Deanship of Graduate Studies
Al-Quds University

Optimization Solid Waste Management in Nablus Joint service council

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MSc. Thesis

Jerusalem – Palestine

2015/1436

Optimization Solid Waste Management in Nablus Joint service council

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A thesis submitted in partial fulfillment of requirements for the Degree of science in environmental studies, department Of Applied Earth and Environmental Studies,-faculty of Science and Technology, Al-Quds University.

2015/1436

Al-Quds University
Deanship of Graduate Studies
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Jerusalem –Palestine

2015/1436

Dedication

بعد عام من العمل لإنجاز هذا البحث أتقدم للإنسان الذي علمني أن عز الإنسان وقيمته في الأشخاص الذين يحبهم ...

لمن علمني أن الصدق مفتاح الحياة والنجاح ....

معكم أحبتي أثق بأن أعظم ما انجزته بعمري هو أنكم بعمري...

أشكركم لأنكم أضفتم لشخصي الكثير ولأنكم موجودون دائماً حتى في أصعب حالاتي ..

زوجي الحبيب ، أبي و أمي ملجأ أماني وأخوتي سندي وعزوتي ، وصديقتي الغالية

شكرًا للوقت و الصدفة التى جمعتنا ...

لكم جميعاً اقدم هذا العمل ...

Declaration

I certify that this thesis submitted for the degree of Master is the result of my Own research, except where otherwise acknowledged and that this thesis (or Any part of the same) has not been submitted for a higher degree to any other University or institution.

Name: Jameela Ameen Elatrash

Signed: …………………………..…

Date: ……………………………..…..

Acknowledgment

I am so much honored to thank my supervisor Dr. Amer Marei for his insightful comments and suggestions.

My special thanks go to Nablus JSC-SWM team for being there always and providing all the data and information needed to support this research.

I am grateful to my family for their patience, encouragement and love. Thanks to Mummy, Daddy, Ahmad, Mohammed, Aseel and Mahmoud.

Finally, I thank all who supported me towards this academic level, especially my lovely husband.

Abstract:

The existing solid waste management system in Nablus Joint Service Council (JSC) is suffering from the absence on a real plan for collection waste from localities with a clear vehicle routes. Therefore, the total process of SWM is affected by; collected fees are not covering the real costs of SWM, and solid waste service revenues normally flow into a general municipal account. Although, about 41% of total solid waste management cost is related to waste collection (Load waste, Expenses waste disposal/Sirafi, and Expenses Landfill); high amount from this cost is related to fuel (16%). Currently, the daily transportation cost for one ton collected by Nablus JSC is 36,718.55 ILS.

In this study, a dynamic waste management model is developed by a proposed liner algebra mathematical model using GAMS software program; to minimize the transportation cost of the SWM process for municipal solid waste management system for identifying optimal Waste-flow-allocation, and to assist decision makers to improve solid waste management in Nablus JSC-SWM.

The model has two scenarios one for minimizing the transportations cost by identifying the best route to transfer solid waste to the nearest transfer station with in Nablus governorate (Al-Sirafi or Beta). The second scenario is to give the optimal route and cost incase a recycling process were done in both transfer stations Al-Sirafi and Beta before delivering the waste to its last distention in Zahret Al-Finjan landfill in Jenin.

The modeling results are valuable for supporting the planning of Nablus JSC management practices. The total transportation costs for the current used system is 36,718.55 ILS / day while applying the first scenario of GAMS model the total daily transportation costs using two transfer station will be 32,718.94 ILS which means is only 12 % of the current used system with 3,946.03 ILS daily saving from costs. Although, the results show that applying the second scenario is the best by including a recycling and re-using processes in the two transfer stations (Beta and Al-Sirafi) before delivering the remaining solid waste after the recycling process to Zahret Al-Finjan land fill in Jenin. The second scenario will make the

total daily transportation cost is only 17,871.94 ILS which leads to 51% reduction on the existing daily total transportation costs.

In order to improve solid waste management in Nablus JSC and the served 24 local government units (LGUs), and to improve the solid waste management for the JSC's surrounding localities the emerging conditions for the adoption and operation of the model need to be addressed through the main stakeholder collaborations under the umbrella of Ministry of Local government (MoLG) as a decision maker to encourage the solid waste sector participation and the development of technological innovations for solid waste management in Palestine.

List of abbreviation

EU	European Union
GAMS	General Algebraic Modeling System
ISL	Israeli Shekels
JICA	Japanese international cooperation agency
JD	Jordanian Diners
JSC	Joint service councils
JSC-SWM	Joint service councils for solid waste management
LF	Land fill
LGUs	local governmental units
MSW	municipal solid waste
MSWM	municipal solid waste management
NSWMS	National solid waste management strategy
PA	Palestinian Authority
PCBS	Palestinian central bureau of statistics
PNA	Palestinian National Authority
PT	Palestinian territory
TS	Transfer station
SW	solid wastes
SWM	solid waste management
UNRWA	United Nations Relief and Works Agency
US$	United states Americana's dollars
Z	Zone

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Chapter One

Introduction

1.1 General Introduction

The last five decades witnessed all over the world a rabid urbanization, industrial development increasing of the population growth, varied Life styles and consumption patterns. Urbanization does not always mean improving situations, including sectors developments (Arshad *et al.* 2013) .The previous patterns changes cause an increase in the quantity and complexity of the generated wastes and overburdens, including water and waste water and solid wastes (SW), with especial attention for municipal solid waste (MSW).MSW commonly known as trash or garbage that consists of everyday items which is used and then thrown away. There are five types of SW considered as MSW such as residential waste industrial or manufacturing waste; commercial waste, medical waste, agricultural and construction waste (Palmer *et al.* 1997) (EPA, USA, 2013). In 2000 Sakurai said that waste is like a mirror that reflects various aspects of a society. Mean though waste is not an ordinary product, and some wastes may be turned into resources (Sefouhi *et al.* 2010).

Now days, the World faces a rabid developing challenges and linked with the global economic crises to meet the requirements of the individuals in order to ensure a decent life for all. One of the main challenges facing almost all the developed and developing countries is the MSW and managing the increasing volume of SW (Table 1.1). It could also be considered as a problem in many developing countries where SW is not adequately managed according to its adverse impacts on environment and public health.

Table 1.1 shows that low income countries (like Yemen, Jordan, Tunisia, and Syria) have the lowest MSW generation rates, which are in the range 0.45 – 0.9 kg/capita/day. While, in high income countries (like Kuwait, Bahrain and Saudi Arabia) range between 1.3 – 1.8 kg/capita/day. From this it's clear that the improvement of living standards cause more municipal solid waste generation rate (Al-Hasawi 1999).

Table 1.1: MSW generation on some Arab and Foreigner Countries

Arab Countries	MSW generation (KG/C/d)	Foreigner Countries	MSW generation (KG/C/d)
Bahrain	1.6	Canada	1.65
Egypt	1.2	Denmark	1.32
Jordan	0.9	Finland	0.47
Kuwait	1.8	France	0.9
Saudi Arabia	1.3	Germany	0.8
Syria	0.5	Japan	1.26
Tunisia	0.6	Netherlands	1.04
Yemen	0.45	USA	1.98

Source: International Conference on the Management of Hazardous and Non-Hazardous waste, Muscat Sultanate of Oman, 2001

Studies have shown that the reasons for inadequacies in solid waste management (SWM) in developing countries are due to a combination of lacking efforts from both authorities and citizens. The outdated SWM collection methods among municipalities and local governmental units (LGUs), lack of enforcement of SWM fee collection, and absence of community participation(Asnani 2006) (Asnani & Zurbrugg 2007). Municipal authorities in developing countries throughout the world face the same problem in terms of fee collection; limited willingness of households to pay their SWM fees. These lead municipalities to lower their performance in managing solid wastes or other services and to reduce their labor force. Example in India, fees collected for SWM was only in wealthier areas which lead to have a better SWM services there (UNICEF) . In the Palestinian territory (PT), SWM fee collection is a major problem beside the lack of using new technologies for reduction waste lead for a weak service with a weak financial base (Table 1.2).

1.2 Solid Waste Management in Palestine

Palestine has an area of 6185 km^2 (including West Bank, Jerusalem and Gaza strip) with 4.42 million inhabitant according to the Palestinian central bureau of statistics (PCBS) 2013 estimation. Palestinian living in the West Bank is about 61.5% of the inhabitants while around 38.4% of the inhabitants are in Gaza strip, and about 44 % of the inhabitants are considered as refuges living between the West Bank and Gaza strip areas. The Palestinian growth rate is 2.96 %.The population in Palestine is considered to be very young due to PCBS indicators 70% of the population is under 29 years old while only 4.4% is elderly 60 years old (PCBS, 2013).

PCBS indicators for 2012 showed that (for persons 15 years and above) for both sexes are 23% in the Palestinian territories (PT). Table 1.2, summarized the socio economic and solid waste management in Palestine. Solid Waste Management has been consistently improving since the formation of the Palestinian Authority (PA) (NSWMS, PNA, 2010).

The total daily solid waste generation in the PT was estimated by PCBS in 2013 with 2,018.6 tons. The estimated daily amount in the West Bank is 1,274.5 tons and in Gaza strip is 744.1 tons. Urban, rural, and the refugees' camps in the PT generated 73%, 18% and 7% respectively. The averaged Palestinian household is six persons; and the daily waste production is 2.7 Kg. In the rural areas the per capita solid waste generation is about 0.5-0.7 kg/day compared with 0.8-2 kg/day in the urban areas. The Municipal generation growth for solid waste is 4% (PCBS, 2009).Figure 1.1 shows the SW components in 2011(PCBS, 2011).

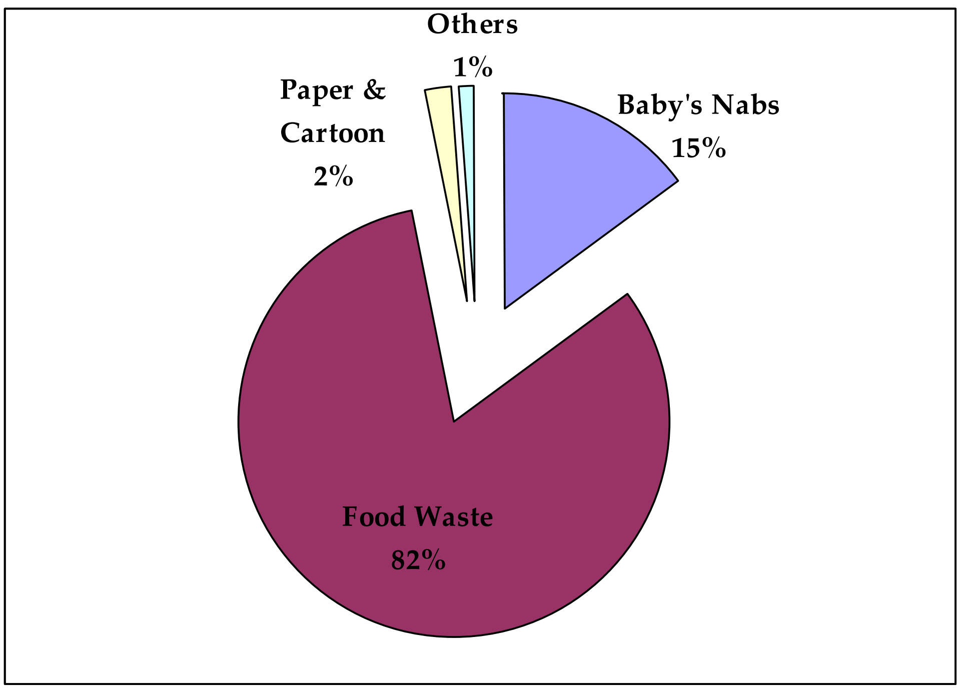


Figure 1.1: Percentage distribution of SW components in 2011

Table1.2: Key Socio-economic and Solid Waste Management Data in Palestine

PT area	$6185\ km^2$	
Population (2013)[1]	4.42 million	
Average household members[1]	6 persons	
Gross national income US$ (2007) [1]	1493.7 US$	
MSW generated (Ton/Year) 2013[1]	1,557,773	
	West Bank areas	932,350 tons
	Gaza strip	625,423 tons
Per capita MSW generated (Kg/day) [1]	Urban areas	0.8-2 kg/day
	Rural areas	0.5-0.7 Kg/day
Municipal composition growth[1]	4 %	
Material composition of MSW %[2]	Organic	70%
	Paper and Cartoon	8%
	Plastic	8%
	Glass	6%
	Metal	3%
	Others	5%
Management of waste %[2]	Composted	0%
	Recycled	2%
	Disposal land filling	22%
	Disposal dumpsites	76%
	Other technologies	0%

Source: [1] (PCBS, 2007, 2013), [2] (NSWMS, PNA, 2010)

Local governmental unit (LGU) is Responsible for Solid Waste collection service. Palestinian LGUS collect SW for 71.5% of households, UNRWA collect 8.5%, and 2.3% of households a special contractor (Table 1.3). The Palestinian LGUs law number 1 for year 1997 and the Joint service councils (JSC) bylaw for year 2003 a number of LGUs have the right to establish a JSC to provide a common service for the member LGUs. One of the services that the JSC could serve the LGUs with is to focus on raising the level of environmental services, which include the areas of solid waste landfills and sanitation, health, environmental awareness. The main concern of the Palestinian Ministry of local government (MoLG) is to achieve the above goal from establishing JSC through the formation of JSC centralized at the level of each governance.

Table1.3: Distribution of localities in Palestine by the Doer Responsible about solid waste collection service and governorate, 2013

Governorate	Doer responsible about SW collection service						No collection service	Total
	LGU	JSC	Another LGU	Special contractor	UNRWA	Others		
Palestine	**291**	**69**	**36**	**26**	**28**	**32**	**75**	**557**
West Bank	**267**	**68**	**36**	**26**	**20**	**32**	**75**	**524**
Jenin	35	6	11	9	1	9	9	80
Tubas	3	6	1	0	1	1	9	21
Tulkarem	15	6	3	5	2	1	3	35
Nablus	29	18	2	4	3	5	3	64
Qalqiliya	22	5	2	2	0	0	3	34
Salfit	10	6	1	0	0	1	2	20
Ramallah & Albira	59	3	1	5	5	0	2	75
Jericho & Alagwar	2	5	1	0	2	1	3	14
Jerusalem	32	1	4	1	2	1	3	44
Bethlehem	23	10	3	0	3	1	5	45
Gaza strip	**24**	**1**	**0**	**0**	**8**	**0**	**0**	**33**

Source: (PCBS, 2013)

In 2013 PCBS reported that 75 localities in the West Bank of 39,642 inhabitant don't have SW collection service, 482 LGUs in the PT transfer SW (served by the LGU or JSC or UNRWA or Special contactor) to sanitary landfills (Zahret Alfenjan, Deir Al-Balah, and Jericho landfill) or dumping sites, while 75 LGUs do not transfer their solid waste to any random dumping sites and responsible of getting rid of their waste with non sanitary process. However, SW from these 75 LGUs is left on the streets uncollected, randomly dumped and sometime burned (Table1.4), (Mahamid & Thawaba 2010),(Arij, 2009), (PCBS, 2005). Table 1.4 presents the most favored tools for SW disposal among non serviced populations are to transfer their waste to another locality waste containers or to burn it.

Table1.4: Fate of SW in localities not covered by waste collection services in the PT

Region	Transferred by Household member to waste containers in another locality	Burdened %	Disposed in common open dumpsites %	Disposed by random open dumping sites (outside dumpsite)%	Used as animal food of fertilizers	Others	Total
Palestine	49.6	37.6	18.7	10.2	0.7	1.5	100
West Bank	35.7	20.9	29.8	9.9	1.1	2.6	100
Gaza strip	72.7	16.7	0	10.6	0	0	100

Source: PCBS, 2005

Options of collection methods used in Palestine are:

- Door to door collection
- Building to building collection
- Public Litter Baskets/Bins collection
- Stationary containers collection (located at a particular location on specified collection day(s) and/or times, and these Containers are returned to pickup point after emptying)
- Waste pooling collection sites (illegal, controlled dumps sites)
- Transfer station to final disposal
- Transfer for land-filling in Israeli-controlled areas for a fee (Al-Khatib *et al.* 2010) (Al-Khatib *et al.* 2007)
- Sanitary landfill

With the absence of environmental legal frameworks in PT the SW final disposal has three scenarios the first is to be disposable in a safe process via sanitary landfills which follow the national and international environmental requirements and standards, such as Zahrat Al-Finjan landfill, Deir Al-Balah and Jericho landfill. The amount of waste that is being dumped in these three landfills is equivalent to 22% (630 tons per day) of the amount of the daily waste produced in the PT. The second scenario to disposal the waste in illegal controlled dump sites owned or rented by one LGU or more, such as Juhr Al-Dik dumpsite, Rafah dumpsite and Al-Bireh dumpsite. The amount of waste dumped with this scenario is about 42%. The third scenario is to disposal the waste into random dumpsites (open areas) which is not controlled or monitored by any LGU and don't follow any environmental requirements or standards. The third scenario waste amount is estimated with 36% from the total SW in the PT, dumped in about 147 sites all over the PT (NSWMS, PNA, 2010).

Subsequently, the three scenarios used in the PT showed that open dumping site is the main disposal method used. Therefore, the lack of sanitary landfills in the PT is the main reason of the widely spread of 147 random dumpsites. According to the Palestinian National strategy of SWM (NSWMS) for 2010-2014 the number of the random dumpsites should be reduced and the current dumpsites should be closed and rehabilitated or to be used as transfer stations.

Only, three sanitary landfills are in the process of planning or construction, two are in the West Bank areas (Ramoun landfill in Ramallah governorate, and Al Minya landfill lays in the border of Hebron and Bethlehem governorates), and one in the Gaza Strip (NSWMS, PNA, 2010). Table 1.5, give an overview for SWM in three key cites in PT.

According to the NSWMS in 2010 a very low percentage of solid waste is being recycled or composted 2-3% mainly by the private sector and most of the initiatives in this field either small scale initiatives or pilot projects. Recently, there is an interest form the private sector for more investment in recycling and composting.

Table 1.5: Waste Generation in Key Cities

City	**Gaza**	**Ramallah**	**Jenin**
Population	496,411	27,000	39,000
Waste Generation (Kg/C/day)	0.99	2.05	0.9
MSW Generated (ton/day)	600	56	40
Collection responsibility	Municipality	Municipality	JSC
Disposal method	Controlled dumpsite	Open dumping	Sanitary land filling
Random dumpsites	0	One, being used	All are closed and rehabilitated
Cost (Total cost of SWM)	100 ILS /Ton	277 ILS/Ton	130 ILS /Ton

Source: (Sweep net, 2012)

Palestine like other countries all over the world is affected by environmental degradation which affects the welfare especially on the healthy life of the population, and economic losses. Table 1.6, shows the main problems facing the SWM sector in Palestine.

