public Health Service recognized 22 human illnesses that are linked to inappropriate solid waste management. The most immediate health risk due to solid waste in developing nations is to the employees, rag pickers and scavengers. Waste employees and rag pickers in developing nations are rarely protected from direct contact and injuries. The co-disposal of dangerous and medical waste materials with public waste presents serious wellness risk. Exhaust fumes from waste collection vehicles, dust stemming from disposal practices, and open burning of waste also contribute to overall health problems (Pradhan, 2008). The magnitude of the health problems due to solid waste in case of developing countries are particularly alarming where the proper collection and disposal of solid waste is impeded by paucity of funds and technological capacity. The areas, which are not serviced, are left with clogged sewers and litters which create serious health problems for the resident population (Khawas 2003). Populating and unclean conditions are major amplifiers of the transferring of contagious diseases. Many contagious diseases flourish where there is a lack of water, and insufficient water flow and drainage, sanitation and solid waste removal (Mcmichael 2002). In a survey prepared for the World Health Organization (WHO), Chang et al. (2001) recognized seven different ways, through which contaminants can transfer back to impact human health condition.

Waste → soil → human.
Waste → soil → plant → human.
Waste → soil → plant → animal →human.
Waste → soil → atmosphere → human.
Waste → soil → surface runoff → surface water → human.
Waste → soil → vadose zone → groundwater → human.
Waste → soil → animal → human, waste → soil → airborne particulate→ human
Source: Chang et al., 2001)

Hence, we discover that in case of inappropriate managing waste will gradually shift back into the system and cause further harm to individual health through the bio-magnifications of toxic substances.

2.5.2 Environmental problems

The effects of solid waste on surroundings is tremendous, from launch of dangerous greenhouse gases (GHGs) to pollution of ground water, inappropriate solid waste can confuse the environmental health. The most severe environmental challenge in terms of solid waste is the exhaust of GHGs. Based on Thorneloe et al (2002), the waste management industry symbolizes 4% of complete anthropogenic GHG pollutants and dumps contribute the biggest anthropogenic source of methane, adding 90% to the entire GHGs discharge from the waste industry in the United State. Methane is a primary component of landfill gas (LFG) and an effective greenhouse gas when introduced to the ambiance. LFG is created as an organic by-product of rotting natural matter, such as food and papers dumped in these landfills and it comprises of about 35-50 % methane (CH_4) and 35-50 % carbon-di-oxide (CO_2), and a trace amount of non-methane natural substances. Daily large numbers of public solid waste are disposed in sanitary dumps and landfills sites around the world. According to Methane to Markets Partnership, website (2004); “worldwide, landfills are the third biggest anthropogenic (human influenced) emission source, comprising about 13 percent of worldwide methane pollutants or over 223 million metric tons of carbon equivalent” (MMTCE). The status of solid waste management system thus significantly impacts the problems associated with global heating and climatic change. Figure 2.5 recognizes some of the nations with significant methane pollutants from landfills.

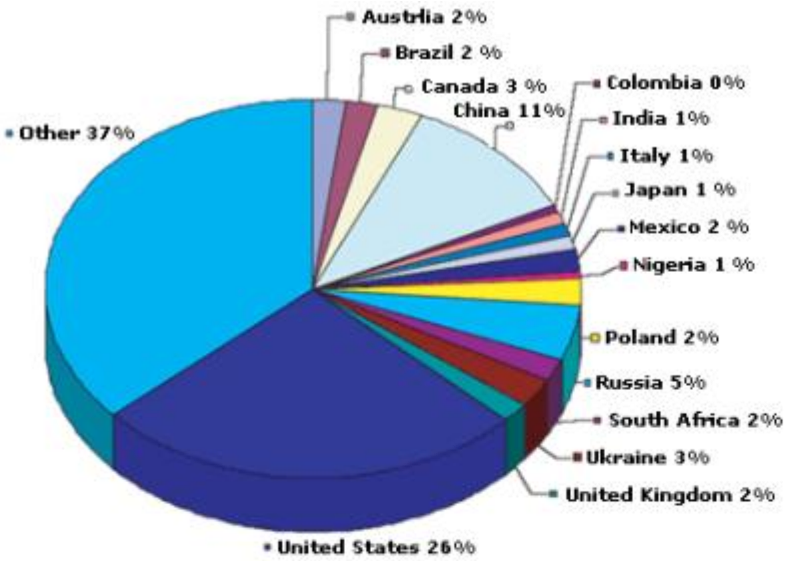


Figure 2.5: Global landfill methane emissions in 2000 (MMTCE) (Pradhan, 2008).

It is to be mentioned that entire world landfill; methane pollutants are more widespread in western world as opposed to developing nations. Further, it has been noticed that the major aspects driving LFG exhaust levels are the amount of natural content placed in landfills, the type of area stuffing methods, and the level of anaerobic decomposition (Jokela et al. 2002). Greater the natural content, higher is the level of methane emission; considering the fact that the waste materials produced in third world nations have high natural content; the potential for ecological damage is tremendous. Although methane can be stuck and used as electrical energy source (Jokela et al. 2002), the shortage of technology and finance restricts the capturing of methane in the third world nations.

Apart from the exhaust of GHGs, solid waste cause ground and surface water pollution; as water filters through any content, chemicals in the content may dissolve in the water, this process is known as leaching and the resulting mixture is known as leachate (Mcmichael 2002). As water percolates through solid waste, it makes a leachate that consists of rotting organic matter combined with iron, mercury, lead, zinc, and other metals from corrosion cans, discarded batteries and appliances. It may also contain pesticides, cleaning fluids, paints, pesticides, newspaper ink, and other ingredients. Contaminated water can have a serious impact on all living beings, including humans, and the environment as a whole. Commonly in developing nations, dump sites are handled by indiscriminately burning up the waste materials. Burning causes pollutants like lead, harmful gases and smoke to propagates over areas. The wind also provides waste, dust and gases triggered by decomposition. Air contamination due to burning of waste and growing of harmful gases causes great number of damage to both environment and human health (Medina 2002). Putrefaction of waste in natural light during day time results in bad odors and reduced exposure and it wrecks the atmosphere of the area.

2.6 Integrated Solid Waste Management

Introduced the huge complexness of problems and challenges in various solid waste control systems across third world nations, it is obvious that the top-down alternatives and control technique will no longer be efficient. Instead, a much wider and more incorporated set of alternatives will be needed to make sure long lasting sustainability of the waste management system. In the western world the most suitable environmentally maintainable growth way to waste is the "Integrated Waste Management" (Cole and Sinclair 2002, Medina 2002, Zerboc 2003). A strategy to waste management including a "hierarchical and synchronized set of actions" (Medina 2002 p.17) attempts to reduce contamination, increase restoration of recyclable and biodegradable components, and defends human health and the surroundings. It will take into consideration group and area specific issues and needs and formulate an incorporated and appropriate set of alternatives "distinctive to each perspective" (Daskalopoulos et al. 1998, Medina 2002, Zerboc 2003). Medina (2002), declares that the "integrated waste control is intended to be socially suitable, financially practical and environmentally good".

Regarding solid waste control in a developing nation composition, it is to be mentioned that alternatives which work for some nations or areas may not be appropriate or proper for others. Specific problems, issues, ecological circumstances and current socio-economic structure determine the suitability of various techniques and engineering in fixing the problem of solid waste. However, various researches on solid waste problems bring about probabilities of certain techniques as being at least convenient to many developing nation circumstances. The main focus is on the four R‟s – reduce, reuse, repair and recycle (creation of less waste and improved content recovery) and finding suitable disposal possibilities (Medina 2002, Zerboc 2003). Zerboc (2003) details out a set of inquiries as intended in the International Source Book on Environmentally Sound Technologies for Municipal Solid Waste.

Management (UNEP 1996) that requires to be requested while creating or analyzing integrated solid waste management plan or framework:

a. Technology has been proposed to achieve its goals based on the financial and human resources availability.
b. Find the most suitable option in terms of cost effective.
c. Project should be environmentally sustainable.
d. Project should be feasible in terms of administrative capabilities.
e. Project should be appropriate with respect to current social and cultural environment.
f. Find out the sectors of society which are likely to be impacted and discover the ways to keep these impacts consistent with overall societal goals. Source: Zerboc (2003).

The solutions to these questions are crucial and will play a role hugely towards the knowledge of the current problems and social structure and will allow the specialist to obtain appropriate alternatives in the given environment. Some possible alternatives following the idea of incorporated waste management have been lightly mentioned as below:

2.6.1 Reduction in Waste Generation

"Protection is better than cure", so goes an old saying, and it is one of routine to manage the problem of solid waste. By avoiding (reducing) the formation of waste itself, can help to eliminate other problems (namely, disposal) relevant to waste to a major degree. In order to lessen waste formation, several techniques or device does apply. Some of which may be:

a. Enacting public policies that discourage the production, sale and consumption of products containing unnecessary packaging material. Places where flow of products cannot be controlled by appropriate policy measures (extended producers responsibility, taxes, economic incentives etc) should be put in place to discourage unnecessary waste generation. Policies should also look into the aspect of encouraging reusable and recyclable products instead of disposable products (Medina 2002).

b. Promotion of local grown products and less reliance on packaged food products go a long way in reducing wastes.
c. Education can play a critical role by creating awareness regarding the waste and related issues among the masses. In a developing country framework, reduction in waste generation should be targeted towards producers; because of excessive packaging, more waste is created. From the consumers side, reduction in waste can be generated by educating the consumers on ways to prevent waste; for instance asking the consumers to use a reusable bag for shopping rather than rely on goods being bagged in numerous poly bags, can significantly reduce the use of poly bags which are the main source of waste in numerous developing countries.

2.6.2 Reuse and Repair

Reuse pertains to the restoration of items to be used again. Reuse guarantees decrease in raw material consumption to save energy and water, decreases contamination and stops the creation of waste. Medina (2003) regards reuse of components and items as more socially suitable than reuse the same components. For example, in India, soft-drinks (Pepsi, Coke etc) are sold in glass containers and a deposit refund system manages. A person deposits some sum of money on purchase of the soft drink, which he/she gets back on depositing the container, thus allowing manufacturer to control his supply of container without having to generate new ones. Products, such as furnishings and equipment, can also be reused. For example Manitoba Hydro contributed their old furnishings and building waste to Manitoba eco-network, which was used to build a new workplace for the network; thus conserving both time and important resources for both Manitoba Hydro and Eco-network. Reuse programs not only help to save money, it also can be a way to obtain income for the companies/households that apply it. The best example would be Interface, which reuses old floor coverings/carpets to generate new ones, thus preserving useful sources and advertising durability at the same time. Public guidelines that provide rewards for companies and individuals to engage in reuse can have an important and beneficial financial and ecological effect (Sudhir et al. 1997, Medina 2002, Zerboc 2003). In a developing nation framework, it is to be mentioned that due to inadequate financial circumstances, fixing and reuse of components and products is a conventional practice, and often individuals in the developing nations reuse much more than individuals living in the western world.

2.6.3 Recycle

Even though recycle is one of the most main reasons of waste management in the developed nations, due to the composition of waste and other aspects, recycle may not be much of an option with regards to developing country. Separation of waste products at the family level is perhaps a worldwide phenomenon. Moreover, the separation of anything useful is performed with care in developing countries, which stops valuable items and reusable components from being discarded. The existence of waste pickers, scavengers etc., restore other useful components from coming into the waste flow. Particularly in developing nations, itinerant customers play an important role in recuperating materials for recycling; they buy every item that has some value, magazines, plastic containers, old shoes etc (Zerboc 2003). It is however, obvious that some enhancement in these conventional systems can be introduced about. A formalized waste recycle or restoration system sustained by community municipality can go a long way in the guarantee health safety for the employees, probability of better income for the rag pickers, scavengers and small-time suppliers working with waste (Zerboc 2003). Recycling waste can be a practical economic choice even for some city areas, where the characteristics and features of waste is quite similar to the developed nations. In case of waste composition not favoring recycle, other options (recovery, diversion etc.) should be seriously considered. In the event that local public government authorities cannot provide recycle service due to lack of resources, private relationships need to be motivated and seemed into as a choice (Sudhir et al 1997, Medina 2002, Zerboc 2003).

2.6.4 Composting

Composting is the best form of waste reduction in developing countries. It is a simple low-technology strategy. Hypothetically the waste management in many third world countries would be ideal for lowering through compost, since it contains higher composition of natural content than developed countries. Hoornweg, et al (1999) measured that on a regular, city in developing countries have 50% natural content in their waste flow. Early research performed by Cointreau (1982), found 78-81% compostable components in the family waste produced in major places of Philippines and Srilanka (Bandung and Colombo respectively). In latest study performed by Zurbrugg (2003) observed that major Asian places like, Hanoi, Karachi, Katmandu and many Indian places has 68-82% compostable waste content. However, it is interesting that compost is not commonly used in the developing nations (Zerboc 2003). The benefits of compost are numerous; it decreases the amount of waste significantly. It can be used as manure and natural manure for farming uses, it also decreases the discharge of gaseous pollutants significantly and since it is a natural process, it decreases the harm to atmosphere. Besides this, the foul smell protecting any waste disposal site is generally produced due to the decaying of natural waste, which will be managed to a large degree if we go for compost instead of enabling the waste to rot (Sudhir et al 1997, Medina 2002, Zerboc 2003). Zerboc (2003) notices that compost can be performed in three levels: Domestic, local community and extensive central level (throughout the municipality). Regrettably, extensive operations have been a hopeless failure; due to large amount of investment required, need to keep the accessories in working circumstances etc. In India, 9 extensive compost made during 1975-1985 had been turned off by 1996 (Zerboc 2003, Drescher and Zurbrugg 2006), the same was true in South america where only 18 of the authentic 54 features were function (Zerboc 2003). Some problems affiliate with the failing of extensive compost functions may be briefly described as:

a. Lack of proper technical knowledge regarding composting.
b. Lack of market and marketing initiatives.
c. Lack of cooperation between composting operations and local municipal government.
d. Lack of institutional support.

Source: Zerboc (2003), Drescher and Zurbrugg (2006).

Generally, composting has been most successful when done at household or community level. Drescher and Zurbrugg (2006) point out the advantages of household or community level (decentralized) composting as follows:

a. Small-scale composting can function as a compliment to primary collection process, thus improving the overall performance of the municipal services and has the potential to significantly improve the hygienic conditions within the service area.
b. Small-scale composting helps in diverting major proportion of waste generated close to the source of generation; thereby, significantly reducing transportation costs and prolonging the life span of landfills; besides enhancing the recycling activities and final disposal.
c. Small-scale composting does not require large investment, and capital requirements can be distributed over long periods of time. This facilitates a stepwise approach towards integrated solid waste management.
d. Due to their smaller size and location, small-scale composting projects are more flexible in management and operation.
e. As composting is mainly labor intensive; composting schemes can be a source of employment particularly for poor and underprivileged people in the neighborhood/community.
f. Finally, decentralized composting activities and the interaction between residents in issues of waste handling, hygiene, cleanliness and environment can significantly enhance environmental awareness in a community.

In developing nations, residence-level compost has the most potential for success, as most of the locations are enclosed by small or large range farming (Drescher and Zurbrugg, 2006). Choice of site for compost can be a key factor in identifying the failure or success of the work. The function of education cannot be ignored, as knowledge is the key to endorsing attention concerning the benefits of compost at family or community level (Medina 2002). Several people do not engage in compost due to their issue for possible illness, smells, and insect problems. Hence, the purpose of education should be targeted towards growing attention regarding the opportunities of compost and how it can be accomplished properly (Medina 2002).

2.6.5 Incineration

Incineration is the method of burning of waste materials under managed circumstances, usually executed in an internal framework. Although incineration has great rate of waste elimination (80-95%), there are many issues that make incineration not so realistic method in developing nations (World Bank 1999). Solid waste incineration facilities usually be among the most expensive solid waste control choices, being highly capital-intensive and require great servicing costs that may be beyond the reach of many of the smaller developing nations (Medina 2002). In comparison to other solid waste control options, incineration needs relatively higher officially qualified employees, and cautious servicing (World Bank 1999); which may not be useful for what you need for the developing nations. Apart from this, there is a major environmental hazard element of incineration; usually most of the developing nations are largely populated and any incineration procedure near individual surrounding can cause a great risk to individual life and atmosphere because of pollutants. Use of scrubbers in incineration can limit the risk significantly. Nevertheless, it needs huge financial participation, which may not be possible for developing nations to maintain (Medina 2002). Another significant barrier towards appropriate performing of incinerators in developing countries is the characteristics and makeup of waste, due to high wetness content in waste; the incinerators do not be effective as in western world, hence appearing extra pressure on the exchequer (Zerboc 2003). Based on Medina (2002), in Lagos, Nigeria, incinerators were intended for 10 Million dollar, but due to the fact of high moisture content of the waste materials, extra energy had to be added to keep burning, which considerably increased the price of incineration process. The result was that the incinerators never managed normally. One was discontinued and the other converted into a community center. Very similar encounters have been seen in India, Mexico, the Philippines, Indonesia, and Turkey. Medina (2002 indicates that because of all these reasons, incineration of MSW is probably not succeeded in many developing nations.

2.6.6 Sanitary Landfills

A sanitary landfill is a service made particularly for the final disposal of waste materials, which is partially better than open dumping; the real difference between a sanitary landfill and open dumping is the amount of technological innovation, planning and management engaged (Zerboc 2003). Sanitary landfill reduces the threats to human health and the surroundings associated with solid waste materials. For a sanitary landfill to be considered as sanitary 4 basic premises requires to be achieved:

a. Full or partial hydro geological isolation through the use of liners to prevent leachate infiltration into the soil and groundwater; collection and treatment infrastructure should be used where leachate is expected to be generated
b. Formal engineering preparations with an examination of geological and hydrological features and related environmental impact analysis, waste tipping plan and final site restoration plan
c. Permanent control, with trained and equipped staff to supervise construction and use.
d. Planned waste emplacement and covering, with waste and soil placed in compacted layers as well as daily and final soil cover to reduce water infiltration and reduce odors and pests. Source: Cointreau (1982)

Sanitary landfills also avoid the subterranean consumption of methane and may also include other contamination management measures, such as collection and cure of leachate, and ventilation or flaring of methane. Production of electric power by burning methane produced by the landfill fumes are being performed in many developing nations. Presently, over 82 MW of electricity is produced by landfill gas in North America (Environment Canada, 2003), but developing nations still lack the finances to capture the source of energy from landfill fumes. Sanitary landfills are necessary; for safely discarding waste materials that cannot be avoided, reprocessed, reused or composted. They mark an impressive improvement over disposal of waste materials in open dumps. Sanitary landfills reduce the threat of polluting the environment and challenges to human health in contrast to open dumping. Even so, disposing of all public waste materials gathered at landfills is not suitable from a social, financial, and surroundings perspective (Median 2002). Sanitary landfills involve municipal authorities to make important investment strategies and finding a proper location for a landfill may be a problem. It cannot be designed near locations where there are human properties. However, landfills can help in developing new projects, decrease contamination and preserve natural resources; hence, redirecting the waste from landfills, by recycle, reuse, compost can not only help in increasing the life of the landfill, but can also help in producing financial benefits (Medina 2002, Zerboc 2003)

2.7 The idea of sustainability in waste management

The term sustainable waste management emphasizes a shift from waste disposal to other waste management options that includes energy and material recovery as well as waste reduction and reuse in addition to the aim of decoupling increase in waste generation from economic growth, a natural progression in many nations (Chung and Lo, 2003; Desmond, 2006). It includes having a strategy in place that is appropriate to the local conditions and has a balance between technical, environmental, social, economic, financial, administrative and political aspects, and is capable of maintaining itself over time without exhausting the resources it needs .To evaluate waste management systems sustainably, the issue of measure of sustainable development arises - this requires transparent and reliable measurement element that must be agreed upon by stakeholders. While the generic principles of sustainable development consist of social, environmental and economic aspects, the administrative aspect has been evaluated in many studies involving waste management. These aspects cover the range of issues associated with the management of solid waste, predict or influence the sustainability of the entire system (Ayuba *et al.*, 2014). Consequently, the pillars of sustainable development are economic prosperity, environmental protection and social equity (see figure 2.6).

