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A DECISION MAKING APPROACH FOR PRIORITIZATION OF MUNICIPAL INFRASTRUCTURE PROJECTS

BY

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نتيجة الحكم على أطروحة ماجستير

بناءً على موافقة عمادة الدراسات العليا بالجامعة الإسلامية بغزة على تشكيل لجنة الحكم على أطروحة الباحث/ **صلاح عبداللطيف محمد طه** المقدمة لكلية الهندسة لنيل درجة الماجستير في كلية الهندسة/ قسم البنى التحتية .

" آلية لصنع القرار لتحديد أولويات مشاريع البنية التحتية في البلديات"

وبعد المناقشة العلنية التي تمت اليوم الثلاثاء 1 رجب 1425هـ الموافق 2004/8/17م الساعة 11 صباحاً، اجتمعت لجنة الحكم على الأطروحة والمكونة من:

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وبعد المداولة أوصت اللجنة بمنح الباحث درجة الماجستير في **كلية الهندسة/ قسم البنى التحتية** .

واللجنة إذ تمنحه هذه الدرجة فإنها توصيه بتقوى الله ولزوم طاعته وأن يسخر علمه في خدمة دينه ووطنه.

والله ولي التوفيق ،،،

عميد الدراسات العليا

أ.د. أحمد يوسف أبوحلبية

قال الله تعالى على لسان نبيه شعيب عليه السلام:

(قَالَ يَا قَوْمِ أَرَأَيْتُمْ إِن كُنتُ عَلَىَ بَيِّنَةٍ مِّن رَّبِّي وَرَزَقَنِي مِنْهُ رِزْقًا حَسَنًا وَمَا أُرِيدُ أَنْ أُخَالِفَكُمْ إِلَى مَا أَنْهَاكُمْ عَنْهُ إِنْ أُرِيدُ إِلاَّ الإِصْلاَحَ مَا اسْتَطَعْتُ وَمَا تَوْفِيقِي إِلاَّ بِاللّهِ عَلَيْهِ تَوَكَّلْتُ وَإِلَيْهِ أُنِيبُ)

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((قَالَتْ إِحْدَاهُمَا يَا أَبَتِ اسْتَأْجِرْهُ إِنَّ خَيْرَ مَنِ اسْتَأْجَرْتَ الْقَوِيُّ الْأَمِينُ))

القصص 26

Dedication

To my Parents and to my Wife,

I Dedicate this Work

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I wish to take this opportunity to express my acknowledgments and gratitude to the research supervisor, Assoc. Prof. Mohammed Ziara for his continued guidance and encouragement throughout the course of this work. It has been a real enjoyment working with Assoc. Prof. Ziara and his enthusiasm has been a constant source of inspiration.

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Salah Abdel Latif Taha

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List of Abbreviations

AHP	Analytical Hierarchy Process
DET	Data elicitation Technique
DM	Decision Making
DMAP	Decision Making Approach
DMT	Decision Making Technique
EO	Expert Opinion
GIS	Geographic Information System
JSCs	Joint Services Councils
LP	Linear Programming
MADM	Multiple Attributes Decision Making
MAUT	Multi-attribute Utility Function
MAV	Multi-attribute Value Function
MCDM	Multi-Criteria Decision Making
MIP	Municipal Infrastructure Projects
MODM	Multiple Objective Decision Making
MP	Mathematical Programming
PDP	Palestinian Development Plan
RHS	Right Hand Side
SMART	Simple Multi Attribute Rating Technique

ABSTRACT

Municipalities in Palestine shoulder great responsibilities in enhancing socioeconomic conditions of people through developing infrastructure. The use of rational decision making techniques enhances the judicious use of limited natural resources in Palestine and maximizes socioeconomic gains to the people. The goal of this thesis is the implementation of strategic prioritization of municipal infrastructure projects. A comprehensive decision making approach was developed to reach this goal.

The thesis investigated and evaluated the experiences of decision making techniques and their applications, data elicitation techniques and decision criteria in both developed and developing countries. The Linear Programming principles have been identified and developed further to make it applicable to the research problem. In addition, a proper data elicitation technique for expert's opinions elicitation has been recommended. The research has investigated the decision making environment in the main five municipalities (Grade "A" municipalities) in the Gaza Strip - Palestine; Jabalia, Gaza, Deir Al Balah, Khan Younis and Rafah. The unique uncertain conditions of Palestine as well as the decision criteria have been discussed. Consequently, a decision making approach has been developed. The approach incorporates the decision making technique, the data elicitation technique and decision criteria. Software has also been developed based on linear programming concepts to facilitate the use of the developed approach. The Solver under the Microsoft Excel environment has been used for this application. Data sheet and a methodology for weighing the criteria without the intervention of decision makers have been developed.

The developed decision making approach consists of three phases, i.e. Input Phase; Decision Analysis Phase and Output Phase. Each phase includes several steps. These steps are; identifying objectives, identifying options, identifying criteria, analysis of options, making choices and feedback. The approach shows that the structuring of the decisions that are related to municipal infrastructure projects over different criteria increases the transparency of decisions. The approach strengthens the methodologies for projects identification, criteria identification and weighting, evaluation and analysis of options. All of these areas have been strengthened by the developed approach. The approach can be generalized, with small modifications, to suit the conditions of all Palestinian municipalities as well as other developing countries. International and local experts have reviewed the approach and provided supporting materials and software, and that has been helpful in formulation. The effectiveness of the developed decision making approach has been demonstrated using a real life application considering Rafah Municipality as a case study. Nine implemented projects have been processed using the developed approach. A group of decision makers and municipal staff participated in approach reviewing, data collection and analysis. The approach was fine-tuned based on the results of the case study. The case study proved the effectiveness and practicality of the approach.

الخلاصة

البلديات في فلسطين تولي مسئولية عظيمة لتعزيز الأوضاع الاجتماعية الاقتصادية للناس من خلال تطوير البنية التحتية. إن استخدام آليات صنع القرار المنطقية يعزز الاستخدام الحكيم للمصادر الطبيعية المحدودة في فلسطين ويزيد العوائد الاجتماعية الاقتصادية للناس. هدف هذه الرسالة هو تنفيذ مشاريع بنية تحتية في البلديات محددة أولوياتها استراتيجيا.وقد تم تطوير منهجية شاملة لصنع القرار للوصول لهذا الهدف.

الرسالة بحثت وقيمت الخبرات في آليات صنع القرار وتطبيقاتها، واليات استنباط المعلومات، ومعايير القرار في كل من الدول المتقدمة والنامية. مبادئ البرمجة الخطية أظهرت وطورت بشكل أكبر لجعلها مطابقة لمشكلة البحث. بالإضافة إلى التوصية بآلية استقصاء مناسبة للاستقصاء انطباعات الخبراء.

البحث استقصى بيئة صنع القرار في البلديات الخمس الرئيسية والمصنفة "أ" في قطاع غزة – فلسطين وهي: جباليا وغزة ودير البلح وخانيونس ورفح. الظروف الاستثنائية والعشوائية في فلسطين وكذلك معايير صنع القرار تم مناقشتها. وبناء على ذلك، تم تطوير منهجية جديدة لصنع القرار.

المنهجية دمجت آلية صنع القرار وآلية استقصاء المعلومات ومعايير صنع القرار. أيضا، برنامج محوسب تم تطويره بناء على مبادئ البرمجة الخطية لتسهيل استخدام المنهجية المطورة. تقنية سولفر (Solver) ضمن بيئة الإكسل (Excel) استخدمت لهذا التطبيق. تم تطوير صفحة معلومات ومنهجية لوزن المعايير بدون تدخل صانعي القرار.

المنهجية المطورة لصنع القرار تتكون من ثلاث مراحل، هي مرحلة المدخلات ومرحلة تحليل القرار ومرحلة المخرجات. كل مرحلة تضم خطوات مختلفة وهذه الخطوات هي: تحديد الأهداف وتحديد الخيارات وتحديد المعايير وصنع القرار والتغذية الراجعة. المنهجية توضح أن بناء القرارات المتعلقة بمشاريع البنية التحتية في البلديات وفق معايير مختلفة يزيد من شفافية القرارات.

المنهجية تعزز طرق تحديد المشاريع وتحديد المعايير ووزنها وتقييم وتحليل الخيارات. كل هذه النقاط تم تعزيزها بواسطة المنهجية المطورة. المنهجية يمكن تعميمها مع بعض التعديلات لتناسب أوضاع جميع البلديات الفلسطينية وكذلك الدول النامية. خبراء دوليون ومحليون راجعوا المنهجية وقدموا مواد مساندة وبرامج محوسبة والتي ساعدت في الصيغة.

تم فحص فاعلية المنهجية المطورة لصنع القرار على تطبيق من الحياة الواقعية باعتبار بلدية رفح كحالة دراسية. تسعة مشاريع منفذة تم معالجتها باستخدام المنهجية المطورة. مجموعة من صانعي القرار و فريق من البلدية شاركوا في مراجعة المنهجية وجمع البيانات وتحليلها. المنهجية كانت على متناغمة ومناسبة بناء على نتائج الحالة الدراسية. الحالة الدراسية أثبتت أن المنهجية عملية وذات فاعلية.

Ch 1 INTRODUCTION

1 INTRODUCTION

1.1 Decision Making Background

1.1.1 Decision Making Significance

Effective Decision Making (DM) for the selection of Municipal Infrastructure Projects (MIP) plays an important role in the development of efficient infrastructure with high quality. The development of infrastructure affects the quality of life of communities as well as enhancing socioeconomic conditions of people, thus scientific DM should be applied in their development. The use of effective DM in countries of limited resources, such as Palestine is even more important. The implementation of proper Decision Making Techniques (DMT) achieves higher standards of living by properly setting priorities and results in improvement in the delivery and provision of basic services. The implementation of proper DMT also ensures more sustainable development and protection of the environment.

1.1.2 Prioritization Importance

Infrastructure projects pass through six basic phases through their lifetime, which are reconnaissance, feasibility, pre-construction engineering and design, acquisition, construction and operations and maintenance [IRC, 1998]. Planning of project alternatives is conducted in the first stage of the project development process, and involves, as in all other project phases, planning and management of activities, resources, communications and scheduling of activities. In infrastructure, the planning of alternatives includes prioritization among alternatives.

Adopting effective DMT for prioritization promotes transparency and accountability in the planning and implementation of projects. A clear and transparent prioritization process has the following advantages:

a) It is essential and useful when there are a large number of alternatives.

b) It helps in structuring the relative importance of the selection criteria and then the alternatives.

c) It makes management of projects easier and strengthens transparency and credibility of the management organizations, e.g. municipalities.

In spite of the importance of MIP prioritization, in the Gaza Strip, the majority of MIPs are selected and implemented following various practices and decision steps without applying formal DMT.

1.1.3 Definitions

Various definitions exit in the literature for the various terminology used in infrastructure sector. It is thus appropriate to define what is meant by the main terms used in the undertaken research work before discussing the decision making processes for the selection of MIP.

Decision-Making: is not an act, as it erroneously sometimes is perceived, but a process [Malczewski, 1999]. By its nature, the decision making process involves choice among a set of alternatives and the choice can only be exercised if there are decision alternatives to choose from. Finding feasible decision alternatives that satisfy decision situation constraints involves searching for opportunities that may identify problem solutions. It is then a matter of testing whether or not these potential alternatives satisfy the basic decision situation constraints in order to be admitted as feasible decision alternatives.

Infrastructure: consists of the physical facilities that move people, goods, commodities, water, waste, energy and information. These facilities include roads, bridges, pipelines, sewers and networks for supplying water, electricity and gas [Bernhardsen, 1992 - Hudson, 1997]. Such facilities are usually interrelated and involve physical, social, ecological, economic, and technological systems. In the local environment the term "infrastructure" is mainly refer to physical infrastructure works; road pavement, water facilities, wastewater facilities and solid waste projects. This definition will be used in this research work.

Strategic Decisions: are the highest level of decisions where the decision involves determining the general direction of activities, long term goals, philosophies and values. Tactical and operational decisions are two lower-level types of decision and depend on strategic decisions for their effectiveness. Decisions pertinent to infrastructure are strategic decisions, since they deal with long term goals and in most cases they are associated with risks and uncertainties [Harris, 1998].

1.1.4 Research Significance

Worldwide, especially in developed countries, the use of effective DMT provides a basis for planners on all levels to achieve their goals through a transparent decision making process. The DMT and implementation practices differ from one country to another as well as from one organization to another. Specifically, for infrastructure projects, there is a wide difference in planning practices and decision making processes between developed and developing countries. The selection criteria are also different.

In the developed world, many DMT have been developed and successfully applied for decision making on both national and local government levels. Most of municipalities in developed countries use infrastructure planning and management systems. The quality of a project, both during the construction process, and during its life as a constructed facility, is a direct consequence of the quality of decisions [Ahmad, 1990].