Table 1.6: Categories of Problems Common to Waste Management in Palestine modified after (SAKURAI, 2000)

External problem	- Population growth - Rapid urbanization - rising in living standards - Socio – economic crises - Absence of community participation - Lack of environmental public awareness - Israeli occupation
Internal problems	- Rapid increase in the volume of MSW - Lack of waste reduction efforts - Weak legal systems - Some conflicts and overlapping exist in the legal framework - The shortage of funds and financial support - Immature system of LGUs - Lack of coordination among sectors, and beneficiaries - Lack of organizational capacity - Inadequate technology - Inadequate operation system - Low willingness to pay fees of the service - Random Dumpsites

Source: (YOSHIDA ,2005)

1.3 State of the problem

Palestine is considered as a developing country with additional special conditions regarding to the Israeli occupation and their continuous interference which reflect on the Palestinian daily style of life. LGUs and JSC are responsible of ensuring that solid waste generated in their area is managed in adequate environmental and economical methods to product the individual's right to live in a safe clean area. LGUs as the law number 5 mentioned are accountable to the public they serve to successfully plan and implement activities to meet the national Palestinian policy. Although, the LGUs and JSCs are responsible to put down a plan to ensure managing their services efficiently but the existing system for solid waste management is still based on the experience with the lack or sometimes the absence of the public accountability and participation. Management based on the experience cause a high consumption from LGUS and JSCs budgets and revenues. Also, there are environmental and political limitations that affect the choices for disposal alternatives. Depending on the donors or the Palestinian national authority (PNA) is the main financial reliance for the LGUs and JSC. Furthermore, the collected fees from the LGUs are not covering the expenses of providing the service. The lack of the sanitary landfills in the West Bank area and all the above mentioned issue related to the SWM system used in Palestine results to high transportation costs. This study aims to design a mathematical model using GAMS software program (Brooke *et al.* 1998) for an optimal scenario to achieve the minimum transportation costs of the current used system for SWM.

1.4 Research Objectives

The general objective from this research is to minimize the transportation cost of the SWM process in Nablus JSC by developing a liner algebra mathematical model using GAMS software program.

The sub objectives for the research are:

a) To find out the best transfer station location to be used for each source of waste served by Nablus JSC.
b) To support cost-effective solid waste collection and transportation
c) To assist decision-makers (Palestinian national level, and the JSC) in identifying concrete realistic actions to improve solid waste management through the potential financial situation and to determine the investments priority

1.5 Research Methodology

1.5.1 Research Question

The key question that will invoke the course of research is narrowed within the framework of research scope and theoretical analysis. The main question tries to investigate the best model to minimize the transportation cost of the MSW in Nablus Municipality by using the nearest transfer station location for SW that tends to bring about solutions to the associated solid waste management.

1.5.2 Research Spatial Scope

This study covers Nablus JSC, in Nablus Governorate only, and the depict reliability of the overall situation of the other JSC is predictable according that the existing JSCs in the West Bank are facing the same challenges and suffers from the lack of a real plan for solid waste management (SWM) in depending to their collection methods, technical equipments used for SWM and their experience (Figure 1.2).

Figure1.1: West Bank Governorates, Nablus governorate

1.5.3 Research Propositions

To advance the research context into a strong, clear and transparent research design that facilitates the development of practical explicit descriptions within the research context, some research propositions have been identified. According to (Gering & Crist 2002), the viability of a case study (Nablus Municipality, in our case) is always proposition-centric or proposition dependent. It depends on what the researcher wish to argue. Propositions help identifying the relevant information about studied causes and represent the reference point against which the collected data is collated and the results generalized. Each proposition directs attention to something that should be examined within the scope of study, and the more a study contains specific propositions, the more it will stay within feasible limits (Yin 2014).

The key propositions that invoke the research study are summarized as follows:

a) All the generated solid waste in Nablus governorate are collected from the Waste sources (zones) and transferred to the transfer station (Al-Sirafi)
b) All the solid waste are daily transferred from transfer station (Al-Sirafi) to Zahret Al-finjan Land fill in Jenin Governorate
c) In Nablus governorate there is no waste separation at the source or at the collection centers
d) Transportation cost is systematic organized for the distance traveled and the carried load
e) Solid waste collection is done away from of the traffic rush hours (between 6:00 A.M -12:00 P.M and between 6:00 P.M -12:00 A.M)
f) All solid waste containers located on the right side of the streets
g) The distances are measured from the centroid of the streets
h) Waste sources (zones) are located in the center of waste generating areas
i) Waste handling operations are executed daily
j) Transportation of SW from the source to the transfer station or to the land fill does not affect through the Israeli

1.5.4 Data Sources and Methods

Two data sources have been identified namely: primary and secondary data sources, (Figure 1.2). The primary data are extracted from data base information, inventories from the JSC and Nablus Municipality to collect needed and information required for the suggested model about the financial status, organization status, served LGUs, served population, the type of residential area, the amounts of MSW collected, frequency of MSW collection, MSW collection equipment, the labor force in the MSW, MSW budget, MSW Collection fees, availability of MSW reuse, MSW finial disposal methods, disposal locations, destination from source to collection and to the final destination, waste discharge amount per day and the final distention of waste. The information is collected from Nablus JSC for SWM based in Nablus city, between August 2013 and March 2014. Concurrently, the JSC-SWM based in Nablus city has been visited and GPS was used to identify the location of its site to place it on maps. The secondary data is built through deliberations on the available data sources in the forms of literature review and published statistics and databases to group together which may be linked to the research propositions or the main question and to be used to formulate the model by using GAMS software program.

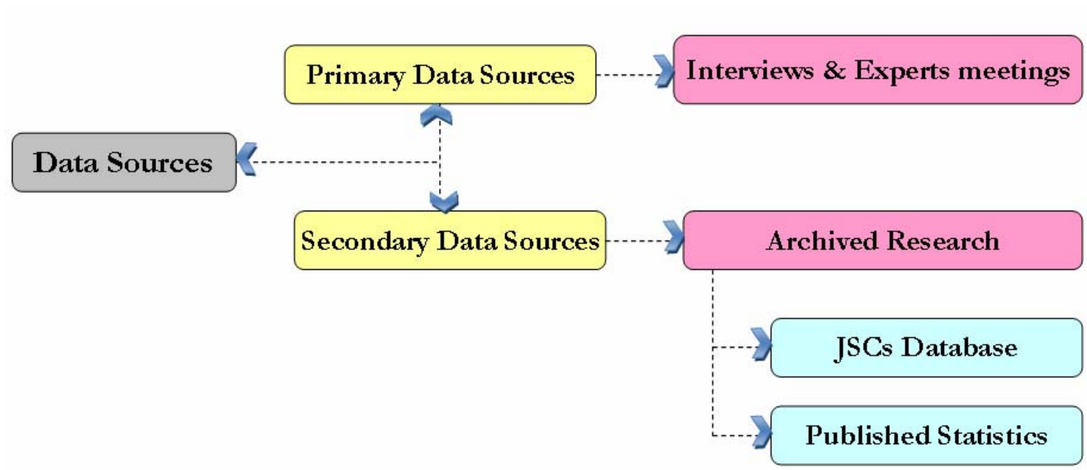


Figure1.2: Sources of information for the Study

1.5.5 Research Thesis Contents

The tentative table of contents is chaptered, as follows:

Abstract (Arabic & English)

Chapter 1: Introduction

Chapter 2: Literature Review

Chapter 3: Description of the case study

Chapter 4: Model formulation and data compilation

Chapter 5: Findings and Discussions

Chapter 6: Conclusions and Recommendations

References

Appendix (es)

Chapter Two

Literature Review

(Lyeme 2011) proposed a mathematical model for municipal solid waste management for Ilala municipality/Dar Asalam –Tanzania. Mixed Integer Programming was used. The proposed model showed the least transportation cost for different transfer stations, and also shows that an increase of the collection centers capacity will cause a decrease of the objective function values.

(Rodionov & Nakata 2011) designed an optimal waste utilization system for St. Petersburg, Russia using a mathematical formulation of the linear program formulated , developed and implemented on GAMS software to minimize the net cost between total cost and revenue of the proposed MSW utilization system. The result of the model showed that the main waste processing option for MSW was recycling. While the study indicated an increase of alternative MSW treatment options which gave positive energy with economical and environmental benefits.

(Otti 2011) determined which type of integrated solid waste management option or programme to be used and implemented to minimize the costs and maximized benefit from SWM over a long period by using linear programming to help the decision makers in Nigeria for long planning period.

(Li & Huang 2010) developed a model for MSWM system under multiple uncertainties to identify optimal waste flow allocation and facility capacity expansion strategies under uncertainty. The model handled uncertainties and to support assessing the risk of violating system constraints by setting scenarios that are representative for universe of possible outcomes. Although, the model was useful for generating a range of decision alternatives under various environmental, Socio-economic, and system-reliability conditions by identifying desired capacity expansion schemes for waste management facilities and to analyze the trade off between the cost of waste management and the risk of system disruption.

(Marković et al. 2010) used analytic hierarchy process for selecting the optimal SWM system in the city of Nis to maximize the efficiency and the satisfaction of the services users. A mathematical model was adopted to correct the existed SWM system in Nis and its performance efficacy by route redaction for SWM collection reduction .

(Rhoma, F., et al, 2010) utilized a model approach to estimate the collection and transportation costs of MSW as well as the environmental impact for Municipal solid waste from Duisburgone, districts one of the populated cities Germany. The developed model helped the municipal authority to control all the waste management activities and to minimize the costs of collection and disposal the MSW.

(Al-Khatib et al. 2010) studied the characterization, quantification and management practices in Nablus, Palestine as a case study of one of the developing countries by developing surveys for household residents' and SWM program operators. The survey results showed that organic is the majority of waste (65.1% by weight) and a recycling waste (16.7% by weight) from here the average MSW recyclable and compostable content of 85% and bio-degradable organic material contains 65%.Although, the study highlighted the main problems of SWM are disposing in unsanitary landfills, ineffective solid waste fees system, increasing solid waste quantities and lacking equipment and the need of experienced personnel. While the main study recommendations were to introduce source of recovery or compost and separation, to enhance sustainable SWM, public awareness, funding, expertise, and equipments.

Manfredi, et al. (2010) supported decision-and policy makers in managing water and solid waste quality in Nepal by developing models to be used as management supporting tools to simulate scenarios identifying and evaluating possible management solutions and interventions. A household questionnaire survey was developed to collect data about the current status of SWM then to be used for simulating possible management scenarios to build consensus understanding of the SWM system.

Ogwueleke, T. C. (2009) proposed a method to generate feasible solution to minimize the overall cost of SWM, time and distance traveled by solid waste collection vehicles. Adapting the proposed method lead to reduce the number of existing vehicles, saving 22.86% in refuse collection cost and 16.31% reduction in vehicle distance traveled length per day. Although the method adapted lead to improve the performance of SWM in Onitsha, Nigeria

(Saeed et al. 2008) analyzed the past and present trends of producing different types of solid wastes by using Microsoft office 2003 Excel spreadsheet assuming a linear behavior. The result of this study showed that the generation of SW is alarming and the city of Kula Lumpur is lacking of efficient SW treatment technologies and insufficient fund and public awareness to solve of SWM.

(Nganda 2007) formulated two different models as integer and mixed integer linear programming problems to help planners in decision making concerning SWM in Kampala, Uganda to get better total cost estimation for transportation of the SWM. Therefore, the model allowed to plan the optimal number of landfills , and the treatment plants to be used. Meanwhile, the model helped to find out the optimal waste quantities and types to be sent for treatment in the treatment plants or to landfills directly or for recycling. Although he was able to determine the type of trucks and their number and deports.

In 2009 Solano Eric developed a mathematical linear program model for integrated solid waste management (ISWM) that incorporates cost and environmental information associated with MSWM activities. The model was developed and tested for generating alternative SWM strategies to examine the effectiveness of SWM programs, such as recycling, yard waste composting, fee and incentive programs, maximizing resource recovery; minimizing landfill utilization; and minimizing environmental emissions.

(Erkut, et al. 2008) designed a SWM plan for the central Macedonia region to obtain a ‘‘fair’’ non dominated solution via a mathematical mixed-integer linear programming model consists of locations and technologies for transfer stations, material recovery facilities, incinerators and sanitary landfills, as well as the waste flow between locations in north Greece. The model helped to minimize the greenhouse effect, the amount of final disposal, and the total opening, transportation, and processing costs with maximizing the amount of material and energy recovery.

(Al-Khatib et al. 2007) assisted MSW conditions in seven major districts in northern West Bank, Palestine (Nublus was included) by focusing on comparing several MSWM elements (collection, budget, and disposal) in LGUs with detailed information regarding the SWM in the LGUs regarding the quantity of waste generated , waste disposal practices, and the collection service availability. A survey was conducted to gather the main information needed. Therefore, the survey results showed collection service was available for 98% of surveyed localities but with inefficient collection of waste disposal fees. While between 2% and 8% of the total budget of the municipalities studied was only for SWM which gave an indicator of a low priority given to SWM in LGUs. Where the most common practice for waste disposal is waste burning in open dumpsites.

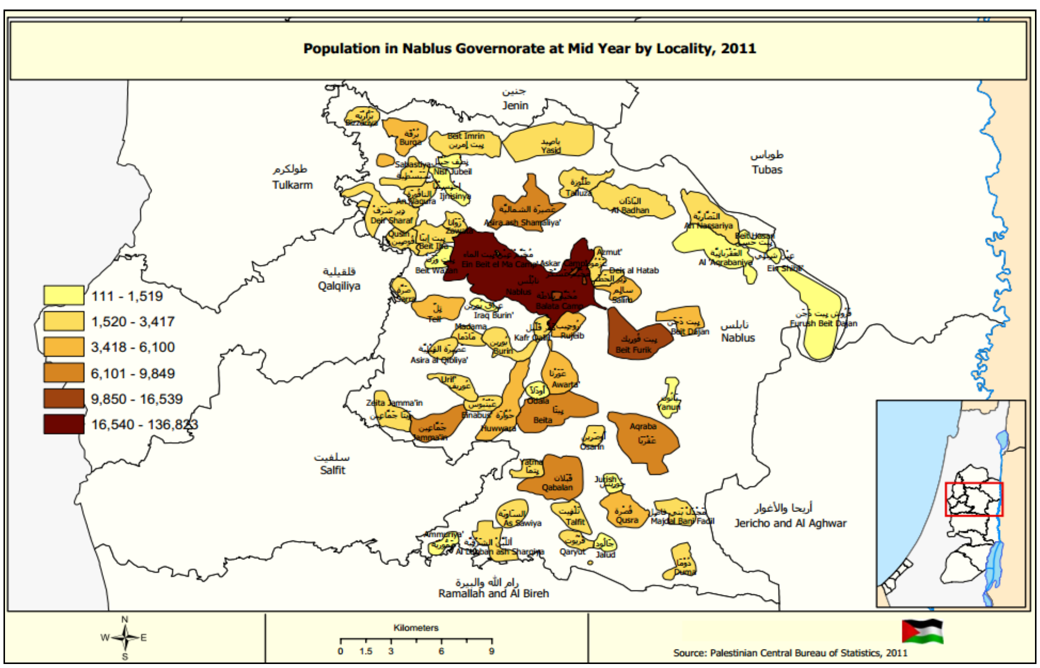
Agha, 2006 optimized the routing system for Deir El-Balah in Gaza Strip, using Mixed Integer-Programming (MIP) model. In order the collection process constituted about 74% of SWM costs the model was to minimize the total distance traveled by the collection vehicles. The resulted model reduced the total distance by 23.47% which lead to 1140 US$ saving per month.

Chapter Three

Description of the Case Study

3.1 Introduction

Historical documents indicate that Nablus governorate is considered as one of the largest Palestinian with total area of 605 km^2. PSBS estimated the Population of Nablus governorate around 372,620 which makes 13.3% from the total population of Palestine (PSBC, 2014).Figure 3.1 shows the population distribution in Nablus governorate by localities (PSBC, 2011).



Source: PCBS, 2011

Figure 3.1: Population distribution in Nablus Governorate, 2011

3.2 Solid waste management in Nablus City

The daily SW production in Nablus city and the three refuges camps estimated at 200 tons per day, which is equivalent to 0.7 Kg/Ca/day, for a population of 179,938 citizen (Nablus JSC-SWM,2014).

Nablus Municipality is responsible of SWM process starting from collecting the waste, transport it to the transfer station (Al-Sirafi). Then, to the final disposal distention in Zahret Al-Finjan sanitary landfill in Jenin Governorate. This landfill is 27 km away from Nablus city.

The beneficiaries' areas from the SWM service are Nablus city, including the old city, where extra work is needed due to the narrow roads. The municipality is responsible also of transferring and dumping SW for three refugees camps (Askar, Balata and Ein Beit El-Maa' Camp), according to an agreement with the United Nation (UN) while the UN is the responsible of waste collection.

Since November 2007, Nablus JSC for solid waste management was established by MoLG decision including the agreement of the decision of the LGUs in Nablus district to insure the quality of solid waste service provided for 56 LGUs in Nablus governorate, through collecting the waste from the 56 LGUs, transfer it to the transfer station, and then to its final destination in Zahret Al-finjan landfill. The formation of Nablus JSC-SWM is based on the Palestinian LGUs law number 1 for year 1997 and the Joint service councils (JSC) bylaw for year 2006. Nablus municipality is the head of Nablus JSC-SWM due to its largest number of population. Nablus JSC-SWM is registered with the directorate of customs date March 1, 2009 (Nablus JSC-SWM, 2014). Currently, the JSC provide a full service for 24 LGUs (Figure 3.2) while still in process to ensure the ability to provide the remaining LGUs members. Five LGUs out of the twenty four LGUs (Ein shibli, Zbedat, Alaqrabanya, Nasaria, and Beit Hasan) have a double membership with Jericho JSC-SWM and served by it due to the geographical location in the Jordan valley.

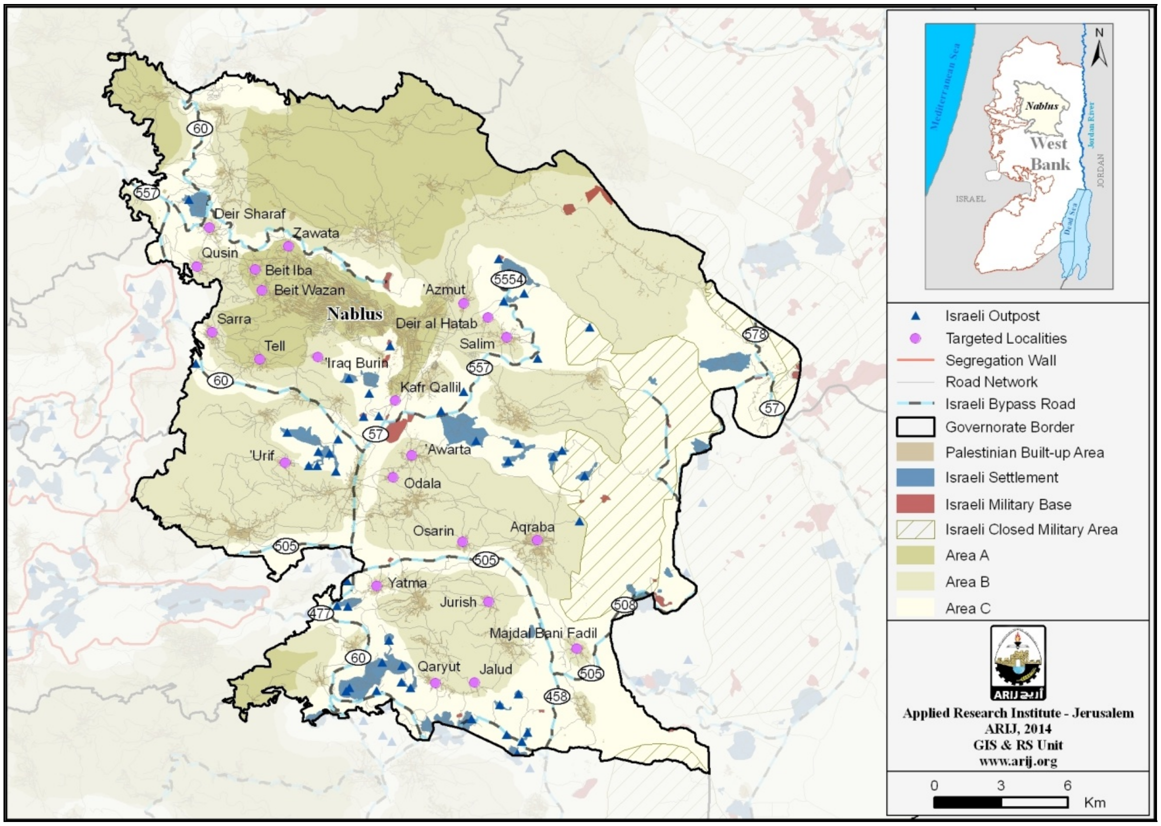


Figure 3.2: Served LGUs

Collection system is consisting of household (primary) waste containers, primary and secondary collections vehicles and equipment, and supplying the labor hand for collection. Solid waste collection is carried out mechanically via Nablus JSC-SWM, by using 5 compacters (Three compacter with 8 m^3 capacity loads, and two with 12 m^3 capacity loads). Nablus JSC-SWM undertakes the responsibility of daily basis waste collection, and some times twice a day. In some area SW collection is twice a week minimum, (Table 3.1). Therefore, the JSC-SWM divided the beneficiaries' area into eighteen zones (Table 3.2); in order to improve its service delivery for all served localities (Figure 3.3).