Environmental sustainability in municipal waste management can be defined through two major objectives, which are conservation of resources and reduction of environmental pollution (Den, 2007). Sample indicators for the environmental sustainability in waste management are the conservation of resources through the collection of secondary raw materials, air emissions, and fuel and electricity consumption and noise (Schluchter, 2012).

Economic sustainability in municipal waste management can be defined as such integration of waste management options as to operate them at the lowest possible cost – acceptable to the community, local government and a municipal waste treatment facility itself. Sample indicators for the economic sustainability in waste management are the investment costs, the annual maintenance costs, personnel employment costs and finally revenues from recovered materials and energy.

Social sustainability in municipal waste management can be defined as provision of appropriate level of waste services to meet health and comfort requirements of participants. Sample indicators for the social sustainability in waste management are the convenience of use, visual impact; odour, noise, and traffic nuisance (Den, 2007).

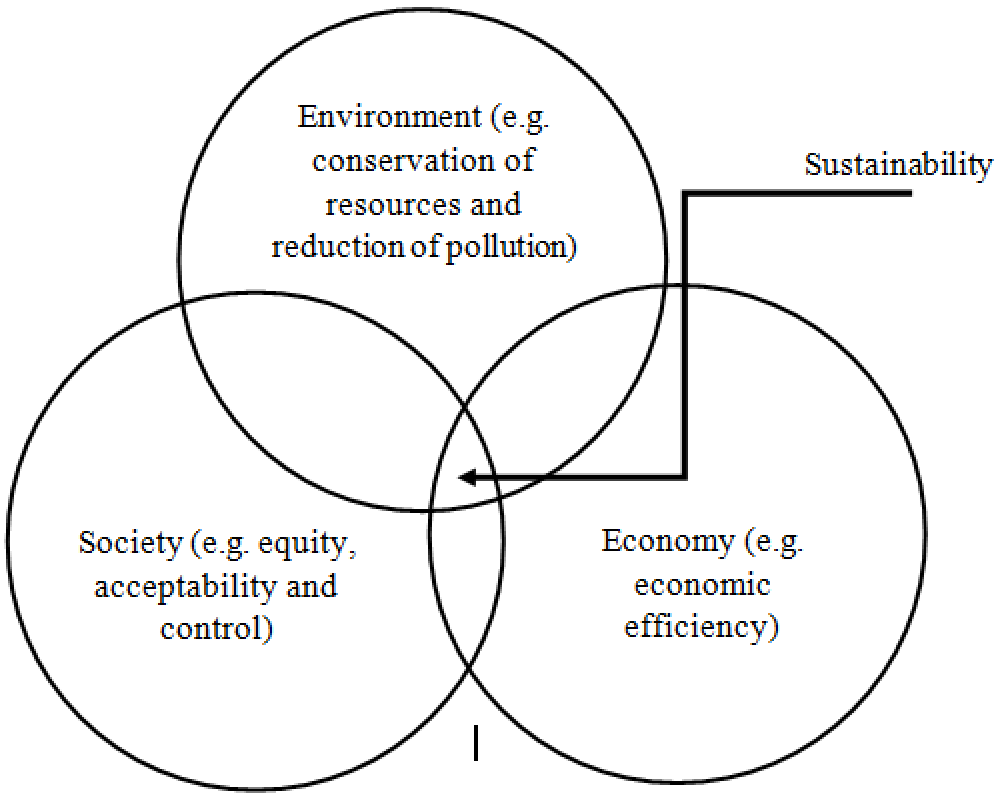


Figure 2.6: The three spheres of sustainable in SWM (http://dlibra.bg.ajd.czest.pl:8080/Content/1267/Pragmata_7_20.pdf)

Improper management of waste causes environmental degradation and loses of aesthetic appeal, in shape of litter on streets, illegal dumping, and garbage burning. Sustainable SWM principles include equity (for all inhabitant that are entitled to an appropriate waste management system due to environmental health reasons, promote the health issues for resident, and minimize the waste production for resident), effectiveness (related to safe removal of waste, protection of environmental quality and sustainability, and maximizing 3R), and efficiency and sustainability of solid waste management related to increasing benefits and decreasing of costs (Shamshiry et al. 2011).

In case of management of SW generated at institutional campus, the aesthetical sustainability is very much important. The waste management is represented at first sight by its aesthetical conditions. As a result, aesthetical sustainability is considered with environmental, economic and social sustainability for integrated SWM at educational SWM. So the spheres of sustainable SWM is presented with the figure 1.

Management, planning, and efforts to find optimal solutions for improving urban residue problems are inevitable, and city authorities seek optimal procedures to remedy urban problems and issues. Successful waste management programs are linked to internal factors (strength and weakness) and external factors (opportunities and threats) for sustainable development (Majlessi et al., 2015).

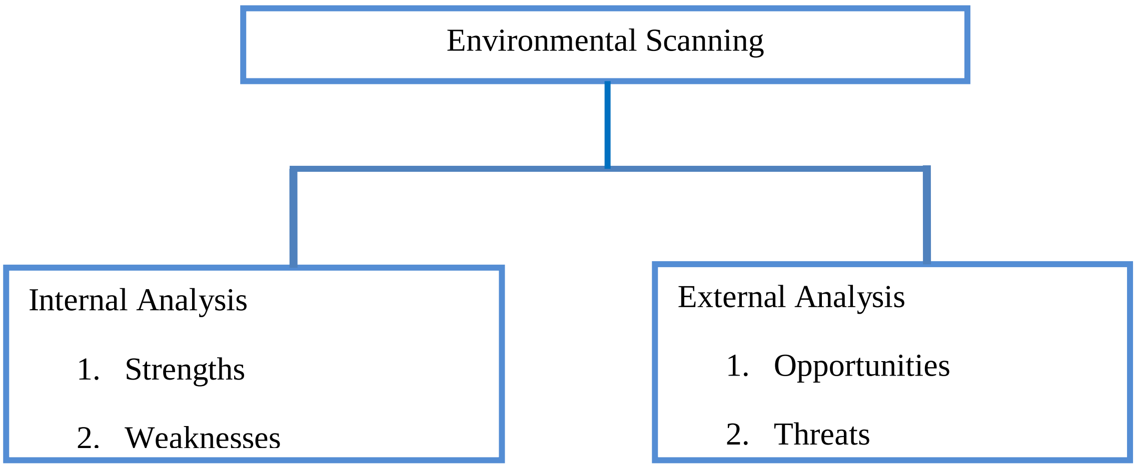
2.8 SWOT Analysis

2.8.1 **The concept of SWOT analysis/ definitions and views**

The SWOT analysis is one of several strategic planning tools that are used by businesses and other organizations to ensure that there is a clear objective defined for the project or venture, and that all factors related to the effort, both positive and negative, are identified and addressed. In order to accomplish this task, the process involves four areas of consideration: strengths, weaknesses, opportunities, and threats. It should be noted that, when identifying and classifying relevant factors, the focus is not just on internal matters, but also external components that could impact the success of the project. The SWOT analysis is part of an organization's strategic planning process where it connects its objectives and strategies to actionable tactics carried out by employees. Specifically, SWOT is part used often of the situation analysis, where the organization determines where it stands on four key strategic areas to better determine what changes to make (Osita et al., 2014).

SWOT analysis is an excellent tool to explore the possibilities and ways for initiating and successfully implementing the MSWM program and by this model, strategic action plans were developed for municipal organization to improve MSWM. SWOT analysis is used to develop four types of strategies, namely SO (strengths-opportunities) strategies, WO (weaknesses-opportunities) strategies, ST (strengths-threats) strategies, and WT (weaknesses-threats) strategies (Babaesmailli *et al*., 2012; Sevkli *et al*., 2012). SO strategies use a firm's internal strengths to take advantage of external opportunities. WO strategies overcome internal weaknesses by capitalizing on external opportunities. ST strategies use a firm's strengths to avoid or reduce the impact of external threats. WT strategies are defensive tactics directed at reducing internal weaknesses and avoiding environmental threats (Weihrich, 1982). According to this model, an appropriate strategy maximizes the strengths and opportunities and minimizes the weaknesses and threats (Nikolaou and Evangelinos, 2010). The strengths and weaknesses are identified by an internal environment appraisal while the opportunities and threats are identified by an external environment appraisal (Dyson, 2004; Chang and Huang, 2006; Markovska *et al*., 2009). SWOT analysis summarizes the most important internal and external factors that may affect the organization's future, which are referred to as strategic factors (Kangas *et al*., 2003). The external and internal environments consist of variables which are outside and inside the organization, respectively. The organization's management has no short-term effect on either type of variable (Houben *et al*., 1999). A SWOT analysis needs to be flexible. Situations change with the time and an updated analysis should be made frequently. Further, we may conclude that SWOT is neither cumbersome nor time-consuming but is effective because of its simplicity (Schmoldt *et al*., 1994). SWOT analysis is used in different sectors and planning and development situations as a tool for organizing and interpreting information, including technology development (Ghazinoory *et al.*, 2009; Ming *et al*., 2014), environmental impact assessment (Nikolaou andEvangelinos, 2010; Paliwal, 2006; Rachid and El Fadel, 2013), tourism management (Kajanus *et al*., 2004; Reihaniana, 2012; Zhang, 2012; Scolozzia *et al*., 2014) and Waste management (Srivastava *et al*., 2005; Halla, 2007; Yuan, 2013), for example, in the discipline of waste management, an investigation on formulating strategic action plans for municipal solid waste management in Lucknow was performed; the study adopted a research method of integrating stakeholder analysis into SWOT analysis and presented a set of concrete strategic action plans for both the community and municipal corporation to improve solid waste management in that region (Srivastava *et al*., 2005). It is evidently demonstrated by those studies that the SWOT analysis approach is a better tool for investigating problems from a strategic perspective. Thus it is adopted in the present study to strategically analyze SWM in KUET campus. In other words, this Study has been performed to develop a strategic action plan of SWM based SWOT analysis with a view to make the KUET campus cleaner and greener. It aimed at identifying the positive and negative factors, as well as internal and external factors, that might have an impact on the proposed SWM program. SWOT analysis of this program and its components was intended to maximize both strengths and opportunities, minimize the external threats, and transform the identified weaknesses into strengths and to take advantage of opportunities along with minimizing both internal weaknesses and external threats (Mir1 and Nabavi, 2015).

2.8.2 SWOT Analysis Framework:



Or can be represented as

Internal forces	**External forces**
Strengths: The good features and positives abilities for SWM at KUET campus	**Opportunities:** Surrounding that might benefits us and the advantages from it
Weaknesses: The features that we need to be improved for SWM at KUET campus	**Threats:** We need to be able to defend ourselves harming from surrounding.

Figure 2.7: SWOT Analysis Framework (Osita et al., 2014).

2.8.3 Internal Analysis

Strengths can be of

Long-serving and committed records staff

a. Good relations between records staff and users
b. Capacious and well-equipped storage areas for paper records
c. Established systems for controlling access and maintaining confidentiality.

Strength may include also

a. Something we do well.
b. Valuable know how.
c. Assets (physical, human, intangible)
d. Competitive capability.
e. Attributes.
f. Ventures, alliances.

One can pose these questions: strengths on that we rely and the strengths that should be ignored.

Weaknesses could be

a. Lack of staff skills, especially in managing electronic records
b. Lack of integration between electronic and paper records
c. No coordination between systems in different parts of the organization
d. Inadequate funding.

Weaknesses can also be

a. Something we do poorly
b. A disadvantage
c. A deficiency in expertise or competence

d. Lack of assets (physical, human, intangible)
e. Missing capabilities

In discussing weakness, the question can be posed about dealing with weaknesses.

2.8.4 External Analysis

Opportunities can also be

a. The good chances facing SWM
b. The interesting trend
c. Benefits due to improved SWM
d. Future available technology

Questions such as: opportunities that we had, the way we improved the opportunity, successes and usefulness.

Threats can also be

a. Obstacles will SWM face
b. Chances for lack of necessary facilities for an improved SWM
c. Threatening SWM due to changes of technology
d. Chances for lack of stakeholder support for SWM

Available threats, the way we will handle them and the treats that we should ignore.

2.8.5 Techniques for SWOT

a. The opportunities of SWM have been find out and necessary measures have been taken to make them successful.
b. The threats of SWM have been searched and necessary precautions have been taken to handle them and to minimize their effect on SWM.
c. The strengths on which we can rely and the strengths which we can ignore have been identified for SWM.
d. The weaknesses of SWM have been discovered and the necessary steps have been made to convert them into strengths.

2.8.6 How to Organize SWOT

SWOT Analyses are often arranged as a 2 by 2 matrices with the lists of strength and weaknesses in the first two boxes in the first row and the lists of opportunities and threats in the second row. By arranging the analysis this fashion, the lists are separated into internal factors that can affect a project on the first row and external factors on the second row. In addition, the first column consists of the positive factors (strengths and opportunities) and the second column consists of negative factors (weaknesses and threats.). This method provides a simple framework to keep lists organized and conceptualize how the lists are related.

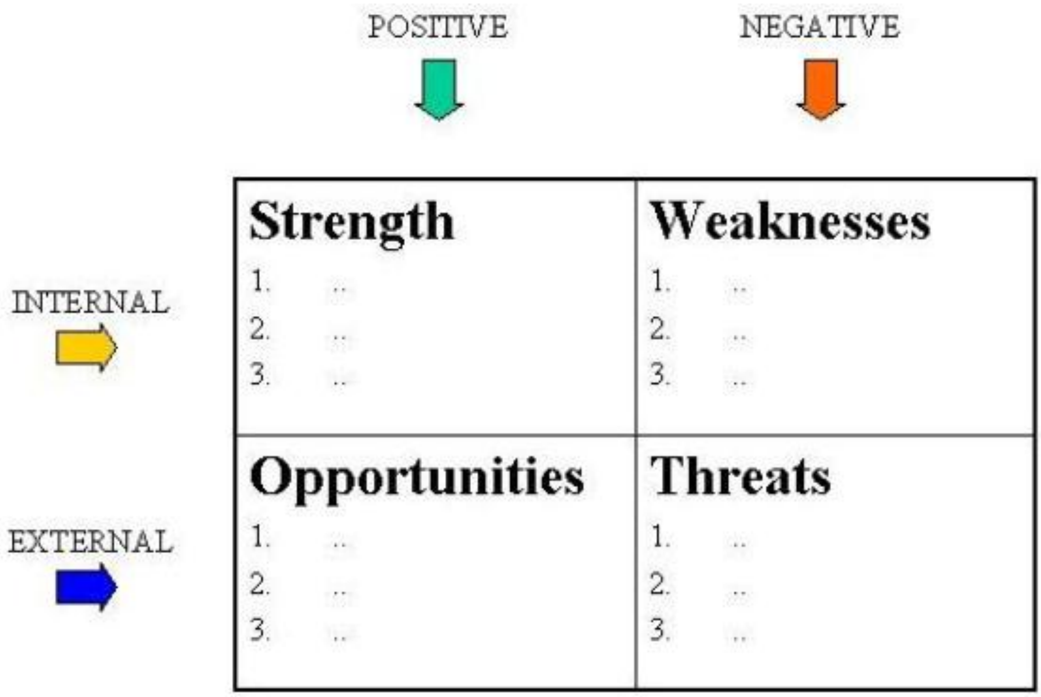


Figure 2.8: SWOT analysis Matrix (Osita et al., 2014).

2.8.7 Advantages of SWOT:

SWOT Analysis is instrumental in strategy formulation and selection. It is a strong tool, but it involves a great subjective element. It is best when used as a guide, and not as a prescription. Successful businesses depend on their strengths, correct their weakness and protect against internal weaknesses and external threats. They also keep eyes on their overall business environment and recognize and exploit new opportunities faster than its competitors. SWOT Analysis helps in strategic planning in following manner:

a. It is a source of information for strategic planning.
b. Builds organization’s strengths.
c. Reverse its weaknesses.
d. Maximize its response to opportunities.
e. Overcome organization’s threats.
f. It helps in identifying core competencies of the firm.
g. It helps in setting of objectives for strategic planning.
h. It helps in knowing past, present and future so that by using past and current data, future plans can be chalked out.

2.8.8 The AHP – Applications

Since its discovery the AHP has been applied in a variety of decision-making scenarios:

a. Choice – selection of one alternative from a set of alternatives.
b. Prioritization/evaluation – determining the relative merit of a set of alternatives.
c. Resource allocation – finding best combination of alternatives subject to a variety of constraints.
d. Benchmarking – of processes or systems with other, known processes or systems.
e. Quality management.

2.9 Ranking of Strengths, Weaknesses, Opportunities and Threats

2.9.1 Analytical Hierarchy Process (AHP) and fuzzy TOPSIS Method

All organizations have to select the projects which are determined to pursue among numerous opportunities. One of the biggest decisions that any organizations are likely to make related to the projects which they would undertake. Once a proposal has been accepted, there are numerous factors that need to be considered before an organization decides to carry out. Actually, there are various project selection methods practiced by the modern business organizations. However, the most popular one is a multi-criteria decision making (MCDM) method which is a tool aimed at supporting decision makers who are faced with making numerous and conflicting evaluations. MCDM aims at highlighting those conflicts and deriving a way to come up with a compromise in a transparent process. Many researchers have studied about tools used in decision-making process to ensure the most appropriate alternative. Meanwhile, they applied the multi-criteria decision making for supporting any decision information process such as Affinity Diagram, Analytic Hierarchy Process (AHP), fuzzy TOPSIS, Analytic Network Process (ANP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) etc (Awasthi and Chauhan, 2012). Many researchers have applied these methods into many organizations and several fields for instance project selection, project performance, logistics and computer system, etc. Awasthi and Chauhan (2012), combined three methods including Affinity Diagram, AHP and fuzzy TOPSIS for improving city sustainability by evaluating 4 city logistics initiatives. For project selection, Beltrán et.al (2014) applied AHP and ANP to help manager to decide project investment. Nikzad Manteghi and Jahromib (2012) used AHP method to select project suitable for distributed generation technology between current and new project. Nooshin Rahmania (2012), applied AHP in IT project selection. Khalil (2012), developed AHP to select the most appropriate project delivery method. Amiri (2012), applied AHP to select oil field project. AHP can be applied in construction and ERP project. Ahmad and Laplante (2006), applied to select software project. Triantaphyllou and Mann (1995), applied to select computer system in engineering department. The most famous tool of the multi-criteria decision making methods is the Analytic Hierarchy Process (AHP) which is a methodology for supporting complex decisions. It is used in business and governmental sectors around the world to improve the quality of decisions. It is very intuitive, easy to use and understandable (Pangsri, 2015).