On the other hand, most of municipalities in developing countries such as Palestine do not follow systematic planning process, if any at all, for selecting important infrastructure projects. In developing countries, efforts thus far have focused on campaigns to satisfy short-term acute needs [Bernhardsen, 1992]. One of the barriers to sustainable development in developing countries is the lack of adequate information and methodologies of information processing and analysis. The lack of political interest coupled with inadequate overviews of natural resources have resulted in inconsistent decision making. The political uncertainty increases the risk factor, limited financial resources delay the development plans, natural resources and social impacts are usually overlooked, and that emphasizes the need for proper and comprehensive decision making technique to improve the DM of MIP in prioritization process.

The applicability of DMT for prioritization of MIP in developing countries is in need for investigation. In general, applications of decision making in the domain of municipal infrastructure remain limited in number and scope. In addition there is no comprehensive approach that addresses the current and future needs for investment planning for municipal engineers and managers. Only partial solutions are available such as Geographic Information System (GIS) [Vanier and Danylo, 1998]. Thus, there is a need to develop an appropriate decision making technique. The decision making in infrastructure environment

would help the decision makers to: prioritize and evaluate alternatives, allocate resources, make meetings more effective and achieve consensus.

1.2 Research Problem

The need for proper, transparent, comprehensive and accountable DMT in Gaza Strip for prioritization of infrastructure is very essential and welcomed by the decision makers and decision stakeholders in Gaza Strip Municipalities. In order to improve the prioritization procedures as well as the whole planning process of infrastructure projects in Gaza Strip municipalities, it is essential to improve the relevant DM process for prioritization of the projects. In this regard, several questions need to be answered. First, are the MIP prioritized according to formal analytical methods or identification system and what are the current practices of prioritization? Second, what is the most reliable DMT that is suitable for dealing with local MIP? Third, what are the selection criteria and decision constraints that need to be considered for prioritizing MIP? And finally, is it possible to develop a comprehensive decision making approach and software to assist the decision makers in the prioritization process?.

In order to find the right answers to these questions, an intensive investigation of the DMT and DM components is necessary. Also, the existing conditions pertinent to dealing with the prioritization of projects and related practices should be evaluated.

The undertaken research problem determines how to implement a recommended DM approach for prioritization of MIP in Gaza Strip considering the DMT and all other DM components; decision criteria, decision players and data elicitation techniques.

The results of the research work are expected to increase the quality and effectiveness of the selection process for MIP, which results in a higher degree of success in implementing important projects by providing a prioritization approach. The activation of the research problem is proposed to enhance, on the long run, the decision maker's ability to find an effective and transparent DMT and to understand the consequences of their decisions on social groups and their environment.

1.2.1 Research Aim and Objectives

The primary aim of the undertaken research is to improve the quality of life for the Palestinians through the implementation of strategically prioritized municipal infrastructure

projects. More specifically, the research work is intended to achieve the following objectives.

1. Development of a decision making approach to help decision makers in the Gaza Strip municipalities to prioritize infrastructure projects among several alternatives considering the special concerns and requirements of Gaza Strip.

2. Identify the decision making areas that are in need for strengthening in local practice.

3. Development of decision making components to suit Palestine, such as decision players, decision criteria, decision making techniques and data elicitation methods.

4. Development of software for MIP prioritization.

1.2.2 Contributions

The main contributions of this research works include the following:

1. Identification of decision players, selection criteria and current practices of DM, which are associated with the selection of MIP in Gaza Strip.

2. The research identifies the areas that are in need for strengthening, such as, project identification and prioritization phases, cooperation with the local community, negotiation with funding agencies and crisis management.

3. The research provided scientific analysis and comparison of the available DMT based on previous studies and applicability to Palestine.

4. The development of an appropriate DM Approach for prioritization of infrastructure projects suitable for use in Gaza Strip municipalities, including all components of DM. The approach includes the development of a user-friendly interactive software to be used by decision makers when implementing the DM approach.

5. The research developed a new methodology for evaluating and weighting the criteria without the intervention of the decision makers.

6. The research is an initiative for capacity building of the municipal staff as well as other decision makers working in the infrastructure environment regarding project

prioritization and decision making procedures. It allows all concerned to investigate decision practices considering all stages of projects life cycle, i.e. planning, design, implementation, operation and evaluation.

1.3 Scope of Work

The objectives of the research were achieved by assessing current local practices related to decision making in terms of project prioritization as well as highlighting the project selection criteria that should be considered during the prioritization process. More specifically the objectives of the study have been achieved by implementing the following methodology steps shown in Figure 1.1.

1.4 Methodology Steps

a) Literature review

The undertaken review of available relevant literature has been wide-ranging in order to the coverage of most information, documents and techniques. The worldwide practices, DMT, Data Elicitation Techniques (DET), DM players, DM criteria and software have been reviewed and conclusions have been made.

b) Meetings and Consultations

The meetings are preliminarily proposed to survey and assess the current practices of decision making regarding the prioritization of MIP in the target municipalities. Several types of meetings and consultation were conducted including:

1. Structured meetings with decision makers.
2. Structured meetings with decision stakeholders.
3. Correspondence with international decision making experts.
4. A workshop with engineers from all municipalities in Gaza Strip. The workshop was conducted at the premises of Ministry of Local Government in Gaza and the participants were representatives (engineers and financial managers) from all Gaza Strip municipalities.

The literature review and meetings were necessary to discuss the current practices of DM in Gaza Strip and identify the DM criteria. The recommendations of these two activities paved the road to developing The DM approach.

c) Developing a DM approach for prioritization of MIP

Based on the literature review of the DMT and other DM components and assessing the decision making practices in Palestine, comprehensive decision making approach for prioritization of MIP has been developed.

d) Software development,

Based on the recommended DMT and other DM components, the software has been constructed.

e) Case study,

The developed DM approach has been implemented using a real-life decision making environment.

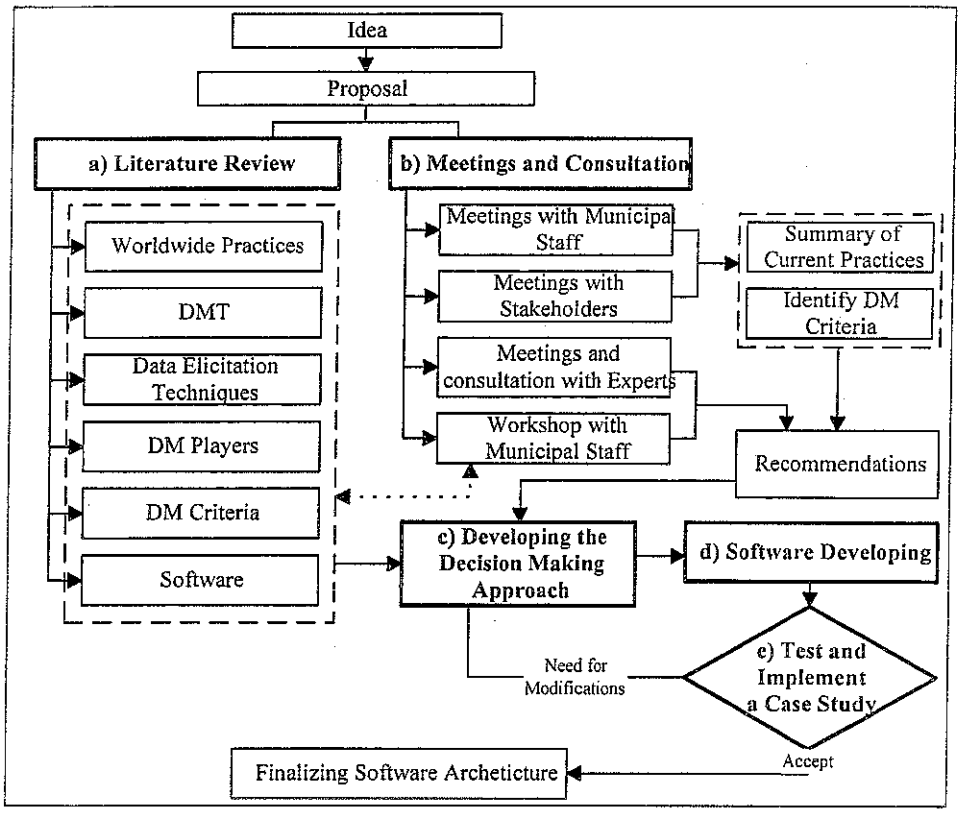

Figure 1.1: Research Methodology

1.5 Thesis Organization

The thesis consists of Eight Chapters as follows:

Chapter 1: is the introduction part which presents the decision making definition, problem statement and subject importance. Chapter one also lists the aim and specific objectives of the research and presents the research methodology.

Chapter 2: is the literature review which includes an investigation of the decision making components; DMT, data elicitation techniques, criteria, constraints and decision players with assessment of the applications in Palestine and recommendation to the relevant techniques.

Chapter 3: is an assessment of the decision making practices in Palestine and introductory for the targeted municipalities. This chapter also highlights the decision making components in Palestine.

Chapter 4: is a summary of the areas of DM that are in need for strengthening in Gaza Strip environment.

Chapter 5: describes the structure of the developed approach and its phases and steps.

Chapter 6: demonstrates the applicability of the approach and software using a real-life case study.

Chapter 7: is the concluding part and includes a summary of the research findings and recommendations.

Ch 2 LITERATURE REVIEW OF DECISION MAKING COMPONENTS

2 LITERATURE REVIEW OF DECISION MAKING COMPONENTS

An effective decision making process consists of several components shown in Figure 2.1 these include [Arsham, 2002]:

1. Decision Making Players,
2. Decision Making Criteria,
3. Decision Making Technique (DMT),
4. Data Elicitation Technique (DET).

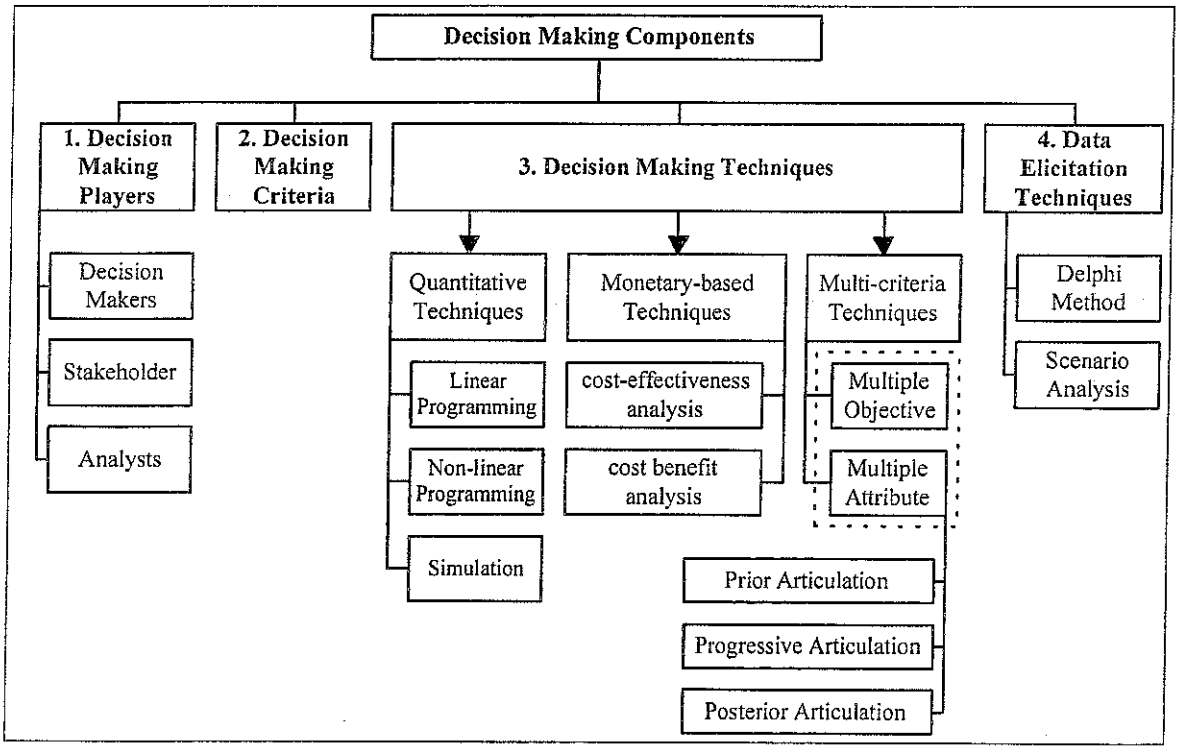

Figure 2.1: The Decision Making Components.

Description of these components, their classification, usage, advantages, disadvantages and their limitations for implementation applications in Palestine are discussed in reference to Figure 2.1 as follows:

2.1 Decision Making Players

There is a number of players involved in the decision situation. Each of them has a significant role and / or can affect the decision.

The decision maker is responsible for choosing the alternative action, however, the analyst can help the decision maker understand the consequences of choosing each alternative. It is the responsibility of the decision maker to ensure that all stakeholders are involved.