Table 3.1: Collection Frequency and waste generated of serviced LGUs in Nablus JSC-SWM

Zone#	Location	Generated waste(tons/month)	Frequently collection
1.	Salem	85	Twice a week
2.	Azmout	60	Twice a week
3.	Deir Al-Hatab	45	Twice a week
4.	Beit Wazan	20	Twice a week
5.	A'warta	140	Daily
6.	Zawata	40	Three times a week
7.	A'qraba	160	Daily
8.	O'ref	65	Twice a week
9.	Yetma	65	Twice a week
10.	Karyout	35	Twice a week
11.	Beit Eba	100	Three times a week
12.	Odalah	22	Once a week
13.	Jaloud	18	Twice a week
14.	Qousreen	32	Three times a week
15.	Tell	70	Three times a week
16.	Alsomara	20	Twice a week
17.	Residential neighborhoods of Nablus (Jabaljanobi)	900	Twice a Day
18.	Deir Sharaf	55	Three times a week
19.	Sara	50	Three times a week
20.	Iraq Boren	16	Three times a week
21.	Jouresh	30	Twice a week
22.	Kofor kalil	45	Twice a week
23.	O'sereen	25	Twice a week
24.	Al-Majdal	25	Twice a week
Total		**2123**	

Source: Nablus JSC-SWM, 2014

Table 3.2: The JSC-SWM Zones and the collection frequency

Zone#	Location	Generated waste(tons/month)	Frequently collection
1.	Salem	85	Twice a week
2.	Azmout	60	Twice a week
3.	Deir Al-Hatab	45	Twice a week
4.	Kofor kalil / Jouresh	75	Twice a week
5.	A’warta	100	5 times a week
6.	Odalah / A’warta	62	Once a week
7.	O’ref	65	Twice a week
8.	Yetma	65	Twice a week
9.	Jaloud / Karyout	53	Twice a week
10.	Al-Majdal/ O’sereen	50	Twice a week
11.	A’qraba	160	Four times a week
12.	Deir Sharaf/ Qousreen / Beit Eba	187	Three times a week
13.	Sara / Iraq Boren/ Tell	136	Three times a week
14.	Western Jabal Janobi	435	Daily
15.	Residential neighborhoods of Nablus / Beit Wazan	30	Twice a week
16.	Residential neighborhoods of Nablus / Zawata	50	Twice a week
17.	Residential neighborhoods of Nablus / Alsomara	30	Twice a week
18.	Eastern Jabal Janobi	435	Daily
Total		**2123**	

Source: Nablus JSC-SWM, 2014

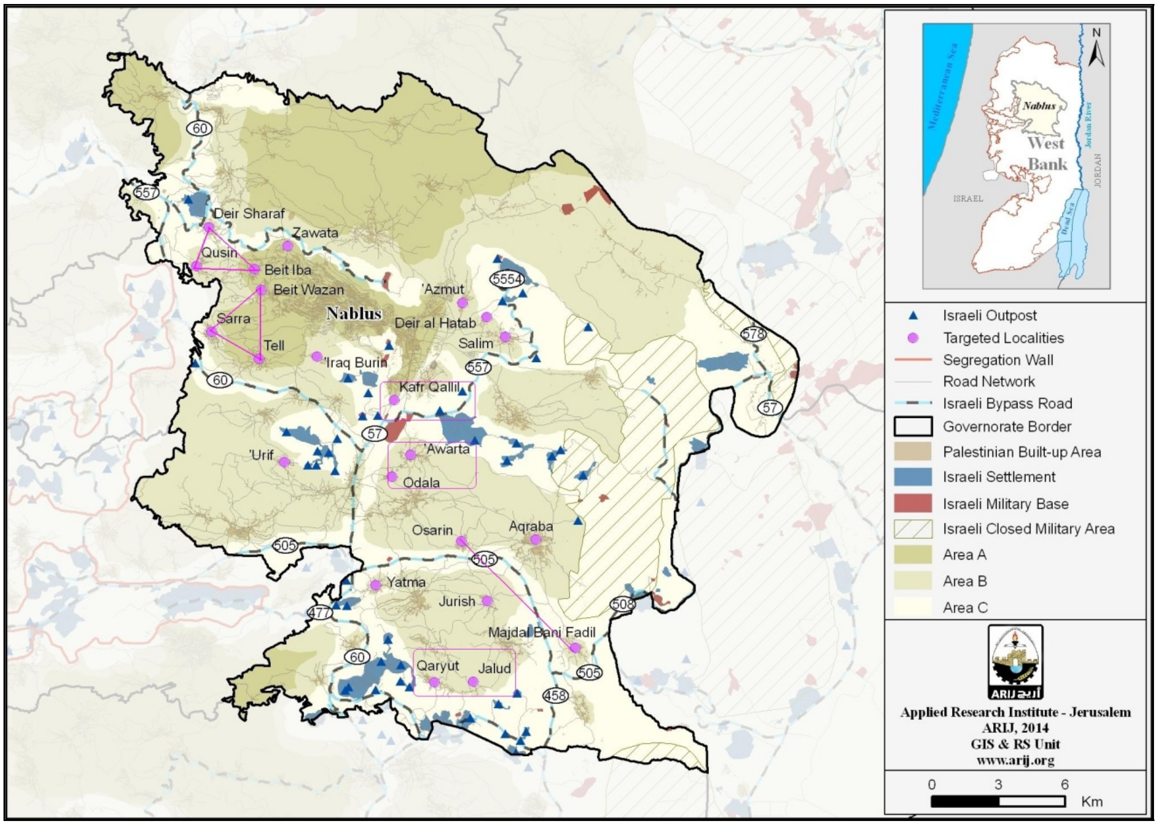


Figure 3.3: Served localities for solid waste collection (Nablus JSC-SWM, 2014)

One of the tools to improve the quality of the SWM service is working within a schedule determined by the joint services council to ensure the provision of effective service to all citizens. Nablus JSC-SWM has twenty employees (Table 3.3); four related to administrative section while the rest are labors and drivers. The working labors are divided as three employees for each collection vehicles (one driver and two employees to empty the containers of SW (Nablus JSC-SWM, 2014). Descriptions of each vehicles type, along with some general observations and application of the equipment, are listed with each type of compactor. Table 3.4 shows the schedule reflect the rotations of the SWM vehicles and number of employees needed.

Table 3.3: Nablus JSC-SWM employees for 2014

	Number	Location	
		Office	On vehicles
Administrative	4	4	-
Labors	10	-	10
Driver	6	-	6

Source: Nablus JSC-SWM, 2014

Table 3.4: SWM Equipment and vehicles Schedule in Nablus JSC-SWM

Vehicle #	capacity of compacter	Shift # / a week	Served location	Shift Time	# of needed employees
1.	8 m^3	2	Salem	12:00-6:00 pm	3
		2	Azmout	12:00-6:00 pm	3
		2	Deir Al-Hatab	12:00-6:00 pm	3
		5	A'warta	6:00 am-12:00pm	3
		1	A'warta / Odalah	6:00 am-12:00pm	3
		2	Kofor kalil / Jouresh	6:00 am-12:00pm	3
2.	8 m^3	2	Yetma	6:00 am-12:00pm	3
		2	Jaloud / Karyout	6:00 am-12:00pm	3
		2	O'ref	6:00 am-12:00pm	3
3.	8 m^3	2	O'sereen/ Al-Majdal	6:00 am-12:00pm	3
		4	A'qraba	6:00 am-12:00pm	3
4.	12 m^3	3	Deir Sharaf/ Qousreen / Beit Eba	6:00 am-6:00pm	3
		3	Sara / Iraq Boren/ Tell	6:00 am-6:00pm	3
		Daily	Western Jabal Janobi	8:00pm-2:00am	3
5.	12 m^3	2	Residential neighborhoods of Nablus / Beit Wazan	10:00am-4:00pm	3
		3	Residential neighborhoods of Nablus / Zawata	10:00am-4:00pm	3
		2	Residential neighborhoods of Nablus / Alsomara	10:00am-4:00pm	3
		Daily	Eastern Jabal Janobi	8:00pm-2:00am	3

Source: Nablus JSC-SWM, 2014

Nablus JSC-SWM distributed 497 garbage containers with 1 m^3 capacity load in the served area streets with one cubic meter capacity. Containers with capacity 1 m^3 supposed to serve 200 persons. The typical distribution model for 1 m^3 containers is one container every 200 meters in the densely populated areas while it is different for other cases with low densely populated areas (Nablus JSC-SWM, 2014). Nablus JSC-SWM applied Geographical Information System (GIS) to distribute the SW containers for the purpose of monitoring the service in Nablus city as a pilot area. The GIS system helps to give a clear route of the containers locations, and the rout of collection vehicles

3.3 Financial status for solid waste management

Adequate budgeting, cost accounting, financial monitoring and financial evaluation are essential to the effective management of solid waste systems for cost recovery and cost reduction (Schübeler et. al.1996). Scarcely the financial monitoring and financial evaluation are employed via LGUs and JSC from here the importance of a detailed study for the financial situation of SWM in Nablus JSC-SWM.

The financing capital investment for SWM in Nablus JSC-SWM is special central government loans or grants from donors. The collection vehicles are donated from the European Union (EU) in 2012 and the administration equipments are donated from the Japanese international cooperation agency (JICA) 2010 grand aid for SWM in Palestine (MoLG, 2014).

The cost components for SWM are primary collection, secondary collection, transportation, treatment, and another supporting activity, beside the design factor for cost recovery. Therefore, the cost analysis is up to the generation rate, population forecast, and the collection rate (Nablus JSC-SWM, 2014).

In 2013 solid waste management fee decision were made by the administrative board of Nablus JSC-SWM decision makers (Nine LGUs, including the JSC chair man, members, and employees).

MSWM fees collection performance in Nablus municipality consider to be good in order to the system used by charging the MSWM fees on the electricity bill or on the pre-paid card of electricity; as shown in Table 3.5

Table 3.5: SWM fees in Nablus Municipality for 2014

Type of waste	Fees (JD or ILS)	Payment
Residence (Houses)	15 ILS /monthly	Electricity bill
Commercial unit	30 ILS / monthly	Electricity bill
Industrial unit	40 JD / container	Collection of the container
Health care unit	40 JD / container	Collection of the container

Source: Nablus Municipality, 2014

The collection fees performance at the other LGUs member in Nablus JSC-SWM is almost the same (10-15 ILS for residence). Although, the fees collected by the LGUs cover the cost of collection solid waste while other costs are not considers like the disposal, separation, and vehicles consumption. The collected fees used only to pay Nablus JSC-SWM for collection and disposal in sanitary landfill (Nablus JSC-SWM, 2014). Table 3.6 shows the costs of SW disposal per ton of waste.

Therefore, the total process of SWM is affected by; collected fees are not covering the real costs of SWM, and solid waste service revenues normally flow into a general municipal account. Also, the potential of increasing the SWM revenues is very limited due to the general economical situation in Palestine. Beside, depending on the support of the intergovernmental transfers, or local taxes, or the donors grant (Nablus JSC-SWM, 2014) (This is clear on Table3.7).

Table 3.6: Costs of SW disposal per Ton of waste

From	To	Item	Cost (ILS)/Ton
Zones	Al-Sirafi TS	Transportation	**52**
Zones	Beta TS*	Transportation	**40**
Al-Sirafi TS or Beta TS*		Collection Center	**8**
Al-Sirafi TS	Zahret Al-finjan LF	Transportation	**34**
Beta TS*	Zahret Al-finjan LF	Transportation	**41**
Zahret Al-finjan LF		Disposal fees	**25**
Total costs (Zones, Al-Sirafi TS, to Al-finjan LF)			**119**
Total costs (Zones, Beta TS*, to Al-finjan LF)			**114**

* suggested transfer station
Source: Nablus JSC-SWM, 2014

The yearly statements of activities for the year ended December, 31st, 2013 for SWM management's total expenses for Nablus JSC-SWM is 3,614,759 ILS or 9,903 ILS per day. Table 3.7, shows the statements of activities for the last two years (2013-2012), while Table 3.8 presents the Balance sheet during December, 31st, 2013 shows the total assets is 1,993,396 ILS and 1,993,396 ILS is the total liabilities and overall surplus for the end of 2013.

Table 3.7: The statements of activities for year 2012 and 2013

Description	Note	31/12/2013 (ILS)	31/12/2012 (ILS)
Revenues:		ILS	ILS
Landfill fees	7	3,492,153	2,239,989
Transport containers		0	3,600
On-Kind donations- 5 waste vehicles	8	0	1,249,060
Total Revenues		**3,492,153**	**3,492,649**
Expenses:			
Salaries and wages		716,970	524,206
Indemnity		39,904	22,337
Rents	9	15,816	16,868
Telecommunications		3,542	2,526
Depreciation of fixed assets	5	549,348	344,310
Electricity		1,731	1,076
Shipping and containers		0	1,200
Car license		954	0
Cost of Alrmsa vehicle		10,250	0
Tires	10	49,050	0
Rewards & incentives		2,000	0
Workers kits (clothing and gloves)		3,281	0
Frees and compensation		8,450	0
Load waste	11	579,914	534,027
Hospitality and cleaning		1,924	551
Stationery		1,053	173
Offices maintenance		1,571	364
Vehicles Maintenance	10	124,773	81,648

Oils and fuels	10	564,446	428,757
Expenses waste disposal/Sirafi	11	124,209	116,195
Advertising		0	610
Work injury insurance		6,198	5,959
Car Insurance		28,133	36,027
Expenses Landfill	11	771,763	444,122
Miscellaneous expenses		785	0
Transportation		2,735	5,813
Commissions and bank interest		1,610	538
Audit fees		4,350	3,078
Total Expenses		3,614,759	2,570,385
Surplus (deficit)for the year		-122,606	922,264

Source: (Khleif & Samman for Auditing & advisory report, 2014)

Table 3.8: Nablus JSC-SWM Balance sheet 31/12/2013

Description	Note	31/12/2013	31/12/2012
Current Assets		**(ILS)**	**(ILS)**
Cash on hand/ ILS		1,739	2,967
Bank of Jordan / ILS	3	58,269	90,124
Checks		0	4,550
Returned checks		10,000	1,911
Accounts Receivables – local councils		457,872	353,037
Total Current Assets		527,880	452,589
Fixed Assets:			
Fixed Assets at cost		2,774,887	2,774,887
Accumulated Depreciation		-1,309,371	-760,023
Net book value of fixed assets		1,465,516	2,014,864
Total Assets		**1,993,396**	**2,467,453**

Liabilities and overall surplus:			
Liabilities:			
Post dated checks		45,831	47,362
Provision for end of service benefits		84,578	44,674
Accrued expenses		49,688	0
Accounts payable		132,362	571,874
Total liabilities		312,459	663,910
Net Surplus:			
Surplus from propr years		1,803,543	881,279
Deficit		-122,606	922,264
Total brought forward surplus		1,680,937	1,803,543
Total liabilities and overall surplus		**1,993,396**	**2,467,453**

Source: (Khleif & Samman for Auditing & advisory report, 2014)

Following there is two examples of using one of the cost charts for the compactors described to compute the cost of the truck. There are two different types of cost charts for each compactor specified to its capacity .Tables 3.9 to 3.10 show the SWM costs according to Nablus JSC-SWM financial records in 2014 for compactor vehicle upon its capacity.

Table 3.9: Unit Cost for Collection and Transportation per Day with Depreciation 8 m^3 Compactor vehicle

#	Item	I trip				II trip
		Qty	Unit	Unit price	ILS	ILS
1.	Fuel (5 L/hour)	5 L	8 hr	6.5	260	520
2.	Lubricant	L.S	L.S	14	14	28
3.	Maintenance	L.S	L.S	30	30	60
4.	Driver	1	pr	90	90	180
5.	Workers	2	pr	70	140	280
6.	Indemnity for Driver	1	pr	7.5	7.5	15
7.	Indemnity for workers	2	pr	5.8	11.6	23.2
8.	Vehicle Insurance	L.S	L.S	30	30	60
9.	Deprecation for wheels	L.S	L.S	10	10	20
10.	Miscellaneous	L.S	L.S	10	10	20
11.	Al-Sirafi TS	5.92	Ton	6	35.52	71.04
12.	Tranfer to Zahret Al-Finjan LD	5.92	Ton	34	201.28	402.56
13.	Final disposal @ Zahret Al-Finjan	5.92	Ton	30	177.6	355.2
Total for Collection for I trip		1017.5 ILS				
Collection cost/Ton* for I trip		171.9 ILS				

*One Ton = 0.74 X m^3

Source: Nablus JSC-SWM, 2014

Table 3.10: Unit Cost for Collection and Transportation per Day with Depreciation 12 m^3 Compactor vehicle

#	Item	I trip				II trip
		Qty	Unit	Unit price	ILS	ILS
1.	Fuel (5 L/hour)	5 L	8 hr	6.5	260	520
2.	Lubricant	L.S	L.S	14	14	28
3.	Maintenance	L.S	L.S	30	30	60
4.	Driver	1	pr	90	90	180
5.	Workers	2	pr	70	140	280
6.	Indemnity for Driver	1	pr	7.5	7.5	15
7.	Indemnity for workers	2	pr	5.8	11.6	23.2
8.	Vehicle Insurance	L.S	L.S	30	30	60
9.	Deprecation for wheels	L.S	L.S	10	10	20
10.	Miscellaneous	L.S	L.S	10	10	20
11.	Al-Sirafi TS	8.88	Ton	6	53.28	106.56
12.	Tranfer to Zahret Al-Finjan LD	8.88	Ton	34	301.92	603.84
13.	Final disposal @ Zahret Al-Finjan	8.88	Ton	30	266.4	532.8
Total for Collection for I trip		1224.7 ILS				
Collection cost/Ton* for I trip		137.9 ILS				

*One Ton = 0.74 X m^3
Source: Nablus JSC-SWM, 2014

The best way to ensure financial sustainability is almost always by cost reduction “doing more with less” (Schübeler *et al.* 1996). According to calculation performed, about 41% of total solid waste management cost is related to waste collection (Load waste, Expenses waste disposal/Sirafi, and Expenses Landfill); high amount from this cost is related to fuel (16%). About 21% of the expenses are related to the work force Salaries and wages, Indemnity, Work injury insurance, Rewards & incentives, Frees and compensation. While the vehicles used in SWM expenses is about 59.5% from the total activities in 2013 related to the vehicles insurance, maintenance and depreciation. Therefore, optimizing the transportation processes will require less transportation and labor costs.