The Analytic Hierarchy Process (AHP) is a multi-criteria decision-making approach and was introduced by Saaty (1977 and 1994). The AHP has attracted the interest of many researchers mainly due to the arranged mathematical properties of the method and the fact that the required input data are rather easy to obtain. The AHP is a decision support tool which can be used to solve complex decision problems. It uses a multi-level hierarchical structure of objectives, criteria, sub criteria, and alternatives. The pertinent data are derived by using a set of pairwise comparisons. These comparisons are used to obtain the weights of importance of the decision criteria, and the relative performance measures of the alternatives in terms of each individual decision criterion. If the comparisons are not perfectly consistent, then it provides a mechanism for improving consistency. Some of the industrial engineering applications of the AHP include its use in integrated manufacturing (Putrus, 1990), in the evaluation of technology investment decisions (Boucher and McStravic, 1991), in flexible manufacturing systems (Wabalickis, 1988), layout design (Cambron and Evans, 1991), and also in other engineering problems (Wang and Raz, 1991)

Technique for Order Performance by similarity to Ideal solution (TOPSIS), one of the most classical methods for solving MCDM problem, was first developed by Hwang and Yoon. It is based on the principle that the chosen alternative should have the longest distance from the negative-ideal solution i.e. the solution that maximizes the cost criteria and minimizes the benefits criteria; and the shortest distance from the positive-ideal solution i.e. the solution that maximizes the benefit criteria and minimizes the cost criteria. In classical TOPSIS the rating and weight of the criteria are known precisely. However, under many real situations crisp data are inadequate to model real life situation since human judgments are vague and cannot be estimated with exact numeric values (Hwang and Yoon, 1981). To resolve the ambiguity frequently arising in information from human judgments fuzzy set theory has been incorporated in many MCDM methods including TOPSIS. In fuzzy TOPSIS all the ratings and weights are defined by means of linguistic variables. A number of fuzzy TOPSIS methods and applications have been developed in recent years. Chen and Hwang (1992) first applied fuzzy numbers to establish fuzzy

TOPSIS. Triantaphyllou and Lin (1996) developed a fuzzy TOPSIS method in which relative closeness for each alternative is evaluated based on fuzzy arithmetic operations. Liang (1999) proposed Fuzzy MCDM based on ideal and anti-ideal concepts. Chen (2000) considered triangular fuzzy numbers and defined crisp Euclidean distance between two fuzzy numbers to extend the TOPSIS method to fuzzy GDM situations. Chu (2002) and Chu and Lin (2002) further improved the methodology proposed by Chen (2000). Chen and Tsao (2008) are to extend the TOPSIS method based on Interval-valued fuzzy sets in decision analysis. Jahanshahloo et al. (2006) and Chu and Lin (2009) extended the fuzzy TOPSIS method based on alpha level sets with interval arithmetic. Chen and Lee (2010) extended fuzzy TOPSIS based on type-2 fuzzy TOPSIS method in order to provide additional degree of freedom to represent the uncertainties and fuzziness of the real world. Fuzzy TOPSIS has been introduced for various multi-attribute decision-making problems. Yong (2006) used fuzzy TOPSIS for plant location selection and Chen et al. (2006) used fuzzy TOPSIS for supplier selection. Wang and Chang (2007) applied fuzzy TOPSIS to help the Air Force Academy in Taiwan choose optimal initial training aircraft in a fuzzy environment. Benitez et al. (2007) presented a fuzzy TOPSIS approach for evaluating dynamically the service quality of three hotels of an important corporation in Gran Canaria Island via surveys. Kahraman et al. (2007) proposed a fuzzy hierarchical TOPSIS model for the multi-criteria evaluation of the industrial robotic systems. Ashtiani et al. (2008) used interval-valued fuzzy TOPSIS method is aiming at solving MCDM problems in which the weights of criteria are unequal, using intervalvalued fuzzy sets concepts. Ekmekcioglu et al. (2010) used a modified fuzzy TOPSIS to select municipal solid waste disposal method and site. Kutlu and Ekmekcioglu (2011) used fuzzy TOPSIS integrated with fuzzy AHP to propose a new FMEA ‘failure modes and effects analysis’ which overcomes the shortcomings of traditional FMEA. Kaya and Kahraman (2011) proposed a modified fuzzy TOPSIS for selection of the best energy technology alternative. Kim et al. (2011) used fuzzy TOPSIS for modeling consumer’s product adoption process.

AHP and fuzzy TOPSIS methods are also very useful to give the rank of different strengths, weaknesses, opportunities and threats of SWM based on different criteria.

CHAPTER III

MATERIALS AND METHODS

3.1 Introduction

This research works has been conducted at Khulna university of engineering and technology (KUET) campus which is situated over 101 acres land about 7000 no. of population. The campus has own SWM techniques including having SWMP, waste storage system, door to door waste collection facilities, manpower etc. For the purposes of SWOT analysis of SWM at this campus, research questions has been set and data has been collected from field level investigations, laboratory tests and with the help of expertise groups. The AHP and fuzzy TOPSIS methods are two important tools for giving the rank of strengths, weaknesses, opportunities and threats associated with the SWM at this campus. The following methodology has been adopted to SWOT analysis of SWM and to find out the hierarchy of the strengths, weaknesses, opportunities and threats through AHP which is illustrated below.

3.2 Study Area

This study was done at KUET campus, Khulna of Bangladesh offering a special focus in the Technological advancement, Engineering Education and investigation. At present, it has about 5000 students, 18 Academic Departments under 3 Faculty, 3 Institutions and having a count of population is around 7000 no's such as students, teachers, officers and other workers. The university having an area of 101 acre appears at the North-West corner of Khulna City, about 12 km from the city center as demonstrated in figure 3.1. The campus has possessed solid waste management manner together with a waste management plant (WMP), waste storage, assortment, transport, treatments and disposal system which makes the campus extra comfortably and environmentally beautiful.

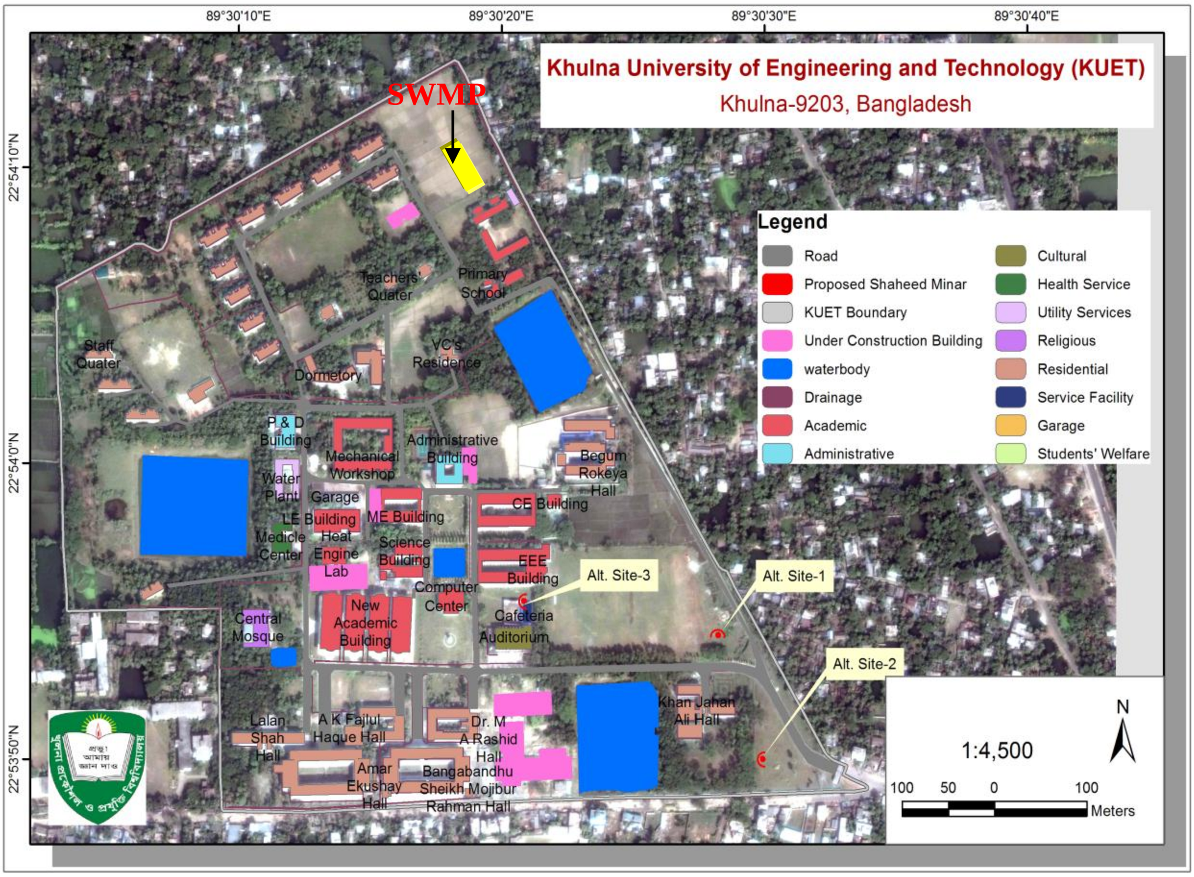


Figure 3.1: Layout plan of KUET campus showing the location of SWMP.

www.kuet.ac.bd

3.3 Research Methods

The research methodology used consists mainly of four parts (Yuan, 2013), which is shown in Figure 3.2. In the first part, for the purpose of answering the following research question: The internal and external factors affecting the effectiveness of the situation of SWM in KUET campus, the necessary actions that should be taken to comply with the legislative framework on integrated SWM; An overview of the latest status of SWM in KUET campus has been performed, the data obtained from a thorough search based on a literature review of journal articles and academic publications, government documents, MSWM related current regulations and studies and interviews, the SWM staff that are responsible for MSW planning and management. Nevertheless, the collection of primary data included interviews, laboratory analyses, and direct observation and focused group discussion.

In the second part, for the aim of searching of different strengths, weaknesses, opportunities and threats involved in SWM at KUET campus: a focused group discussion, stakeholders and staffs engaged in SWM at this campus has been made.

From the questionnaire survey, the intensity of importance of different strengths, weaknesses, opportunities and threats of SWM has been given with the help of Saaty rating scale and the ranking of strengths, weaknesses, opportunities and threats have been made through AHP process in the third part.

In the fourth part, after getting the hierarchy of SWOT, a strategic guideline has been provided to maximize the strengths and opportunities and minimizes the weaknesses and threats relevant to SWM at KUET campus.

Situation of SWM at KUET campus	**a. Searching, analyzing related regulations, literature** **b. Interviews with stakeholders, focused group and SWM staff**
Developing Research Questions	a. Setting research questions aiming in diagnosing factors external and internal environments
SWOT Analysis	a. Strengths b. Weaknesses c. Opportunities d. Threats
Ranking of SWOT	a. Ranking of strengths, weaknesses, opportunities and threats through analytical hierarchy process (AHP)
Suggested Strategy (intuitional level)	a. Proposing strategies based on the principle of "maximizing strengths and opportunities, transferring weaknesses to strengths, and minimizing threats."

Figure 3.2: Research methodology (Mir and Nabavi, 2015).

3.4 SWOT Analysis of SWM at KUET Campus

Strengths, weaknesses, opportunities and threats associated with SWM at KUET campus has been identified from baseline study/existing condition of SWM at KUET campus and from focused group discussions and questionnaire survey.

A group of research questions are formulated aiming at diagnosing the strengths, weaknesses, opportunities and threats of SWM in KUET. Identification of relevant factors of the external and internal environments (namely strengths, weaknesses, opportunities and threats) by a baseline survey using an questionnaire (Table 3.1) and interviews with the stakeholders (including staff responsible for SWM and authority, experts from civil engineering department, Institute of Disaster Management and Urban and Regional Planning Department and engineers involved in projects and SWM activities in this campus, and thus they are knowledgeable about the SWM practices in KUET. In SWOT analysis, multiple perspectives are always needed (Heinonen, 1997). In the third part, a detailed SWOT analysis is performed based on the research questions. Answers to those questions are extracted through analyzing information obtained from viewpoints major stakeholders and focused group concerned. The data was grouped according to four action areas; environmental aspects, economic aspects and social aspects and aesthetical aspects. Pair wise comparisons among factors were conducted within every SWOT group. When making the comparisons, the questions at stake were: (i) which of the two factors compared was greater, and (ii) and the intensity of greatness. With these comparisons as the input, the relative local priorities of the factors were computed using SWOT analysis (Srivastava *et al*., 2005).

KUET has own solid waste management plant (SWMP) including burning unit has been built in 2014. To support SWM at this campus it has four waste collectors, one green-watch man, one waste separator, two supervisors and one waste management in-charge and the authority has direct support for WM at KUET campus.

KUET campus has door-to-door collection system of SW. For the purposes of this study, the whole campus has been divided into four zones i.e. academic premises, student's dormitories, residential buildings and common facilities. Two plastic bins have been provided at every student dormitory, residential building and academic building to collect rapidly biodegradable and slowly/non-biodegradable wastes separately. Solid wastes from common facilities have been collected into plastic bins which are supported by light weight concrete block to withstand from tilting and overturning. Special types of dustbins have been integrated with biodegradable hygienic bags for the collection of special types of hazardous biodegradable wastes (gauge, bandage, sanitary napkin, baby's diaper, etc.) provided at some specified points i.e. at source such as female students' dormitory, residential buildings and medical center.

These SW have been transported every day to the WMP by using rickshaw van for final treatment. These special bags were transported every day to the WMP and directly put into the burning unit.

Waste management plant of KUET consists of waste receiving, sorting, composting, recycling and burning unit sections. Solid wastes were sorted into different categories at WMP. Separation is the key to effective waste management. At KUET campus about 45 no. of waste bins from academic and common places and 18 no. of large drum of waste from different student halls and around 60 no. of waste bins from residential areas has been collected; separated plastic types, biological waste, plant material, paper and glass. Materials can be effectively recycled or processed, reducing landfill size and raw material consumption.

There are several strengths, weaknesses, opportunities and threats of SWM at KUET campus and the following research questions has been set for SWOT analysis.

Table 3.1: Research questions for SWOT analysis (Mir and Nabavi, 2015).

Factors	Questions
Strengths	a. The advantages b. SWM can do as well c. The factors supporting SWM
Weaknesses	a. Obstacles preventing the promotion of SWM b. Elements, that SWM need to be strengthened c. Improvement that can be made d. Work that is not done properly e. Factors should be avoided f. Source of the complaints
Opportunities	a. Good chances facing SWM b. The interesting trends c. Benefits that would occur to facilitate an improved SWM d. Changes in usual practices and available technology on both a broad and narrow scale that may occur e. Possible changes in Government Policy related to SWM Possible changes in socio-economic patterns, SWM practices, life-style and economic standards of project beneficiaries that may occur
Threats	a. Obstacles that SWM face b. Lack of support and facilities for an improved SWM situation c. The changing technology threatening SWM d. Disinterest and lack of willingness the stakeholders for supporting SWM.

3.5 Ranking of different Strengths, Weaknesses, Opportunities and Threats through Analytical Hierarchy Process (AHP)

The AHP is based on the experience gained by its developer, T.L. Saaty, while directing research projects in the US Arms Control and Disarmament Agency. It was developed as a reaction to the finding that there is a miserable lack of common, easily understood and easy-to-implement methodology to enable for taking complex decisions.

Since then, the simplicity and power of the AHP has led to its widespread use across multiple domains in every part of the world. The AHP has found use in business, government, social studies and defense and other domains involving decisions in which choice, prioritization or forecasting is needed. Owing to its simplicity and ease of use, the AHP has found ready acceptance by busy managers and decision-makers. It helps structure the decision-makers thoughts and can help in organizing the problem in a manner that is simple to follow and analyze.

Broad areas in which the AHP has been applied include alternative selection, resource allocation, forecasting, business process re-engineering, quality function deployment, balanced scorecard, benchmarking, public policy decisions, healthcare, and many more. Basically the AHP helps in structuring the complexity, measurement and synthesis of rankings. These features make it suitable for a wide variety of applications.

The AHP has proved a theoretically sound and market tested and accepted methodology. It is almost universal adoption as a new paradigm for decision-making coupled with its ease of implementation and understanding constitute its success. More than that, it has proved to be a methodology capable of producing results that agree with perceptions and expectations.

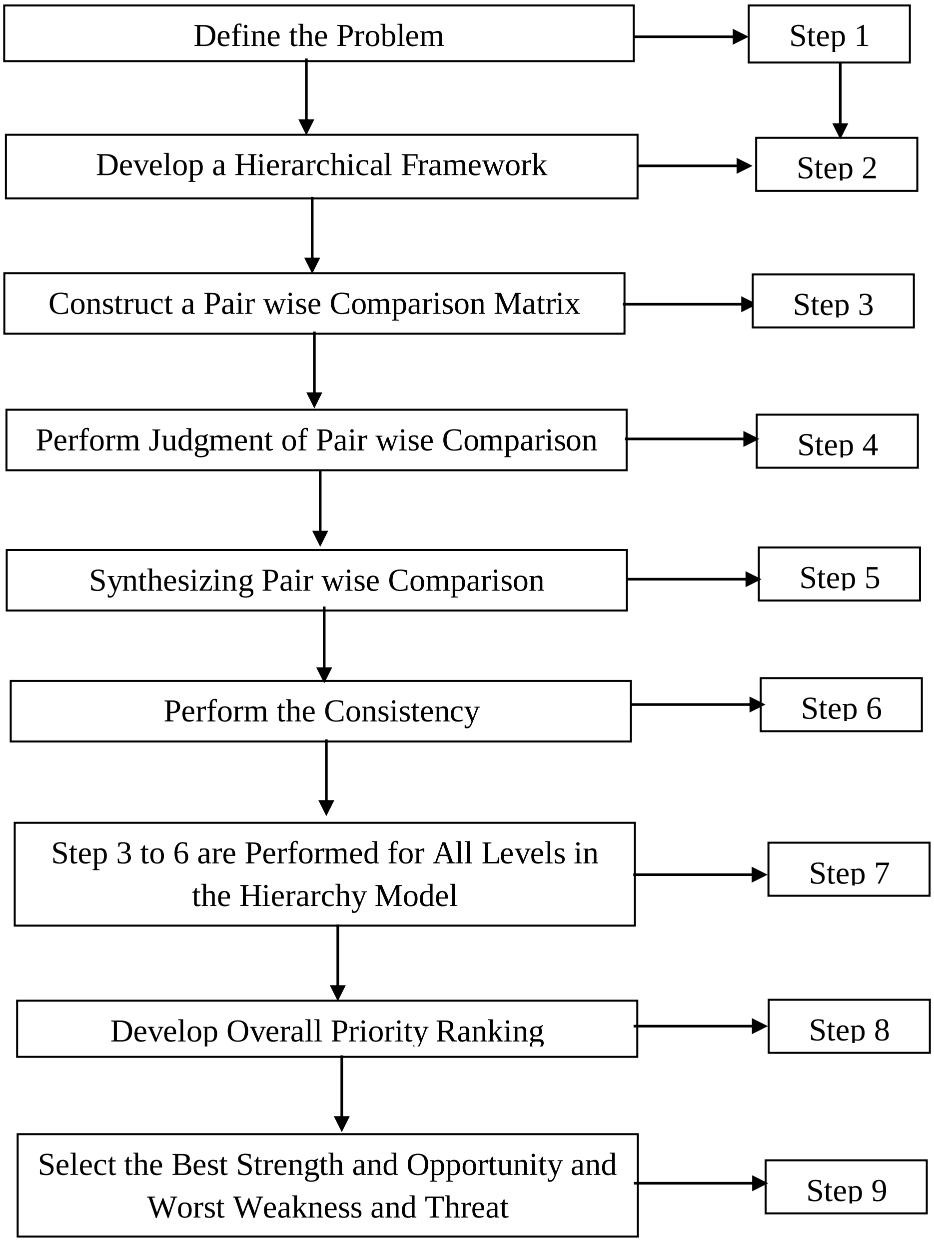


Figure 3.3: Flow chart of AHP process (Muhisn et al. 2015)

The AHP provides a means of decomposing the problem into a hierarchy of sub problems which can more easily be comprehended and subjectively evaluated. The subjective evaluations are converted into numerical values and processed to rank each alternative on a numerical scale. The methodology of the AHP can be explained in following steps:

3.5.1 Define the Problem

The research focuses to rank of strengths, weaknesses, opportunities and threats in SWOT analysis of SWM at KUET campus. There are four main decision criteria nine strengths, six weaknesses, four opportunities and five threats have been identified. Thus, the objective is to give the rank of strengths, weaknesses, opportunities and threats by using AHP technique.