The decision players in Gaza Strip can be grouped into the following categories:

1- The decision maker: individual or group that has the authority to make or approve the decision.

2- The stakeholders: individual or group that influence the decision and / or affected by the decision.

3- The analyst: individual or group that synthesize the subjective and objective inputs of the decision maker and stakeholders into meaningful outputs that aid in making a selection.

2.2 Decision Making Criteria

The criteria and sub-criteria are the measures of performance by which the options will be judged. Because the criteria serve as the performance measures for the DMT, they need to be operational. A measurement or a judgment needs to specify how well each option meets the objectives expressed by the criteria [Dodgson et al, 1998].

The potential sources of decision criteria are diverse and include values, goals and objectives, laws and regulations, scientific theories and data, aspirations and concerns of individuals and social groups [Jankowski, 2003]. Often, criteria can be derived by critically examining the hierarchy; *values, then goals, then objectives then criteria.*

Infrastructure performance is measured in terms of the effectiveness, efficiency, and reliability of its contribution to providing or enabling movement of goods and people, clean water supplies, waste disposal, and a variety of other services that support other economic and social activities, a safe and healthful environment, and a sustainability high quality of life [NRC, 1995 – Jankowski, 2003]. This means there are three factors that should be included in selection process of priorities, i.e., effectiveness, efficiency, and reliability.

2.2.1 Properties of Criteria

Every criterion should be [Jankowski , 2003 - Dodgson et al, 1998]:

Comprehensive; clearly indicates the achievement of the associated objective,

Measurable; lends itself to a quantification/measurement.

The set of evaluation criteria should be

Complete; cover all relevant aspects of a decision problem, from the perspective of the decision maker(s) and members of the society impacted by a decision,

Operational; be understandable to decision makers and meaningful to a decision situation,

Decomposable; be amenable to partitioning into subsets of criteria, which may be necessary to facilitate a hierarchical approach to decision analysis,

Non-redundant; avoid the double-counting of decision consequences,

Minimal; have the property of the smallest complete set of criteria characterizing the consequences of a decision.

2.2.2 Worldwide Recognized Decision Criteria

Investigation of criteria and factors that influence the decision making and prioritization among alternative infrastructure projects shows that worldwide, there are two types of criteria:

The first is the criteria in the developed countries which are mainly related to the maintenance phase, construction of international projects, or implementing projects like bridges and tunnels. Cultural and legal conditions, political conditions, support for long term economic growth and enhancement of the quality of the environment are examples of the prioritization criteria in developed countries [Han, 2001 - ICP, 2003 – Ababutain and Bullen, 2003 – Youjie, 2002]. Han [Han, 2001] classified the variables into Controllable variables, Uncontrollable variables, Successor variables and Outcome variables and identified the relation / impact between all variables as significant, moderate and slight. Reducing both project cost and time may be critical to make the trade-off between projects, thus, their cost and time are used as evaluation criteria [Zheng, 2004].

The second is the criteria in the developing countries which emphasize the development of new infrastructure projects. Research discussing the selection criteria in these countries is limited. The criteria in such countries may include; risk (political, legal and financial), culture, size of the project, technical complexity, availability of funds, contract type, experience and time limitations [Dikmen, 2002].

2.2.3 Characteristics of Decision Criteria in Palestine

All the aforementioned requirements are available in the infrastructure environment as it is a physical environment and understandable for persons involved. The evaluation criteria of alternatives in Palestine should coincide with these restrictions and include more criteria to suit the special conditions of Palestine such as risk factors, uncertainty and unavailability of funds.

Constraints impose limitations on decision alternatives. The decision alternatives that satisfy constraints are called feasible decision alternatives. The alternatives that do not satisfy constraints are called infeasible decision alternatives. A constraint represents a certain requirement concerning an attainment of standard or threshold [Malczewski, 1999].

In developing countries, the constraints may also include inefficient institutional structures, lack of motivation, lack of sector data, and external or internal political influences [Ziara et al, 2002]. However, within the undertaken research, all constraints are considered and evaluated as decision criteria.

2.3 Decision Making Techniques

Simple problems that involve few objectives and small number of alternatives can usually be solved adequately without the use of sophisticated methods. When the number of objectives and alternatives becomes large, however, the need for more formal analytical techniques becomes pronounced.

In real life, the decision is very seldom made on the basis of one criterion (Moeffaert, 2003). If one criterion is used in decision making, then it is most likely to be price and the decision maker chooses the cheapest alternative using monetary-based techniques.

In more complex decisions, there are more criteria which have to be considered at the same time. In these circumstances Multi-Criteria Decision Making techniques (MCDM) may be

useful. In particular MCDM techniques can provide more flexibility than monetary-based techniques, and are more comprehensive in their coverage (Dodgson et al, 1998).

2.3.1 Role of Decision Making Techniques

In general, the DMT is to deal with the difficulties that human decision-makers have been shown to have in handling large amounts of complex information in a consistent way. DM is both an approach and a set of techniques, with the goal of providing an overall ordering of options, from the most preferred to the least preferred option [Dodgson et al, 1998]. DMT can be used to identify a single most preferred option, to rank options, to short-list a limited number of options for subsequent detailed appraisal, or simply to distinguish acceptable from unacceptable possibilities [Malczewsk, 1999].

2.3.2 Proper Decision Making Technique

A comparative study shown in Figure 2.2 has been undertaken in this research to decide on a suitable DMT that would be adopted in the developed DM approach. The Framework of the comparative study consists of the following activities [Moeffaert, 2003 with modifications to suit Palestinian conditions]:

a. Literature review of the past experience of the DMT with a summary of the advantages, disadvantages and limitations of each technique. Several issues fit the broad circumstances of MCDM [Dodgson et al, 1998];

1. Theoretical background of each technique.
2. The amount or nature of data available to support the analysis.
3. The time available to undertake the analysis, formulation and demonstration.
4. The analytical skills of those supporting the decision (decision making players) and the administrative culture and requirements of organizations.
5. Transparency and simplicity as well as the necessary intervention of preferences of the decision makers.
6. Applicability for generalization and applicability for Palestinian conditions.
7. Availability of supporting software.

b. Confrontation of the Results; based on the above assessment criteria of the available DMT with conclusions about the recommended techniques.

c. Motivation of choice of the DMT, this step has been primarily considered to suit the local conditions.

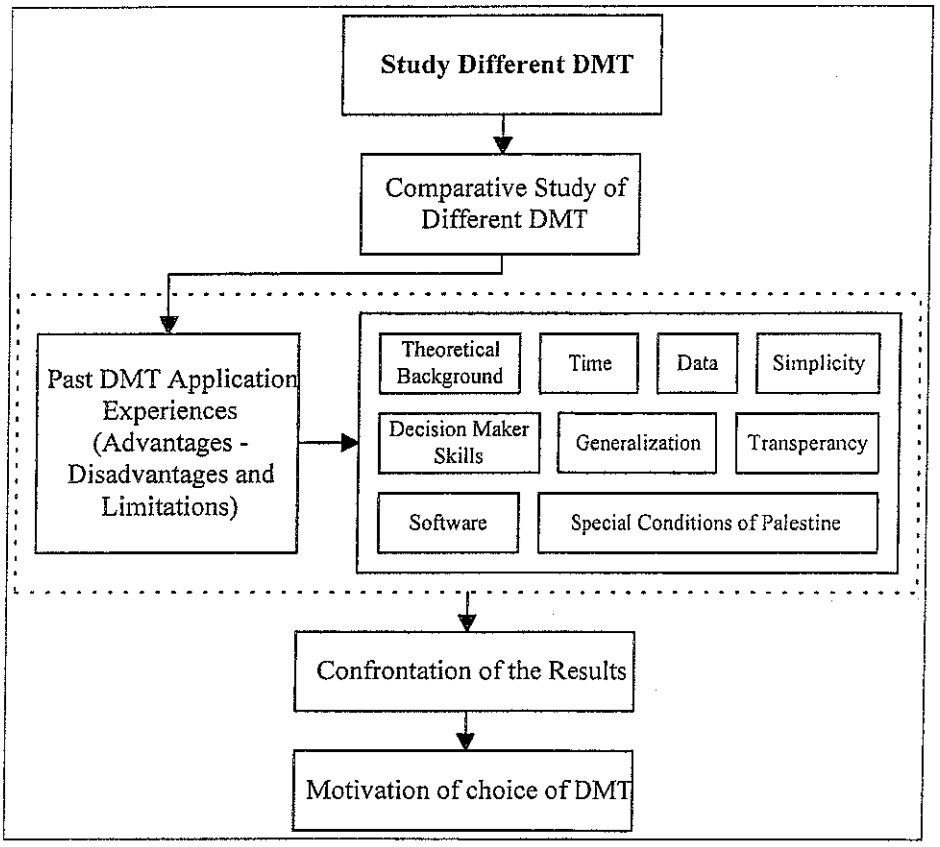

Figure 2.2: The Framework of the Selection of a Decision Making Technique

This framework is used to highlight the logic of each technique as well as advantages and disadvantages or limitations. The applicability of each technique for Palestinian municipalities has been assessed during the course of the study as will be discussed in the following sections.

2.3.3 Comparison between the Decision Making Techniques

Several criteria are to be considered for the selection of a DMT technique. The internal consistency and logical soundness, transparency, ease of use, data requirements, realistic time and manpower resource, ability to provide an audit trail, and software availability, are the evaluation aspects of criteria that have been considered for evaluation of the DMT [Dodgson et al, 1998].

The following are the main assumptions which are considered as criteria for evaluating the most relevant technique for the conditions of Palestine:

1. The approach will be used by municipal and other involved decision makers who are not primarily experts with DMT. The principles of the decision making technique should be programmed in a user friendly computer software.

2. Considering the uncertainty and risk factors as well as the unstable political conditions which may result in changes in the development projects during implementation.

3. Unavailability of funds and dependency on donors as the municipalities are not able to implement projects from their budgets. The accumulated arrears to residents prevent the development due to the current crises and hard unemployment conditions after September 2000 (Al Aqsa) Intifada. Municipal budgets had been very limited to implement projects even before September 2000, and had been used to maintain some basic services and very small development activities.

4. The alternatives are mainly physical infrastructure projects, e.g. water, wastewater and road facilities, as the local communities are still in urgent need for development and rehabilitation of the provided basic services.

5. The technique should have the ability for future development and maintenance to suit future requirements due to the unstable political conditions in Palestine.

6. The basic principles and theoretical background of the developed methodology should be simple enough to be discussed with decision makers.

2.3.4 Reviewed Decision Making Techniques

Decision making techniques may be classified into many groups. Three groups of most recognized decision making techniques are discussed in the following paragraphs. These are Monetary-Based Techniques, Quantitative Decision Making Techniques and the Multi-criteria Decision Making Techniques. Their usage is decided based on the components of the decision environment and type of the problem discussed accordingly.

1. Monetary-Based Techniques

Monetary-based techniques are decision-support techniques which are based primarily on monetary valuation of the impacts of options.

Cost-*effectiveness analysis (CEA)* is the most common form, "An assessment of the costs of alternative options which all achieve the same objective". Less common, although widely used in transport, health and safety, is *cost benefit analysis (CBA)*, "An assessment of all the costs and benefits of alternative options in which some important non-marketed outputs are explicitly valued in money terms" [Dodgson et al, 1998]. Both CEA and CBA are analytical ways of comparing different forms of input or output, by giving them money values [Dodgson et al, 1998].

In conclusion CEA and CBA have limitations, which include both being criticized on political or philosophical grounds and their being short of taking account of the interactions between different impacts. Also, in real life, no money values can be given for other decision criteria. So, the monetary-based techniques are not transparent, accountable or credible technique for evaluation of infrastructure alternatives.

In Palestine, most of the infrastructure projects are implemented by donations from funding agencies of donor countries. The decision makers consider the total cost of each alternative project rather than their cost effectiveness or benefits. The municipalities seek to implement projects to increase coverage and improve the level of the provided services. Municipalities neglect the value of financial return of the projects or provided services (i.e. financial return is not one of the decision making criteria).