3.4 Evaluation of collection system

The evaluation of collection systems involves a number of considerations such as type and size of containers, compacters, schedule of collection, and the frequency of collection. One of the most important considerations is the number of population serviced per collection vehicle (Table 3.11). If the productivity is examined on the basis of population served, the values around the world exhibit a wide range, about 3,000 to 20,000 persons served per collection vehicle, as shown by the data in Table 3.12 Many factors, as described in this chapter, govern vehicle productivity. Table 3.12 shows the main indicators of solid waste service.

Table 3.11: Number of population serviced per collection vehicle

Vehicle #	compacter	Served location	Population (PSBC,2010)	Total
1*.	8 m^3	Azmout	482	23,058
		Salem	6,337	
		Deir Al-Hatab	2,814	
		A'warta	7,245	
		Kofor kalil	3,106	
		Jouresh	1,725	
		Odalah	1,349	
2.	8 m^3	Yetma	3,717	10,899
		Jaloud	564	
		O'ref	3,540	
		Karyout	3,078	
3.	8 m^3	O'sereen	2,032	14,641
		A'qraba	9,887	
		Al-Majdal	2,722	
4.**	12 m^3	Iraq Boren	961	42,649
		Qousreen	2,161	
		Beit Eba	4,074	
		Tell	5,908	
		Deir Sharaf	3,440	
		Sara	3,605	
		Western Jabal Janobi	22,500	
5*.	12 m^3	Beit Wazan	1,396	36,815
		Zawata	2,369	
		Alsomara	550	
		Eastern Jabal Janobi	22,500	
		Residential neighborhoods of Nablus	10,000	
Total				**128,062**

* Served two shifts / day
** Served three shifts / day

Table 3.12: Solid waste service indicators

<table>
<tr><th>Indicator</th><th>Unit</th><th>Nablus JSC-SWM</th></tr>
<tr><td>Number of service regions</td><td>#</td><td>24</td></tr>
<tr><td>Population served(2010)</td><td>Person</td><td>128,062</td></tr>
<tr><td>Population served by worker</td><td>workers</td><td>27</td></tr>
<tr><td>Daily quantity of collected SW</td><td>tonnes/day</td><td>70.8</td></tr>
<tr><td rowspan="4">Average number of containers per Km of collection route</td><td>Urban area #</td><td>≥ 20/km</td></tr>
<tr><td>Rural area#</td><td>≤ 10/km</td></tr>
<tr><td>Optimal 8 m^3</td><td>8</td></tr>
<tr><td>Optimal 12 m^3</td><td>12</td></tr>
<tr><td>Average cost of collection and transport</td><td>ILS/Ton</td><td>86</td></tr>
<tr><td>Average daily SW collected by workers</td><td>Ton/worker/day</td><td>4.4</td></tr>
</table>

Chapter Four

Model Formation and Data compilation

4.1 Introduction

This chapter presents a detailed description about SWM model in Nablus JSC-SWM according to a mathematical formulation of GAMS Linear integer programming model (Lee *et al.* 1996). The model presents an innovative of a possible more efficient SWM systems and the applicability of the GAMS model.

4.2 The model

4.2.1 Model Assumption

Assumptions needed to formulate the GAMS mixed integer programming model are:

a) All the generated solid waste in Nablus governorate are collected from the Waste sources (zones) and transferred to the transfer station (Al-Sirafi)
b) All the solid waste are daily transferred from transfer station (Al-Sirafi) to Zahret Al-finjan Land fill in Jenin Governorate

c) In Nablus governorate there is no waste separation at the source or at the transfer stations
d) Transportation cost is systematic organized for the distance traveled and the carried load
e) Solid waste collection is done away from of the traffic rush hours (between 6:00 A.M -12:00 P.M and between 6:00 P.M -12:00 A.M)
f) All solid waste containers located on the right side of the streets
g) The distances are measured from the centroid of the streets
h) Waste sources (zones) are located in the center of waste generating areas
i) Waste handling operations are executed daily
j) Transportation of SW from the source to the transfer station or to the land fill does not affect through the Israeli Occupation

4.2.2 Proposed model of SWM for Nablus Municipality

The proposed model is formulated according to the MSW collection flow for Nablus JSC-SWM. Figure 4.1 & 4.2 shows the schematic diagram of MSW collection flow for Nablus JSC-SWM through two transfer stations. The current one, which is Al-Sirafi transfer station (TS), and the second potential transfer station locate in Beta city.

MSW is currently disposed in containers locate within eighteen zones distributed in Nablus JSC-SWM. The JSC-SWM is responsible for collection and transferring and disposing in Zahert Al-finjan sanitary land fill in Jenin area.

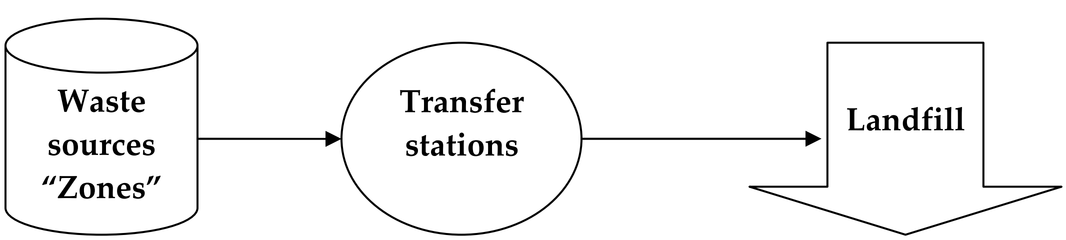


Figure 4.1: MSW flow

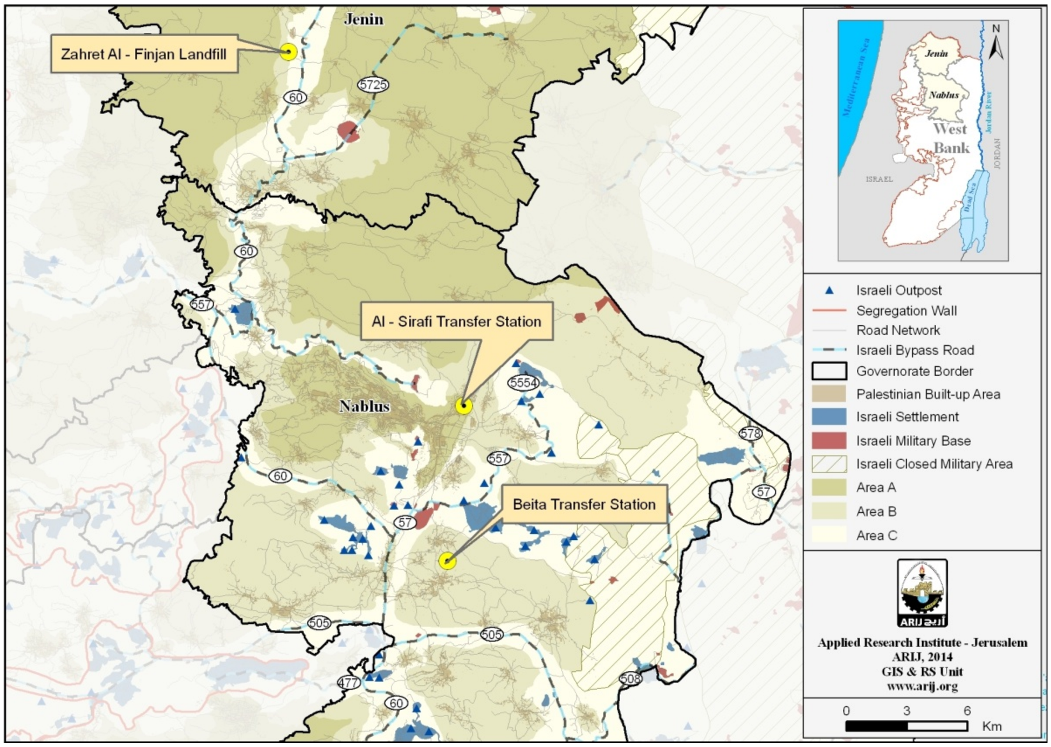


Figure 4.2: MSW flow from TS to LF

4.2.3 Model Objective

Currently, Nablus governorate has no treatment process on the solid waste management system because of missing a treatment plant; therefore the driving parameters and variables are:

1. Amounts of waste produce at zones
2. Solid waste capacity of the transfer stations
3. Waste capacity of the sanitary landfill
4. Transportation costs
5. Handling fees at the transfer station
6. Handling fees at the sanitary landfill

Hence we need to minimize the cost of transporting MSW from the sources (zones) to Zahret Al-finjan landfill in Jenin through the transfer station (Al-Sirafi or the suggested transfer station in Beta). Consequently, the objective of the model is to select between the two transfer stations or to find the best attitude to follow in order to minimize the transportation cost for the MSW.

4.2.4 Decision Variables

To explain the relationships that exist among independent measured quantities in an experiment a model usually designed; these are the variables of the model (Bard 1974). Model variables are not random variables they are important for model evaluation and can be controlled. Decision variables are defined as following:

- X_{ij} is amount in ton of the daily SW collected from the source i to the transfer station j (i=1,2,…,I ; j = 1,2,…,J)
- y_{jk} is amount in ton for daily SW removed from the transfer stations j to landfill k (j = 1,2,…,J ; k= 1,2,…, K)
- Q_j is a variable which can take value of one to zero. It takes the value one if a transfer station is to be set up at the location j and zero otherwise (j =1, 2… J)

4.2.5 Parameters

Parameters are the boundaries that define the scope of a particular process or activity and an important element to be considered in evaluating the project, or situation. The proposed model uses the following parameters:

- W_i is a mount of daily waste generated at source $_i$
- C_j is a daily capacity of the transfer station j
- L_k is a daily capacity of the landfill k
- T_{ij} is distance in Kilometers between Zone i to transfer station j (i=1,2,…,I ; j = 1,2,…, J)
- T_{jk} distance in Kilometers between transfer station j and Landfill k (j = 1,2,…,J ; k= 1,2,…, K)
- S_j is a fixed cost of transfer waste from source to transfer station

- F_j is a fixed cost of transfer station represented as daily fixed cost
- F_k is a fixed cost for handling one ton of waste in the landfill
- F is fuel cost in ILS for one Kilometer distance

4.2.6 Data used to test the model

The data for the parameters and variables are given in Tables 4.1-4.4 below.

Table 4.1: Waste amount at waste sources

Waste source (i)	Daily Waste amount in ton (W_i)	Waste source (i)	Daily Waste amount in ton (W_i)
Zone 1	2.8	Zone 13	0.6
Zone 2	2	Zone 14	1.1
Zone 3	1.5	Zone 15	2.3
Zone 4	0.7	Zone 16	0.7
Zone 5	4.7	Zone 17	30
Zone 6	1.3	Zone 18	1.8
Zone 7	5.3	Zone 19	1.7
Zone 8	2.2	Zone 20	0.5
Zone 9	2.2	Zone 21	1
Zone 10	1.2	Zone 22	1.5
Zone 11	3.3	Zone 23	0.8
Zone 12	0.7	Zone 24	0.8

Source: Nablus JSC-SWM, 2014

Table 4.2: Transfer stations capacities, and cost of opening and waste handling

Transfer station j	Waste Capacity in ton C_j	Transfer station fixed cost (ILS) F_j	transporting cost to the landfill* (ILS) T_{jk}
Al-Sirafi	250	8	368.5
Beta (POTINTAL)	80	25	402

* Fuel cost was for 1 Km = 6.7 ILS
Source: Nablus JSC-SWM, 2014

Table 4.3: Landfill capacity, cost of opening land fill, and handling cost for one ton waste

Landfill k	**Waste capacity** L_k	**Fixed cost for handling one ton of waste (ILS)** F_k
Zahret Al-finjan	1200	25

Source: Nablus JSC-SWM, 2014

Table 4.4: Distance from Transfer station j to the landfill k in (Km)

Transfer station j	**Distance to the landfill** k **(Km)**
Al-Sirafi	55
Beta (POTINTAL)	60

Source: Nablus JSC-SWM, 2014

4.3 Mathematical Formulation

4.3.1 Objective function

The minimum cost problem for each MSW management scenario investigated in this study can be shown as the following mathematical statements. The main aim of the model is to minimize Z. Therefore, the objective function is expressed as Z of the model represents the overall daily waste management costs (ILS); the first component gives the fixed costs FC (ILS), and the second component represents the transportations costs TC (ILS).

The fixed costs is calculated using the equation (4.1) & (4.2)

For transfer station: $$FC(x) = \sum_{i=1}^{I}\sum_{j=1}^{J} x_{ij}\, HJ \quad (4.1)$$

For Landfill: $$FC(y) = \sum_{j=1}^{J}\sum_{k=1}^{K} y_{jk}\, Dk \quad (4.2)$$

From above two equations, the total fixed costs are the sum of fixed cost in the transfer station and landfill

FC= FC(x) +FC(y)

$$FC\,(x,y) = \sum_{i=1}^{I}\sum_{j=1}^{J} x_{ij}\,HJ + \sum_{j=1}^{J}\sum_{k=1}^{K} y_{jk}\,Dk \quad \text{..........} \quad (4.3)$$

While the transportation costs are consisted from two components. The first component TC_1 is refers to the transportation costs of the one ton of waste form the source i to the transfer stations j times the amount of waste to be removed (equation 4.4). The second component TC_2 is refers to the transportation costs of one ton of solid waste from the transfer station j to the landfill k (equation 4.5).

$$TC(x) = \sum_{i=1}^{I}\sum_{j=1}^{J} D_{ij}\;x_{ij} \quad \text{..........} \quad (4.4)$$

$$TC(y) = \sum_{J=1}^{J}\sum_{K=1}^{K} O_{jk}\;y_{jk} \quad \text{..........} \quad (4.5)$$

From above two equations, the transportation costs are the sum of equation (4.4 and 4.5):

TC (x,y)= TC(x) + TC(y)

$$TC\,(x,y) = \sum_{i=1}^{I}\sum_{j=1}^{J} T_{ij}\;x_{ij} + \sum_{J=1}^{J}\sum_{K=1}^{K} T_{jk}\;y_{jk} \quad \text{..........} \quad (4.6)$$

Since

Z(x,y) = FC ((x,y)+TC (x,y)

Thus,

$$Z(x,y) = \sum_{i=1}^{I}\sum_{j=1}^{J} x_{ij}\,HJ + \sum_{J=1}^{J}\sum_{K=1}^{K} y_{jk}\,Dk + \sum_{i=1}^{I}\sum_{j=1}^{J} T_{ij}\;x_{ij} + \sum_{J=1}^{J}\sum_{K=1}^{K} T_{jk}\;y_{jk} \quad \text{..........} \quad (4.7)$$

4.3.2 Constraints

Seven constraints are included in the mathematical model regarding the volume of waste flow from zones to transfer stations, then to the landfill. As well as, the capacity of the transfer stations, the capacity of the landfill and the number of transfer stations opened with their total capacity.

The following equations elaborate more the seven constraints that have been included in the formulation of the mathematical model.

Constraint #1: Waste from zones to transfer stations

As assumed in assumption (a), all generated waste are collected from the Waste zones and transferred to the transfer stations. Thus,

$$\sum_{j=1}^{J} X_{ij} = \sum_{i=1}^{I} w_i \text{ for } i = (1,\ldots, I), j=(1,\ldots,J) \quad \ldots\ldots (4.8)$$

Constraint #2: Waste from the transfer stations to landfill

As assumed previously in assumption (b), the entire solid waste are daily transferred from transfer stations to Zahret Al-finjan Land fill in Jenin Governorate. Thus,

$$\sum_{i=1}^{I}\sum_{j=1}^{J} x_{ij} = \sum_{j=1}^{J}\sum_{k=1}^{K} y_{jk} \quad \ldots\ldots (4.9)$$

Constraint # 3: Capacity of the transfer stations

All the quantity of waste generated and transported from zones to transfer stations is less than the capacity of the transfer stations .Thus,

$$\sum_{j=1}^{J} X_{ij} \leq C_j \quad \text{for } j = (1,\ldots, J) \quad \ldots\ldots (4.10)$$

Constraint # 4: Capacity of the landfill

All the waste coming from the transfer stations should be not exceed the landfill capacity. So,

$$\sum_{k=1}^{K} y_{jk} \leq L_k \quad \text{for } k = (1,\ldots, K) \quad \ldots\ldots (4.11)$$

Constraint # 5: The total capacity of the transfer stations selected to be larger than the total daily generated waste by the model. Therefore, the total capacity for all the transfer stations should be more or equal to all MSW generated from the zones.

$$\sum_{j=1}^{J} C_j \geq \sum_{i=1}^{I} w_i \quad \text{...} (4.12)$$

Constraint # 7: Non negativity constraints of the decision variables

To make sure that all the variables are greater or equal to zero, so:

$X_{ij} \geq 0$, $y_{jk} \geq 0$, for j=(1,…,J, i=1,….,I, k=1,....,K) .... (4.13)

Then, to obtain the main objective from this study and from the model via combining the objective function and constrains the final formulation of the mixed integer model is written as the following:

$$\text{Min } Z(x,y)= \sum_{i=1}^{I}\sum_{j=1}^{J} x_{ij}\, HJ + \sum_{J=1}^{J}\sum_{K=1}^{K} y_{jk}\, Dk + \sum_{i=1}^{I}\sum_{j=1}^{J} T_{ij}\; x_{ij} + \sum_{J=1}^{J}\sum_{K=1}^{K} T_{jk}\; y_{jk}$$

Subjected to

$$\sum_{i=1}^{I}\sum_{j=1}^{J} X_{ij} \leq \sum_{i=1}^{I} w_i$$

$$\sum_{i=1}^{I}\sum_{j=1}^{J} x_{ij} = \sum_{j=1}^{J}\sum_{k=1}^{K} y_{jk}$$

$$\sum_{j=1}^{J} X_{ij} \leq \sum_{j=1}^{J} C_j \quad \text{for } j = (1,\ldots, J)$$

$$\sum_{j=1}^{J} y_{jk} \leq L_k$$

$X_{ij} \geq 0$, $y_{jk} \geq 0$, for j=(1,…,J, i=1,….,I, k=1,....,K)

Where,

i= Zone (source of waste)

j= Transfer stion

k= Landfill

4.3.3 Data compilation (synthesis/ component)

The following data is required to run the mathematical model:

a. Waste sources
b. Waste transfer stations
c. Location of the transfer stations (transfer stations)
d. landfill
e. Transport costs

4.3.4 Waste sources data

Nablus JSC-SWM is responsible to collect from twenty four zones, these zones considered to be the waste generation sources. Therefore, the model will has twenty four waste zones (i=24). Distances are measured from the center of each waste zone location (Figure 4.3). The waste generated amounts for each zone were taken from Nablus JSC-SWM records of 2014.