3.5.2 Questionnaire Design and Results of Survey

A survey was conducted among thirty persons including experts, stakeholders and waste management staffs. The objective of this survey was to assess the importance of the mentioned factors as criteria to be incorporated in the AHP model for the ranking of strengths, weaknesses, opportunities and threats in SWM at KUET campus.

The problem is decomposed into a hierarchy of goal, criteria and alternatives. This is the most creative and important part of decision-making. Structuring the decision problem as a hierarchy is fundamental to the process of the AHP. Hierarchy indicates a relationship between elements of one level with those of the level immediately below. This relationship percolates down to the lowest levels of the hierarchy and in this manner every element is connected to every other one, at least in an indirect manner. A hierarchy is a more orderly form of a network. An inverted tree structure is similar to a hierarchy. Saaty suggests that a useful way to structure the hierarchy is to work down from the goal as far as one can and then work up from the alternatives until the levels of the two processes are linked in such a way as to make comparisons possible.

Figure 3.4 shows a generic hierarchic structure. At the root of the hierarchy is the goal or objective of the problem being studied and analyzed. The leaf nodes are the alternatives to be compared. In between these two levels are various criteria and sub-criteria. It is important to note that when comparing elements at each level a decision-maker has just to compare with respect to the contribution of the lower-level elements to the upper-level one. This local concentration of the decision-maker on only part of the whole problem is a powerful feature of the AHP.

Questionnaires were used for data collection to prioritize the criteria and rate the relative importance of each criterion and prioritize the alternatives and rate the relative importance of alternative with respect to each criterion used in the AHP model.

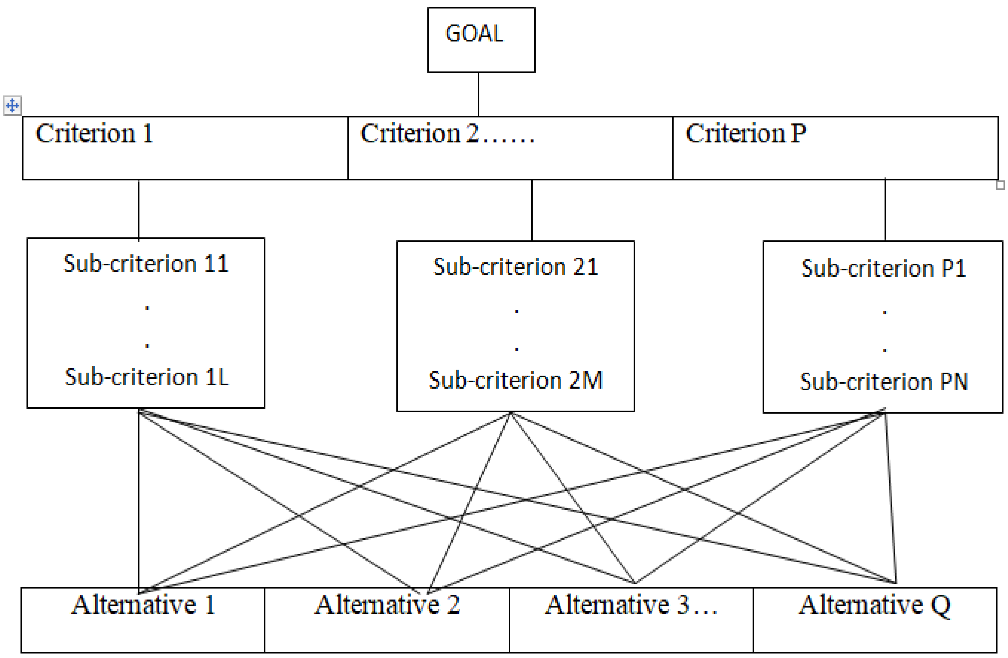


Figure 3.4: Generic hierarchic structure

A								X		B
	Extremely Strong	Very Strong	Strong	Marginally Strong	Equal	Marginally Strong	Strong	Very Strong	Extremely Strong	

Figure 3.5: Format for pair wise comparison

3.5.3 Pair Wise Comparison Matrix of Criterion and Alternative

Data are collected from experts or decision-makers corresponding to the hierarchic structure, in the pair wise comparison of alternatives on a qualitative scale as described below. Experts can rate the comparison as equal, marginally strong, strong, very strong, and extremely strong. The opinion can be collected in a specially designed format as shown in Figure 3.5 "X" in the column marked "Very strong" indicates that B is very strong compared with A in terms of the criterion on which the comparison is being made. The comparisons are made for each criterion and converted into quantitative numbers as per Table 3.2.

Table 3.2: The AHP rating scale (Saaty, 1980)

Intensity of importance	Definition	Explanation
1	Equal importance	Two factors contribute equally to the objective
3	Somewhat more important	Experience and judgment slightly favor one over the other.
5	Much more important	Experience and judgment strongly favor one over the other.
7	Very much more important	Experience and judgment very strongly favor one over the other. Its importance is demonstrated in practice.
9	Absolutely more important	The evidence favoring one over the other is of the highest possible validity
2,4,6,8	Intermediate values	When compromise is needed

The pair wise comparisons of various criteria are organized into a square matrix. These matrixes consist of n columns and n rows; it is a square matrix (i.e. 'A' matrix) as shown in equation (1). Each element of the matrix represent the preference of the factor in rows *i* to the factor in column j. All diagonal elements in the matrix are equal to 1. Also, all element in the lower triangle of the matrix can be calculated by $a_{ji} = 1 / a_{ij}$ as describe in equation (1).

$$A = \begin{pmatrix} 1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots a_{ij} \\ \ldots\ldots\ldots\ldots 1 \ldots\ldots\ldots\ldots \\ 1/a_{ij} \ldots\ldots\ldots\ldots\ldots\ldots\ldots 1 \end{pmatrix} \quad ....(1)$$

3.5.4 Perform Judgment of Pair Wise Comparison

The decision makers should compare each element with the other by using the fundamental scale for pair wise comparisons as shown in Table 3.3. Pair wise comparison starts with compare between two selected elements at same level to get relative importance between them. There are n (n-1)/2 judgments necessary for preparation a set of matrixes in step 3.5.3

3.5.5 Synthesizing Pair Wise Comparison

Saaty (1980) demonstrated mathematically that the eigenvector method was the best approach to determine the priorities from each pair wise matrix in order to get importance of criteria and alternative performance.

According to Hsiao (2002), the Average of Normalized Column (ANC) method is used for calculate the eigenvectors for priorities. The ANC process can be divided into three steps:

1) Sum of each column in matrix

2) Divide each elements of matrix with the sum of its column

3) Normalized principle of Eigen vector and that can be done by add the element in each resulting row and then divide this sum by the number of elements in the row (*n*).

In a mathematical form, the eigenvector (priorities) could be calculated as described in equation (2)

$$W_i = \frac{1}{n}\sum_{j=1}^{n}\frac{a_{ij}}{\sum_i^n a_{ij}}, i, j = 1, 2, \ldots\ldots\ldots n \qquad \ldots\ldots\ldots(2)$$

Where, a_{ij} is the element of the matrix.

3.5.6 Perform the Consistency

Since the comparisons are performed through subjective judgments or personal, possible occurrence some of inconsistency. To ensure the judgment are consistent, the last process called consistency verification, which is considered as one of the significant task of AHP, is included to measure the degree of consistency among the pair wise comparisons by computing the consistency ratio (Ho, 2008).

According to Saaty (1980), if the Consistency Ratio (CR) is more than 0.1 the judgment is untrustworthy due to they are close for comfort to random and the exercise is should be repeated or valueless.

There are three steps to calculate the Consistency Ratio (CR) as follows:

1) Calculation of Eigenvalue (λmax)

$$AX = \lambda max\ X \qquad \text{………..(3)}$$

Where, A is the comparison matrix with size $n \times n$, X is the eigenvector of size $n \times 1$.

2) Calculation of Consistency Index (CI).

$$CI = (\lambda max - n)/(n-1) \qquad \text{………..(4)}$$

Where, n is the size of matrix.

3) Calculation of Consistency Ratio (CR).

$$CR = CI/RI \qquad \text{………..(5)}$$

Table 3.3: Value of Random Index (RI) (Saaty, 1980).

N	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Steps 3.5.3 to 3.5.6 are performed for all levels in the hierarchy model. As all criteria and alternatives have CR value less than 0.1, the judgments are acceptable.

3.5.7 Overall Priority Matrix

The overall priorities were determined by multiplying the priority (eigenvector) matrix of the criteria by the priorities (eigenvector) for each alternative decision for each objective.

3.5.8 Selection of the Best Strength and Opportunity and Worst Weakness and Threat

Selection of best strength and opportunity can be made depending upon the ranking of overall priority of strengths and opportunities respectively. Worst weakness and threat associated with SWM at KUET campus can be found from the ranking of overall priority of weaknesses and threats respectively.

CHAPTER IV

RESULTS AND DISCUSSIONS

4.1 Introduction

The SWOT analysis of SWM at KUET campus has been performed through field level investigation, group discussions, laboratory investigation and questionnaire survey. For the purposes of ranking of strengths, weaknesses, opportunities and threats, the criteria has been selected with group discussion. The different strengths, weaknesses, opportunities and threats have been illustrated below and their ranking has been obtained through AHP

4.2 Solid Waste Generation

From previous study at KUET campus the solid waste generation rate is obtained 0.074 kg/capita/day and compostable and non compostable wastes have been found as 66.67% and 33.33%, respectively (Khondoker et al., 2015). Figure 4.1 represents the monthly SW generation at different month at KUET campus. The average SW generation has been observed as 531 kg/day and SW generation rate has been found as 0.099 kg/capita/day at KUET campus during September, 2016 to March, 2017.

The estimated SW generation rate in Khulna is 0.50 kg/capita/day (Ahmed and Rahman, 2007). The SW generated at KUET campus is excluded construction waste and street sweeping waste. The waste generation rate at this campus is found very low compared to the national level SW generation rate. The SW generation is very low in students dormitory compared the number of students and the first year students and some of the teachers, officers and staffs lives out of the campus. They have less contribution for SW generation at this campus. The SW generation at residential areas except student's territory, the SW generation rate may be high as national level SW generation rate.

It has been clearly noticed that the waste generation rate is increased day by day. Nevertheless waste generation relies upon specific facts like as food items, weather, campus holiday and organizing various sorts of program and so on.

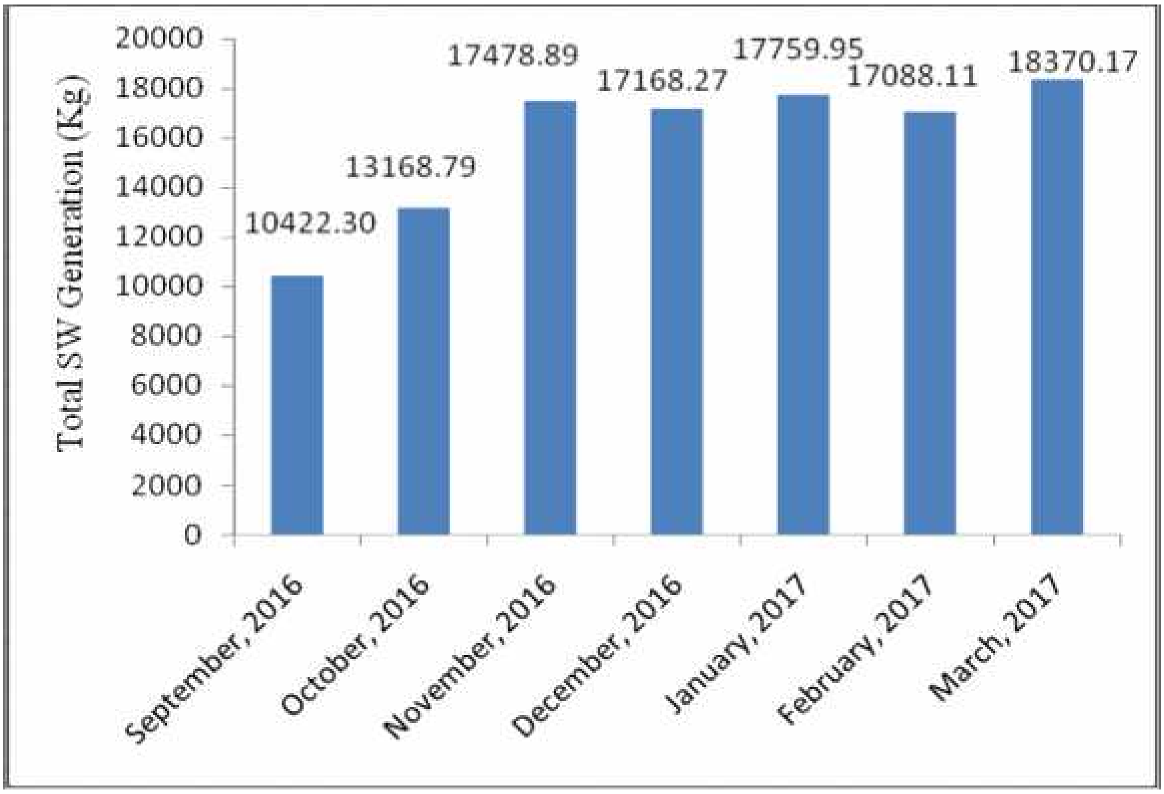


Figure 4.1: Solid waste generation at different month

4.3 Composition of Solid Waste

Figure 4.2 symbolizes the composition of SW at KUET campus where food and vegetable, paper, and plastic waste have been found as predominant and observed as 52.04%, 42.01% and 3.70% respectively. Some lemon peel, eggshells and others waste also has been generated noticed as 0.30%, 0.20% and 1.75% during the time period of September, 2016 to March, 2017.

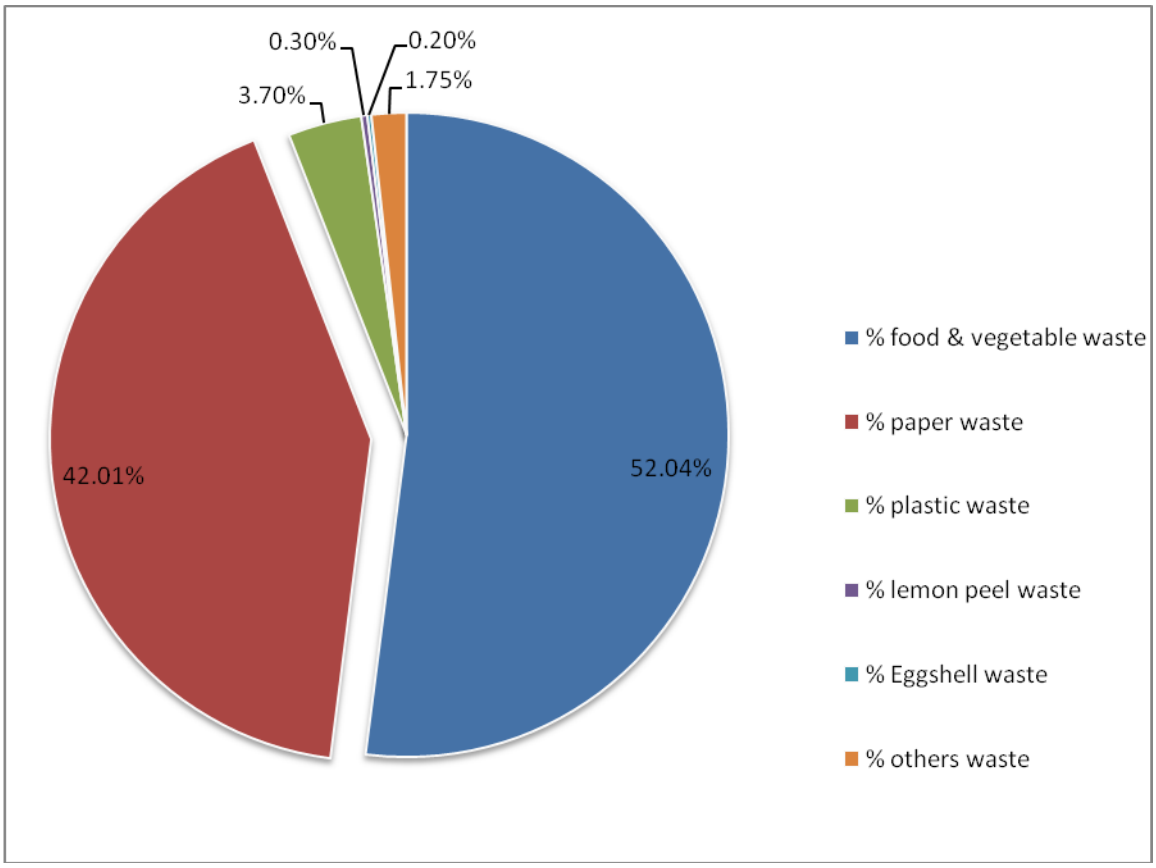


Figure 4.2: Composition of SW generation at KUET campus

4.4: Recyclable Part of Solid Waste

Figure 4.3 indicates the monthly plastic waste generation at KUET campus and it has been seen that the average monthly plastic waste creation is 297.19 kg and primarily produced from academic areas, typical places, student dormitories, housing areas and cafeteria.

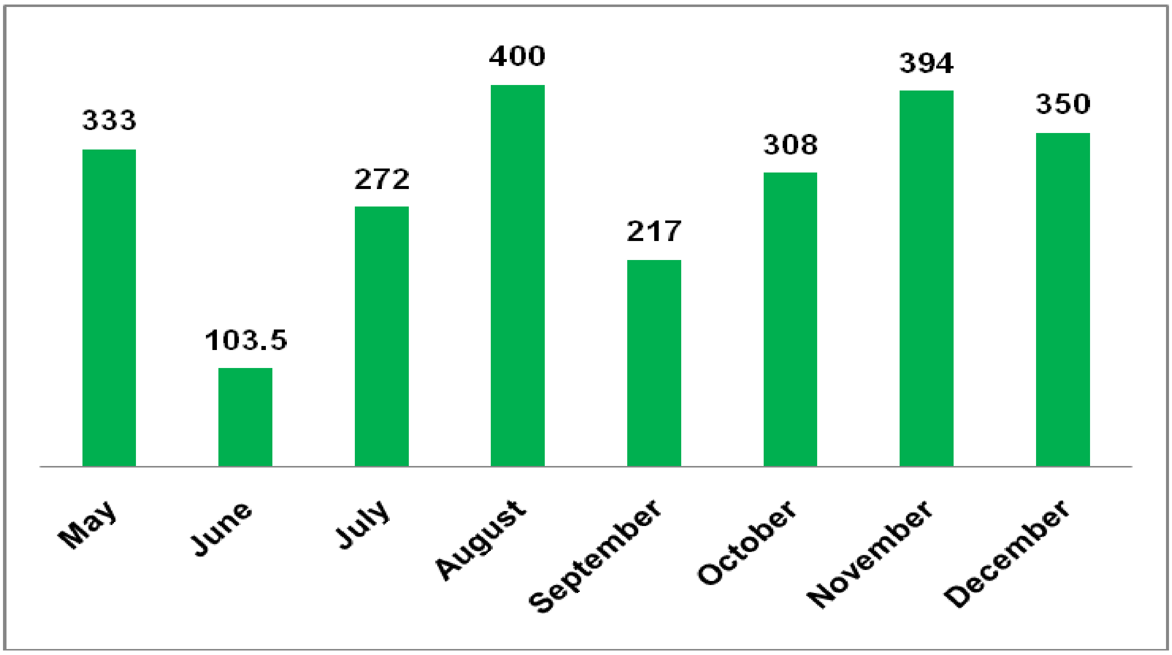


Figure 4.3: Generation of Plastic Waste at KUET campus in 2016 (Sarder et al. 2017)

Plastic waste is reused to increase the aesthetical perspective of statue and preserve from deterioration of vital accessories. Figure 4.4 symbolizes the Durbar Bangla (KUET) where each electrical spot light has been protected by means of half of single easy green pet plastic bottle (cold drink bottle is divided into two constituents) made-up by Azim, which increase the elegance of sculpture and expensive energy light has been stored from breakdown (Sarder et al. 2017).