2. Quantitative Methods

Quantitative Methods used for decision making include but are not limited to the following methods:

i. Mathematical Programming (Linear or nonlinear)
ii. Simulation
iii. Queuing Theory
iv. Decision Trees
v. Dynamic Programming

Quantitative methods are the means and not the ends of an evaluation process. Simply, they are processes of measuring and quantifying the marginal benefit of one alternative over another and presenting them in an understandable format, so the decision maker can make a more rational choice.

a. Mathematical Programming (MP) (Linear or nonlinear) as the most common quantitative method is very suitable for problems involving blending, continuous flow processing, production and distribution, and strategic planning [Eudoxus, 2003]. The principles of MP also apply to problems involving logistics and scheduling [Simons,1994].

b. Simulation and queuing theory are useful in formulating models for systems operation rather than priority analysis of alternatives. They are predictive models of the expected behavior of a system, i.e. they may be used for resources management in factories, offices, etc. They are used in general in the operation level rather than the strategic level.

c. The decision tree is a model that integrates the relevant components of the decision analysis in a systematic manner suitable for analytical evaluation of the optimal alternatives. Creating a decision tree involves structuring, quantification and computation. The representation of decision tree is completely visual and all calculations are done geometrically. The decision tree represents quantitative information by directly writing numbers. Hence the need to represent quantitative information directly is a limitation of the decision tree. In addition, problem structuring is very cumbersome. These limitations do not make the decision tree a proper technique for MIP which may have large number of alternatives and criteria [Bordley, 2002].

d. Dynamic programming is an approach used to decompose problems into "stages" and combine the solutions from each stage into a complete solution for the original problem. Dynamic programming is most appropriately applied for problems in which optimal solutions may be obtained for sub-problems independently. One example of the type of problem on which Dynamic programming may be successfully applied is the shortest-path network algorithm. There are two shortcomings of dynamic programming that are important in this context. The first

shortcoming is that most scheduling problems cannot be partitioned into stages since decisions made and the solution method requires the consideration of all possible state variables at a given stage. The second shortcoming is that the number of these variables rises at an exponential rate with the size of the problem [East, 1998].

In conclusion, by using MP the decision maker can consider the uncertainty and risk factors and consider the integration between the alternatives. MP Minimizes the contribution or effects of decision maker preferences. MP provides the decision maker with the optimal ranking of alternatives and sensitivity analysis.

On the other hand MP has several shortcomings; in real life application it is not uncommon to be facing several objectives at once with no obvious way of deciding that one should be the objective function and the rest be represented as constraints. The main problem with MP (tableau) is the maintaining the complete non-basic portion of the tableau.
Considering the advantages of the MP and in spite of its shortcomings, its worth to be investigated further and compared with the other decision making techniques.

3. Multi-Criteria Decision Making Techniques

Multi-Criteria Decision Making (MCDM) involves a structured (organized) approach to decision making [Malczewsk, 1999]. There are many MCDM techniques and their number is still rising. Over the last two decades many MCDM techniques have been developed [Mendoza and Macoun, 1999 and Mateu, 2002]. All MCDM techniques make the options and their contribution to the different criteria explicit, and all require the exercise of judgment [Dodgson et al, 1998].

In conclusion; an important consideration in any decision making is risk and uncertainty which can be considered by some types of MCDM techniques. MCDM techniques have a different philosophical perspective and deal with making decisions in the presence of multiple, usually conflicting criteria [Vihakapirom, 2000 and Moeffaert, 2003]. Also, the MCDM approach involves describing a decision problem with six elements [Malczewsk, 1999]. These are; Value: (physical or environmental), Goal: (provide more services), Objective: (increase no. of beneficiaries), Decision Maker, Decision Alternatives, Criteria and Outcomes. So, the evaluation of infrastructure alternatives can be strongly supported

by the MCDM. For Palestine where there are many conflicting criteria for evaluation of alternative projects it is recommended to develop a MCDM approach for prioritization of MIP. However, the usage, worldwide practices and limitations of each MCDM technique should be considered.

2.3.5 Classification of Multi-Criteria Decision Making Techniques

The MCDM techniques range from the very simple to the rather sophisticated. The importance and complexity of the decision problem influence the selected technique for a decision. Literature review has shown that some MCDM techniques are complex and untested in practice; others lack sound theoretical foundations and others are suitable only in some environments or can be used for a certain objective and cannot be generalized.
The decision problems that involve multiple criteria are classified into multiple objective and multiple attribute problems [Mollaghasemi, 1997].

a. **Multiple Objective Problems;**
   Multiple Objective Decision Making (MODM) problems have a large number of feasible alternatives where the objectives and constraints are functionally related to the decision variables.

b. **Multiple Attribute Problems;**
   Multiple Attributes Decision Making (MADM) problems generally involve a finite set of alternatives and a relatively large set of attributes where alternatives are represented in terms of attributes. The goal of this type of problem is to choose the best alternative of those studied, sort and rank alternatives in a decreasing order of preference.

The MADM approach requires that the choice (selection) be made among decision alternatives described by their attributes (criteria as attributes). MADM problems are assumed to have a predetermined, limited number of decision alternatives, limited meaning tens or hundreds. One hundred decision alternatives constitute a large set. Solving a MADM problem involves sorting and ranking.

In the MODM approach, contrary to MADM approach, the decision alternatives are not given. Instead, MODM provides a mathematical framework for designing a set of decision alternatives. Each alternative, once identified, is judged by how close it satisfies an

objective or multiple objectives. In the MODM approach, the number of potential decision alternatives may be large. Solving a MODM problem involves selection of alternatives [Malczewski, 1999].

According to the discussed classification it can be concluded that the infrastructure problems are multiple attribute problems. The municipal decision makers have a set of predetermined alternatives and need to sort and rank them considering the decision criteria.

There are three generic types of MCDM problems, [Malczewski, 1999].

1. *Selection.* Given a set A of alternatives (also called options), the selection task operation involves finding a subset A' of A composed of as small as possible a number of alternatives, judged by decision makers as the most satisfying.
2. *Sorting.* The sorting operation (also called classification) consists of assigning each alternative from A to one of the predefined categories. The assignment is based on the intrinsic measure of a criterion for an alternative and not on its comparison with other alternatives from A. However, in practice assignment is often based on relative differences of alternatives along a criterion.
3. *Ranking.* The ranking operation involves establishing a preferred pre-order on the set of alternatives A. The pre-order represents a priority list of the alternatives.

The solution of multiple criteria problems involves general sub-processes [Mollaghasemi, 1997];

1. Articulation of the decision maker's preference structure over the multiple criteria
2. Optimization of the preference structure.

The various methods can be categorized according to the timing of these sub-processes relative to one another.

1- Prior articulation

2- Progressive articulation

3- Posterior articulation

Table 2.1 summarizes the articulation classes, description, advantages and disadvantages of each class.

Table 2.1: Methods and Articulation Classes

Method	Description	Advantages and Limitations	Conclusion
Prior articulation (Direct)	- The decision maker preferences are obtained through detailed interviews between the decision maker and the analyst prior to the start of the decision making process.	**Disadvantages** - The process of determining the preference structure is often difficult and time consuming.	- The preferences need to be implemented in the assessment which reflects as accurate as possible the human mind directly.
Progressive Articulation	- Interaction between the decision maker, computer and analyst. - DM provides information regarding preferences. - Formulation of a single criterion sub-problem. - Solution and values of criteria and present them to DM to provide new information. - Repeat the process until reaching a solution.	**Advantages:** - Less information from DM - The DM is involved through the process - Satisfactory solution within a reasonable time. **Disadvantages:** - Complicated and difficult to understand - Involve mathematical sophistication - Less transparent to users	- Transparency, simplicity and solid mathematical backgrounds are necessary. So, the progressive articulation is not recommended for decisions of MIP.
Posterior Articulation (Indirect)	- Find all non-dominated solutions - Present to DM to select the preferred one	**Disadvantages:** - Algorithms are complex and difficult. - Multiple objective problems are too large to be solved by this approach - Leads to very large number of non-dominated solutions.	- Simplicity is necessary for decision making. - The decision maker needs the optimum solution. Large number of non-dominated solutions are usually confusing. - The posterior articulation is not recommended with MIP.

According to the above classification it can be concluded that the infrastructure problems have a prior articulation methodology. However, most of the well-known MCDM methods require prior articulation preferences [Moeffaert, 2003].

2.3.6 Examination of MCDM Techniques

Finding the truly best solution to a MCDM problem may never be humanly possible [Triantaphyllou, 1995]. Although the search for finding the best MCDM method may never end, research in this area of decision making is still critical and valuable [Triantaphyllou, 1998]. However, understanding the details of the decision problem can help the analyst and/or the decision maker to select the most suitable MCDM methods which suit the decision environment and can successfully deal with the related alternatives, criteria and constraints.

Special terms are used for each DMT. In order to evaluate and understand the available MCDM techniques the following terms should become comprehensible.

1) **Ordinal and Cardinal Importance**

   Ordinal Importance refers to the order of importance of the list of elements involved. For example, which one comes first, second, etc.

   Cardinal Importance refers to the difference in magnitude between the importance (levels) of two elements. For example, one element might be three times more important than another one.

   Both ordinal and cardinal measures of importance are necessary for decision making and sensitivity analysis in the infrastructure environment. But for simplicity, the ordinal importance is more common.

2) **Ranking and Rating**

   The simplest methods for assessment of the MCDM are Ranking and Rating. ***Ranking*** involves assigning each decision element a rank that reflects its perceived degree of importance relative to the decision being made. The decision elements can then be ordered according to their rank (first, second, etc.).

   Rating is similar to ranking, except that the decision elements are assigned 'scores' between 0 and 100. The scores for all elements being compared must add up to 100.

Thus, to score one element higher means that at least one other element must be scored lower.

Rating provides both ordinal and cardinal measures of importance for each alternative. Ranking, on the other hand, only provides a measure of ordinal importance. So, the rating is considered in this research.

3) Pair-Wise Comparison

Pair-wise comparison makes one-on-one comparisons between each of the decision elements; criteria. How important is criterion "A" relative to criterion "B"?, these are termed pair-wise comparisons.

The Pair-wise comparison method provides a much finer analysis of the responses provided by the expert team. The analysis is finer because [Mendoza, 1999]:

a. The pair-wise comparison method measures both ordinal and cardinal importance of the different criteria;

b. The responses of the experts have to consider each criteria or alternative importance in relation to all the other criteria or alternatives and,

c. The pair-wise comparison method can be analyzed for consistency. This consistency index can indicate when there is a great inconsistency among the responses, and help to pin point where the inconsistencies have occurred. This can help to make the analysis more reliable and accurate.

4) Dominance

The situation where, in a pair-wise comparison of two options, the first scores higher than the second on at least one criterion and no lower on any of the others. In this case the first option is said to dominate the second.

5) Quantitative vs. Qualitative

All decisions involve both quantitative and qualitative factors such as cost, performance, employee morale, and customer satisfaction [Forman and Selly, 2001]. Qualitative factors may be just as important, or even more important than the

quantitative factors. Decision-makers would be shirking their responsibility by deciding on the basis of the quantitative factors alone.

6) Objectivity vs. Subjectivity

Normally important or crucial decisions have more than one objective. In a decision with more than one objective, the relative importance of the objectives influences the choice of the best alternative. Since every important decision has more than one objective, and since the relative importance of the objectives is subjective, every important decision is subjective.

Most people agree that values are subjective. All important decisions are influenced by decision maker values (determining the relative importance of the objectives) and hence are subjective [Forman and Selly, 2001]. The decision maker's contribution to the decision process is the subjective part [Buchanan and Henig, 1997].

Table 2.2 summarizes the reviewed DMT and includes remarks about the theoretical and practical application of each technique. More details about the investigated techniques as well as advantages and disadvantages are attached in Annex (I).

Table 2.2: Methods based on the Prior Articulation of Preferences.

Method	Theoretical and Practical Conclusion
- **Scoring Methods (Linear Additive Model) (Weighted Sum Model - WSM)** - **Weighted Product Model (WPM)** (Multi-attribute, deterministic and the output is based on ordinal ranking) [Dodgson et al, 1998].	-This technique is not recommended with multi conflicting criteria decisions. -It can be used for simpler environment with projects of less importance. -It is difficult to deal with the integration between alternatives. -With MIP the criteria are conflicting and sometimes dependents and uncertainty should be considered, so, the method is simplistic and not recommended.
Performance Matrix (Consequence Table) [Dodgson et al, 1998].	-It is subjected to biases of decision makers (human judgment) during the evaluation of options. It is not recommended for MIP. -Some principles may be studied to be incorporated to strengthen other techniques.

Method	Theoretical and Practical Conclusion
Preference Based Methods Multi-attribute Value Function (MAV) is a multi-attribute and multi-objective, deterministic and the output is based on cardinal ranking. Multi-attribute Utility Function (MAUT) is a multi-attribute and multi-objective, uncertain outcomes and the output is based on cardinal ranking) [Mollaghasemi, 1997]	-MAV is not recommended as Uncertainty is involved in the MIP. -MAUT is a complex technique and recommended to be used by experts. Also, MAUT cannot handle qualitative information and indifference and weak preference articulation. It is considered to be inappropriate to use in this case.
The Analytical Hierarchy Process (AHP) (Multi-attribute, deterministic and the output is based on cardinal ranking – ratio scale). [Mollaghasemi, 1997 – Dodgson et al, 1998 - Moeffaert, 2003, Nigim, et al, 2003 and Steiguer, 1995]	-Concerns about the theoretical background of the methods may limit its applications. -Concerns about the ranking of projects and possibility of adding new projects for the list of projects being evaluated may be solved using another approach association with the AHP. -The availability of software (expert choice) makes it one of the easiest and most common methods. -AHP is in need for more investigation to be associated with other techniques.
Goal Programming (Multi-objective, deterministic and the output identifies the best compromise solution)	-MIPs are multi-attribute problems, but as mentioned before, some stages may include multi-objective problems. So the using of goal programming can be used for some stages but it is not recommended for MIP.
Methods based on fuzzy sets	-Methods based on fuzzy sets are unlikely to be of much practical use for the foreseeable future.
Simple Multi Attribute Rating Technique (SMART)	-SMART can not handle qualitative information and indifference and weak preferences articulation, it is considered to be inappropriate to use in this test case.
Outranking Methods (multi-attribute, deterministic and the output is based on partial or complete ordinal ranking)	-Outranking methods: the use of direct weighting to assess a relative importance between the different criteria is practically experienced as a weak point in the decision making process. (It is difficult to give real values weights. -Its potential for widespread public use seems limited
Outranking Methods - The Novel Approach to Imprecise Assessment and Decision environment (NAIADE)	-The method is need for review for internal consistency and logical soundness. - This method can be used for special problems with limited alternatives. Generalization for problems with large numbers of options is difficult.