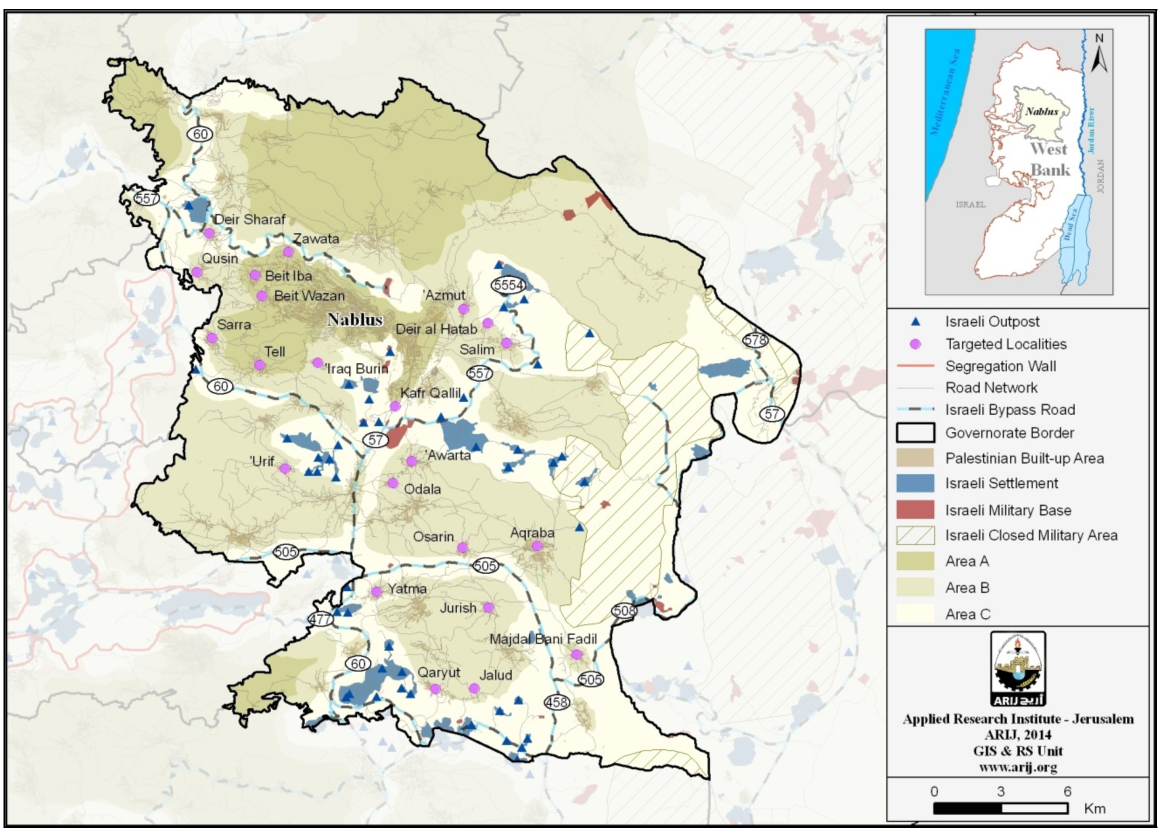


Figure 4.3: Sources of information for the Study

4.3.5 Waste transfer stations

Currently, Nablus JSC- SWM has one transfer station (Al-Sirafi TS) working and another transfer station which is under construction (Beta TS). The collection is daily basis, done by the JSC. The needed data for the model is based on the daily capacity of Al-Sirafi TS and the potential collection station in Beta. Also, data regarding the daily fixed cost and collection costs are required for developing the model.

Solid waste generated by zones covered by Nablus JSC-SWM is about 70.8 tons/day. The capacity of the transfer station should be equal or more than 70.8 tons. The maximum capacity for the Beta and Al-Sirafi transfer stations is between 80 to 250 tons.

4.3.6 Location of the Transfer stations

Figure 4.4 shows the location of Al-Sirafi transfer station and the potential location of Beta transfer station.

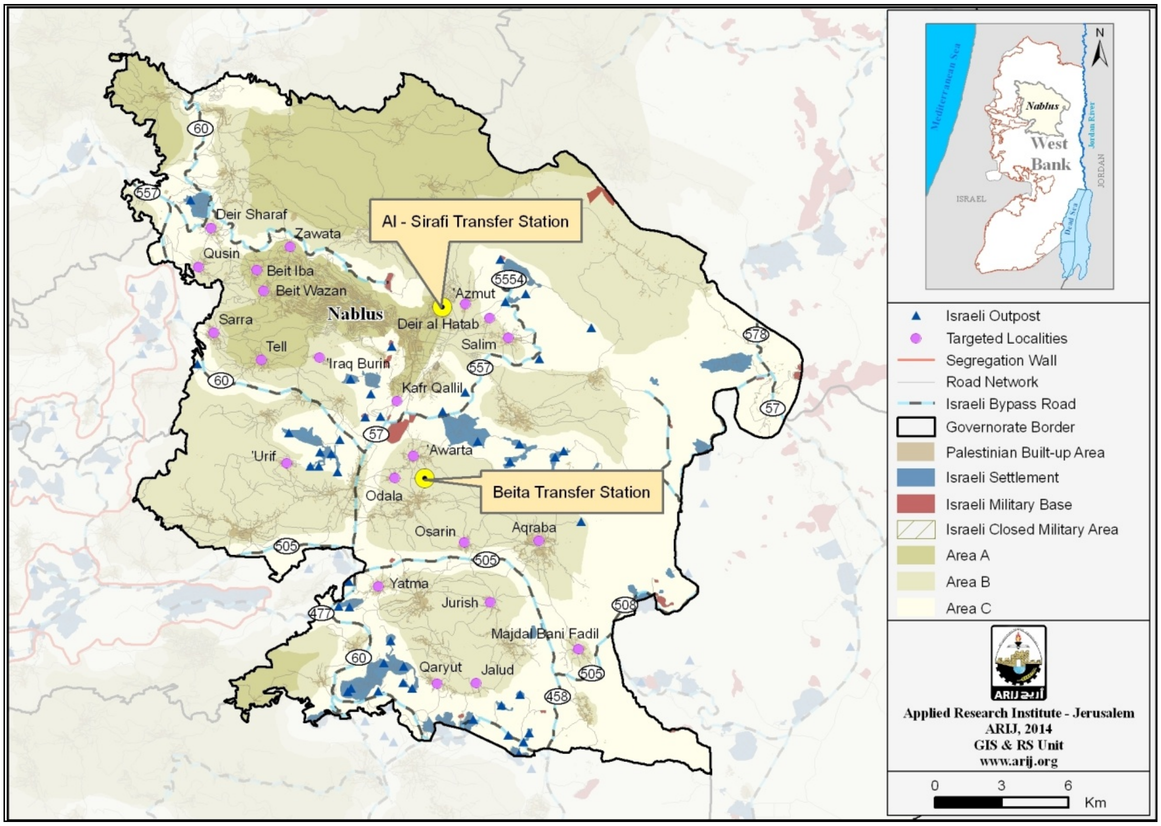


Figure 4.4: Transfer stations location

4.3.7 Landfill Data

The only available sanitary landfill in the northern area of West Bank is Zahert Al-finjan landfill in Jenin. Zahert Al-finjan provides the service of dumping MSW for all the LGUs of North West Bank. Zahert Al-finjan capacity is 1200 tons/day (Jenin JSC-SWM). Zahert Al-finjan is a way from the center of Nablus city about 27 km. In our case study, the model will consider the capacity of Zahert Al-finjan is 1200 tons/days which is the waste generated and transferred via Nablus JSC-SWM. Zahert Al-finjan is 55 Km away form Al Sirafi, while it is 60 Km from Beta (Figure4.5).

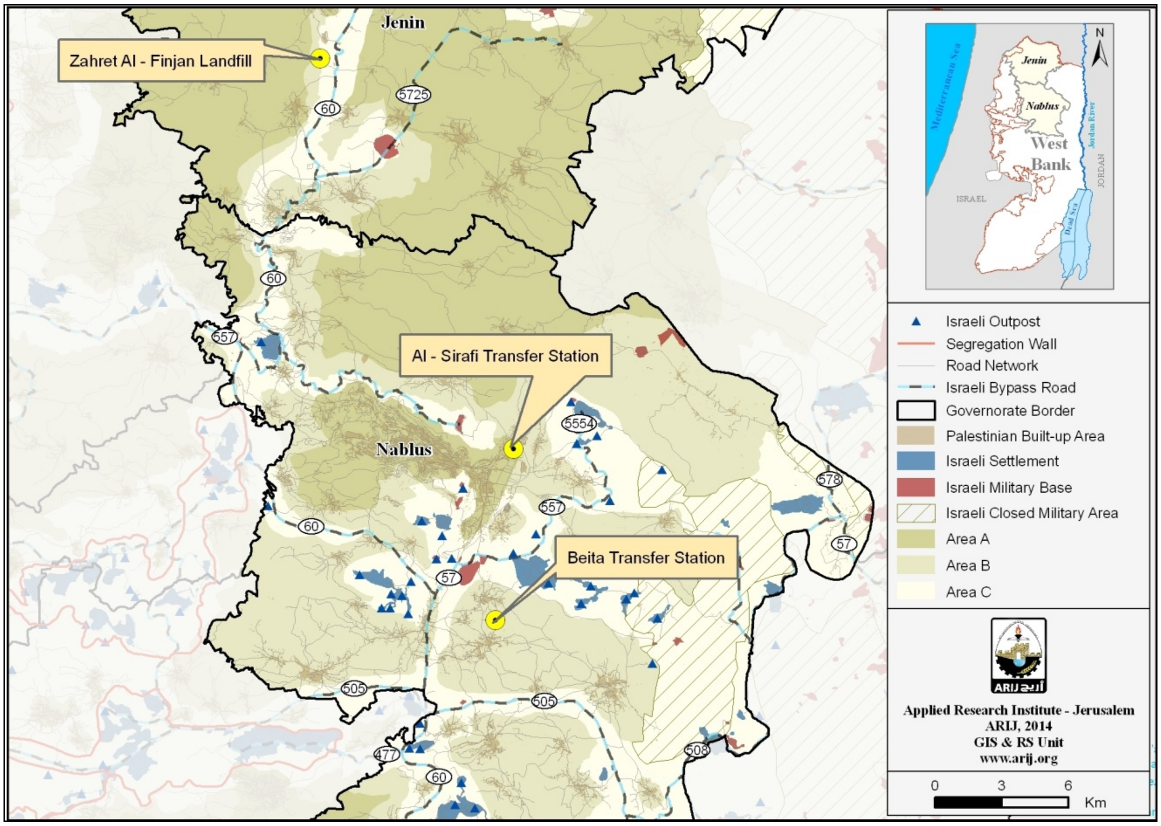


Figure 4.5:Location of Transfer stations and Zahret Al-finjan landfill

4.3.8 Transport costs

The transportation costs were determined by calculating the cost of one ton of waste transported on each route with considering the length of the traveled distance in kilometers, (Table 4.5 to 4.8).

Table 4.5 shows the distance from both Beta and Al-Sirafi transfer stations and the zones served via Nablus JSC-SWM, then the cost of transportation were calculated depending on the distance and the fuel cost at the period of the study.

Table 4.5: Transportation cost of SW from zones to transfer stations

Zone #	Distance (Km)		Cost*/ton/km	
	Al-Sirafi	Cost (ILS)	Beta	Cost (ILS)
Z 1	4	26.8	30	201
Z 2	2	13.4	32	214.4
Z 3	4	26.8	32	214.4
Z 4	8	53.6	37	247.9
Z 5	20	134	5	33.5
Z 6	10	67	37	247.9
Z 7	30	201	15	100.5
Z 8	25	167.5	12	80.4
Z 9	30	201	12	80.4
Z 10	30	201	10	67
Z 11	10	67	40	268
Z 12	20	134	7	46.9
Z 13	30	201	12	80.4
Z 14	10	67	40	268
Z 15	15	100.5	45	301.5
Z 16	10	67	35	234.5
Z 17	5	33.5	30	201
Z 18	10	67	40	268
Z 19	15	100.5	45	301.5
Z 20	15	100.5	40	268
Z 21	30	201	10	67
Z 22	6	40.2	30	201
Z 23	32	214.4	15	100.5
Z 24	32	214.4	15	100.5

*Fuel cost was for 1 Km = 6.7 ILS
Cost= Distance (km) x Fuel cost for 1 km (6.7 ILS)
Source: Nablus JSC-SWM, 2014

Table 4.6 shows the transportation costs for waste delivered to Zahret Al-Finjan land fill from the two transfer stations (Beta and Al-Sirafi) depending on the real destination between the transfer stations Beta and Al-Sirafi from Zahret Al-finjan landfill in Jenin governorate.

Table 4.6: Transportation cost of SW from transfer stations to Zahret Al finjan

Transfer station	Distance (Km)	Cost (ILS)*
Al-Sirafi	55	368.5
Beta	60	402

* One trip
Source: Nablus JSC-SWM, 2014

Table 4.7 summarize the transportation cost for zones served via Nablus JSC-SWM to transfer waste to Al-Sirafi and Beta transfer stations depending on zones destination from the transfer stations.

Table 4.7: Transportation cost matrix of waste from zones to the transfer station (in ILS)

Zone #	Al-Sirafi	Beta	Zone #	Al-Sirafi	Beta
Z 1	26.8	201	Z 13	201	80.4
Z 2	13.4	214.4	Z 14	67	268
Z 3	26.8	214.4	Z 15	100.5	301.5
Z 4	53.6	247.9	Z 16	67	234.5
Z 5	134	33.5	Z 17	33.5	201
Z 6	67	247.9	Z 18	67	268
Z 7	201	100.5	Z 19	100.5	301.5
Z 8	167.5	80.4	Z 20	100.5	268
Z 9	201	80.4	Z 21	201	67
Z 10	201	67	Z 22	40.2	201
Z 11	67	268	Z 23	214.4	100.5
Z 12	134	46.9	Z 24	214.4	100.5

Source: Nablus JSC-SWM, 2014

Table 4.8 shows the fixed costs on one ton of waste transferred from Beta or Al-Sirafi transfer station to Zahret Al-Finjan land fill in Jenin.

Table 4. 8: Fixed cost matrix of waste transferred frim the transfer station to landfill (in ILS/1 Ton)

Cost/Ton/Km	Al-Sirafi	Beta
Zahret Al finjan	34	65

Source: Nablus JSC-SWM, 2014

Chapter Five

Findings and Discussions

5.1 Introduction

The model has been formulated as an integer linear programming model using GAMS software programme.

GAMS serve for General Algebraic Modeling System. GAMS, is a high level language that enables the development and work with complicated models. GAMS was developed by a group of economists' experts from the World Bank to facilitate the resolution of linear, nonlinear and mixed integer optimization problems models on personal computer and a word processor such as Microsoft Word (Robichaud 2010). In 1987 the operation research society of America awarded GAMS the Computer Science Technical Section prize (Rutherford 1995).

5.2 Results

5.2.1 Scenario One : Two transfer stations

In this scenario, two transfer stations Al-Sirafi and Beta are supposed to accept waste from Nablus JSC-SWM. The model was left to choose the best transfer station to be used for each zone served by Nablus JSC-SWM. An optimal solution was obtained from setting the location of the two used transfer stations, Al-Sirafi and Beta TS (Table 5.1).

Running the model for the first scenario by GAMS took 0.015 seconds as an execution time. In the optimal value, one optimal value gave the minimum daily transportation cost of the waste transfer from Zones (24 LGUs served by Nablus JSC-SWM) using the best route for the nearest transfer station (Al-Sirafi TS or Beta TS) and then to the final distinction disposal in landfill (Zahert Al-Finjan) is 32,718.94 ILS.

Table 5.1: Best route for Waste from Zones to nearest Transfer station (TS)

Zones #	LGU Name	Best TS	Zones #	LGU Name	Best TS
Z 1	**Salem**	Al-Sirafi	**Z 13**	**Jaloud**	Beta
Z 2	**Azmout**	Al-Sirafi	**Z 14**	**Qousreen**	Al-Sirafi
Z 3	**Deir Al-Hatab**	Al-Sirafi	**Z 15**	**Tell**	Al-Sirafi
Z 4	**Beit Wazan**	Al-Sirafi	**Z 16**	**Alsomara**	Al-Sirafi
Z 5	**A'warta**	Beta	**Z 17**	**Jabaljanobi**	Al-Sirafi
Z 6	**Zawata**	Al-Sirafi	**Z 18**	**Deir Sharaf**	Al-Sirafi
Z 7	**A'qraba**	Beta	**Z 19**	**Sara**	Al-Sirafi
Z 8	**O'ref**	Beta	**Z 20**	**Iraq Boren**	Al-Sirafi
Z 9	**Yetma**	Beta	**Z 21**	**Jouresh**	Beta
Z 10	**Karyout**	Beta	**Z 22**	**Kofor kalil**	Al-Sirafi
Z 11	**Beit Eba**	Al-Sirafi	**Z 23**	**O'sereen**	Beta
Z 12	**Odalah**	Beta	**Z 24**	**Al-Majdal**	Beta

Table 5.2 shows the amount of waste that will be removed daily from Beta and Al-Sirafi transfer stations while using the best route from zones to the nearest transfer station as mentioned before in Table 5.1. From Table 5.2 the daily waste delivered and removed from Al-Sirafi TS 51.2 Tons equals 20% from Al-Sirafi real daily capacity which is 250 tons/day, while for Beta TS its 23 % from its daily capacity which is 80 tons/day. Therefore, these

results gave a good indicator to accept serving new LGUs by Nablus JSC-SWM if new vehicles were add to the JSC team.

Table 5.2: Amount in ton for daily SW removed from the transfer station to Zahert Al-Finjan

TS	Removed (Tons/Day)	Actual Capacity (Tons/Day)
Al-Sirafi	51.200	250.000
Beta	19.500	80.000

Table 5.3 shows the real daily capacity of Zahret Al-Finjan LF and the real waste that will be transferred daily via the two transfer stations (Beta and Al-Sirafi).

Table 5.3: Landfill Zahret Al-Finjan capacity

Landfill	Level (Tons/Day)	Upper (Tons/Day)
Zahert Al-finjan	70.700	1200.000

Table 5.4 shows the daily solid waste (in Tons) collected by Nablus JSC-SWM from the 24 localities and the nearest transfer station as a result of GAMS model running.

Table 5.4: Amount in ton of the daily SW collected from sources to the nearest transfer station

Zone #	LGU Name	Nearest TS	Daily SW collected (Tons)
Z 1	**Salem**	Al-Sirafi	2.800
Z 2	**Azmout**	Al-Sirafi	2.000
Z 3	**Deir Al-Hatab**	Al-Sirafi	1.500
Z 4	**Beit Wazan**	Al-Sirafi	0.700
Z 5	**A'warta**	Beta	4.700
Z 6	**Zawata**	Al-Sirafi	1.300
Z 7	**A'qraba**	Beta	5.300
Z 8	**O'ref**	Beta	2.200
Z 9	**Yetma**	Beta	2.200
Z 10	**Karyout**	Beta	1.200
Z 11	**Beit Eba**	Al-Sirafi	3.300
Z 12	**Odalah**	Beta	0.700
Z 13	**Jaloud**	Beta	0.600
Z 14	**Qousreen**	Al-Sirafi	1.100
Z 15	**Tell**	Al-Sirafi	2.300
Z 16	**Alsomara**	Al-Sirafi	0.700
Z 17	**Jabaljanobi**	Al-Sirafi	30.00
Z 18	**Deir Sharaf**	Al-Sirafi	1.800
Z 19	**Sara**	Al-Sirafi	1.700
Z 20	**Iraq Boren**	Al-Sirafi	0.500
Z 21	**Jouresh**	Beta	1
Z 22	**Kofor kalil**	Al-Sirafi	1.500
Z 23	**O'sereen**	Beta	0.800
Z 24	**Al-Majdal**	Beta	0.88

Table 5.5 summarizes a comparison between the current destination between the zones from Al-Sirafi TS with the cost of one ton per one Km with the GAMS proposed best route to the nearest transfer stations (Beta or Al-Sirafi) and the cost for traveling one ton per on Km .