Figure 4.5 signifies that the month-to-month plastic waste has been provided into market from May, 2016 to December, 2016. The average plastic waste which has been supplied to the market has been found as 51.75 kg/month which is the 17.41% of entire plastic waste produced at campus and still attempting to gain levels of this number in accordance with the market centered recycling (Sarder et al. 2017).

Figure 4.4: Electrical spot light of Beautiful Durbar-Bangla is covered by mountain dew bottle (Suggested by Shahidul Islam Azim, Staff of KUET)

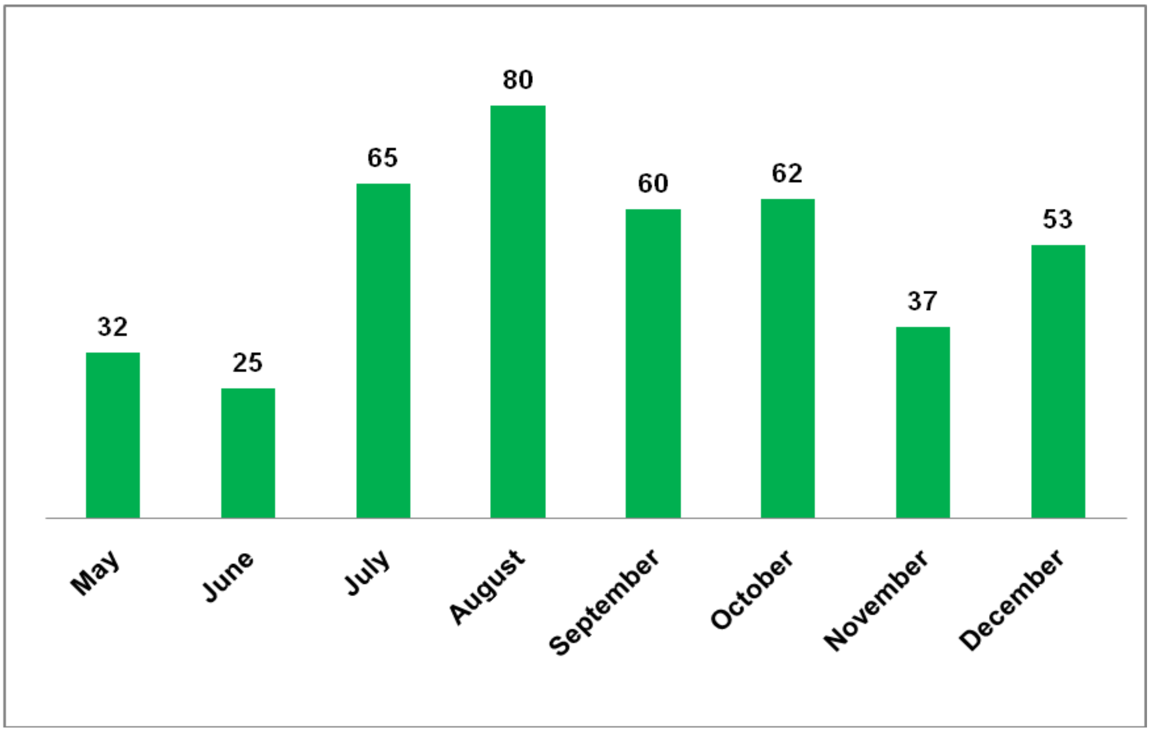


Figure 4.5: Total plastic waste sold into market in 2016 (Sarder et al. 2017).

Figure 4.6 describes the monthly paper waste generation rate during September, 2016 to March, 2017. The average paper waste generation at KUET campus has been observed as 4027.63 kg/month.

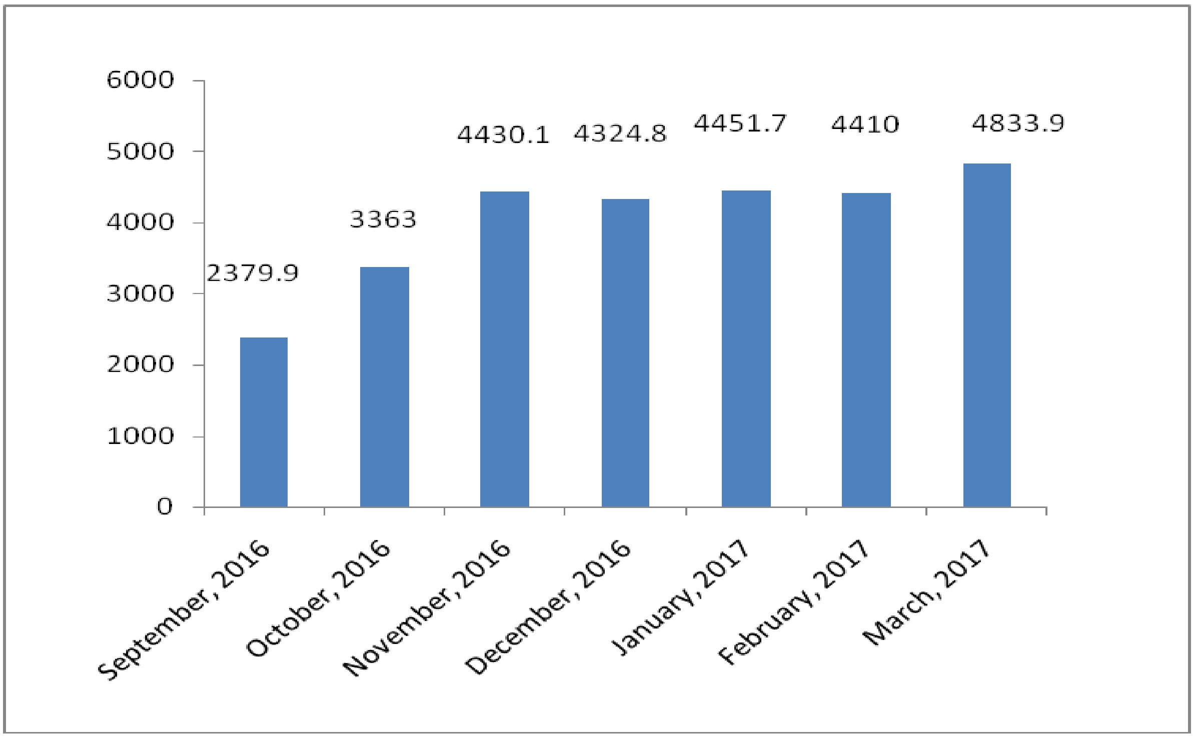


Figure 4.6: Generation of paper waste at different month in 2017.

Figure 4.7 deleniates the monthly paper waste offered into the market during January, 2017 to September, 2017. The monthly paper waste sell into the market has been found as 63.34 kg/month which is very neglegible compared to paper waste generation.

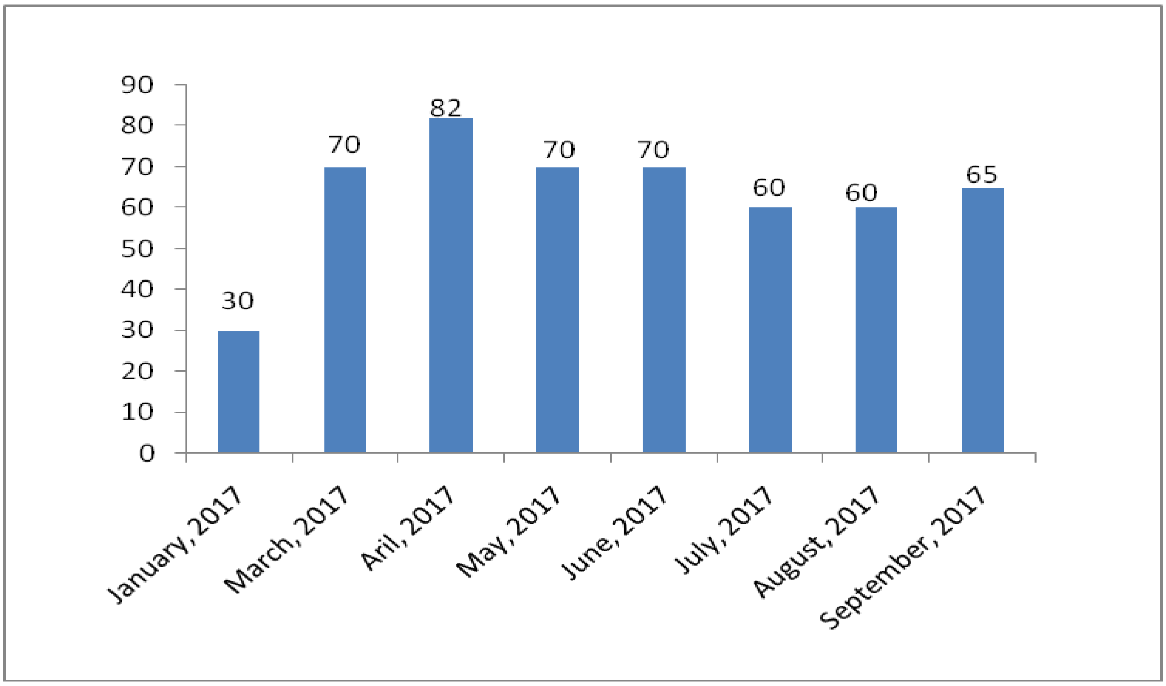


Figure 4.7: Total paper waste sold into market in 2017

4.5: Compostable Part of Solid Waste

Figure 4.8 presents the amount of compostable wastes at different month and average compostable waste that has been found as 3898 kg/month. Figure 4.9 describes the generation of compost at different months and the average compost generation has been obtained as 48.57 kg/month during in the year of 2015 and the produced compost has been totally sold into the market. The produced compost has great demand in gardening, agriculture and fishiculture etc. and the compost is sold in the market at 12 tk/kg (Sutradhar et al. 2016).

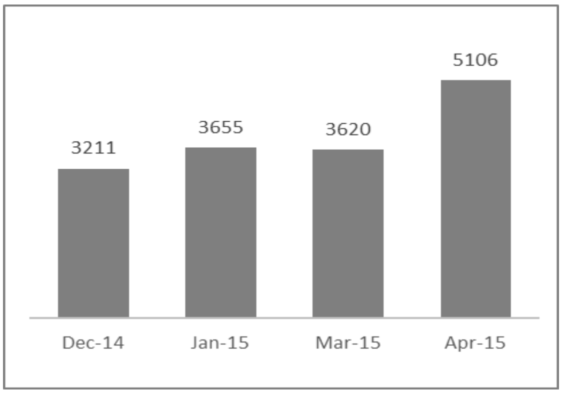


Figure 4.8: Monthly compostable waste generation (kg) (Sutradhar et al. 2016)

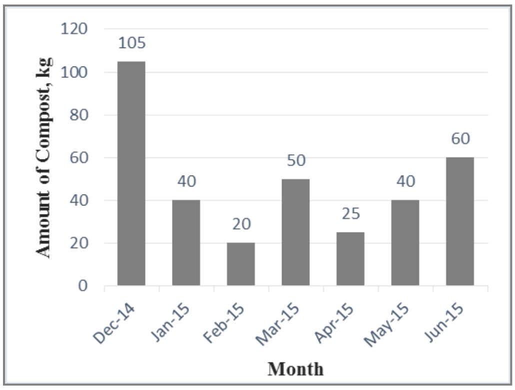


Figure 4.9: Monthly compost production (kg) (Sutradhar et al. 2016)

4.6 SWM techniques Adopted at KUET Campus

For the purposes of the SWM, the whole campus has been divided into four zones i.e. academic premises, student’s dormitories, residential buildings and common facilities. Two plastic bins have been provided at every student dormitory, residential building and academic building to collect rapidly biodegradable and slowly/non biodegradable wastes separately. Solid wastes from common facilities have been collected into plastic bins which are supported by light weight concrete block to withstand from tilting and overturning (Figure 4.10a). These wastes have been transported every day to the WMP by using rickshaw van (Figure 4.10b) for final treatment.

Special types of dustbins have been integrated with biodegradable hygienic bags (Figure 4.10c) for the collection of special types of hazardous biodegradable wastes (gauge, bandage, sanitary napkin, baby’s diaper, etc.) provided at some specified points i.e. at source such as female students’ dormitory, residential buildings and medical center. These special bags were transported every day to the WMP and directly put into the burning unit. WMP at KUET consists of waste receiving, sorting, composting, recycling and burning unit sections (Figure 4.10d). Solid wastes were sorted into different categories at WMP.

(a)

(b)

(c) (d)

Figure 4.10: Pictorial view of WMP and some components of SWM in KUET campus: (a) concrete supported dustbin for SW storage, (b) transportation of SW, (c) hygienic biodegradable bag for special waste collection and (d) WMP including burning unit (Sarder et al. 2015).

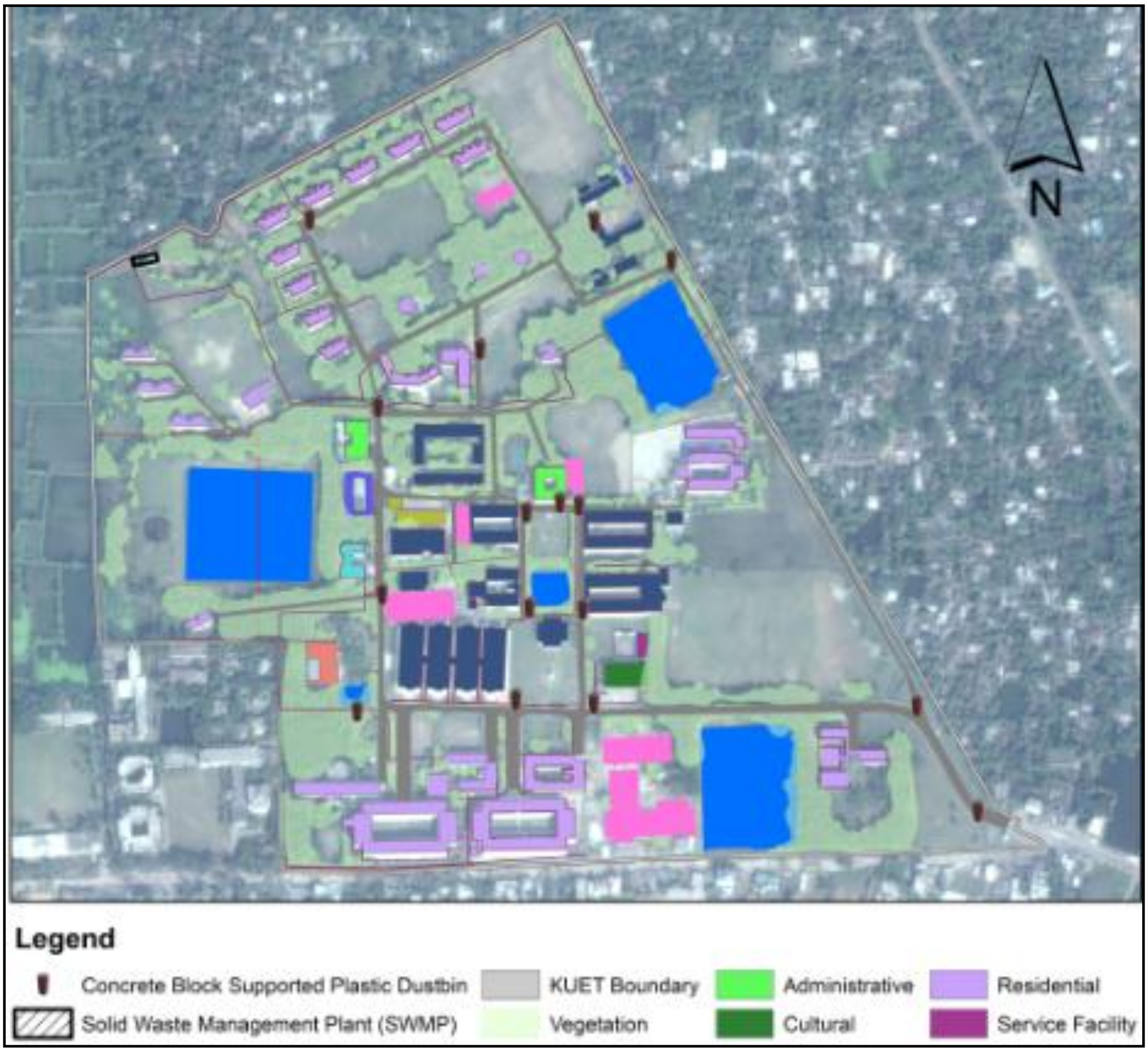


Figure 4.11: Location of plastic dustbin at KUET campus

Figure 4.11 represents the location of light weight concrete block supported plastic waste bins at academic zones and common premises. The waste generated at the academic and common premises mainly non-biodegradable, stored into these bins and collected through rickshaw van regularly.

4.7 SWOT Analysis of SWM at KUET Campus

Identification of relevant factors of the external and internal environments (namely strengths, weaknesses, opportunities and threat) for SWM at KUET campus by a baseline survey using an semi-structure questionnaire (Table 4.1) and interviews with the stakeholders (including WM staff responsible for SWM and engineers involved in SWM activities at KUET campus, and thus they are knowledgeable about the SWM practices KUET campus. In SWOT analysis, multiple perspectives are always needed (Heinonen, 1997). A detailed SWOT analysis is performed based on the research questions. Answers to those questions are extracted through analyzing information obtained from viewpoints of major stakeholders and focused groups discussion.

Table 4.1: Results SWOT profile at KUET Campus for SWM

Internal conditions	**External conditions**
Strengths	**Opportunities**
1. Door to door collection system of SW (S-1) 2. Transportation system of SW (S-2) 3. Sorting system of SW (S-3) 4. Composting system of SW (S-4) 5. Recycling of SW (high density polythene, steel, glass, paper) (S-5) 6. Burning system of sanitary SW (S-6) 7. Manpower and equipment for SWM (S-7) 8. Enforcement and awareness for SWM (S-8) 9. Financial support for SWM (S-9)	1. Resource Recovery from Eggshells (O-1) 2. Resource Recovery from Citrus Peel (O-2) 3. Market Based Recycling of SW (O-3) 4. Route Selection for SW Collection and Transportation (O-4)
Weaknesses	**Threats**
1. Route Selection for Collection and Transportation of SW (W-1) 2. Time for Decomposition of Degradable SW during Composting (W-2) 3. Recycling of paper and polythene (low density) Waste (W-3) 4. Burning Temperature at Burning Unit and Related Air Pollution (W-4) 5. Roadside Construction Waste Deposition (W-5) 6. Training Program among Staff (W-6)	1. Accidents among staff in Collecting, Transporting and Sorting of SW (T-1) 2. Damages of Roadside Waste Bins (T-2) 3. Damages of Waste Management Plant (WMP) (T-3) 4. Damages of Equipment like Rickshaw-van (T-4) 5. Difficulties in Transporting of SW to the Ultimate Disposal Site. (T-5)

N.B. Weaknesses and threats are expressed in negative aspects.

Due to the rapid increase of solid waste generation, there is a need to work towards a sustainable waste management system, which requires environmental, economic, aesthetical and social sustainability. Performance of such systems depends on the meaningful participation of individuals, KUET authorities, and producers of SW at KUET campus. In this study, SWOT analysis was applied by judging it on four aspects environmental, economic, social and aesthetical in order to optimize the SWM system. It was observed that the SWOT analysis is an excellent tool to explore the possibilities and ways for initiating and successfully implementing the SWM program.