2.3.7 Concluded Remarks on MCDM Techniques

Worldwide recognized MCDM techniques were investigated and discussed in the preceding section based on several issues; theoretical background, sophistication and complexity, past experience and success implementation. The applicability of the techniques in Palestine was also considered. It can, therefore, be concluded that:

1- No role to control a DMT whether it belongs to the quantitative methods or MCDM techniques. However, the problem of decision making of infrastructure projects using the mathematical programming based on several criteria and constraints can be classified as MCDM.

2- The scoring method and performance matrix are simple and may be incorporated with other techniques. Dealing with conflicting criteria under constraints and considering the integration between alternatives is impossible with these two techniques.

3- The uncertainty should be considered in dealing with infrastructure projects in Palestine which makes MAV not recommended. Based on the principle of articulation and method of dealing with data, the MAUT is not recommended.

4- In spite of several concerns over the theoretical background of the AHP it is one of the most common techniques. AHP has been used for several decision problems and it was remarkably successful. It can deal with the problem considering all the related issues. Uncertainty could be considered during implementation of the AHP formulation. It would be a subject for further discussion and comparison with other recommended techniques as shown in the next section.

5- Goal programming is a multi objective technique. Some objectives may be conflicting in nature and it is impossible to find a solution that optimizes all objectives simultaneously when they are conflicting. Goal programming, in addition, is a strict quantitative method.

6- The decision making approach is proposed to be used by the decision making in the local municipalities. They are not specialists with decision making techniques and looking for simple algorithms and practical use which are not available with fuzzy techniques.

7- The use of direct weights to assess a relative importance between the different criteria is practically experienced as a weak point in the decision making process which makes the outranking techniques such as ELECRE I, II and III not recommended since it is difficult to give real-value weights.

8- NAIADA has a solid theoretical background. The method is useful for dealing with a limited number of alternatives (three or four). Also the using of fuzzy principles makes it complicated and difficult to understand for non-specialists.

2.3.8 Applicability to Palestine

From the above discussion it can be concluded that, all the MCDM techniques have a successful implementation stories. All of them can be used for different purposes in Palestine. Specifically, for the MIP, and based on examination of the available DMT, the use of AHP or MP is relevant. More investigation was required to decide on the suitable technique. The Linear Programming (LP) was considered as the problems of MIP can be represented by LP. Table 2.3 presents a comparison between the recommended techniques.

Table 2.3: Comparison between the AHP and LP

Evaluation Criteria	AHP	LP
Objective	- Helps the decision making process by providing weight to criteria and alternatives, as well as a ranking of alternatives.	- Helps the decision making process by selecting an alternative, or providing a ranking of them and by determining non-subjective values to criteria. - LP gives optimal solution and/or ranking of the alternatives using the same data.
Multiple Attributes Or Multiple Objectives	- Multiple Attributes	- Can be classified as Multiple Attribute, it is employing many different criteria to gauge each alternative.
Qualitative and quantitative	- AHP uses a verbal scale (qualitative), which enables the DM to incorporate subjective input, personal experience, elicited expert opinions and intuition in a natural way.	- Allows the determination of criteria weights without human intervention. - LP considers both qualitative and quantitative values. Qualitative values can be translated to quantitative.

Evaluation Criteria	AHP	LP
Objectivity vs. Subjectivity	- AHP is based on elicitation of expert opinions in which data are subjectively weighted to come to a cardinal ranking of alternatives. - AHP elicits opinions to pair-wise compare the different criteria that are considered qualitative (subjective).	- LP relies on elicitation of expert opinions, but in a less subjective and more objective manner. However, the initial evaluation of each alternative as a function of each criterion, LP is completely objective. - LP doesn't use any weights for criteria, because these are mathematically determined from the interaction of values established for each alternative and each criterion.
Number and type of alternatives	- Is not very suitable for a large number of alternatives.	- Any type of unit can be used and mixed in this matrix, as long as there is a consistency of units across a specified row - LP can work with hundreds of alternatives and hundreds of criteria - Can consider a lot more of real life situations than AHP, which works only with people's preferences
Risk and Uncertainty	- AHP can consider the uncertainty and risk factors as selection criteria by assigning weights to each criterion.	- LP can consider the uncertainty and risk factors. By assigning a pair of values to each risk criterion, as a minimum and a maximum threshold. - Can consider projects period and construction schedule
Theoretical background	- Easy to understand but it is difficult to explain to a non-mathematical audience and employs a dedicated software. - The mathematical basis of the method has been somehow questioned.	- It is based on matrix algebra and can be difficult to explain the solution process. - There is not dedicated software for LP since there are hundreds of codes which can solve the problem.
Supporting software	- Expert Choice, is a comprehensive software. But it is not available locally.	- There is not dedicated software but there is software packages can solve the formulated problems (Solver, LNDO, etc,). - The formulation of a problem can be

Evaluation Criteria	AHP	LP
		difficult. The using of solver formulated problem is simple. - LINDO and Solver are available
Previous local applications	- [Ziara et al 2002], Ziara, M., Nigim, K., Enshassi, A., Ayyub, B., "Strategic Implementation of Infrastructure Priority Projects: A Case Study in Palestine - [Al Kharoubi and Ziara 2003], AL Kharoubi, A. and Ziara, M., Risk-Informed Strategic Planning Approach for Infrastructure: Water Sector Case Study in Gaza city	- [Rustom and Taha, 2004], Rustom, R., and Taha, T., Optimal Models for Concrete Mixes Composition.
Future development	- It is impossible to change the structure of the software.	- LP has an open architecture (to modify projects and criteria). - Can be modified based on the expert opinion elicitation technique outputs.

Linear Programming has more advantages than the AHP, thus, the Linear Programming principles have been adopted for MIP prioritization implementation in Gaza.

2.3.9 Mathematical Programming Characteristics

2.3.9.1 Mathematical Programming Philosophy

Mathematical programming is a term which represents the maximization or minimization of objective functions. The maximization or minimization is done subject to constraints. According to MacCrimmon (1973), the values of the variables represent a combination of the attributes, the linear constraints are conjunctive constraints or combinations of attributes, and there is a linear compensatory objective function [Tarp and Helles, 1995]. However, Mathematical Programming is not just Linear Programming (LP) and its extensions, such as non-linear programming, integer programming and quadratic programming. It also embraces heuristics and algorithms designed to tackle specific problems [Simons, August 1994]. LP is a tool for solving optimization problems and it typically deals with the problem of allocating limited resources among competing activities in an attempt to find the best possible solution i.e., optimal [Winston, 1995]. LP uses a mathematical model to describe the problem of concern and it involves the planning of

activities to obtain an "optimal" result using a maximization or minimization objective function and subject to restrictions (constraints).

2.3.9.2 World Experience with Mathematical Programming

LP can play an important role in strategic planning. It does not supplant human judgment but is used as a tool to find combinations of plans which deserve further study [Simons, 1994]. Several applications have been successfully implemented over the world using the available software packages e.g. Solver, LINDO, etc. The following paragraphs present examples of LP applications:

The Sequential Interactive Model for Urban Sustainability (SIMUS) has been developed in Canada [Nigim et al., 2003]. SIMUS objective is to provide a final listing of demand-driven projects that are identified and prioritized according to a rational criterion and taking into account existing restrictions. SIMUS was used for selection of storm-drain projects as well as pavement projects in the city of Cordoba, Argentina, with construction schedule and cash-flow, for a three years plan. Also, it was used for urban development and projects selection in Canada, Mexico and Spain. Other examples of LP applications in decision making includes; Oil Industry [Simons, 1994], Forests Management and Planning [Tarp and Helles, 1995], Optimization of concrete mixes, [Rustom and Taha, 2004].

2.3.9.3 Linear Programming Principles

The LP is a tool for solving optimization problem [Winston, 1995]. LP problem is one in which the decision player is looking to find the maximum or minimum value of a linear expression (aX1 + bX2 + cX3 + ...), called the objective function. The objective function is subjected to a number of linear constraints of the form (AX1 + BX2 + CX3 + . . .) which equal, greater than or less than (N), (N) is the Right Hand Side (RHS) value. The variables (X1, X2, X3, ...) are called the decision variables. It is necessary to add a restriction (X1, X2, X3 $\geq$ 0) which is called non-negativity constraints [Winston, 1995 – Simons, 1994]. The parameters of any LP problem are [Frontline, 1996]:

1. **The Objective Function;** the decision maker needs to maximize or minimize the objective function. The value of the objective function must satisfy the decision constraints.

2. **Decision Variables;** are the input values which may be variable quantities. The computerized LP technique changes decision variables automatically in order to maximize or minimize the objective function.

3. **Constraints;** Constraints are relations such as A1 >= 0. A constraint is satisfied if the condition specifies it true within a small tolerance.

The input values of a LP problem may be fixed numbers associated with the problem "parameters of the model". A solution (values for the decision variables) for which all of the constraints in the Solver model are satisfied is called a feasible solution. However, the goal of LP is to find which one of the feasible solutions is " best" as measured by the value of the objective function in the model. Two classes of solutions can be achieved using LP; optimal or feasible [Winston, 1995].

1. **Optimal Solution:** The largest or smallest value of the objective function is called the optimal value.

2. **Feasible Solution:** The feasible solution is a solution for which all the constrains are satisfied. It is possible for a problem to have no feasible solution.

The following is an example of a LP model from the infrastructure environment.

Example:

A municipality has a specific budget allocated to improve the local water network. Three projects are proposed as options. The network at each project is the installation of water pipe line with 6 inches in diameter. The decision maker is in need for increasing the number of installed pipes (meters).

Table **2.4** shows the related issues of each project.

Table 2.4: LP example

Project	Working days / meter	Cost / unit	Maintenance requirements
Project X1	0.53	25	2
Project X2	0.55	30	2
Project X3	0.56	35	2

The decision maker has the following conditions:

1- The total available budget is US$ 100,000.

2- The total generated working days should be at least 1,850 working days.

3- The maintenance requirements should be less than US$ 7,000.

LP formulation

Any LP problem has the following formulation:
Objective function: Maximize the Value of =(aX1 + bX2 + cX3)
Constraints:

A1X1 + B1X2 + C1X3 < N1	(Constraint 1)
A2X1 + B2X2 + C2X3 < N2	(Constraint 2)
A3X1 + B3X2 + C3X3 < N3	(Constraint 3)
X1, X2, X3 > 0.0	(Non-negativity Constraint)

Where

a, b, c	Given Factors, a=1, b=1 and c=1
X1, X2, X3	Decision Variables
A1, A2, A3	Given Factors, for the first project, A1 = working days, A2 = cost and A3 = maintenance requirements.
B1, B2, B3	Given Factors, for the second project, B1 = working days, B2 = cost and B3 = maintenance requirements.
C1, C2, C3	Given Factors, for the third project, C1 = working days, C2 = cost and C3 = maintenance requirements.
N1, N2, N3	Values of constraints

Considering the value of installed quantities (meters) as decision variables, the problem can be formulated as follows:

1- The objective function: is to maximize the total number of installed meters, using the General form:
aX1 + bX2 + cX3
Maximize X1 + X2 + X3 (factors: a, b and c are equal to 1.0)

2- Constraints: three constraints exist, using the general form AX1 + BX2 + CX3 (<, >, or = N)
Constraint 1,Working days: $0.53X1 + 0.55X2 + 0.56X3 \geq 1,850$
Constraint 2, Cost: $25X1 + 30X2 + 35X3 \leq 100,000$
Constraint 3, Maintenance: $2X1 + 2X2 + 2X3 \leq 7,000$

3- Non-negativity constraints: $X1, X2$ and $X3 \geq 0.0$

Solving the problem shows that the optimal solution is:

X1= 2,250 meters

X2= 0.0 meters

X3= 1,250 meters

So, the value of the objective function is, *aX1 + bX2 + cX3 = 2250 + 0.0 + 1250 = 3500 meters.*

2.3.9.4 Graphical Representation of Linear Programming

Graphic solution of LP problem is a method of identifying solutions that are within the bounds of constraints and choosing from them a solution that optimizes the objective function. Graphic solution steps:

1) Graph each constraint,
2) Identify feasible region,
3) Graph the objective function for at least one value of f(x),
4) Consider lines parallel to the graphed objective function to find the one with the optimum feasible solution.