Table 5.5 : Comparison between the existing status and GAMS model results

Zone #	LGU Name	Daily SW collected (Tons)	Current TS	Distance from zone to TS (Km)	Current transportation cost for one ton (ILS)	Proposed TS	Distance From zone to TS (Km)	The model transportation cost for one ton (ILS)
Z 1	Salem	2.800	Al-Sirafi	4	26.8	Al-Sirafi	4	26.8
Z 2	Azmout	2.000	Al-Sirafi	2	13.4	Al-Sirafi	2	13.4
Z 3	Deir Al-Hatab	1.500	Al-Sirafi	4	26.8	Al-Sirafi	4	26.8
Z 4	Beit Wazan	0.700	Al-Sirafi	8	53.6	Al-Sirafi	8	53.6
Z 5	A'warta	4.700	Al-Sirafi	20	134	Beta	5	33.5
Z 6	Zawata	1.300	Al-Sirafi	10	67	Al-Sirafi	10	67
Z 7	A'qraba	5.300	Al-Sirafi	30	201	Beta	15	100.5
Z 8	O'ref	2.200	Al-Sirafi	25	167.5	Beta	12	80.4
Z 9	Yetma	2.200	Al-Sirafi	30	201	Beta	12	80.4
Z 10	Karyout	1.200	Al-Sirafi	30	201	Beta	10	67
Z 11	Beit Eba	3.300	Al-Sirafi	10	67	Al-Sirafi	10	67
Z 12	Odalah	0.700	Al-Sirafi	20	134	Beta	7	46.9
Z 13	Jaloud	0.600	Al-Sirafi	30	201	Beta	12	80.4
Z 14	Qousreen	1.100	Al-Sirafi	10	67	Al-Sirafi	10	67
Z 15	Tell	2.300	Al-Sirafi	15	100.5	Al-Sirafi	15	100.5
Z 16	Alsomara	0.700	Al-Sirafi	10	67	Al-Sirafi	10	67
Z 17	Jabaljanobi	30.00	Al-Sirafi	5	33.5	Al-Sirafi	5	33.5
Z 18	Deir Sharaf	1.800	Al-Sirafi	10	67	Al-Sirafi	10	67
Z 19	Sara	1.700	Al-Sirafi	15	100.5	Al-Sirafi	15	100.5
Z 20	Iraq Boren	0.500	Al-Sirafi	15	100.5	Al-Sirafi	15	100.5
Z 21	Jouresh	1	Al-Sirafi	30	201	Beta	10	67
Z 22	Kofor kalil	1.500	Al-Sirafi	6	40.2	Al-Sirafi	6	40.2
Z 23	O'sereen	0.800	Al-Sirafi	32	214.4	Beta	15	100.5
Z 24	Al-Majdal	0.88	Al-Sirafi	32	214.4	Beta	15	100.5

Table 5.6 shows a compression between the used system and after applying the GAMS model result for using new Beta as a new transfer station by Nablus JSC-SWM. Although, the table shows the amount that will be saved from using the nearest transfer station (Beta or Al-Sirafi) when GAMS model is applied. It is important to highlight that the transportation cost for table 5.5 and table 5.6 is only depending on the distance from zones to transfer station while the model calculated the total transportation costs for scenario one in order to the distance , and the fixed costs in transfer stations and land fill. Table 5.6 shows that, a bout

2,081.42 ILS will be saved daily only from the transport costs by using two transfer stations (Beta and Al-Sirafi).

Table 5. 6 : Compression between the daily cost of transportation between the existing system and GAMS proposed results

Zone #	LGU Name	Daily cost of waste	proposed cost for waste	Difference
Z 1	**Salem**	75.04	75.04	0
Z 2	**Azmout**	26.8	26.8	0
Z 3	**Deir Al-Hatab**	40.2	40.2	0
Z 4	**Beit Wazan**	37.52	37.52	0
Z 5	**A'warta**	629.8	157.45	-472.35
Z 6	**Zawata**	87.1	87.1	0
Z 7	**A'qraba**	1065.3	532.65	-532.65
Z 8	**O'ref**	368.5	176.88	-191.62
Z 9	**Yetma**	442.2	176.88	-265.32
Z 10	**Karyout**	241.2	80.4	-160.8
Z 11	**Beit Eba**	221.1	221.1	0
Z 12	**Odalah**	93.8	32.83	-60.97
Z 13	**Jaloud**	120.6	48.24	-72.36
Z 14	**Qousreen**	73.7	73.7	0
Z 15	**Tell**	231.15	231.15	0
Z 16	**Alsomara**	46.9	46.9	0
Z 17	**Jabaljanobi**	1005	1005	0
Z 18	**Deir Sharaf**	120.6	120.6	0
Z 19	**Sara**	170.85	170.85	0
Z 20	**Iraq Boren**	50.25	50.25	0
Z 21	**Jouresh**	201	67	-134
Z 22	**Kofor kalil**	60.3	60.3	0
Z 23	**O'sereen**	171.52	80.4	-91.12
Z 24	**Al-Majdal**	188.672	88.44	-100.232
Total Cost in ILS		**5769.102**	**3687.68**	**-2081.42**

Figure 5.1 shows the difference in amount of waste transferred from both transfer stations Beta and Al-Sirafi before and after applying the model.

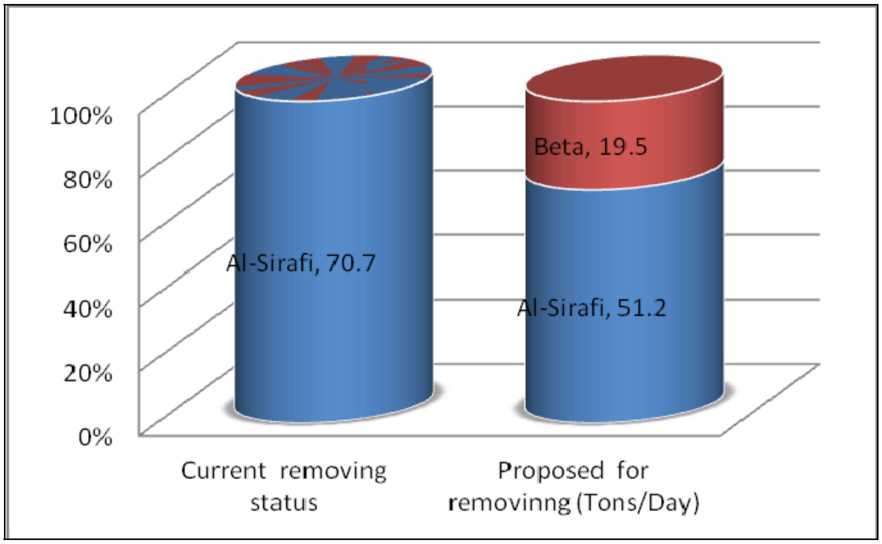


Figure 5.1: Current and Proposed waste transferred from Beta and Al-Sirafi in Tons

The total daily transportation costs for the current used system is 36,664.97 ILS while if GAMS model was applied the total daily transportation costs using two transfer station will be 32,718.94 ILS which means that the new scenario is cost only 89.2 % of the current used system with 3,946.03 ILS daily saving from costs (Figure 5.2).

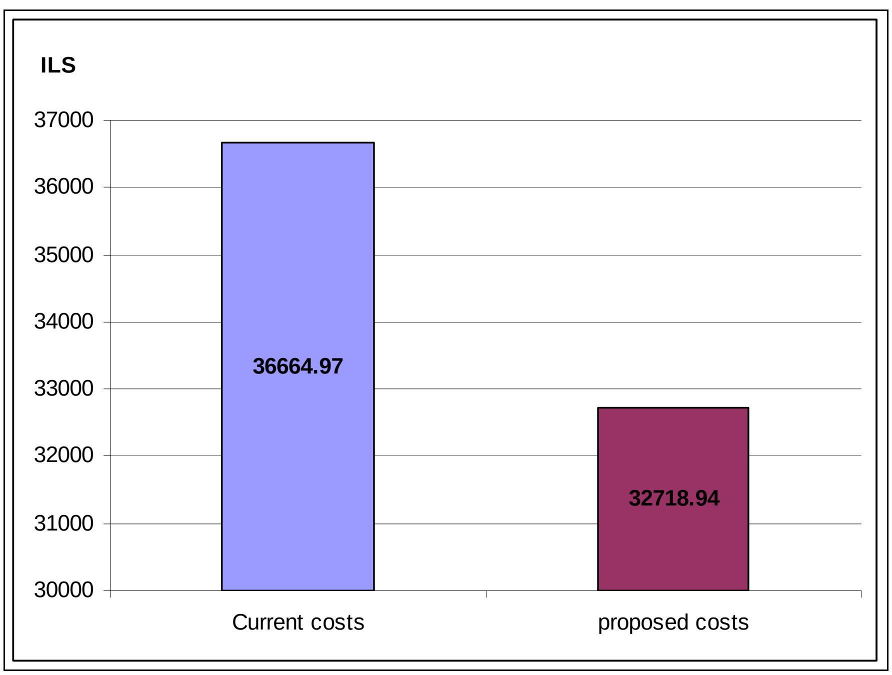


Figure 5.2 : Comparison between the current transportation costs and the transportation costs after applying GAMS model (in ILS)

5.2.2 Scenario Two: Recycling process for the first scenario

In this scenario, the model was left to give the optimal transportation costs in case a recycling process were done in both transfer stations Al-Sirafi and Beta before transferring solid waste to Zahret Al-Finjan in Jenin. During the study time the JSC reports showed that the organic, glass, plastic and metals are the main component of the MSW collected via the JSC's vehicles (Table 5.7). Therefore, a need to minimize the cost of handling MSW is essential and one of the suggested solutions is to allow a recycling process in both transfer stations or to sell these components by weight (Ton) for individuals or companies (free collectors) for recycling or reusing them (Table 5.8).

Table 5.7: MSW components

Type	Percentage %
Organic	50%
Glass	1%
Plastic	11%
Metal	2%
Paper & carton	2%
Others	34%

Table 5. 8: Price in ILS for one ton

Type	Price* (ILS)/ Ton
Cartoon and paper	181
Plastic (PP &PE)	500
Plastic chairs	900
TVs and Computers	400
Iron and tank	500
Aluminum-White	4,200
Aluminum-Black	3,500
Aluminum- Poured	4,200
Aluminum-canned & Tim	1,700
Aluminum-shatter	1,200
Copper-Yellow	12,000
Copper-Red	19,000
Copper- Plastic Cables	6,000
Electronic Boards	10,000
Cans	6,000
Glass- Bottles of juice for 10,000 units	1,000
Plastic Water bottles 500 ml for 10,000 units	1,000
Wood	400

* Prices used in Higher JSC-SWM for Al-menya Landfill
Source: Higher JSC-SWM, 2014

In this case four components were tested in case a recycling process was implemented (Compost, Glass, Plastic and metal) in both transfer stations Al-Sirafi and Beta, depending on the first scenario optimal route and transfer station to be used to minimize the transportation costs of MSW in Nablus JSC-SWM.

Running the model for the second scenario by GAMS took 0.015 seconds as an execution time. One optimal value gave the minimum daily transportation cost of the waste transfer from Zones (24 LGUs served by Nablus JSC-SWM) using the best route for the nearest transfer station (Al-Sirafi TS or Beta TS) then a recycling and re-using processes take place in the transfer stations before delivering the remaining solid waste to its final distinction to be disposed in (Zahert Al-Finjan) landfill which is 17,871.94 ILS.

Therefore, the optimal solution for the objective was found 17,871.94 ILS that means that the costs were 51 % (18,793.03 ILS) reduced from the current costs if a recycling and re-using processes take place beside applying the first scenario of GAMS model.

Chapter Six

Conclusion & Recommendations

6.1 Conclusion

Solid Waste collection, transportation, and fuel consumption contribute to about 41% of the total solid waste management costs. This research shows through applying GAMS software that the cost of the total SWM could be reduced by 12 % if an additional TS is created in Beta location and 51 % of the total cost of SWM could be reduced by introducing a recycling process in the transfer stations. Mean while, the first scenario of the model shows that the proposed total SW to be transfer to Beta TS in only 19.5 tons and this is not a reasonable quantity to open a transfer station with daily capacity not less than 80 tons in Beta. Therefore, Nablus JSC-SWM should integrate additional LGUs to be served in specially in the southern part of Nablus district such as “ Alsawaya, Aluban, Talfeet, Doma, Zeta, Jama’en, Einabous, Huwara, and Yanoun”, and LGUs from the eastern part of Salfeet district.

On the other hand, Al-Sirafi TS with a daily capacity of 250 tons can serve additional LGUs which are already a member in Nablus JSC-SWM such as “ Asira, Taloza, Yasid, Alfara’ refugee camp, Alfara’, Jensinia, Beit mrin, Sabastya, and Al-Nasaria” and LGUs from western part of Tubas district.

The financial deficit of Nablus JSC-SWM for 2013 was 122,606 ILS , through the optimization of the first scenario without any recycling process occurred it is possible to save about 215,040 ILS yearly (about 650 ILS daily). This means that the deficit of the JSC could be covered by opening a new TS in Beta. While applying the second scenario (Two TSs with recycling process) it is possible to save 3,015.45 ILS daily.

Therefore, the GAMS model (Linear) helps to improve minimizing the JSC budget for waste management activities and to predict a reasonably effective way for vehicles fuel consumption to help in costs reduction. The main limitation of this model was the quality of input data; some of the transfer vehicles may be partially full and this may lead to errors in computing the total cost measuring waste amount and the benefit values. The actual accurate optimal solution is reached only with high detailed data for the zones generated, collected, disposable wastes and capacity of transfer stations and landfill.

6.2 Recommendations

Through applying GAMS program following recommendation could be extracted :

1. Opening a new transfer station in Beta where new LGUs could be served via Nablus JSC-SWM and this could decrease the finical deficit and improve the service of the JSC through having new compacters and new source of revenues
2. Ensure that the vehicles used for collection are full with waste and not partially filled before going to the transfer station to get the optimal objectives
3. Strengthen institutions on the technical capacity of SWM and focus on improving used technology
4. Improve the financial status of Nablus JSC-SWM via develop a cost recovery model by reallocate the fees and taxation paid for SWM services in order to minimize the funding gap.
5. Improve information of Solid waste in Nablus Governorate. Collect, waste steam, vehicles, equipments, labor, documents, local problems, risks, waste main components, and good local practices

6. optimize the technical equipments (volume of waste containers, and compacters) used in the SWM process
7. Develop collaboration between Nablus JSC-SWM and privet sector to operate the two transfer stations in order to reduce the operational costs
8. On the National level development of bylaws, relevant regulations, and detailed guidelines are essential to improve toward integrated SWM in Palestine
9. more effort is needed to increase investments in public environmental information, like educational programs to enhance the environmental knowledge, attitudes, practices and people participation.
10. For future work: new research is needed to optimize other components of SWM

References

Agha, Salah R. (2006) Optimizing routing of municipal solid waste collection vehicles in Deir El-Balah-Gaza Strip. *The Islamic University Journal (Series of Natural Studies and Engineering*) 14.2: 75-89.

Al-Hasawi, H. (1999) Investigation of municipal solid waste management in GCC states.

Al-Khatib, I. A., H. A. Arafat, T. Basheer, H. Shawahneh, A. Salahat, J. Eid & W. Ali (2007) Trends and problems of solid waste management in developing countries: A case study in seven Palestinian districts. *Waste Management,* 27(12), 1910-1919.

Al-Khatib, I. A., M. Monou, A. S. F. Abu Zahra, H. Q. Shaheen & D. Kassinos (2010) Solid waste characterization, quantification and management practices in developing countries. A case study: Nablus district–Palestine. *Journal of Environmental Management,* 91(5), 1131-1138.

Arij (2009) Study: Feasbility study for Solid waste management in Nablus district, funded by JICA, 2009

Arshad, S., A. Shafqat, A. A. Khan & Q. Safdar (2013) Youth environmental complaints in Bahawalpur City, Pakistan: An informational intervention for local environmental governance. *Human Geographies--Journal of Studies & Research in Human Geography,* 7(1).

Asnani, P. (2006) Solid waste management. *India Infrastructure Report,* 570.

Asnani, P. & C. Zurbrugg (2007) Improving municipal solid waste management in India: A sourcebook for policymakers and practitioners. *World Bank Publications.*

Bard, Y. (1974) *Nonlinear parameter estimation.* Academic Press New York.

Brooke, A., D. Kendrick, A. Meeraus, R. Raman & U. America (1998) The General Algebraic Modeling System. *GAMS Development Corporation*.

Erkut, Erhan, et al. (2008) A multicriteria facility location model for municipal solid waste management in North Greece. *European Journal of Operational Research 187.3: 1402-1421.*

EPA, USA.(2013)."Municipal Solid Waste". *EPA, Environmental Protection Agency, n.d. Web. 15 August 2013.*

Gering, J. C. & T. O. Crist (2002) The alpha–beta–regional relationship: providing new insights into local–regional patterns of species richness and scale dependence of diversity components. *Ecology Letters,* 5(3), 433-444.

Higher Joint service council (2014) *interview and database, Hebron- Palestine, 2014*.

Khleif and Samman for Auditing & advisory (2014) Nablus Joint Service council for Solid waste management Auditing reports for year 2012 and 2013.

Lee, H., J. M. Pinto, I. E. Grossmann & S. Park (1996) Mixed-integer linear programming model for refinery short-term scheduling of crude oil unloading with inventory management. *Industrial & Engineering Chemistry Research,* 35(5), 1630-1641.

Li, Y. & G. Huang (2010) Modeling municipal solid waste management system under uncertainty. *Journal of the Air & Waste Management Association,* 60(4), 439-453.

Lyeme, A. (2011) Optimization of municipal solid waste management system. M. Sc. Dissertation, Department of Mathematics, *University of Dar es salaam, Tanzania.*

Mahamid, I. & S. Thawaba (2010) Multi criteria and landfill site selection using GIS: a case study from Palestine. *Open Environmental Engineering Journal,* 3, 33-41.

Marković, D., D. Janošević, M. L. Jovanović & V. Nikolić (2010) Application method for optimization in solid waste management system in the city of Niš. *Facta universitatis-series: Mechanical Engineering,* 8(1), 63-76.

Manfredi, et al. (2010) Solid waste and water quality management models for Sagarmatha National Park and Buffer Zone, Nepal: implementation of a participatory modeling framework. *Mountain Research and Development 30.2* : 127-142.

MoLG (2014) Minisity of local governement, Ramallah, Palestine, interviews and database.

Nabluse JSC-SWM (2014) *Nablus Joint service council for solid waste management interview and database , Nablus.*

Nganda, M. K. (2007) Mathematical Models in Municipal Solid Waste Management.

NSWMS, PNA, (2010) Study: National Solid waste management strategy 2010-2014, Palestine.

Ogwueleke, T. C. (2009) Route optimization for solid waste collection: Onitsha (Nigeria) case study. *Journal of Applied Sciences and Environmental Management* 13.2

Otti, V. (2011) A model for solid waste management in Anambra State, Nigeria. *Journal of Soil Science and Environmental Management,* 2(2), 39-42.

Palmer, K., H. Sigman & M. Walls (1997) The cost of reducing municipal solid waste. *Journal of Environmental Economics and Management, 33(2), 128-150.*

Rhoma, F., et al.(2010) Environmental and economical optimization for municipal solid waste collection problems, a modeling and algorithmic approach case study. *Proc. of the 12th WSEAS International Conference on Mathematical Methods, Computational Techniques And Intelligent Systems (MAMECTIS'10).*

Robichaud, V. (2010) An introduction to GAMS.

Rodionov, M. & T. Nakata (2011) Design of an optimal waste utilization system: a case study in St. Petersburg, Russia. *Sustainability,* 3(9), 1486-1509.

Rutherford, T. F. (1995) Extension of GAMS for complementarity problems arising in applied economic analysis. *Journal of Economic Dynamics and control,* 19(8), 1299-1324.

Saeed, M. O., M. N. Hassan & M. Abdul Mujeebu (2008) Development Of Municipal Solid Waste Generation And Recyclable Components Rate Of Kuala Lumpur: Perspective Study.

Schübeler, D., C. Mielke, K. Maass & J. Bode (1996) Scaffold/matrix-attached regions act upon transcription in a context-dependent manner. *Biochemistry,* 35(34), 11160-11169.