4.8 Ranking of SWOT through Analytical Hierarchy Process

4.8.1 Ranking of Strengths through Analytical Hierarchy Process

Four criteria has been selected to study the rank or priority of strengths, weaknesses, opportunities and threats of SWM at KUET campus with focused group discussions and these criteria are environmental, economic, social and aesthetic.. The average relative importance of these criteria is given in the Table 4.2 (according to the Saaty, 1980) scale.

Table 4.2: Intensity of importance of different criteria obtained from questionnaire survey

Criteria	Intensity of Importance
Environmental	7.5
Economic	2.5
Social	6.5
Aesthetical	8.24

Aesthetical criteria represent the beauty and perspective of KUET campus. Proper SWM enriches the aesthetical view of a campus. Social aspect has been considered as the second criteria. It includes inhibitors and visitors into the campus and their comfort due to proper SWM otherwise they will experience odor nuisance. In case of SWM at KUET campus, environmental aspect has been considered as the third criterion which includes conservation of resources and reduction of environmental pollution. The fourth aspect has been selected from economic point of view which focuses the investment costs, the annual maintenance costs, personnel employment costs and finally revenues from recovered materials and energy.

The intensity of importance obtained from questionnaire survey and focused group discussion for criteria and alternatives have been converted into pair wise comparison. The pair wise comparison for criteria has been shown in the table 4.3.

Table 4.3: Pair wise comparison matrix of different criteria

Criteria	Environmental	Economic	Social	Aesthetical
Environmental	1	3	1.15	0.91
Economic	0.333	1	0.4	0.303
Social	0.87	2.5	1	0.789
Aesthetical	1.1	3.3	1.267	1
Sum =	3.303	9.8	3.817	3.002

Table 4.4: Synthesized Matrix for the Criteria

Criteria	Environmental	Economic	Social	Aesthetical	Eigenvector (Priority)
Environmental	0.302755	0.306122	0.301284	0.303131	0.303323
Economic	0.100817	0.102041	0.104794	0.100933	0.102146
Social	0.263397	0.255102	0.261986	0.262825	0.260827
Aesthetical	0.333031	0.336735	0.331936	0.333111	0.333703
Sum =	1	1	1	1	1

Eigenvalue λmax X = $AX = 4$, where A is the comparison matrix with size $n \times n$, X is the eigenvector of size $n \times 1$.

Consistency Index (CI) = (λmax–n) / (n–1), where n is the size of matrix = 4.

Consistency Ratio (CR) = CI / RI.

For the matrix size 4 x 4, the random index will be RI = 0.90, after that Consistency Ratio (CR) was calculated. For instance, the calculation of consistency test for the criteria, CR = CI/RI, CR= $7.92 \times 10^{-05}/0.90 = 8.8 \times 10^{-05}$. As the value of CR is less than 0.1, the judgment is acceptable.

Table 4.5: Pair wise Comparison Matrix of Strengths with respect to Environmental aspects

Strengths	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9
S-1	1	1.422	1.228	1.286	1.228	1.5	1.08	1.385	1.125
S-2	0.703	1	0.864	0.904	0.864	1.055	0.76	0.974	0.791
S-3	0.814	1.157	1	1.047	1	1.222	0.88	1.128	0.916
S-4	0.778	1.106	0.955	1	0.955	1.167	0.84	1.077	0.875
S-5	0.814	1.157	1	1.047	1	1.222	0.88	1.128	0.916
S-6	0.667	0.948	0.818	0.857	0.818	1	0.72	0.923	0.75
S-7	0.926	1.316	1.136	1.19	1.136	1.389	1	1.282	1.041
S-8	0.722	1.027	0.887	0.929	0.887	1.083	0.78	1	0.813
S-9	0.889	1.264	1.092	1.143	1.092	1.333	0.961	1.23	1

Table 4.6: Synthesized Matrix of Strengths with respect to Environmental aspects

Strengths	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	Eigen vector
S-1	0.136743	0.13677	0.136748	0.136765	0.136748	0.136724	0.136692	0.136763	0.136745	0.136744
S-2	0.09613	0.096182	0.096214	0.09614	0.096214	0.096163	0.09619	0.096179	0.096147	0.096173
S-3	0.111309	0.111282	0.111359	0.111347	0.111359	0.111385	0.111378	0.111385	0.111341	0.111349
S-4	0.106386	0.106377	0.106347	0.106349	0.106347	0.106371	0.106316	0.106349	0.106357	0.106356
S-5	0.111309	0.111282	0.111359	0.111347	0.111359	0.111385	0.111378	0.111385	0.111341	0.111349
S-6	0.091207	0.09118	0.091091	0.091141	0.091091	0.091149	0.091128	0.091142	0.091163	0.091144
S-7	0.126624	0.126575	0.126503	0.126555	0.126503	0.126607	0.126566	0.126592	0.126535	0.126562
S-8	0.098728	0.098778	0.098775	0.098798	0.098775	0.098715	0.098722	0.098746	0.098821	0.098762
S-9	0.121564	0.121574	0.121604	0.121557	0.121604	0.121502	0.12163	0.121457	0.121551	0.12156

Where, consistency ratio, CR = $-3.1 \times 10^{-6} < 0.1$, so the judgments are acceptable.

Table 4.7: Pair wise Comparison Matrix of Strengths with respect to Economic aspects

Strengths	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9
S-1	1	1	0.5	0.438	0.456	1.167	1.75	1	0.583
S-2	1	1	0.5	0.438	0.456	1.167	1.75	1	0.583
S-3	2	2	1	0.875	0.913	2.333	4	2	1.167
S-4	2.283	2.283	1.143	1	1.043	2.667	4	2.286	1.333
S-5	2.193	2.193	1.095	0.959	1	2.557	3.835	2.191	1.278
S-6	0.857	0.857	0.429	0.375	0.391	1	1.5	0.857	0.5
S-7	0.571	0.571	0.25	0.25	0.261	0.667	1	0.571	0.333
S-8	1	1	0.5	0.437	0.456	1.167	1.751	1	0.583
S-9	1.715	1.715	0.857	0.75	0.782	2	3.003	1.715	1

Table 4.8: Synthesized Matrix of Strengths with respect to Economic aspects

Strengths	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	Eigen vector
S-1	0.079246	0.079246	0.079694	0.079319	0.079194	0.079253	0.077471	0.079239	0.079212	0.079097
S-2	0.079246	0.079246	0.079694	0.079319	0.079194	0.079253	0.077471	0.079239	0.079212	0.079097
S-3	0.158491	0.158491	0.159388	0.158457	0.158562	0.158438	0.177077	0.158479	0.15856	0.16066
S-4	0.180918	0.180918	0.18218	0.181094	0.181139	0.181121	0.177077	0.181141	0.181114	0.180745
S-5	0.173786	0.173786	0.17453	0.173669	0.173671	0.17365	0.169773	0.173613	0.173641	0.173347
S-6	0.067913	0.067913	0.068377	0.06791	0.067906	0.067912	0.066404	0.067908	0.067935	0.067798
S-7	0.045249	0.045249	0.039847	0.045273	0.045328	0.045297	0.044269	0.045246	0.045245	0.044556
S-8	0.079246	0.079246	0.079694	0.079138	0.079194	0.079253	0.077516	0.079239	0.079212	0.079082
S-9	0.135906	0.135906	0.136595	0.13582	0.135811	0.135823	0.132941	0.135895	0.13587	0.135619

Where, consistency ratio, CR = 0.000114 < 0.1, so the judgments are acceptable.

Table 4.9: Pair wise Comparison Matrix of Strengths with respect to social aspects

Strengths	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9
S-1	1	1.136	1.666	1.136	1.249	1.924	1	1.041	1.111
S-2	0.88	1	1.466	1	1.099	1.693	0.88	0.916	0.977
S-3	0.6	0.682	1	0.682	0.75	1.155	0.6	0.625	0.667
S-4	0.88	1	1.466	1	1.099	1.693	0.88	0.916	0.977
S-5	0.801	0.91	1.333	0.91	1	1.54	0.801	0.834	0.889
S-6	0.52	0.591	0.866	0.591	0.649	1	0.52	0.541	0.577
S-7	1	1.136	1.667	1.136	1.248	1.923	1	1.041	1.111
S-8	0.961	1.092	1.6	1.092	1.199	1.848	0.961	1	1.067
S-9	0.9	1.024	1.499	1.024	1.125	1.733	0.9	0.937	1

Table 4.10: Synthesized Matrix of Strengths with respect to Social aspects

Strengths	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	Eigen vector
S-1	0.132591	0.13254	0.132612	0.13254	0.132618	0.132607	0.132591	0.132595	0.132641	0.132593
S-2	0.11668	0.116673	0.116692	0.116673	0.116691	0.116686	0.11668	0.116673	0.116643	0.116677
S-3	0.079554	0.079571	0.079599	0.079571	0.079635	0.079606	0.079554	0.079608	0.079632	0.079592
S-4	0.11668	0.116673	0.116692	0.116673	0.116691	0.116686	0.11668	0.116673	0.116643	0.116677
S-5	0.106205	0.106172	0.106105	0.106172	0.10618	0.106141	0.106205	0.106229	0.106137	0.106172
S-6	0.068947	0.068953	0.068933	0.068953	0.068911	0.068923	0.068947	0.068908	0.068887	0.068929
S-7	0.132591	0.13254	0.132691	0.13254	0.132512	0.132538	0.132591	0.132595	0.132641	0.132582
S-8	0.12742	0.127406	0.127358	0.127406	0.127309	0.127369	0.12742	0.127372	0.127388	0.127383
S-9	0.119332	0.119473	0.119319	0.119473	0.119452	0.119443	0.119332	0.119348	0.119389	0.119395

Where, consistency ratio, $CR = 8.71 \times 10^{-6} < 0.1$, so the judgments are acceptable.

Table 4.11: Pair wise Comparison Matrix of Strengths with respect to Aesthetical aspects

Strengths	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9
S-1	1	1.228	1.689	1.349	1.228	2.079	1.689	1.8	3
S-2	0.814	1	1.375	1.099	1	1.693	1.375	1.466	2.443
S-3	0.592	0.727	1	0.799	0.727	1.231	1	1.066	1.777
S-4	0.741	0.91	1.252	1	0.91	1.54	1.251	1.334	2.223
S-5	0.814	1	1.376	1.099	1	1.693	1.375	1.466	2.443
S-6	0.481	0.591	0.812	0.649	0.591	1	0.812	0.866	1.443
S-7	0.592	0.727	1	0.799	0.727	1.232	1	1.066	1.777
S-8	0.556	0.682	0.938	0.75	0.682	1.155	0.938	1	1.667
S-9	0.333	0.409	0.563	0.45	0.409	0.693	0.563	0.6	1

Table 4.12: Synthesized Matrix of Strengths with respect to Aesthetical aspects

Strengths	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	Eigen vector
S-1	0.168833	0.16882	0.168816	0.168752	0.16882	0.168805	0.168849	0.168792	0.168795	0.168809
S-2	0.13743	0.137476	0.137431	0.137478	0.137476	0.137463	0.137459	0.137472	0.137456	0.13746
S-3	0.099949	0.099945	0.09995	0.09995	0.099945	0.099951	0.09997	0.099962	0.099983	0.099956
S-4	0.125106	0.125103	0.125137	0.125094	0.125103	0.125041	0.125062	0.125094	0.125077	0.125091
S-5	0.13743	0.137476	0.137531	0.137478	0.137476	0.137463	0.137459	0.137472	0.137456	0.137471
S-6	0.081209	0.081248	0.081159	0.081186	0.081248	0.081195	0.081176	0.081208	0.081191	0.081202
S-7	0.099949	0.099945	0.09995	0.09995	0.099945	0.100032	0.09997	0.099962	0.099983	0.099965
S-8	0.093871	0.093759	0.093753	0.09382	0.093759	0.09378	0.093772	0.093773	0.093794	0.093787
S-9	0.056222	0.056228	0.056272	0.056292	0.056228	0.056268	0.056283	0.056264	0.056265	0.056258

Where, consistency ratio, CR = $-1.8 \times 10^{-5} < 0.1$, so the judgments are acceptable.

Table 4.13: Priority Matrix of Strengths with respect to overall criteria

Strengths	Environment	Economic	Social	Aesthetical
S-1	0.136744	0.079097	0.132593	0.168809
S-2	0.096173	0.079097	0.116677	0.13746
S-3	0.111349	0.16066	0.079592	0.099956
S-4	0.106356	0.180745	0.116677	0.125091
S-5	0.111349	0.173347	0.106172	0.137471
S-6	0.091144	0.067798	0.068929	0.081202
S-7	0.126562	0.044556	0.132582	0.099965
S-8	0.098762	0.079082	0.127383	0.093787
S-9	0.12156	0.135619	0.119395	0.056258

Table 4.14: Ranking of Strengths

Strengths	Overall Priority	Ranking
Door to Door Collection System of SW (S-1)	0.140473	1
Transportation System of SW (S-2)	0.113554	4
Sorting System of SW (S-3)	0.104301	6
Composting System of SW (S-4)	0.122898	3
Recycling of SW (S-5)	0.125049	2
Burning System of Sanitary Waste (S-6)	0.079647	9
Manpower and Equipment for SWM (S-7)	0.11088	5
Enforcement and awareness for SWM (S-8)	0.102557	7
Financial Support (S-9)	0.10064	8

From this study, the following outlines of strength of SWM at KUET campus have been delineated as below “

1. Door to door collection system of SW (S-1)” has been found as the best strength in SWM. Door to door collection system of SW has great influence on proper SWM at KUET campus which includes neat and clean, odor nuisance free and aesthetically beautiful and environmentally friendly campus.

2. Recycling of SW (S-5) has been seen as the second strength. High density polythene, steel, glass, paper has been separated daily and sold into the market for the purposes of recycling. Recycling is mainly important for reducing the energy consumption, creating employment, making earning source and prolonging the life of landfill.

3. Composting system of SW (S-4) has been noticed as the third strength in case of SWM at KUET campus. From the SW composition, about 50 to 60% of SW is the food and vegetable waste which is compostable. By composting process, huge amount of SW can be minimized and converted into soil conditioner and also helpful for making earning source and saves the landfill spaces.

4. Transportation system of SW (S-2) has been represented as the fourth strength in SWM. Daily transportation of SW in SWMP through rickshaw van which makes the campus more aesthetically beautiful and eco-friendly.

5. The fifth strength of SWM at KUET campus has been found as Manpower and equipment for SWM (S-7). KUET authority has own rickshaw van, SWMP, waste collector and supervisor, green watch man and waste separator which makes the SWM more effective.

6. Sorting system of SW (S-3) has been observed as the sixth strength of SWM at KUET campus. Sorting of SW enhances the composting and recycling system as well as saves the more landfill spaces. Partial sorting has been done at the source of waste generation. The waste mainly sorted into degradable and non-degradable at the source of waste generation. Sorting is mainly important for waste reusing, recycling and composting.

7. Enforcement and awareness for SWM (S-8)" has been delineated as the seventh strength for SWM. Throwing of waste from windows of residential and academic buildings and waste littering in KUET campus is strictly discouraged by the KUET authority. Awareness among staff, students and visitors imparts the effective SWM at this

campus. Every year a waste management initiatives program is held to make awareness among students during orientation program for new coming students.

8. Financial support for SWM (S-9) has been noticed as the eighth strength for SWM at this campus. Financial support for constructing rickshaw van, dustbin including concrete supporting stand, buying mask, gumboot, gloves, apron and for disposal of SW to ultimate disposal site helps the sustainable SWM.

9. Burning system of sanitary SW (S-6) has been found as the ninth strength of SWM at this campus. KUET has made a burning unit integrated with SWMP for burning of sanitary waste. A little amount of sanitary waste has been generated including gauge, bandage, napkin etc. especially from medical center and female dormitory. These wastes have been burnt into this burning unit.

4.8.2 Ranking of Weaknesses through Analytical Hierarchy Process

Table 4.15: Pair wise Comparison Matrix of Weaknesses with respect to Environmental aspects

	W-1	W-2	W-3	W-4	W-5	W-6
W-1	1	0.876	0.561	0.584	1.272	0.667
W-2	1.142	1	0.64	0.666	1.452	0.761
W-3	1.783	1.563	1	1.041	2.27	1.19
W-4	1.712	1.502	0.961	1	2.18	1.143
W-5	0.786	0.689	0.441	0.459	1	0.524
W-6	1.499	1.314	0.84	0.875	1.908	1

Table 4.16: Synthesized Matrix of Weaknesses with respect to Environmental aspects

Weaknesses	W-1	W-2	W-3	W-4	W-5	W-6	Eigenvector (Priority)
W-1	0.126231	0.126152	0.126266	0.12627	0.126165	0.126206	0.126215
W-2	0.144156	0.144009	0.144047	0.144	0.144019	0.143992	0.144037
W-3	0.225069	0.225086	0.225073	0.225081	0.225154	0.225166	0.225105
W-4	0.216107	0.216302	0.216295	0.216216	0.216227	0.216272	0.216237
W-5	0.099217	0.099222	0.099257	0.099243	0.099187	0.099149	0.099213
W-6	0.18922	0.189228	0.189061	0.189189	0.189248	0.189215	0.189194

Where, consistency ratio, CR = $7.34 \times 10^{-5} < 0.1$, so the judgments are acceptable.

Table 4.17: Pair wise Comparison Matrix of Weaknesses with respect to Economic aspects

	W-1	W-2	W-3	W-4	W-5	W-6
W-1	1	1.126	0.857	2.575	2	1.126
W-2	0.888	1	0.761	2.288	1.777	1
W-3	1.167	1.314	1	3.004	2.333	1.313
W-4	0.388	0.437	0.333	1	0.777	0.437
W-5	0.5	0.563	0.429	1.287	1	0.563
W-6	0.888	1	0.762	2.288	1.776	1

Table 4.18: Synthesized Matrix of Weaknesses with respect to Economic aspects

Weaknesses	W-1	W-2	W-3	W-4	W-5	W-6	Eigenvector (Priority)
W-1	0.206996	0.206985	0.206905	0.20696	0.206975	0.207023	0.206974
W-2	0.183813	0.183824	0.183728	0.183893	0.183897	0.183857	0.183835
W-3	0.241565	0.241544	0.241429	0.24144	0.241436	0.241405	0.24147
W-4	0.080315	0.080331	0.080396	0.080373	0.08041	0.080346	0.080362
W-5	0.103498	0.103493	0.103573	0.10344	0.103488	0.103512	0.103501
W-6	0.183813	0.183824	0.183969	0.183893	0.183794	0.183857	0.183858

Where, consistency ratio, CR = $1.87 \times 10^{-05} < 0.1$, so the judgments are acceptable.

Table 4.19: Pair wise Comparison Matrix of Weaknesses with respect to Social aspects

	W-1	W-2	W-3	W-4	W-5	W-6
W-1	1	1.201	0.8	0.571	0.705	0.632
W-2	0.833	1	0.666	0.476	0.587	0.526
W-3	1.25	1.502	1	0.714	0.882	0.79
W-4	1.751	2.101	1.401	1	1.235	1.106
W-5	1.418	1.704	1.134	0.81	1	0.896
W-6	1.582	1.901	1.266	0.904	1.116	1

Table 4.20: Synthesized Matrix of Weaknesses with respect to Social aspects

Weaknesses	W-1	W-2	W-3	W-4	W-5	W-6	Eigenvector (Priority)
W-1	0.127649	0.127644	0.127653	0.127598	0.127602	0.127677	0.127637
W-2	0.106331	0.106281	0.106271	0.106369	0.106244	0.106263	0.106293
W-3	0.159561	0.159634	0.159566	0.159553	0.159638	0.159596	0.159591
W-4	0.223513	0.223297	0.223552	0.223464	0.223529	0.223434	0.223465
W-5	0.181006	0.181103	0.180948	0.181006	0.180995	0.18101	0.181011
W-6	0.20194	0.202041	0.202011	0.202011	0.201991	0.20202	0.202002

Where, consistency ratio, CR = 2.97 x 10^{-05} <0.1, so the judgments are acceptable.