2.4 Data Elicitation Techniques

Information is a vital component in the decision-making process and thus, it is one of the most important strategic factors that influence development [Ziara et al, 1997 and Ziara et al, 2002]. Therefore, it is important that decisions related to the selection of infrastructure projects for implementation must be based on adequate data. In the undertaken research work, available Data Elicitation Techniques (DET) have been reviewed and their advantages and disadvantages have been studied in order to identify the most relevant technique for the local conditions in Gaza Strip municipalities [Cooke and Goossens, 2000]. The main objective of applying DET of expert opinions is to enhance rational consensus.

2.4.1 Expert Opinions

The use of experts opinions in decision making is not completely new. But, the use of Expert Opinion (EO) in a structured way is relatively new [Roest, 2002]. EO elicitation is a heuristic process of gathering data or answers to the questions on issues or problems of concern [Ziara et al 2002], such as environmental impacts, social impacts and staff capacity. Experts can be classified in to two groups

- Decision Making Players (Decision Maker, Analyst, Stakeholders)
- Technical Adviser; any person or group hired by the decision maker or the institutions which is in need for prioritization for their alternatives.

EO elicitations can be a low-cost and quick method that relies on knowledgeable, experienced people [Roest, 2002]. Expert opinion is affected by the process of gathering it and choosing the wrong method may lead to bad results.

2.4.2 Difficulties of Elicitation

There are conflicts between knowledge from different sources as people have conflicting goals and have different understanding of the problem. People may not be free or they may not want to provide the needed information because of some political and organizational factors [Steve, 2003]. One or more members may dominate the group and experts may be incompetent [Roest, 2002].

2.4.3 Examination of Elicitation Techniques

Expert opinion is the judgment, based on knowledge and experience that an expert makes in responding to certain questions about a subject [Roest, 2002]. The experts can be decision makers or any decision players. Expert opinion is used to identify the decision maker preferences regarding the decision criteria and constraints.

The foundation of expert opinion has originally been laid by the RAND Corporation. RAND has developed two very important methodologies for elicitation of expert opinion: the Delphi method and Scenario analysis. Each DET has several advantages and disadvantages, therefore, there is no neutral technique, no perfect technique and no one right way. Although there are many elicitation methods, there are few systematic frameworks to guide choice of an appropriate technique [Rugg, 2003]. One quite widely used approach is triangulation, in which two or more techniques are used to cross-check each other.

2.4.3.1 Scenario Analysis

A scenario is defined as a hypothetical sequence of events that are constructed to focus attention on causal processes and decision points. Scenario analysis attempts to answer two questions: (1) how might some hypothetical situation come about, step by step, and (2) what alternatives or choices exist for each actor or party to the situation, at each step, for preventing, diverting, or facilitating the process. The Scenario analysis is not able to deliver likelihood predictions to decision makers but only long-term trend.

2.4.3.2 Delphi Method

The Delphi method is based on a structured process for collecting and distilling knowledge from a group of experts by means of a series of questionnaires combined with controlled opinion feedback. A group of experts are asked individually to provide their views on what will happen in the future.

2.4.4 Data Elicitation Technique Characteristics

The framework described in Figure 2.3 offers a systematic, theoretically grounded way of EO elicitation. It consists of a variation of the Delphi technique and scenario analysis. It follows what Ayyub (2000) and Ziara et al (2002) suggested with some modifications to make it more simple and applicable based on the Cooke and Goossens (2000) suggestions. The suggested framework shows how to deal with problems of MIP.

The EO elicitation process is preferable to include a face-to-face meeting of experts. In advance of this meeting, background information, objectives, list of issues, and anticipated outcomes from the meeting should be sent to the experts. The meeting of the experts should be conducted after communicating this information to them [Ziara et al, 2002]. The DET consists of the following phases and steps:

a. Preparation for Elicitation Phase

The DET starts from the needs for solving a problem. the preparation phases consists of the followings:

1. Identify Need for an Expert Elicitation Process

   The responsibility of the decision players to identify the problem of consideration. Also, all the problem parameters to be assessed by experts are identified and listed. The decision players select the study leader and identify the experts. The term "expert" is used in this context to designate a person whose present or past field contains the subject of the expert panel in question, and who is regarded by others as being one of the more knowledgeable about the subject. In this step a (as large as possible) list of names of experts is collected. The selection of experts may take place through a formal procedure with a selection committee, or by the project staff. It is recommended to select at least four experts.

2. Train Experts for Elicitation

   Most experts are not familiar, in their daily practice, with stating their degree of belief over variables. They need to be trained in providing assessments. The training will facilitate the group interaction and introduce the elicitation of opinions.

3. Check the Components of the DMT

   The DMT and its components were generalized to suit any infrastructure prioritization problem. Some specific issues are in need for more clarification or criteria. The experts in cooperation with the study leader and staff are responsible to check the components.

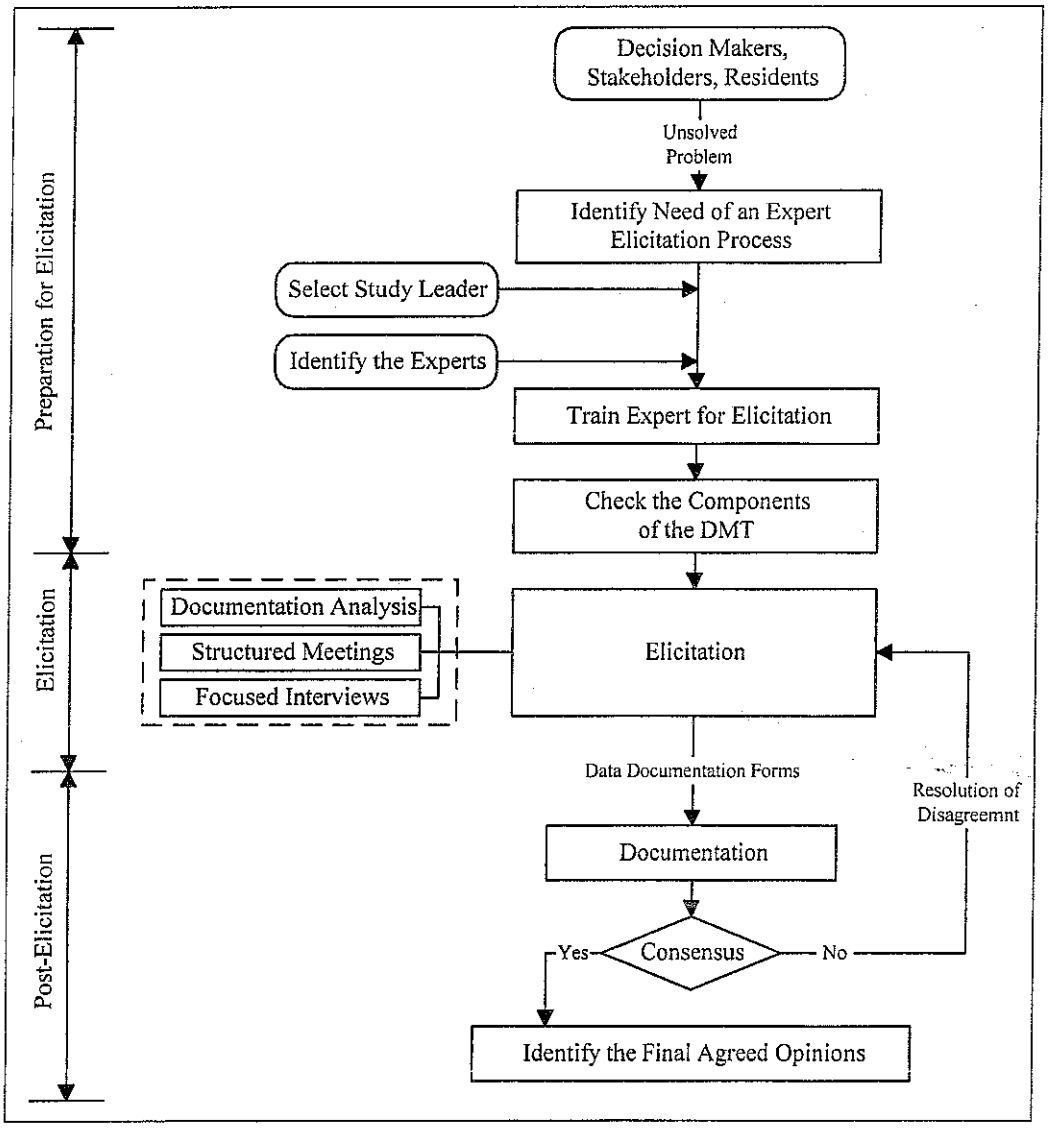

Figure 2.3 :Data Elicitation Technique

b. Elicitation Phase

The experts should agree about the components of DMT and they identify the needed modifications. The elicitation is conducted based on the Delphi Technique and Scenario Analysis. The elicitation includes, Analysis, aggregation, revision, resolution of disagreement, and consensus estimation of needed evaluation and weighting of criteria as well as the methodology of prioritization. The documentation analysis, structured meetings and focus interviews are helpful in elicitation process.

c. Post-Elicitation Phase

1. Documentation

   This phase concludes the elicitation by noting down all relevant information and data, to be presented to the decision maker and to the experts, in a formal report.

2. Consensus

   It is a necessary step to feedback the treated data. If the experts are consensus about the elicitation outputs, they identify the final agreed opinions. If the consensus does not occur, the experts feedback their elicitation to resolve the disagreement.

3. Identify the Final Agreed Opinions

   The final agreed opinions should be reported.

2.5 General Conclusion to the Decision Making Components

The decision players in MIP are the decision makers, analysts and stakeholders. The stakeholders may be institutions or individuals. Investigating the decision making criteria worldwide shows that the developed countries consider mainly; cost, time and environment in planning of alternatives. In the developing countries the criteria include risk and experience. However, the decision criteria should be comprehensive and measurable.

Investigating the DMT shows that several techniques are available. Most of them have been developed from the practical experience based on some mathematical formulas and implemented successfully. The research concludes that the LP is the suitable technique for planning of MIP in the Palestinian environment and it is in need for formulation and validation of a real-life case study. A framework of the Data Elicitation Technique was suggested based on the Scenario analysis and Delphi technique.

Ch 3 ASSESSMENT OF DECISION MAKING PRACTICES IN PALESTINE

3 ASSESSMENT OF DECISION MAKING PRACTICES IN PALESTINE

3.1 Infrastructure History in Gaza Strip

Gaza Strip, 365 km^2, is a coastal strip along the Eastern Mediterranean sea. It is 40 km long and its width ranges from 6 to 12 km. Gaza Strip is a densely populated area with population of 1,406,423 according to middle of year 2004 projected statistics [PCBS, 2004 - MOPIC, 1994]. Figure 3.1 shows the location of Gaza Strip and its five Governorates.