Sefouhi, L., M. Kalla & L. Aouragh (2010) Trends and problems of municipal solid waste management in Batna city and prospects for a sustainable development. *Int. J. Sustainable Water & Environmental Systems,* 1(1), 15-20.

Solano, Eric (1999). Integrated solid waste management alternatives in consideration of economic and environmental factors: a mathematical model development and evaluation. *Diss. North Carolina State University.*

Sweep net, (2012). Country report about solid waste management in the Palestinian teritory.

UNICEF ADB.(2011). *Non-state providers and public-private partnerships in education for the poor. Bangkok: UNICEF.*

PCBS (2005). Area Statistics in the Palestinian Territory 2005, *Palestinian National Authority Palestinian Central Bureau of Statistics*,2005.

PCBS (2009). Population, Housing and Establishment Census 2007, Final Results-Housing Report – Nablus Governorate. *Palestinian Central Bureau of Statistics, Ramallah - Palestine*, 2009.

PCBS (2009) Area Statistics in the Palestinian Territory. *Palestinian National Authority Palestinian Central Bureau of Statistics*,2009.

PCBS (2009). Census Final Results – Population Report Nablus Governorate. *Palestinian Central Bureau of Statistics ,Ramallah - Palestine, 2009.*

PCBS(2010). Number of communities and residents who do not have waste collection service in the Palestinian territories by the province 2010,*Palestinian National Authority Palestinian Central Bureau of Statistics*,2010.

PCBS(2011) Selected Indicators of household solid waste in the Palestinian territories 2011, *Palestinian National Authority Palestinian Central Bureau of Statistics*,2011.

PCBS(2011). West Bank Northern Governorates Statistical. *Palestinian Central Bureau of Statistics, Ramallah, Palestine*,2011.

PCBS(2012) Household Environmental Survey, *Palestinian National Authority Palestinian Central Bureau of Statistics*, Ramallah- Palestine, 2012.

PCBS (2013) Percentage Distribution of Households by hand in Palestine and the region to collect solid waste 2013. *Palestinian Central Bureau of Statistics, Ramallah, Palestine*,2013.

PCBS (2014). Statistical Yearbook of Palestine 2014, No. 15. *Palestinian Central Bureau of Statistics, Ramallah, Palestine,* 2014.

Yin, R. K. (2014) *Case study research: Design and methods.* Sage publications.

YOSHIDA Mitsuo (2005) *report : Supporting Capacity Development in Solid Waste Management in Developing Countries .Towards Improving Solid Waste Management Capacity of Entire Society ,Chapter one:Characteristics of Solid Waste Problems in Developing Countries,* JICA .

Appendices

Appendix 1: First Scenario

```
SETS
i   SW Zone
/
Z1  "Salem",
Z2  "Azmout",
Z3  "Deir Al-Hatab"
Z4  "Beitwazan"
Z5  "Awarta"
Z6  "Zawata "
Z7  "Aqraba"
Z8  "Oref"
Z9  "Yetma"
Z10 "Karyout"
Z11 "Beit Eba"
Z12 "Odalah"
Z13 "Jaloud"
Z14 "Qousreen"
Z15 "Tell"
Z16 "Alsomara"
Z17 "Jabaljanobi"
Z18 "Deirsharaf"
Z19 "Sara"
Z20 "Iraqboren"
Z21 "Jouresh"
Z22 "Koforkalil"
Z23 "Osereen"
Z24 "Almajdal"
/
j  Transferstation  / alsirafi,beta /
k   Landfill    / zahretalfinjan/;

PARAMETERS
       w(i) Daily Generated SW in Ton from Zone i
              /Z1             2.8
               Z2             2
               Z3             1.5
               Z4             0.7
               Z5             4.7
               Z6             1.3
               Z7             5.3
               Z8             2.2
               Z9             2.2
               Z10             1.2
               Z11             3.3
               Z12             0.7
               Z13             0.6
               Z14             1.1
               Z15             2.3
```

```
          Z16          0.7
          Z17          30
          Z18          1.8
          Z19          1.7
          Z20          0.5
          Z21          1,
          Z22          1.5
          Z23          0.8
          Z24          0.8 /
      c(j)  Daily capacity of transferstation j in Ton
          /   AlSirafi  250
              Beta      80  /
      S(j) fixed costs in ILS at the transfer station j
        /     AlSirafi 34
              Beta 65      /
     l(k) Daily capacity of the landfill in Ton
          /zahretalfinjan  1200/ ;

* Error : the table was transposed  i are lines and j columns
TABLE d(i,j)  distance in Kilometers between Zone i to transferstation j
        AlSirafi   Beta
Z1        4        30
Z2        2        32
Z3        4        32
Z4        8        37
Z5        20        5
Z6        10       37
Z7        30       15
Z8        25       12
Z9        30       12
Z10       30       10
Z11       10       40
Z12       20        7
Z13       30       12
Z14       10       40
Z15       15       45
Z16       10       35
Z17       5        30
Z18       10       40
Z19       15       45
Z20       15       40
Z21       30       10
Z22       6        30
Z23       32       15
Z24       32       15
;

* You need an alias for i (to be used in the constraints below)
alias (i,ii);
```

```
* Error : the table was transposed  j are lines and k columns
TABLE O(j,k)  distance in Kilometers between transfer station j and Landfill k
            zahretalfinjan
AlSirafi          55
Beta              60   ;

SCALAR

HJ fixed cost in ILS of transfer station /8/
DK fixed cost in ILS of Landfill /25/
F  Fuel cost in ILS of one Kilometer /6.7/;

PARAMETER T(i,j) transport cost of one tone of waste from the source i to the transfer
station j;
        T(i,j) = w(i)* d(i,j)* F;

PARAMETER P(j,k) transport cost of one ton of waste from the transfer station j to the
landfill k;
        P(j,k) = c(j) * O(j,k) * F ;

VARIABLES
     x(i,j)  amount in ton of the daily SW collected from the source i to the transferstation
j

     y(j,k) amount in ton for daily SW removed from the transferstation j to landfill k

     z       total transportation costs in ILS;


POSITIVE VARIABLES X,Y;

EQUATIONS
     COST         define objective function
     CON1         waste generated
     CON2         waste generated and transfered to transfer station j
     CON3         Transfer stations capacity and the daily transfered waste
     CON4         Landfill k capacity ;

COST.. z  =E= SUM ((i,j),T(i,j) * x(i,j)) + SUM ((j,k), P(j,k) * y(j,k))+ sum ((i,j), x(i,j)*
HJ)+ sum ((j,k), y(j,k)* DK) ;

* This is actually a set of |i| equations. Then must be indexed by i
* Note that on right hand side we use the alias ii for i
CON1(i).. sum(j, x(i,j)) =l= sum(ii,w(ii));
CON2.. sum((i,j),x(i,j)) =e= sum((j,k),y(j,k));
* This is actually a set of |i| equations. Then must be indexed by i
CON3(i).. sum(j,x(i,j)) =l= sum(j,c(j));
* This is actually a set of |k| equations. Then must be indexed by k
CON4(k).. sum(j, y(j,k)) =l= L(k);
```

```
MODEL TRANSPORT /ALL/ ;
SOLVE TRANSPORT USING LP MINIMIZING Z ;

* I corrected the GAMS syntax only
* Please, check the mathematics

display x.l
```

Appendix 2: : Second Scenario

```
SETS
i   SW Zone
/
Z1  "Salem",
Z2  "Azmout",
Z3  "Deir Al-Hatab"
Z4  "Beitwazan"
Z5  "Awarta"
Z6  "Zawata "
Z7  "Aqraba"
Z8  "Oref"
Z9  "Yetma"
Z10 "Karyout"
Z11 "Beit Eba"
Z12 "Odalah"
Z13 "Jaloud"
Z14 "Qousreen"
Z15 "Tell"
Z16 "Alsomara"
Z17 "Jabaljanobi"
Z18 "Deirsharaf"
Z19 "Sara"
Z20 "Iraqboren"
Z21 "Jouresh"
Z22 "Koforkalil"
Z23 "Osereen"
Z24 "Almajdal"
/

j  Transferstation  / alsirafi,beta /
k   Landfill    / zahretalfinjan/

r material
/
composte
glass
plastic
metal
/
;

PARAMETERS
      w(i) 'Daily Generated SW in Ton from Zone i'
            /Z1             2.8
             Z2             2
             Z3             1.5
             Z4             0.7
             Z5             4.7
```

```
              Z6              1.3
              Z7              5.3
              Z8              2.2
              Z9              2.2
              Z10              1.2
              Z11              3.3
              Z12              0.7
              Z13              0.6
              Z14              1.1
              Z15              2.3
              Z16              0.7
              Z17              30
              Z18              1.8
              Z19              1.7
              Z20              0.5
              Z21              1
              Z22              1.5
              Z23              0.8
              Z24              0.8 /
        c(j) 'Daily capacity of transferstation j in Ton'
            /    AlSirafi  250
                 Beta      80 /
       l(k) 'Daily capacity of the landfill in Ton'
            /zahretalfinjan  1200/

e(r) yield in ton
/
composte   0.5
glass      0.01
plastic    0.11
metal      0.02
 /
;

* Error : the table was transposed  i are lines and j columns
TABLE d(i,j)  distance in Kilometers between Zone i to transferstation j
          AlSirafi    Beta
Z1          4          30
Z2          2          32
Z3          4          32
Z4          8          37
Z5          20          5
Z6          10          37
Z7          30          15
Z8          25          12
Z9          30          12
Z10          30          10
Z11          10          40
Z12          20          7
Z13          30          12
```

```
Z14         10         40
Z15         15         45
Z16         10         35
Z17         5          30
Z18         10         40
Z19         15         45
Z20         15         40
Z21         30         10
Z22         6          30
Z23         32         15
Z24         32         15
;

TABLE O(j,k)  'distance in Kilometers between transfer station j and Landfill k'
            zahretalfinjan
AlSirafi          55
Beta              60 ;

parameter
H(j) 'fixed cost in ILS of transfer station'
         /   AlSirafi  8
             Beta      8 /
;
parameter s(r) price in ILS for one Ton
/
composte   50
glass      1200
plastic    500
metal      500
/
;
SCALAR
DK 'fixed cost in ILS of Landfill' /25/
F  'Fuel cost in ILS of one Kilometer' /6.7/;

PARAMETER T(i,j) 'transport cost of one tone of waste from the source i to the transfer
station j';
        T(i,j) = d(i,j)* F;

PARAMETER P(j,k) 'transport cost of one ton of waste from the transfer station j to the
landfill k';
        P(j,k) = O(j,k) * F ;

VARIABLES
      x(i,j) 'amount in ton of the daily SW collected from the source i to the transferstation
j'

      y(j,k) 'amount in ton for daily SW removed from the transferstation j to landfill k'

      z      'total transportation costs in ILS';
```

```
POSITIVE VARIABLES x,y;
EQUATIONS
      COST          define objective function
      CON1          waste generated
      CON2          waste generated and transfered to transfer station j
      CON3          Transfer stations capacity and the daily transfered waste
      CON4          Landfill k capacity ;

COST.. z  =E= SUM ((i,j),T(i,j) * x(i,j)) + SUM ((j,k), P(j,k) * y(j,k))+ sum ((i,j), x(i,j)*
H(j))+ sum ((j,k), y(j,k)* DK) - sum ((i,j), x(i,j)*210);

* Constraint 1 : for each station i, the total waste produced is transported to transfere
stations
* This is actually a set of I equations. Then must be indexed by i
CON1(i).. sum(j, x(i,j)) =e= w(i);

* Constraint 2 : for each transfer station j, the total input is transported to the landfills
CON2(j).. sum(i,x(i,j)) =e= sum(k,y(j,k));

* Constraint 3 : for each transfer station j, the capacity should not be exceeded
* This is actually a set of J equations. Then must be indexed by j
CON3(j).. sum(i,x(i,j)) =l= c(j);

* Constraint 4 : for each landfill k, the capacity should not be exceeded
* This is actually a set of K equations. Then must be indexed by k
CON4(k).. sum(j, y(j,k)) =l= L(k);


MODEL TRANSPORT /ALL/ ;
SOLVE TRANSPORT USING LP MINIMIZING Z ;
```

Appendix 3: Solve Transporter using LP for the first Scenario

```
Solution Report     SOLVE TRANSPORT Using LP

            S O L V E     S U M M A R Y

    MODEL   TRANSPORT          OBJECTIVE  z
    TYPE    LP               DIRECTION  MINIMIZE
    SOLVER  CPLEX              FROM LINE  157

**** SOLVER STATUS     1 Normal Completion
**** MODEL STATUS      1 Optimal
**** OBJECTIVE VALUE           32718.9400
```

RESOURCE USAGE, LIMIT 0.031 1000.000
ITERATION COUNT, LIMIT 0 2000000000

IBM ILOG CPLEX 24.2.2 r44857 Released Mar 4, 2014 VS8 x86/MS Windows
Cplex 12.6.0.0

Space for names approximately 0.00 Mb
Use option 'names no' to turn use of names off
LP status(1): optimal
Cplex Time: 0.00sec (det. 0.04 ticks)
Optimal solution found.
Objective : 32718.940000

	LOWER	LEVEL	UPPER	MARGINAL
---- EQU COST	.	.	.	1.000

COST define objective function

---- EQU CON1 waste generated

	LOWER	LEVEL	UPPER	MARGINAL
Z1	2.800	2.800	2.800	428.300
Z2	2.000	2.000	2.000	414.900
Z3	1.500	1.500	1.500	428.300
Z4	0.700	0.700	0.700	455.100
Z5	4.700	4.700	4.700	468.500
Z6	1.300	1.300	1.300	468.500
Z7	5.300	5.300	5.300	535.500
Z8	2.200	2.200	2.200	515.400
Z9	2.200	2.200	2.200	515.400
Z10	1.200	1.200	1.200	502.000
Z11	3.300	3.300	3.300	468.500
Z12	0.700	0.700	0.700	481.900
Z13	0.600	0.600	0.600	515.400
Z14	1.100	1.100	1.100	468.500
Z15	2.300	2.300	2.300	502.000
Z16	0.700	0.700	0.700	468.500
Z17	30.000	30.000	30.000	435.000
Z18	1.800	1.800	1.800	468.500
Z19	1.700	1.700	1.700	502.000
Z20	0.500	0.500	0.500	502.000
Z21	1.000	1.000	1.000	502.000
Z22	1.500	1.500	1.500	441.700
Z23	0.800	0.800	0.800	535.500
Z24	0.800	0.800	0.800	535.500

---- EQU CON2 waste generated and transfered to transfer station j

```
           LOWER     LEVEL     UPPER    MARGINAL

alsirafi      .         .         .    -393.500
beta          .         .         .    -427.000

---- EQU CON3  Transfer stations capacity and the daily transfered waste

           LOWER     LEVEL     UPPER    MARGINAL

alsirafi     -INF     51.200   250.000      .
beta         -INF     19.500    80.000      .

---- EQU CON4  Landfill k capacity

                LOWER     LEVEL     UPPER    MARGINAL

zahretalfinjan     -INF     70.700  1200.000      .

---- VAR x  amount in ton of the daily SW collected from the source i to the tra
           nsferstation j

               LOWER     LEVEL     UPPER    MARGINAL

Z1 .alsirafi      .        2.800     +INF       .
Z1 .beta          .         .        +INF    207.700
Z2 .alsirafi      .        2.000     +INF       .
Z2 .beta          .         .        +INF    234.500
Z3 .alsirafi      .        1.500     +INF       .
Z3 .beta          .         .        +INF    221.100
Z4 .alsirafi      .        0.700     +INF       .
Z4 .beta          .         .        +INF    227.800
Z5 .alsirafi      .         .        +INF     67.000
Z5 .beta          .        4.700     +INF       .
Z6 .alsirafi      .        1.300     +INF       .
Z6 .beta          .         .        +INF    214.400
Z7 .alsirafi      .         .        +INF     67.000
Z7 .beta          .        5.300     +INF       .
Z8 .alsirafi      .         .        +INF     53.600
Z8 .beta          .        2.200     +INF       .
Z9 .alsirafi      .         .        +INF     87.100
Z9 .beta          .        2.200     +INF       .
Z10.alsirafi      .         .        +INF    100.500
Z10.beta          .        1.200     +INF       .
Z11.alsirafi      .        3.300     +INF       .
Z11.beta          .         .        +INF    234.500
Z12.alsirafi      .         .        +INF     53.600
Z12.beta          .        0.700     +INF       .
Z13.alsirafi      .         .        +INF     87.100
Z13.beta          .        0.600     +INF       .
```

```
Z14.alsirafi    .     1.100    +INF      .
Z14.beta        .       .      +INF   234.500
Z15.alsirafi    .     2.300    +INF      .
Z15.beta        .       .      +INF   234.500
Z16.alsirafi    .     0.700    +INF      .
Z16.beta        .       .      +INF   201.000
Z17.alsirafi    .    30.000    +INF      .
Z17.beta        .       .      +INF   201.000
Z18.alsirafi    .     1.800    +INF      .
Z18.beta        .       .      +INF   234.500
Z19.alsirafi    .     1.700    +INF      .
Z19.beta        .       .      +INF   234.500
Z20.alsirafi    .     0.500    +INF      .
Z20.beta        .       .      +INF   201.000
Z21.alsirafi    .       .      +INF   100.500
Z21.beta        .     1.000    +INF      .
Z22.alsirafi    .     1.500    +INF      .
Z22.beta        .       .      +INF   194.300
Z23.alsirafi    .       .      +INF    80.400
Z23.beta        .     0.800    +INF      .
Z24.alsirafi    .       .      +INF    80.400
Z24.beta        .     0.800    +INF      .

---- VAR y  amount in ton for daily SW removed from the transferstation j to lan
         dfill k

                          LOWER     LEVEL     UPPER    MARGINAL

alsirafi.zahretalfinjan     .      51.200     +INF       .
beta    .zahretalfinjan     .      19.500     +INF       .

                      LOWER     LEVEL     UPPER    MARGINAL

---- VAR z             -INF  32718.940     +INF       .

  z  total transportation costs in ILS


**** REPORT SUMMARY :        0     NONOPT
                             0 INFEASIBLE
                             0  UNBOUNDED

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G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
E x e c u t i o n


----    161 VARIABLE x.L  amount in ton of the daily SW collected from the sourc
                    e i to the transferstation j
```

	alsirafi	beta
Z1	2.800	
Z2	2.000	
Z3	1.500	
Z4	0.700	
Z5		4.700
Z6	1.300	
Z7		5.300
Z8		2.200
Z9		2.200
Z10		1.200
Z11	3.300	
Z12		0.700
Z13		0.600
Z14	1.100	
Z15	2.300	
Z16	0.700	
Z17	30.000	
Z18	1.800	
Z19	1.700	
Z20	0.500	
Z21		1.000
Z22	1.500	
Z23		0.800
Z24		0.800

---- 164 VARIABLE y.L amount in ton for daily SW removed from the transferst
ation j to landfill k

	zahretalf~
alsirafi	51.200
beta	19.500

EXECUTION TIME = 0.015 SECONDS 3 MB 24.2.2 r44857 WIN-VS8

Appendix 4: Solve Transporter using LP for the Second Scenario

SOLVE TRANSPORT Using LP

---- COST =E= define objective function

COST.. 175.2*x(Z1,alsirafi) + x(Z1,beta) + 188.6*x(Z2,alsirafi)

- 12.4*x(Z2,beta) + 175.2*x(Z3,alsirafi) - 12.4*x(Z3,beta)

+ 148.4*x(Z4,alsirafi) - 45.9*x(Z4,beta) + 68*x(Z5,alsirafi)

+ 168.5*x(Z5,beta) + 135*x(Z6,alsirafi) - 45.9*x(Z6,beta) + x(Z7,alsirafi)