Table 4.21: Pair wise Comparison Matrix of Weaknesses with respect to Aesthetical aspects

	W-1	W-2	W-3	W-4	W-5	W-6
W-1	1	1.996	0.94	1.141	0.666	1.141
W-2	0.501	1	0.471	0.572	0.334	0.572
W-3	1.064	2.123	1	1.214	0.709	1.214
W-4	0.876	1.748	0.824	1	0.584	1
W-5	1.502	2.994	1.41	1.712	1	1.713
W-6	0.876	1.748	0.824	1	0.584	1

Table 4.22: Synthesized Matrix of Weaknesses with respect to Aesthetical aspects

Weaknesses	W-1	W-2	W-3	W-4	W-5	W-6	Eigenvector (Priority)
W-1	0.171851	0.171936	0.171878	0.171863	0.171782	0.171837	0.171858
W-2	0.086097	0.08614	0.086122	0.086158	0.086149	0.086145	0.086135
W-3	0.182849	0.182875	0.182849	0.182859	0.182873	0.182831	0.182856
W-4	0.150541	0.150573	0.150667	0.150625	0.150632	0.150602	0.150607
W-5	0.25812	0.257903	0.257817	0.25787	0.257931	0.257982	0.257937
W-6	0.150541	0.150573	0.150667	0.150625	0.150632	0.150602	0.150607

Where, consistency ratio, CR = $-7.4 \times 10^{-06} < 0.1$, so the judgments are acceptable.

Table 4.23: Priority Vector for Criteria

	Priority
Environmental	0.303323
Economic	0.102146
Social	0.260827
Aesthetical	0.333703

Table 4.24: Priority Vector for Weaknesses with respect to different Criteria

	Environmental	Economic	Social	Aesthetical
W-1	0.126215	0.206974	0.127637	0.171858
W-2	0.144037	0.183835	0.106293	0.086135
W-3	0.225105	0.24147	0.159591	0.182856
W-4	0.216237	0.080362	0.223465	0.150607
W-5	0.099213	0.103501	0.181011	0.257937
W-6	0.189194	0.183858	0.202002	0.150607

Table 4.25: Ranking of Weaknesses

Weaknesses	Final Priority	Ranking
Route Selection for Collection and Transportation of SW (W-1)	0.150066	5
Time for Decomposition of Degradable SW during Composting (W-2)	0.118936	6
Recycling of paper and polythene (low density) Waste (W-3)	0.19559	1
Burning Temperature at Burning Unit and Related Air Pollution (W-4)	0.182342	2
Roadside Construction Waste Deposition (W-5)	0.173953	4
Training Program among Staff (W-6)	0.179113	3

From this study (Table 4.25), the following outlines of weakness of SWM at KUET campus have been described as below "

1. "W-3" means recycling of paper and plastic (low density plastic). If authority can't find any option for recycling of paper and low density plastic (polythene) then it is responsible for creating environmental problem and need more landfill space for their disposal, need more money for their carriage to the ultimate disposal site and also authority deprived from earning money from these wastes. To minimize this problem, authority finds an option to sell them at low price to the buyer. The buyer are buying these wastes from the WMP of KUET and as a result, it saves the cost for disposal of these wastes and also earns some money from these wastes and it indirectly saves the landfill spaces and prevents environmental problems.
2. "W-4" means burning temperature at burning unit and related air pollution is the second weakness of SWM. The burning unit's temperature has been observed as 563°C and 561°C for sample 1 and sample 2, respectively calculated through infrared gauge (Sutradhar et al. 2017).

   The temperature produced is a function of the heating value of the waste and additional energy, incinerator or burn unit design, air supply and combustion control.

Entire burning needs high temperatures. Normally, temperatures that exceed 650°C with a period of 1 to 2 seconds will cause total combustion of most food and other household waste. Segregation of waste is essential when using methods that do not regularly gain these temperatures. Dual chamber incinerators, which are designed to burn complex mixtures of waste, harmful waste and biomedical waste, must provide a temperature higher than 1000°C and a period of at least one second to assure complete burning and reduce dioxin and furan pollutants. When these high temperatures and periods are obtained, waste will be completely burnt off and ash, smoke and pollutant quantities will be reduced (Nunavut Department of Environment, 2012).

3. "W-6" entitled training program among staff has been observed as the third weakness. Without appropriate training, the staff cannot handle, collect, transport and separate wastes properly. To make them efficient staff for SWM, it is very important to arrange training program on WM by authority at a certain interval.

4. "W-5" means roadside construction waste deposition which is represented by the "figure 4.12" is the fourth weakness of SWM because it hampers the aesthetical view of this campus and also creates dust.

Figure 4.12: Destruction of Aesthetical View through construction Waste Deposition

Roadside construction waste deposition occurs during construction period. This problem can be minimized by removing these wastes immediately after deposition. To keep the campus aesthetically beautiful, KUET authority already imposed the rule into the contract agreement with contractor, during construction it is not allowed to hampers the aesthetical view of this campus.

5. Weakness “W-1” means route selection for collection and transportation of SW is the fifth intensive weakness for SWM at KUET campus. Without best route selection, collection and transportation of SW will be laborious and time costly.

6. Time for decomposition of waste known “W-2” is the sixth weakness in case of SWM at KUET campus. From the study it has been observed that the time needed for decomposition of compostable waste is about three months and creates the space limitation into SWMP.

4.8.3 Ranking of Opportunities through Analytical Hierarchy Process

Table 4.26: Pair wise Comparison Matrix of Opportunities with respect to Environmental aspects

Opportunities	O-1	O-2	O-3	O-4
O-1	1	1.079	0.584	2.335
O-2	0.927	1	0.541	2.165
O-3	1.712	1.848	1	4
O-4	0.428	0.462	0.25	1

Table 4.27: Synthesized Matrix of Opportunities with respect to Environmental aspects

Opportunities	O-1	O-2	O-3	O-4	Eigen Vector
O-1	0.245881	0.245842	0.245895	0.245789	0.245852
O-2	0.227932	0.227842	0.227789	0.227895	0.227865
O-3	0.420949	0.421053	0.421053	0.421053	0.421027
O-4	0.105237	0.105263	0.105263	0.105263	0.105257

Where, consistency ratio, CR = $-5.4 \times 10^{-05} < 0.1$, so the judgments are acceptable.

Table 4.28: Pair wise Comparison Matrix of Opportunities with respect to Economic aspects

Opportunities	O-1	O-2	O-3	O-4
O-1	1	1.126	0.75	0.948
O-2	0.888	1	0.666	0.842
O-3	1.333	1.502	1	1.264
O-4	1.055	1.188	0.791	1

Table 4.29: Synthesized Matrix of Opportunities with respect to Economic aspects

Opportunities	O-1	O-2	O-3	O-4	Eigen Vector
O-1	0.233863	0.233804	0.233863	0.233843	0.233843
O-2	0.207671	0.207641	0.207671	0.207696	0.20767
O-3	0.31174	0.311877	0.311818	0.311791	0.311806
O-4	0.246726	0.246678	0.246648	0.24667	0.24668

Where, consistency ratio, CR = $2.13 \times 10^{-05} < 0.1$, so the judgments are acceptable.

Table 4.30: Pair wise Comparison Matrix of Opportunities with respect to Social aspects

Opportunities	O-1	O-2	O-3	O-4
O-1	1	0.94	0.666	0.842
O-2	1.064	1	0.709	0.896
O-3	1.502	1.41	1	1.264
O-4	1.188	1.116	0.791	1

Table 4.31: Synthesized Matrix of Opportunities with respect to Social aspects

Opportunities	O-1	O-2	O-3	O-4	Eigen Vector
O-1	0.210349	0.210479	0.21036	0.210395	0.210396
O-2	0.223812	0.223914	0.223942	0.223888	0.223889
O-3	0.315944	0.315719	0.315856	0.315842	0.31584
O-4	0.249895	0.249888	0.249842	0.249875	0.249875

Where, consistency ratio, CR = $2.21 \times 10^{-05} < 0.1$, so the judgments are acceptable.

Table 4.32: Pair wise Comparison Matrix of Opportunities with respect to Aesthetical aspects

Opportunities	O-1	O-2	O-3	O-4
O-1	1	0.924	0.571	0.705
O-2	1.082	1	0.619	0.764
O-3	1.751	1.616	1	1.235
O-4	1.418	1.309	0.81	1

Table 4.33: Synthesized Matrix of Opportunities with respect to Aesthetical aspects

Opportunities	O-1	O-2	O-3	O-4	Eigen Vector
O-1	0.19044	0.190555	0.190333	0.190335	0.190416
O-2	0.206056	0.206228	0.206333	0.206263	0.20622
O-3	0.33346	0.333265	0.333333	0.333423	0.33337
O-4	0.270044	0.269953	0.27	0.269978	0.269994

Where, consistency ratio, CR = $9.22 \times 10^{-07} < 0.1$, so the judgments are acceptable.

Table 4.34: Priority Matrix of Opportunities with respect to overall criteria

Opportunities	Environmental	Economic	Social	Aesthetical
O-1	0.245852	0.233843	0.210396	0.190416
O-2	0.227865	0.20767	0.223889	0.20622
O-3	0.421027	0.311806	0.31584	0.33337
O-4	0.105257	0.24668	0.249875	0.269994

Table 4.35: Ranking of Opportunities

Opportunities	Overall Priority	Ranking
Resource Recovery from Eggshells (O-1)	0.216878	3
Resource Recovery from Citrus Peel (O-2)	0.217542	2
Market Based Recycling of SW (O-3)	0.353184	1
Route Selection for SW Collection and Transportation (O-4)	0.212396	4

Table 4.35 represents the following outlines of opportunity of SWM at KUET campus have been delineated as below "

1. Opportunity 3 named "Market Based Recycling of SW" is the main opportunities of SWM at KUET campus. Lots of recyclable SW has been generated at this campus including plastic, polythene, iron, glass, paper etc. and most of them has been sold into the local market which is the source of earning money and saves the landfill spaces. Previously low density polythene and some paper could not sold into the market which were responsible for increasing the management cost due to disposal at ultimate disposal site named "Rajbandh, Khulna" which is 20 km far from the campus. But now we found some buyer for selling them which enhance the SWM at KUET campus in terms of economic and environmental aspects. The amount of recyclable material can be increased by proper sorting of SW at SWMP and by source separation of SW. More recyclable material provides sustainable SWM and makes earning source for SWM. Figure 4.13 delineates the recyclable materials generated at KUET campus.

Figure 4.13: Recyclable Waste Generated at KUET Campus

2. “Resource Recovery from Citrus Peel” has been found as the second opportunity, peel waste has been generated at KUET campus has been observed as 28.60 kg/month and from the laboratory analyses, citrus peel comprises lots of aromatic and anti-insecticidal, anti-bacterial and anti-fungicidal compounds and can be used as an effective air freshener, floor and tiles cleaner and as an insect repellent. Table -1 describes the characteristics of essential oil extracted from lemon peel generated at KUET campus through GC-MS analysis.

Table 4.36: Some Characteristics of Essential Oil Extracted from Lemon Peel (Sarder and Alamgir, 2017).

Name of the Compound	**RT**	**Area**	**Area%**	**R. Match**	**BC**
1R-alpha-Pinene	5.550	6.721E6	1.48	900	VM
Bicyclo[2.2.1]heptane,7,7-dim ethyl-2-me	6.395	3.003E7	6.61	823	VM
2,6-Dimethyl-1,3,5,7-octatetraene,E,E-	6.876	1.009E6	0.22	806	TF
(+)-4-Carene	7.093	446651	0.10	889	MV
Limonene	7.379	6.000E7	13.21	N/A	VB
Spiro[2,4]hepta-4,6-diene	7.656	1.016E6	0.22	914	TF
1,4-Cyclohexadiene, 1-methyl-4-(1-meth	7.867	1.781E6	0.39	884	TF
.alpha.-Methyl-.alpha.-[4-methyl-3-pente	8.123	4.163E6	1.59	776	TS
Bicyclo[2.2.1]heptan-2-ol,1,3,3-trimeth	8.641	1.145E7	2.52	723	VM
Ether,p-menth-6-en-2-yl methyl	9.027	1.988E6	0.44	700	VV
trans-p-Mentha-2,8-dienol	9.109	3.709E6	0.82	848	VV
p-Menth-2-en-7-ol,cis-	9.227	609308	0.13	756	VV
Limonene oxide, cis-	9.312	1.225E6	0.27	860	VV
cis-p-Mentha-2,8-dien-1-ol	9.393	3.103E6	0.68	832	VV
1,3-Dioxolan-2-one, 3-methyl-3-(4,8-dime	9.439	1.653E6	0.36	781	VV
trans-Pinocarveol	9.504	1.340E6	0.29	783	VV
7-Oxabicydo[4.1.0]heptane, 1-methyl-4-(	9.601	2.215E6	0.49	778	VV
Bicyclo[3.1.1]hept-3-en-2-ol,4,6,6-trim	9.783	3.065E6	0.67	801	VV
1-Cyclohexene-1-methanol,.alpha.,2,6,6	9.916	773126	0.17	701	VV
Bornyl chloride	10.024	2.193E6	0.48	871	VV
Artemiseole	10.125	6.607E6	1.45	769	VV
2-Cyclohexen-1-ol, 1-methyl-4-(1-methyl	10.224	5.182E6	1.14	769	VV
Benzenemethanol, .alpha.,.alpha.,.alpha.,4-trime	10.387	1.230E6	0.27	741	VV
Phosphoric acid, tribornyl ester	10.555	4.863E7	10.68	701	VV
2-Cyclohexen-1-ol, 3-methyl-6-(1-methyl	10.720	514900	0.11	823	TF
Squalene	10.995	1.449E7	3.19	713	VV
exo-2-Hydroxycinede	11.130	2.880E6	0.63	762	VV
6-Nonenal,3,7-dimethyl-	11.598	2.245E6	0.49	717	VV
1-Acetyl-2-(2'-oxo-propyl)-cyclopentane	11.899	938923	0.21	799	TF
Z,Z,Z-4,6,9-Nonadecatriene	12.193	732783	0.16	766	TF

Table 4.36 contd.

1-Cydohexene-1-methamol,4-(1-methyle	12.346	1.007E6	0.22	850	TF
Epoxy-.alpha.-terpenyl acetate	12.504	1.426E6	0.31	794	TF
Oxiranem ethanol,3-methyl-3-(4-methy-3	12.878	480594	0.11	815	TF
7-Oxabicyclo[4.1.0]heptane,1-methyl-4-(	12.922	754216	0.17	760	TF
1,2-Cyclohexanediol,1-methyl-4-(1-meth	13.141	1.793E6	0.39	791	VV
2,6-Odadien-1-ol, 3,7-dimethyl-,acetat	13.211	1.866E6	0.41	817	VV
Limonen-6-ol, pivalate	13.376	5.850E6	1.29	764	VV
Butanoic acid, 3,7-dimethyl-2,6-octadien	13.524	6.004E6	1.32	762	VV
Ethanone,1-(6-methyl-7-oxabicyclo[4.1.0	13.694	452686	0.10	758	VV
Cyclohexane,1-ethenyl-methyl-1-methyl-2,4-bis(	13.805	1.899E6	0.42	881	VV
Z-(13,14-Epoxy)tetradec-11-en-1-ol acet	14.008	632227	0.14	729	VV
2-Methyl-Z,Z-3,13-octadecadienol	14.062	1.550E6	0.34	815	VV
trans-p-Mentha-2,8-dienol	14.117	354815	0.19	799	VV
Bicydo[3.1.1]hept-2-en-6-one,2,7,7-tri	14.288	544835	0.12	849	VV
1,3-Cydohexadiene-1-methanol,4-(1-me	14.382	639924	0.14	791	VV
Bicyclo[3.1.1]hept-2-en- 6-one, 2,7,7-tri	14.288	544835	0.12	849	VV
1,3-Cyclohexadiene-1-methanol, 4-(1-me	14.382	639924	0.14	791	VV
Bicyclo[3.1.1]hept-2-ene,2, 6-dimethyl-6	14.490	5.167E6	1.14	875	VV
1,6,10-Dodecatriene,7,11-dimethyl-3-me	14.724	817502	0.18	892	VV
1-Hexadecanol	15.084	699543	0.15	868	MV
1,6,10-Dodecatriene,7,11-dimethyl-3-me	15.313	455590	0.10	841	VV
Azulene,1,2,3,5,6,7,8,8a-octahydro-1,4-	15.467	1.075E6	0.24	891	VV
1,4-Methano-1H-indene,octahydro-1,7a-	15.668	1.707E7	3.76	836	VV
9,19-Cyclolanostan-24-one,3-acetoxy-25	16.046	795320	0.18	813	VV
Farnesene epoxide,E-	16.220	1.411E6	0.31	861	VV
9-(3,3-Dimethyloxiran-2-yl)-2,7-dimethyl	16.340	997885	0.22	770	VV
1,6,10-Dodecatrien-3-ol,3,7,11-trimethy	16.422	1.235E6	0.27	815	VV
9,19-Cyclolanostan-24-one,3-acetoxy-25	16.566	1.296E6	0.29	779	VV
Caryophyllene oxide	16.926	4.911E6	1.54	896	VV
Lanceol, cis	17.344	2.953E6	0.65	849	VV
Alloaromaclendrene oxide-(1)	17.646	422078	0.09	771	VV
Tetracyclo[6.3.2.0(2,5).0(1,8)]tridecan-	17.714	1.024E6	0.23	817	VV
Isoaromadendrene epoxide	17.959	3.996E6	0.88	796	VV

Table 4.36 contd.

1-Naphthalenol,decahydro-1,4a-dimethyl	18.020	2.648E6	0.58	836	VV
Diepicedrene-1-oxide	18.159	4.675E6	1.03	791	VV
.alpha.-Bisabolol	18.325	3.954E6	0.87	893	VB
Hexadeca-2,6,10,14-tetraen-1-ol,3,7,11,	18.635	438282	0.10	868	VV
Aromadendrene oxide-(2)	18.942	1.525E6	0.34	823	VV
Isoaromadendrene epoxide	19.906	486534	0.11	780	VV
1,2-Epoxy-5,9-cyclododecadiene	19.980	884340	0.19	802	VV
Longifolene chloride	20.009	965214	0.21	714	VV
Cedren-13-ol,8-	20.124	828643	0.18	798	VV
6,10-Dodecadien-1-yn-3-ol,3,7,11-trimet	20.355	560345	0.12	785	VM
7,9-Di-tert-butyl-1-oxaspiro(4,5)deca-6,	21.452	981910	0.22	838	VV
Dibutyl phthalate	22.383	1.824E6	0.40	922	VB
Phytol	26.282	416916	0.09	851	BB
Phenol,4,4'-(1-methylethylidene)bis-	28.856	1.753E6	0.39	901	BB
1,2-Benzenedicarboxylic acid, diisooctyl	44.812	898137	0.20	901	BB

3. "Resource Recovery from Eggshells" has been found as the third opportunities in case of SWM at this campus. From the study it has been found that the eggshells generation has been found 16.27 kg/month which is the 0.20% of the total SW. From some measured representative characteristics, it can be seen that the calcium content of eggshells is very high as 31.50%, while carbon, nitrogen, C/N ratio and pH has been observed as 13.23%, 0.84%, 15.75, and 7.6 respectively (Sarder et al. 2016). As a highly calcium content material, the eggshells is very helpful to provide necessary calcium to the plants if it mixed with soil. Soil can easily absorbed calcium from eggshell powder and helpful for prevention of BER disease and enriched pH of acidic soil and may be used as calcium supplement for human.