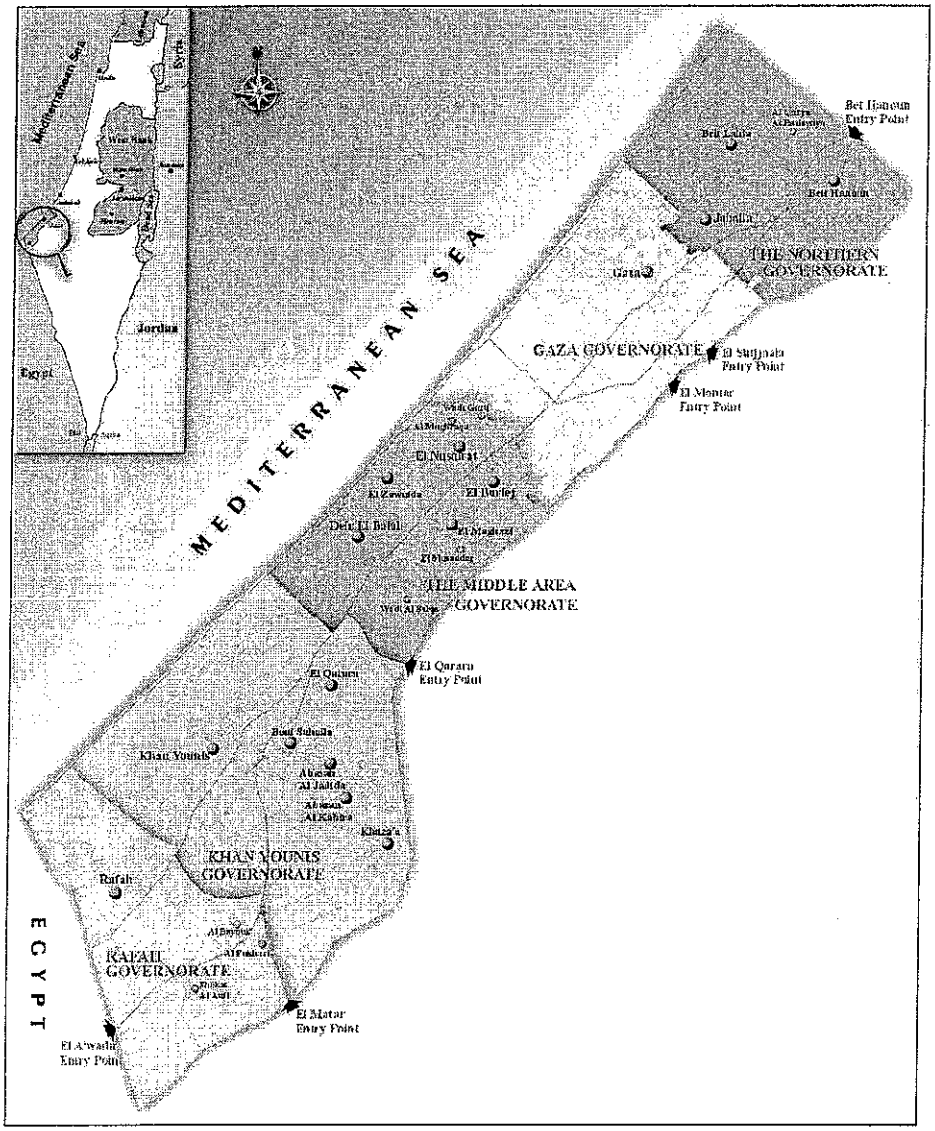

Figure 3.1: Location of Gaza Strip and Boundaries of the Five Governorates

Investment in infrastructure maintains the contiguity of the Palestinian areas through roads, and opens access to the outside world through the airport and the harbor. It also raises the standard of living of the population and improves health conditions and environmental conditions [MOPIC, 1998].

In Palestine, the actual disbursement of funds by donor countries, by sector, for the period of 1994-1997 shows that about (457Million Dollar out of 1819Million Dollar - 25.1%) was invested in infrastructure. The rest was invested in social, productive and institutional building activities [PDP, 2003]. Almost half of the total Plan budget, 48%, is allocated to infrastructure over the period of 1999-2003. It is worth mentioning that the Palestinian Development Plan was prepared in 1998 before Al Aqsa Intifada in September 2000.

The planning of infrastructure in Gaza Strip municipalities has been characterized by irregularity that varied in accordance with imposed political changes during four distinguished eras. For technical purposes, these eras are classified as occupation period (1967 –1987), first Intifada (1987-1994), Palestinian Authority (1994-2000) and Palestinian Authority-Al Aqsa Intifada (2000-2004). The research field activities were performed between March 2003 and May 2004.

3.1.1 Occupation Period (1967 –1987)

During the occupation period, infrastructure was almost totally neglected and planning for most needed infrastructure was done by the Israeli Civil Administration. The Israeli Civil Administration did not put the Palestinian national interests and objectives as first priority. Essential infrastructure was mostly inexistent in that period and in the few cases to the contrary, it was in disrepair. Municipalities and local authorities were permitted to function within a specified framework only. Some international organizations, such the United Nations Relief and Work Agency (UNRWA) and the United Nations Development Program (UNDP) carried out limited infrastructure projects [Jensen, 1997 and Khamaisi 1997].

3.1.2 Occupation Period - First Intifada Period (1987-1994)

During the first Intifada, urban development was extremely limited and planning was carried out with very little participation from Palestinians. During that period total neglect of infrastructure development was observed. Roads were mostly unpaved or deteriorated and closed, sewer systems were in bad conditions and the communities depended mainly on cesspits and open channels and water was poor in terms of quantity and quality. Also electricity and communication networks were totally neglected.

3.1.3 Palestinian Authority Period (1994-2000)

After the Oslo Accord in 1993, the Palestinian National Authority (PNA) was established and many Palestinians were able to come back to Gaza Strip. Since that time donor countries and agencies have been financing a large number of infrastructure projects through central and local Palestinian governments. For management purposes, in November 1996 Gaza Strip was subdivided into five Governorates as shown in Figure 3.1. These are Northern, Gaza, Middle, Khan Younis, and Rafah Governorates. In addition to the Palestinian ministries which were established in 1994, special national agencies have been also established to manage the water, power and the environment. Currently, the local government system in Gaza Strip consists of 25 Local governmental Units; Municipalities and Village Councils. In the areas outside the municipal boundaries, Ministry of Local Government is responsible for licensing any civil activities [MOLG, 1998].

3.1.4 Palestinian Authority Period -Al Aqsa Intifada Period (2000-2003)

Upon the start of Al Aqsa Intifada, most of planning activities in Gaza municipalities have been directed towards emergency programs and projects that have been committed by donors to relieve economic hardship. The infrastructure projects in this period have been characterized by flexibility, small size and fast disbursement. Procurement rules have been simplified and procedures decentralized, with an increasing trend toward consultation with municipalities and village councils on the choice and design of projects [World Bank, 2002].

3.2 Municipal System Structure

The Ministry of Local Government is responsible for issuing the policies of the local governmental units (municipalities and village councils) and to supervise their fulfillment of their responsibilities and duties. The Ministry is responsible for the projects, budgets, financial monitoring, administration and legal monitoring. Each municipality / village council has an independent financial management system and is entrusted with responsibilities and authorities according to Law No. 1 of year 1997 [Alwaqae, 1997].

Each municipality / village council is managed by a municipal council or village council, which consists of councilors. The councilors are headed by one person who is the mayor of the municipality or chief of the village council. Since the advent of the Palestinian

Authority (1994), many villages have been upgraded to municipalities. The local governmental units (municipalities and village councils) are classified according to the number of population served by each unit. Grade "A" municipalities are the main cities in each Governorate, Grade "B" for more than 15,000 residents, Grade "C" for more than 8,000 , and the rest is Grade "D" or village councils which have less than 8,000 residents. The following sections provide some information about Grade A, Municipalities. Table 3.1 shows the residents, employees and area of grade "A" municipalities [MOLG, 2004].

Table 3.1: Grade "A" Municipalities and their Areas and Population

Municipality Name*	No. of Residents (PCBS, 2002)	No. of Employees*	Area* (Km^2)
Jabalia	144,330	317	16
Gaza	448,791	1,850	45
Deir Al Balah	52,886	98	14.7
Khan Younis	164,135	433	53.8
Rafah	136,955	331	40.6

* [Ministry of Local Government Publications, 2003]

1. Municipality of Jabalia

Jabalia Municipality is the Capital of the Northern Area Governorate, located on the northern seaboard of the Gaza Strip, and is the second largest population center next to Gaza. The municipality consists of Jabalia City and Jabalia Camp. The municipal council consists of 13 councilors.

2. Municipality of Gaza

Gaza City has the highest population. The city is the capital of Gaza Strip. It compromises several urban neighborhood areas and the beach camp. The city is one of the oldest cities in Palestine. The municipal council consists of 10 councilors.

3. Municipality of Deir Al Balah

The municipality serves the city and its camp. The municipal council consists of 13 members. It is one of the oldest cities in Gaza

4. Municipality of Khan Younis

Khan Younis City has the largest land area in Gaza Strip. The municipality serves the city and its camp. The municipal council consists of 14 members

5. Municipality of Rafah

Rafah is one of the oldest cities in Palestine. Located to the south of the Gaza Strip and overlooking the Mediterranean, it is the main link between Palestine and Egypt, and historically, its location has always made it a crossroads to invaders. The municipal council of Rafah consists of 15 members. The Municipality of Rafah is the case study which will be subjected for further investigation during the course of research.

3.3 Municipal Financial Situation

Donor programs are currently essential to the economic life of West Bank-Gaza and could become more so if well targeted [Ford, 2000]. Municipalities have been unable to respond effectively to demand for a variety of reasons: limited managerial capacity, resulting in lower revenues and higher expenses than feasible; and, inadequate systems and financing for proper operations and maintenance of existing assets [Ford, 2000]. With the onset of the political crisis of Al Agsa Intifada, the Palestinian Authority fiscal accounts have deteriorated markedly, causing a severe fiscal crisis [MOLG, 2003]. This is the common situation with all governmental institutions, specifically municipalities. The reason of that was a sharp decline in revenue collection because of limited ability of the target communities to pay. However, the donations for infrastructure projects, services and other municipal expenditures helped the municipalities to sustain development and overcome some of the crisis impacts. The municipal revenues include; governmental transfers, taxes, local services (building licenses, public properties and others), utilities revenues (water, wastewater, solid waste, electricity) and international donations. The municipal expenditures include general administration, local services, utility expenditures and municipal development [Ford, 2000 – World Bank, 2002].

3.4 Services Provision

Article 15, Sub-article (A) of the Local Authorities Act 1 of year 1997 lists services that local authorities are mandated to provide. The following are the major services;

1) Providing City Planning and Roads.
2) Controlling building activities.
3) Water, wastewater and electricity provision.
4) Solid waste management.

5) Constructing, managing, organizing several activities within the unit jurisdictions.

All the Palestinian municipalities are in charge of providing services according to the municipalities' master plans, needs of the local communities and availability of financial resources. However, village councils, and lower grade municipalities provide only a limited number of them; mainly water, wastewater and solid waste removal. The quality of provided services is varied from municipality to another, it depends on the level of experience of the municipal staff and availability of resources and funds. Integration and cooperation are essential in order to achieve efficiency in providing services. The services in the municipalities are provided through one of the following methods [EMCC, 2001 and Rustom et al, 2004]:

First: Services provided directly by the village council or the municipality.

Second: Services provided by the Joint Services Councils (JSCs).

Third: Services provided by the municipality in cooperation with the local authorities for services management; water authority and energy authority.

Fourth: Services provided directly by Ministries such as the education and health services.

Some neighboring municipalities have cooperated to provide services through establishing Joint Services Councils (JSCs). JSCs are properly conceived of under the Local Authorities Act as vehicles for multi-jurisdictional service provision [Ford, 2000 and EMCC, 2001]. Examples of the JSC includes:

I- Jabalia, Bait Hanoun, Bait Lahia municipalities and Um Al Nasser Village Councils are joined under the Common Services Council which manage the water and wastewater services in the Northern Area of Gaza Strip. The Council was established under supervision and follow up of the Palestinian Water Authority (PWA).

II- The Solid Waste Management Council which serves eleven Municipalities in the Middle area Governorate and Khan Younis Governorate of Gaza Strip. It is responsible for regulating, collection and disposal of solid waste. It was established in 1996 with the help and support of the German agency (GTZ).

III- Other small inter-municipal service councils have been established to manage infrastructure services such as water council in the Middle Area of Gaza Strip and water council in the eastern villages of Khan Younis Governorates.

It is noticed that, no inter-municipal councils or joint technical units are established for technical issues or decision making.

3.4.1 Infrastructure Assets in Gaza Strip

There are no records or statistics available in Palestine concerning the infrastructure assets.

3.4.2 Construction Materials

Palestine is not well endowed with either natural resources or raw materials. Only sand is available in Gaza Strip. The sandy dunes which are considered the source of the sand in Gaza Strip spread along the strip especially in Khan Younis, Rafah and Bait Lahia. Sandy dunes are on the way to run out rapidly. The other natural resources are imported from the West Bank; aggregates and base coarse. Several materials are manufactured locally in Gaza Strip like concrete, blocks, curbstones, asphalts, interlock, some types of pipes and fittings. Cement, bitumen, paints, woods and steel are imported from Israel or other countries [Ministry of Trade and Economic, 2002].

3.4.3 Implementation of Infrastructure Projects

Infrastructure in Palestine is implemented by local contractors. Some projects such as treatment plants and electricity plant have been awarded to international contractors. However, the construction activities were performed by local subcontractors under supervision of the international contractors.

Recently, the Palestinian Contractors Union has successfully implemented several training programs for local contractors, in order to build their capacity and improve the quality of works [EMCC, 2003]. The contractors union plans to continue training to include all categories of contractors as well as their technical staff, engineers, accountants and financial managers. However, the capacity of local contractors is considered by the municipal staff as a decision criterion.

3.4.4 Relevant Funding and Implementing Organizations

The stakeholders in infrastructure projects planning and implementation include several agencies. The funding agency, implementing agency and the benefiting agency (owner) are the main three primary stakeholders that have responsibilities during the propjet phases. According to the nature of the project the stakeholders' list would include other ministries or governmental agencies. The community is also considered as one of the main stakeholders in some projects. The contractor and the consultant have roles and their contribution may change the form of relationship and the progress of project [Enshassi and Taha, 2004].