+ 101.5*x(Z7,beta) + 34.5*x(Z8,alsirafi) + 121.6*x(Z8,beta)

+ x(Z9,alsirafi) + 121.6*x(Z9,beta) + x(Z10,alsirafi) + 135*x(Z10,beta)

+ 135*x(Z11,alsirafi) - 66*x(Z11,beta) + 68*x(Z12,alsirafi)

+ 155.1*x(Z12,beta) + x(Z13,alsirafi) + 121.6*x(Z13,beta)

+ 135*x(Z14,alsirafi) - 66*x(Z14,beta) + 101.5*x(Z15,alsirafi)

- 99.5*x(Z15,beta) + 135*x(Z16,alsirafi) - 32.5*x(Z16,beta)

+ 168.5*x(Z17,alsirafi) + x(Z17,beta) + 135*x(Z18,alsirafi)

- 66*x(Z18,beta) + 101.5*x(Z19,alsirafi) - 99.5*x(Z19,beta)

+ 101.5*x(Z20,alsirafi) - 66*x(Z20,beta) + x(Z21,alsirafi)

+ 135*x(Z21,beta) + 161.8*x(Z22,alsirafi) + x(Z22,beta)

- 12.4*x(Z23,alsirafi) + 101.5*x(Z23,beta) - 12.4*x(Z24,alsirafi)

+ 101.5*x(Z24,beta) - 393.5*y(alsirafi,zahretalfinjan)

- 427*y(beta,zahretalfinjan) + z =E= 0 ; (LHS = 0)

---- CON1 =E= waste generated

CON1(Z1).. x(Z1,alsirafi) + x(Z1,beta) =E= 2.8 ; (LHS = 0, INFES = 2.8 ****)

CON1(Z2).. x(Z2,alsirafi) + x(Z2,beta) =E= 2 ; (LHS = 0, INFES = 2 ****)

CON1(Z3).. x(Z3,alsirafi) + x(Z3,beta) =E= 1.5 ; (LHS = 0, INFES = 1.5 ****)

REMAINING 21 ENTRIES SKIPPED

---- CON2 =E= waste generated and transfered to transfer station j

CON2(alsirafi).. x(Z1,alsirafi) + x(Z2,alsirafi) + x(Z3,alsirafi)

+ x(Z4,alsirafi) + x(Z5,alsirafi) + x(Z6,alsirafi) + x(Z7,alsirafi)

+ x(Z8,alsirafi) + x(Z9,alsirafi) + x(Z10,alsirafi) + x(Z11,alsirafi)

+ x(Z12,alsirafi) + x(Z13,alsirafi) + x(Z14,alsirafi) + x(Z15,alsirafi)

+ x(Z16,alsirafi) + x(Z17,alsirafi) + x(Z18,alsirafi) + x(Z19,alsirafi)

+ x(Z20,alsirafi) + x(Z21,alsirafi) + x(Z22,alsirafi) + x(Z23,alsirafi)

+ x(Z24,alsirafi) - y(alsirafi,zahretalfinjan) =E= 0 ; (LHS = 0)

CON2(beta).. x(Z1,beta) + x(Z2,beta) + x(Z3,beta) + x(Z4,beta) + x(Z5,beta)

+ x(Z6,beta) + x(Z7,beta) + x(Z8,beta) + x(Z9,beta) + x(Z10,beta)

+ x(Z11,beta) + x(Z12,beta) + x(Z13,beta) + x(Z14,beta) + x(Z15,beta)

+ x(Z16,beta) + x(Z17,beta) + x(Z18,beta) + x(Z19,beta) + x(Z20,beta)

+ x(Z21,beta) + x(Z22,beta) + x(Z23,beta) + x(Z24,beta)

- y(beta,zahretalfinjan) =E= 0 ; (LHS = 0)

---- CON3 =L= Transfer stations capacity and the daily transfered waste

CON3(alsirafi).. x(Z1,alsirafi) + x(Z2,alsirafi) + x(Z3,alsirafi)

+ x(Z4,alsirafi) + x(Z5,alsirafi) + x(Z6,alsirafi) + x(Z7,alsirafi)

+ x(Z8,alsirafi) + x(Z9,alsirafi) + x(Z10,alsirafi) + x(Z11,alsirafi)

+ x(Z12,alsirafi) + x(Z13,alsirafi) + x(Z14,alsirafi) + x(Z15,alsirafi)

+ x(Z16,alsirafi) + x(Z17,alsirafi) + x(Z18,alsirafi) + x(Z19,alsirafi)

+ x(Z20,alsirafi) + x(Z21,alsirafi) + x(Z22,alsirafi) + x(Z23,alsirafi)

+ x(Z24,alsirafi) =L= 250 ; (LHS = 0)

CON3(beta).. x(Z1,beta) + x(Z2,beta) + x(Z3,beta) + x(Z4,beta) + x(Z5,beta)

+ x(Z6,beta) + x(Z7,beta) + x(Z8,beta) + x(Z9,beta) + x(Z10,beta)

```
    + x(Z11,beta) + x(Z12,beta) + x(Z13,beta) + x(Z14,beta) + x(Z15,beta)

    + x(Z16,beta) + x(Z17,beta) + x(Z18,beta) + x(Z19,beta) + x(Z20,beta)

    + x(Z21,beta) + x(Z22,beta) + x(Z23,beta) + x(Z24,beta) =L= 80 ; (LHS = 0)


---- CON4  =L=  Landfill k capacity

CON4(zahretalfinjan)..  y(alsirafi,zahretalfinjan) + y(beta,zahretalfinjan) =L=
     1200 ; (LHS = 0)

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G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
Column Listing      SOLVE TRANSPORT Using LP From line 180


---- x  amount in ton of the daily SW collected from the source i to the transfe
        rstation j

x(Z1,alsirafi)
                (.LO, .L, .UP, .M = 0, 0, +INF, 0)
      175.2     COST
        1       CON1(Z1)
        1       CON2(alsirafi)
        1       CON3(alsirafi)

x(Z1,beta)
                (.LO, .L, .UP, .M = 0, 0, +INF, 0)
        1       COST
        1       CON1(Z1)
        1       CON2(beta)
        1       CON3(beta)

x(Z2,alsirafi)
                (.LO, .L, .UP, .M = 0, 0, +INF, 0)
      188.6     COST
        1       CON1(Z2)
        1       CON2(alsirafi)
        1       CON3(alsirafi)

REMAINING 45 ENTRIES SKIPPED

---- y  amount in ton for daily SW removed from the transferstation j to landfil
        l k

y(alsirafi,zahretalfinjan)
                (.LO, .L, .UP, .M = 0, 0, +INF, 0)
```

```
    -393.5     COST
      -1       CON2(alsirafi)
       1       CON4(zahretalfinjan)

y(beta,zahretalfinjan)
                (.LO, .L, .UP, .M = 0, 0, +INF, 0)
    -427       COST
      -1       CON2(beta)
       1       CON4(zahretalfinjan)


---- z  total transportation costs in ILS

z
                (.LO, .L, .UP, .M = -INF, 0, +INF, 0)
       1       COST
```

```
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G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
Model Statistics    SOLVE TRANSPORT Using LP From line 180


MODEL STATISTICS

BLOCKS OF EQUATIONS           5     SINGLE EQUATIONS           30
BLOCKS OF VARIABLES           3     SINGLE VARIABLES           51
NON ZERO ELEMENTS           199


GENERATION TIME      =        0.031 SECONDS      4 MB  24.2.2 r44857 WIN-VS8


EXECUTION TIME       =        0.047 SECONDS      4 MB  24.2.2 r44857 WIN-VS8

GAMS 24.2.2  r44857 Released Mar  4, 2014 WIN-VS8 x86/MS Windows 11/23/14
11:56:08 Page 5
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
Solution Report     SOLVE TRANSPORT Using LP From line 180


               S O L V E      S U M M A R Y

     MODEL   TRANSPORT          OBJECTIVE  z
     TYPE    LP                 DIRECTION  MINIMIZE
     SOLVER  CPLEX              FROM LINE  180

**** SOLVER STATUS     1 Normal Completion
**** MODEL STATUS      1 Optimal
**** OBJECTIVE VALUE            17871.9400

 RESOURCE USAGE, LIMIT          0.016      1000.000
 ITERATION COUNT, LIMIT         0    2000000000

IBM ILOG CPLEX   24.2.2 r44857 Released Mar  4, 2014 VS8 x86/MS Windows
Cplex 12.6.0.0

Space for names approximately 0.00 Mb
Use option 'names no' to turn use of names off
LP status(1): optimal
Cplex Time: 0.02sec (det. 0.04 ticks)
Optimal solution found.
Objective :       17871.940000
                       LOWER     LEVEL     UPPER    MARGINAL

---- EQU COST                      .         .         .         1.000
```

COST define objective function

---- EQU CON1 waste generated

	LOWER	LEVEL	UPPER	MARGINAL
Z1	2.800	2.800	2.800	218.300
Z2	2.000	2.000	2.000	204.900
Z3	1.500	1.500	1.500	218.300
Z4	0.700	0.700	0.700	245.100
Z5	4.700	4.700	4.700	258.500
Z6	1.300	1.300	1.300	258.500
Z7	5.300	5.300	5.300	325.500
Z8	2.200	2.200	2.200	305.400
Z9	2.200	2.200	2.200	305.400
Z10	1.200	1.200	1.200	292.000
Z11	3.300	3.300	3.300	258.500
Z12	0.700	0.700	0.700	271.900
Z13	0.600	0.600	0.600	305.400
Z14	1.100	1.100	1.100	258.500
Z15	2.300	2.300	2.300	292.000
Z16	0.700	0.700	0.700	258.500
Z17	30.000	30.000	30.000	225.000
Z18	1.800	1.800	1.800	258.500
Z19	1.700	1.700	1.700	292.000
Z20	0.500	0.500	0.500	292.000
Z21	1.000	1.000	1.000	292.000
Z22	1.500	1.500	1.500	231.700
Z23	0.800	0.800	0.800	325.500
Z24	0.800	0.800	0.800	325.500

---- EQU CON2 waste generated and transfered to transfer station j

	LOWER	LEVEL	UPPER	MARGINAL
alsirafi	.	.	.	-393.500
beta	.	.	.	-427.000

---- EQU CON3 Transfer stations capacity and the daily transfered waste

	LOWER	LEVEL	UPPER	MARGINAL
alsirafi	-INF	51.200	250.000	.
beta	-INF	19.500	80.000	.

---- EQU CON4 Landfill k capacity

LOWER LEVEL UPPER MARGINAL

zahretalfinjan -INF 70.700 1200.000 .

---- VAR x amount in ton of the daily SW collected from the source i to the tra
nsferstation j

	LOWER	LEVEL	UPPER	MARGINAL
Z1 .alsirafi	.	2.800	+INF	.
Z1 .beta	.	.	+INF	207.700
Z2 .alsirafi	.	2.000	+INF	.
Z2 .beta	.	.	+INF	234.500
Z3 .alsirafi	.	1.500	+INF	.
Z3 .beta	.	.	+INF	221.100
Z4 .alsirafi	.	0.700	+INF	.
Z4 .beta	.	.	+INF	227.800
Z5 .alsirafi	.	.	+INF	67.000
Z5 .beta	.	4.700	+INF	.
Z6 .alsirafi	.	1.300	+INF	.
Z6 .beta	.	.	+INF	214.400
Z7 .alsirafi	.	.	+INF	67.000
Z7 .beta	.	5.300	+INF	.
Z8 .alsirafi	.	.	+INF	53.600
Z8 .beta	.	2.200	+INF	.
Z9 .alsirafi	.	.	+INF	87.100
Z9 .beta	.	2.200	+INF	.
Z10.alsirafi	.	.	+INF	100.500
Z10.beta	.	1.200	+INF	.
Z11.alsirafi	.	3.300	+INF	.
Z11.beta	.	.	+INF	234.500
Z12.alsirafi	.	.	+INF	53.600
Z12.beta	.	0.700	+INF	.
Z13.alsirafi	.	.	+INF	87.100
Z13.beta	.	0.600	+INF	.
Z14.alsirafi	.	1.100	+INF	.
Z14.beta	.	.	+INF	234.500
Z15.alsirafi	.	2.300	+INF	.
Z15.beta	.	.	+INF	234.500
Z16.alsirafi	.	0.700	+INF	.
Z16.beta	.	.	+INF	201.000
Z17.alsirafi	.	30.000	+INF	.
Z17.beta	.	.	+INF	201.000
Z18.alsirafi	.	1.800	+INF	.
Z18.beta	.	.	+INF	234.500
Z19.alsirafi	.	1.700	+INF	.
Z19.beta	.	.	+INF	234.500
Z20.alsirafi	.	0.500	+INF	.
Z20.beta	.	.	+INF	201.000
Z21.alsirafi	.	.	+INF	100.500
Z21.beta	.	1.000	+INF	.

Z22.alsirafi	.	1.500	+INF	.
Z22.beta	.	.	+INF	194.300
Z23.alsirafi	.	.	+INF	80.400
Z23.beta	.	0.800	+INF	.
Z24.alsirafi	.	.	+INF	80.400
Z24.beta	.	0.800	+INF	.

---- VAR y amount in ton for daily SW removed from the transferstation j to lan
dfill k

	LOWER	LEVEL	UPPER	MARGINAL
alsirafi.zahretalfinjan	.	51.200	+INF	.
beta .zahretalfinjan	.	19.500	+INF	.

	LOWER	LEVEL	UPPER	MARGINAL
---- VAR z	-INF	17871.940	+INF	.

z total transportation costs in ILS

**** REPORT SUMMARY : 0 NONOPT
0 INFEASIBLE
0 UNBOUNDED

EXECUTION TIME = 0.015 SECONDS 2 MB 24.2.2 r44857 WIN-VS8

تحسين إدارة النفايات الصلبة في مجلس الخدمات المشترك في نابلس

إعداد: جميلة أمين أحمد الأطرش

المشرف: د. عامر مرعي

الملخص:

يعاني نظام إدارة النفايات الصلبة الموجود في مجلس الخدمات المشترك لإدارة النفايات الصلبة في محافظة نابلس كمعظم المجالس المشتركة لإدارة النفايات الصلبة في فلسطين من غياب خطة حقيقيه واضحة لآلية جمع و نقل النفايات من الهيئات المحلية التي يقدم لها المجلس المشترك خدمة إدارة النفايات وهي أربعة وعشرون هيئة محلية ضمن حدود محافظة نابلس. كما ولا يوجد خطة واضحة لمسار آليات المجلس المشترك لعملية جمع النفايات الصلبة. و لذلك، تتأثر العملية الكلية لإدارة النفايات الصلبة بنسبة الرسوم المحصلة من الهيئات والتي لا تغطي التكاليف الحقيقة لإدارة النفايات الصلبة من قبل المجلس المشترك هذا ويجدر الإشارة بأن معظم إيرادات خدمة إدارة النفايات الصلبة المدفوعة من المواطنين للهيئات المحلية تتدفق عادة في الحساب البنكي العام للهيئات المحلية مما يجعل من الصعب أحياناً تخصيصها لتطوير خدمة إدارة النفايات الصلبة في الهيئات المحلية أو مجلس الخدمات المشترك. كما يتم إنفاق ما معدله 41٪ من إجمالي تكلفة إدارة النفايات الصلبة في مجلس خدمات نابلس على عملية جمع النفايات، و تحميلها وترحيل النفايات إلى محطة الترحيل في الصيرفي ونفقات مكب زهرة الفنجان ورسوم الطمر الصحي للنفايات الصلبة في مكب زهرة الفنجان. فيما تتراوح نسبة التكلفة المنفقة على وقود آليات المجلس المشترك 16٪ من اجمالي تكلفة إدارة النفايات الصلبة ضمن مجلس خدمات محافظة نابلس.

في هذه الدراسة، تم تطوير نموذج إدارة النفايات الصلبة بواسطة نموذج رياضي مقترح باستخدام برنامج GAMS لتقليل تكلفة نقل و جمع النفايات الصلبة من خلال تحديد الآلية الأمثل لجمع النفايات الصلبة، ومساعدة صانعي القرار لتحسين إدارة النفايات الصلبة في مجلس الخدمات المشترك لإدارة النفايات الصلبة في محافظة نابلس.

تم استخدام البرمجة الخطية في النموذج المقترح بواسطة برنامج GAMS وتم اقتراح سيناريوهات عمل لإدارة النفايات الصلبة في مجلس خدمات محافظة نابلس. السيناريو الأول يهدف للتقليل من التكاليف المدفوعة لجمع و نقل النفايات الصلبة من 24 هيئة محلية إلى مكب زهرة الفنجان في محافظة جنين وذلك من خلال تحديد أفضل طريق لجمع و نقل النفايات الصلبة إلى أقرب محطة ترحيل في محافظة نابلس (محطة الصيرفي أو محطة بيتا) وذلك اعتماداً على بُعد الهيئات المحلية عن محطتي الترحيل. في حين أن السيناريو الثاني يعتمد على تقليل تكلفة نقل وجمع النفايات الصلبة بناءً على السيناريو الأول ولكن على أن تكون هنالك عملية إعادة استخدام لبعض المواد القابلة للتدوير وإعادة استخدام لبعض النفايات المجموعة من قبل المجلس المشترك في كل من محطة بيتا ومحطة الصيرفي للترحيل قبل ارسال ما تبقي للمحطة النهائية ليطمر صحياً في مكب زهرة الفنجان في محافظة جنين.

تعتبر النتائج قيمة لدعم التخطيط لإدارة النفايات الصلبة في مجلس خدمات محافظة نابلس في حين أن مجموع تكاليف النقل اليومية للنظام الحالي المستخدم هي 36,718.55 شيكل اسرائيلي فقد أظهرت النتائج أنه في حال تطبيق السيناريو الأول من سيكون مجموع تكاليف النقل اليومية في حال استخدام محطتي ترحيل بيتا والصيرفي يكون 32,718.94 شيكل اسرائيلي وهو ما يعني ان السيناريو الأول سيعمل فقط على ما هو حوالي 12 ٪ فقط من تكاليف النظام الحالي المستخدم مع توفير يومي علي تكاليف النقل تبلغ 3,946.03 شيكل اسرائيلي.فيما قد بينت النتائج أن تطبيق السيناريو الثاني هو الأفضل في حال اعتماد السيناريو الأول بما يشمل إعادة التدوير وإعادة استخدام النفايات الصلبة التي يتم ترحيلها لمحطتي ترحيل بيتا و الصيرفي قبل ترحيل النفايات الصلبة المتبقية بعد عملية إعادة التدوير للطمر الصحي في مكب زهرة الفنجان في محافظة جنين. حيث أن إجمالي تكلفة النقل اليومي فقط 17,971.94 شيكل اسرائيلي الأمر الذي سيؤدي إلى تخفيض 51٪ من إجمالي تكاليف النقل اليومية الحالية. وهذه النتائج تعني أنه حال تطبيق هذه الآلية في العمل سيتسنى للمجلس المشترك تقديم خدمة إدارة النفايات لعدد من الهيئات المحلية القريبة في المستقبل القريب.

من أجل تحسين إدارة النفايات الصلبة في مجلس الخدمات المشترك لإدارة النفايات الصلبة في محافظة نابلس، وتحسين إدارة النفايات الصلبة للهيئات المحلية الاعضاء في المجلس المشترك و الهيئات المحلية القريبة والمحيطة فهنالك ضرورة ملحة لتعاون أصحاب المصلحة الرئيسيين تحت

مظلة وزارة الحكم المحلي باعتبارها صانع القرار الرئيس لإدارة النفايات على المستوي الوطني لتشجيع المشاركة في تطوير قطاع النفايات الصلبة وتطوير الابتكارات التكنولوجية لإدارة النفايات الصلبة في فلسطين.