4. "Route Selection for SW Collection and Transportation" has been seen as the fourth opportunity for SWM at KUET campus. Proper route selection helps to saves the time for collecting and transporting SW.

4.8.4 Ranking of Threats through Analytical Hierarchy Process

Table 4.37: Pair wise Comparison Matrix of Threats with respect to Environmental aspects

Threats	T-1	T-2	T-3	T-4	T-5
T-1	1	0.722	0.619	0.619	0.619
T-2	1.385	1	0.857	0.857	0.857
T-3	1.616	1.167	1	1	1
T-4	1.616	1.167	1	1	1
T-5	1.616	1.167	1	1	1

Table 4.38: Synthesized Matrix of Threats with respect to Environmental aspects

Threats	T-1	T-2	T-3	T-4	T-5	Eigen Vector
T-1	0.138255	0.138235	0.138293	0.138293	0.138293	0.138274
T-2	0.191483	0.191461	0.191466	0.191466	0.191466	0.191468
T-3	0.22342	0.223435	0.223414	0.223414	0.223414	0.223419
T-4	0.22342	0.223435	0.223414	0.223414	0.223414	0.223419
T-5	0.22342	0.223435	0.223414	0.223414	0.223414	0.223419

Where, consistency ratio, CR = $5.53 \times 10^{-05} < 0.1$, so the judgments are acceptable.

Table 4.39: Pair wise Comparison Matrix of Threats with respect to Economic aspects

Threats	T-1	T-2	T-3	T-4	T-5
T-1	1	0.904	1.055	1	1.355
T-2	1.106	1	1.167	1.106	1.499
T-3	0.948	0.857	1	0.948	1.285
T-4	1	0.904	1.055	1	1.355
T-5	0.738	0.667	0.778	0.738	1

Table 4.40: Synthesized Matrix of Threats with respect to Economic aspects

Threats	T-1	T-2	T-3	T-4	T-5	Eigen Vector
T-1	0.208681	0.20868	0.208704	0.208681	0.208654	0.20868
T-2	0.230801	0.23084	0.230861	0.230801	0.230828	0.230826
T-3	0.19783	0.19783	0.197824	0.19783	0.197875	0.197838
T-4	0.208681	0.20868	0.208704	0.208681	0.208654	0.20868
T-5	0.154007	0.15397	0.153907	0.154007	0.153988	0.153976

Where, consistency ratio, CR = $-1.80 \times 10^{-05} < 0.1$, so the judgments are acceptable.

Table 4.41: Pair wise Comparison Matrix of Threats with respect to Social aspects

Threats	T-1	T-2	T-3	T-4	T-5
T-1	1	1.4	1.235	1.235	1.499
T-2	0.714	1	0.882	0.882	1.071
T-3	0.81	1.134	1	1	1.214
T-4	0.81	1.134	1	1	1.214
T-5	0.667	0.934	0.824	0.824	1

Table 4.42: Synthesized Matrix of Threats with respect to Social aspects

Threats	T-1	T-2	T-3	T-4	T-5	Eigen Vector
T-1	0.249938	0.249911	0.249949	0.249949	0.249917	0.249933
T-2	0.178455	0.178508	0.178506	0.178506	0.17856	0.178507
T-3	0.202449	0.202428	0.202388	0.202388	0.202401	0.202411
T-4	0.202449	0.202428	0.202388	0.202388	0.202401	0.202411
T-5	0.166708	0.166726	0.166768	0.166768	0.166722	0.166738

Where, consistency ratio, CR = $6.67 \times 10^{-05} < 0.1$, so the judgments are acceptable.

Table 4.43: Pair wise Comparison Matrix of Threats with respect to Aesthetical aspects

Threats	T-1	T-2	T-3	T-4	T-5
T-1	1	0.666	1.141	0.761	0.842
T-2	1.502	1	1.713	1.143	1.264
T-3	0.876	0.584	1	0.667	0.738
T-4	1.314	0.875	1.499	1	1.106
T-5	1.188	0.791	1.355	0.904	1

Table 4.44: Synthesized Matrix of Threats with respect to Aesthetical aspects

Threats	T-1	T-2	T-3	T-4	T-5	Eigen Vector
T-1	0.170068	0.170072	0.170095	0.170056	0.170101	0.170078
T-2	0.255442	0.255363	0.255367	0.255419	0.255354	0.255389
T-3	0.14898	0.149132	0.149076	0.14905	0.149091	0.149066
T-4	0.223469	0.223442	0.223465	0.223464	0.223434	0.223455
T-5	0.202041	0.201992	0.201998	0.202011	0.20202	0.202012

Where, consistency ratio, CR = $3.84 \times 10^{-06} < 0.1$, so the judgments are acceptable.

Table 4.45: Priority Matrix of Threats with respect to overall criteria

Threats	Environmental	Economic	Social	Aesthetical
T-1	0.138274	0.20868	0.249933	0.170078
T-2	0.191468	0.230826	0.178507	0.255389
T-3	0.223419	0.197838	0.202411	0.149066
T-4	0.223419	0.20868	0.202411	0.223455
T-5	0.223419	0.153976	0.166738	0.202012

Table 4.46: Ranking of Threats

Threats	Overall Priority	Ranking
Accidents among staff in Collecting, Transporting and Sorting of SW (T-1)	0.185203	5
Damages of Roadside Waste Bins (T-2)	0.213438	2
Damages of Waste Management Plant (WMP) (T-3)	0.190515	4
Damages of Equipment like Rickshaw-van (T-4)	0.216446	1
Difficulties in Transporting of SW to the Ultimate Disposal Site. (T-5)	0.194398	3

From the observation of Table 4.46, the following outlines of threat of SWM at KUET campus have been explained as below "

1. "Damages of Equipment like Rickshaw-van" is the first threat for SWM at KUET campus. Damages of rickshaw-van hamper the collection and transportation of SW and affect the whole SWM at this campus with respect to social, aesthetical, economic and environmental point of view.

2. "Damages of Roadside Waste Bins" has been found as the second threat for SWM. Roadside dustbin helps to storage of SW which enhances the aesthetics of this campus. Damages of these bins hamper the aesthetical and environmental conditions around the surroundings.

3. "Difficulties in Transporting of SW to the Ultimate Disposal Site" has been considered as the third threat in terms of SWM at this campus. Sometimes SW generation has been observed as high specially in rainy season and during national and international seminar held in this campus and complexities arises to disposed them into ultimate disposal site because the authority needs to depend on the vehicles from other organization and private sector.

4. "Damages of Waste Management Plant (WMP)" has been examined as the fourth threat associated with SWM. Damages of WMP through fire causes or storm will create very dangerous effects on SWM, but the chances are very less.

5. "Accidents among staff in Collecting, Transporting and Sorting of SW" from the AHP analysis has been identified as the least important threat in case of SWM.

CHAPTER V

CONCLUSIONS AND RECOMMENDATION

5.1 Conclusions

Based on this study the following conclusions can be made:

i. The SW generation rate has been found as 0.099 kg/capita/day excluding construction, demolish and street sweeping waste. In which food and vegetable, paper, and plastic waste have been found as predominant and observed as 52.04%, 42.01% and 3.70%, respectively. Some lemon peel, eggshells and others waste also has been generated noticed as 0.30%, 0.20% and 1.75%, respectively. The SW generation rate at KUET campus is very low and it is natural for institutional areas. SW generation rate also depends on the campus vacation and number of population permanently staying in the campus. The SW generation at residential areas of KUET except student’s territory, the SW generation rate may be high as national level SW generation rate.

ii. The average monthly plastic waste generation has been noticed as 297.15 kg. The average plastic waste which has been supplied to the market has been found as 51.75 kg/month which is the 17.41% of entire plastic waste produced in the KUET campus.

iii. The average monthly paper waste production has been noticed as 4027.63 kg. The average paper waste which has been supplied to the market has been found as 63.34 kg/month which is negligible in contrast to paper waste.

iv. In the year of 2015, the average amount of compostable wastes has been seen as 3898 kg/month and the average compost generation has been obtained as 48.57 kg/month.

v. SWOT analysis of SWM has been done through field level investigation, laboratory tests and questionnaire survey. There are nine strengths, six weaknesses, four opportunities and five threats of SWM at KUET campus have been identified in this study. A hirerchay of strengths, weaknesses, opportunities and threats has been made through AHP.

vi. Through AHP, a ranking has been made among different strengths, weaknesses, opportunities and threats.

vii. Door to door collection system of SW, Recycling of SW, Composting system of SW, Transportation system of SW, Manpower and equipment for SWM, Sorting system of SW, Enforcement and awareness for SWM, Financial support for SWM, Burning system of sanitary SW has been found as the first, second, third, fourth, fifth, sixth, seventh, eighth and ninth strength, respectively.

viii. Recycling of paper and polythene (low density) Waste, Burning Temperature at Burning Unit and Related Air Pollution, Training Program among Staff, Roadside Construction Waste Deposition, Route Selection for Collection and Transportation of SW, Time for Decomposition of Degradable SW during Composting has been seen as the first, second, third, fourth, fifth, sixth weakness of SWM, respectively.

ix. Market Based Recycling of SW, Resource Recovery from Citrus Peel, Resource Recovery from Eggshells and Route Selection for SW Collection and Transportation has observed as the first, second, third and fourth opportunities in case of SWM at KUET campus, respectively.

x. Damages of Equipment like Rickshaw-van, Damages of Roadside Waste Bins, Difficulties in Transporting of SW to the Ultimate Disposal Site, Damages of Waste Management Plant and Accidents among staff in Collecting, Transporting and Sorting of SW has been noticed as the first, second, third, fourth and fifth threats of SWM, respectively.

5.2 Recommendations for Future Study

Based on the present study the following recommendations for future research can be made:

i. Market based recycling option for waste like low density plastic, some paper, broken glass which could not sold into market should be searched for more effective SWM. It will create money from waste, reduce the disposal cost of waste and will increase the life cycle of landfill.

ii. A further study on air pollution associates with burning of sanitary waste and necessary precautions for minimizing the pollution should be performed.

iii. Some instructions for waste handling among staff have been made but it is not sufficient. Some training among staff for waste collecting, transporting, sorting, burning, treatment and disposal should be made within six months interval for effective SWM.

iv. Construction waste should be removed as early as possible from the period of generation to ensure the aesthetics of the campus.

v. Time and labor can be minimized by selecting best route for collection and transportation of SW generated at this campus. A study should be made to select the best route through GIS for collecting and transporting SW.

vi. Any damages of rickshaw van can be minimized by repairing as soon as possible when damages occur and SWM system can be run smoothly by the backup of extra rickshaw van.

vii. Damages of waste bin and waste management leaflet can be minimized by proper monitoring through adjacent security guard.

viii. Fire extinguisher and sufficient water should be available to avoid future fire hazards into WMP.

ix. To avoid accident among staff they must work carefully by wearing apron, gumboot, hand gloves and the necessary fist aid should be provided at SWMP.

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APPENDICES

Annex-1: AHP Scale adapted from (Saaty, 1980)

Intensity of importance	Definition	Explanation
1	Equal importance	Two elements contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one over the other.
5	Strong importance	Experience and judgment strongly favor one over the other.
7	Very strong importance	Experience and judgment very strongly favor one over the other. Its importance is demonstrated in practice.
9	Extreme importance	The evidence favoring one over the other is of the highest possible validity
2,4,6,8 can be used to express intermediate values. Intensities 1.1, 1.2, 1.3 etc. can be used for elements that are very close in importance.		

Annex-2: Average Intensity of Importance of different criteria of SWM at KUET campus

Criteria	Intensity of Importance (according to Table-1)			
Environmental	7.5			
Economic	2.5	2.5		
Social	6.5	6.5	6.5	
Aesthetic	8.24	8.24	8.24	8.24

Annex 3: Pair wise Comparison of Criteria

Criteria	extremely preferred			strongly preferred			equally preferred					strongly preferred			extremely preferred			Criteria
Environmental	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Economic
Environmental	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Social
Environmental	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Aesthetic
Economic	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Social
Economic	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Aesthetic
Social	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Aesthetic

Annex-4: Average Intensity of Importance of different strengths/positive aspects of SWM at KUET campus with respect to different criteria

Criteria	Strengths/Positive Aspects of SWM at KUET Campus	Intensity of Importance (according to Table-1)								
Environmental point of View	Door to Door Collection System of SW	9								
	Transportation System of SW	6.33	6.33							
	Sorting System of SW	7.33	7.33	7.33						
	Composting System of SW	7	7	7	7					
	Recycling of SW	7.33	7.33	7.33	7.33	7.33				
	Burning System of Sanitary Waste	6	6	6	6	6	6			
	Manpower and Equipment for SWM	8.33	8.33	8.33	8.33	8.33	8.33	8.33		
	Enforcement and awareness for SWM	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	
	Financial Support	8	8	8	8	8	8	8	8	8
Economic point of View	Door to Door Collection System of SW	3.5								
	Transportation System of SW	3.5	3.5							
	Sorting System of SW	7	7	7						
	Composting System of SW	8	8	8	8					
	Recycling of SW	7.67	7.67	7.67	7.67	7.67				
	Burning System of Sanitary Waste	3	3	3	3	3	3			
	Manpower and Equipment for SWM	2	2	2	2	2	2	2		
	Enforcement and awareness for SWM	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	
	Financial support	6	6	6	6	6	6	6	6	6
Social point of View	Door to Door Collection System of SW	8.33								
	Transportation System of SW	7.33	7.33							
	Sorting System of SW	5	5	5						
	Composting System of SW	7.33	7.33	7.33	7.33					
	Recycling of SW	6.67	6.67	6.67	6.67	6.67				
	Burning System of Sanitary Waste	4.33	4.33	4.33	4.33	4.33	4.33			
	Manpower and Equipment for SWM	8.33	8.33	8.33	8.33	8.33	8.33	8.33		
	Enforcement and awareness for SWM	8	8	8	8	8	8	8	8	
	Financial support	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
Aesthetical point of View	Door to Door Collection System of SW	9								
	Transportation System of SW	7.33	7.33							
	Sorting System of SW	5.33	5.33	5.33						
	Composting System of SW	6.67	6.67	6.67	6.67					
	Recycling of SW	7.33	7.33	7.33	7.33	7.33				
	Burning System of Sanitary Waste	4.33	4.33	4.33	4.33	4.33	4.33			
	Manpower and Equipment for SWM	5.33	5.33	5.33	5.33	5.33	5.33	5.33		
	Enforcement and awareness for SWM	5	5	5	5	5	5	5	5	
	Financial support	3	3	3	3	3	3	3	3	3

Annex-5: Average Intensity of Importance of different weaknesses/limitations of SWM at KUET campus with respect to different criteria

Criteria	Weaknesses/Limitations of SWM at KUET Campus	Intensity of Importance (according to Table-1)					
Environmental point of View	Route Selection for Collection and Transportation of SW	4.67					
	Time for Decomposition of Degradable SW during Composting	5.33	5.33				
	Recycling of some Inorganic SW	8.33	8.33	8.33			
	Burning Temperature at Burning Unit and Related Air Pollution	8	8	8	8		
	Roadside Construction Waste Deposition	3.67	3.67	3.67	3.67	3.67	
	Training Program among Staff	7	7	7	7	7	7
Economic point of View	Route Selection for Collection and Transportation of SW	6					
	Time for Decomposition of Degradable SW during Composting	5.33	5.33				
	Recycling of some Inorganic SW	7	7	7			
	Burning Temperature at Burning Unit and Related Air Pollution	2.33	2.33	2.33	2.33		
	Roadside Construction Waste Deposition	3	3	3	3	3	
	Training Program among Staff	5.33	5.33	5.33	5.33	5.33	5.33
Social point of View	Route Selection for Collection and Transportation of SW	4					
	Time for Decomposition of Degradable SW during Composting	3.33	3.33				
	Recycling of some Inorganic SW	5	5	5			
	Burning Temperature at Burning Unit and Related Air Pollution	7	7	7	7		
	Roadside Construction Waste Deposition	5.67	5.67	5.67	5.67	5.67	
	Training Program among Staff	6.33	6.33	6.33	6.33	6.33	6.33
Aesthetical point of View	Route Selection for Collection and Transportation of SW	5.33					
	Time for Decomposition of Degradable SW during Composting	2.67	2.67				
	Recycling of some Inorganic SW	5.67	5.67	5.67			
	Burning Temperature at Burning Unit and Related Air Pollution	4.67	4.67	4.67	4.67		
	Roadside Construction Waste Deposition	8	8	8	8	8	
	Training Program among Staff	4.67	4.67	4.67	4.67	4.67	4.67

Annex-6: Average Intensity of Importance of different opportunities of SWM at KUET campus with respect to different criteria

Criteria	Future Opportunities of SWM at KUET Campus	Intensity of Importance (according to Table-1)			
Environmental point of View	Resource Recovery from Eggshells	4.67			
	Resource Recovery from Citrus Peel	4.33	4.33		
	Market Based Recycling of Inorganic SW	8	8	8	
	Route Selection for SW Collection and Transportation	2	2	2	2
Economic point of View	Resource Recovery from Eggshells	6			
	Resource Recovery from Citrus Peel	5.33	5.33		
	Market Based Recycling of Inorganic SW	9	9	9	
	Route Selection for SW Collection and Transportation	6.33	6.33	6.33	6.33
Social point of View	Resource Recovery from Eggshells	5.33			
	Resource Recovery from Citrus Peel	5.67	5.67		
	Market Based Recycling of Inorganic SW	8	8	8	
	Route Selection for SW Collection and Transportation	6.33	6.33	6.33	6.33
Aesthetical point of View	Resource Recovery from Eggshells	4			
	Resource Recovery from Citrus Peel	4.33	4.33		
	Market Based Recycling of Inorganic SW	7	7	7	
	Route Selection for SW Collection and Transportation	5.67	5.67	5.67	5.67

Annex-7: Average Intensity of Importance of different Threats of SWM at KUET campus with respect to different criteria

Criteria	Future Threats of SWM at KUET Campus	Intensity of Importance (according to Table-1)				
Environmental point of View	Accidents among stuff in Collecting, Transporting and Sorting of SW	4.33				
	Damages of Roadside Waste Bins	6	6			
	Damages of Waste Management Plant (WMP)	7	7	7		
	Damages of Equipment like Rickshaw-van	7	7	7	7	
	Difficulties in Transporting of SW to the Ultimate Disposal Site.	7	7	7	7	7
Economic point of View	Accidents among stuff in Collecting, Transporting and Sorting of SW	6.33				
	Damages of Roadside Waste Bins	7	7			
	Damages of Waste Management Plant (WMP)	6	6	6		
	Damages of Equipment like Rickshaw-van	6.33	6.33	6.33	6.33	
	Difficulties in Transporting of SW to the Ultimate Disposal Site.	4.67	4.67	4.67	4.67	4.67
Social point of View	Accidents among stuff in Collecting, Transporting and Sorting of SW	7				
	Damages of Roadside Waste Bins	5	5			
	Damages of Waste Management Plant (WMP)	5.67	5.67	5.67		
	Damages of Equipment like Rickshaw-van	5.67	5.67	5.67	5.67	
	Difficulties in Transporting of SW to the Ultimate Disposal Site.	4.67	4.67	4.67	4.67	4.67
Aesthetical point of View	Accidents among stuff in Collecting, Transporting and Sorting of SW	5.33				
	Damages of Roadside Waste Bins	8	8			
	Damages of Waste Management Plant (WMP)	4.67	4.67	4.67		
	Damages of Equipment like Rickshaw-van	7	7	7	7	
	Difficulties in Transporting of SW to the Ultimate Disposal Site.	6.33	6.33	6.33	6.33	6.33