> *"The Palestinian Ministry of Finance was unfortunately not in a position to fulfill its intent to cover the requirements of planning activities due to budgetary exigencies" [PDP, 1998].*

Several MIP have been implemented since 1994, including, water and wastewater networks, pumping stations, etc. The implemented projects varied in terms of their size, physical components, environmental impacts, community satisfaction, standards and specifications. In addition, the implementing agencies varied in terms of their capacities, resources and objectives. Ministries, municipalities and non-governmental organizations as well as donor agencies have all dealt with infrastructure projects, which in some cases resulted in overlapping of responsibilities. All of these factors have increased the complexity of infrastructure project management and planning in the municipalities of Gaza Strip.

Even after establishing the Palestinian National Authority in 1994, the majority of development projects were (and still are) funded by donors. The donations are granted by several consulates of donor countries or through their representatives in Palestine. Other type of funds are granted by international agencies working in Palestine such as; World Bank, UNRWA, United Nations Development Program (UNDP), Community Housing Foundation (CHF), the Department of International Development (DFID), Save the Children (SC), Japanese International Cooperation Agency (JICA), Islamic Development Bank, USAID, and others.

The implementing agencies of municipal infrastructure projects are mostly, the Ministry of Local Government, municipalities and the Palestinian Economic Council for Development

and Reconstruction (PECDAR). Other infrastructure projects are implemented according to the sector by the Ministry of Public Works and Housing, the Ministry of Natural Resources and Energy, the Ministry of Communications, etc. The UNRWA implemented projects in camps.

3.4.5 Local Methodologies of Projects Implementation

The investigated funding agencies can be classified into two categories in reference to their funding procedures [Enshassi and Taha, 2003].

First Category: Agencies that provide funds through the Ministry of Local Government (MOLG). The Ministry allocates and distributes the funds to the local municipalities and finalizes the selection criteria of the targeted project sectors. In this category the Ministry is the implementing agency of the projects.

Second Category: where the funding agency targets a specified municipality or Governorate. In the second category the funding agency and the targeted party cooperate closely and prepare a memorandum of understanding including project information and implementation methodology.

Some funding agencies oblige the community to participate in the different phases of the project in order to provide the funds. Others list the community participation as one of the operational management issues and leave the responsibility of execution to the municipality without monitoring. The policies regarding community involvement in priority identification and other phases of project development are neglected and/or not active in most municipalities.

3.5 Local Components of Decision Making

3.5.1 Current Practices of Decision Making

In Gaza Strip municipalities, there is no formal or accountable decision making approach for prioritization of infrastructure projects. However, in some cases there are decision steps, procedures and an understandable system followed by the decision makers regarding the alternative projects prioritization. It should be emphasized that during Israeli occupation (1967 – 1994) all planning was done outside the municipalities without involvement from local staff. Similar to other developing countries, the decision making processes in many municipalities in Palestine have not effectively utilized systematic techniques for the

selection of MIP. Limited resources, socioeconomic constraints, political instability and lack of planning experience have together adversely affected the decision making process in most municipalities in Palestine.

It can be concluded that the existing decision making system for infrastructure projects has been characterized by uncertainties during the different periods. In many cases municipal projects have been identified and implemented in an ad hook fashion that does not follow formal procedures. Some projects have been selected randomly or based on donor priorities. On the other hand, some projects have been selected recognizing the following considerations [EMCC, 2001]:

a. Meetings with local committees to solicit public requests of infrastructure services.
b. Discussion of public requests by municipality councils.
c. Revision of identified projects in accordance with the municipal master plan.
d. The "final word" regarding the project selection is the responsibility of the municipality chief or mayor.
e. Opinion of donors is considered as top priority.
f. Prioritize and implementation of projects in accordance with available funds.

The existing system has some limitations and disadvantages. The decision makers in the municipalities and decision stakeholders in the relevant institutions are looking for introducing a comprehensive approach to help in this regard.

3.5.1.1 Projects Identification Phase

Procedures of project identification and prioritization depend on the scale of the municipality and its organizational structure. Other factors influence projects identification and processing such as the staff's capacity, availability of community committees and willingness to contribute financially.

The typical local practices of project identification and prioritization as shown in **Error! Reference source not found.** can be summarized by the following activities:

a. Identification Channels, there are three channels for identifying the projects;

1- The decision makers, i.e. mayor and councilors and municipality staff identify projects based on their understanding of the community needs and master plan of the city. Master plan is available in Jabalia, Gaza, Deir Al Balah, Khan Younis and Rafah.

2- The donor countries or funding agencies ask the municipalities to identify a specific scale or sector projects with emphasis on some criteria such as small community projects with maximum beneficiaries and employment generation.

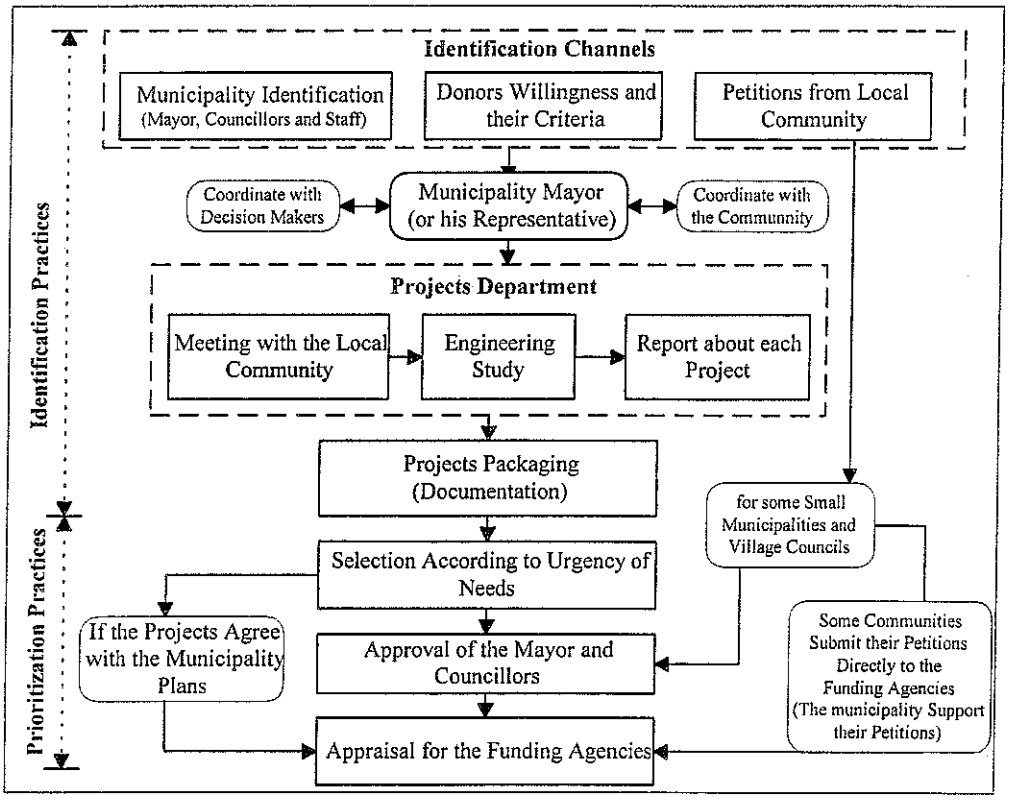

Figure 3.2: Local Practices of Projects Identification and Prioritization.

3- The residents take the initiative and submit petitions requesting a specific service in their community to the municipalities' mayors. They submit the petitions to the municipalities by their representatives or the local community committees. The councilors sometimes propose projects based on their understanding of the community needs. Based on the needs assessment of the services in the local communities, the decision makers initiate thinking to make

some improvements. Sometimes the communities sign petitions requesting a specific service in their community.

b. The municipality mayor transfers the petitions to the responsible department, i.e. the Projects Preparation Department. The mayor or his representative is responsible for coordination with the local community as well as other decision makers, i.e. councilors.

c. The municipality representatives conduct a meeting to discuss the needs with the local community committees or representatives. In most of the municipalities, the meetings are documented. Those meetings are conducted by the mayor in cooperation with the projects preparation department, the public awareness departments and other relevant departments, e.g. water or wastewater.

d. The municipality (projects department in cooperation with other relevant departments) studies the mentioned projects, conducts site visit, surveys the area, surveys the quantities, prepares the project budget and checks the compatibility with the master plan.

e. The projects department prepares a report about each proposed project. For example the Projects Department in Kahan Younis municipality provides feedback to mayor about the situation.

f. All the identified and studied projects are packaged and documented in the municipal archive to be prioritized and appraised by the funding agencies.

3.5.1.2 General Remarks to Identification Procedures

a. No comprehensive, written or programmable procedures for project identification.

b. The procedures vary among the municipalities according to the municipality or the capacity of local community committees.

c. The Ministries of the Palestinian National Authority, i.e. Ministry of Planning and Ministry of Public Works and Housing sometimes ask a specific municipality to implement a project. The ministries coordinate with the relevant municipalities served by a specific common project like Salah Eddin Street and Al Rasheed Street.

d. In some areas, the community committees are experienced and submit their petitions directly to the funding or implementing agencies like Save the Children (SC), Community Housing Foundation (CHF) and Palestinian Economic Council for Development and Reconstruction (PECDAR) as reported in Rafah municipality. In Khan Younis, the Camp Committees cooperate with local and international agencies to fund development projects in their areas with the municipality's support. In Jabalia municipality, a group of college graduates students effectively coordinate between the municipality and the local community in order to facilitate implementation of projects. For specific projects, the municipalities ask the funding agencies to fund projects in the cities, after approval, the municipality appoints local community committees if they are not available in the proposed areas and conducts meeting with them in order to inform their communities (it is the process in Deir Al Balah municipality).

e. Some of the international funding agencies in Palestine target specific sectors and limit the size of projects. The size and objective of donations influence the characteristics of the identified projects, e.g. emergency and job creation projects during Al Aqsa Intifada.

f. Master plan compatibility, projects integration and understanding of the decision maker with the needs of the local communities also are considered when the projects are proposed.

g. Appraisal and identification reports describe some proposals and their objectives, technical issues, beneficiaries, environmental and social impacts and priorities are conducted before approving the initial list of the sub-projects. This is the procedure in three Emergency Job Creation Programs that were funded by DANIDA (2002), Islamic Development Bank (2003) and DFID (2002) and implemented during Al Aqsa Intifada (2000-2003).

In conclusion, the municipalities follow different methodologies for project identification. Within a municipality, the methodology varies from period to period and from donor to donor. So, the practices of identification are in need for strengthening.

3.5.1.3 Prioritization Procedures

For small municipalities, the project department selects the projects according to the urgency of needs and submits the list of selected projects to the councilors and mayor for approval. However, the municipalities implement the projects according to the availability of funds. In the largest municipality, Gaza Municipality, the following procedures are followed, (If fund is available),

a. The Project Preparation Department studies the identified projects (as discussed in the identification channels) and arranges them according to the population density and technical perspective (i.e. water networks before pavement projects).

b. After arrangement, the municipal development committee studies the projects and selects some projects according to the urgency of needs. The arrangement is managerial and technical perspective, i.e. project components, sector, impacts, availability expertise, cost and other criteria.

c. Transfer the projects to the municipality mayor and councilors for approval.

d. Submit the prioritized projects to the funding agencies directly or through the Ministry of Local Government or other implementing agencies like PECDAR.

e. If the fund is not available, the project reports are archived in the municipality for future use.

3.5.1.4 General Remarks on the Prioritization Procedures

In all Gaza strip municipalities, it is difficult to expect the yearly developmental budgets. Mainly, the developmental budgets of infrastructure projects are donations. The prioritization is carried out based on the experience of the decision maker or other staff. According to the literature review of implemented projects, the following projects are identified as having the highest priority projects in all municipalities:

a. Rehabilitation of polluted water networks always has the first priority. Water is available in most communities and there are plans to rehabilitate the old networks. All water projects are proposed in cooperation with the Palestinian Water Authority, which is the Regulatory and Managerial Body of water in Palestine. The first priority for

investment within the infrastructure sector in Palestine is water and wastewater [AL Kharoubi and Ziara, 2003].

b. Storm water drainage and wastewater projects are a priority as the improper disposal of wastewater through using cesspits or open channels always harms the residents and is associated with social, environmental and health impacts. The high cost of wastewater facilities (pumping stations and treatment plants), however, prevent and delay the development. UNRWA implements project in Jabalia and Deir al Balah Camps which assists the municipalities of Jabalia and Deir al Balah.

c. Pavement projects are a priority if the underground infrastructure is implemented. The municipalities pave the internal roads with Interlock in order to increase the level of employment generation.

The prioritization is the main theme of this thesis and it is in need for improvement by a comprehensive decision making approach.

3.5.2 Decision Making Players

The decision players in Gaza Strip are:

a. The decision makers; municipality mayors, heads of departments and Ministry of Local Government representatives (head of the project department and staff).

b. The stakeholders, including communities, funding agencies, other ministries, other governmental parties (e.g. Environmental Quality Agency "EQA", Palestinian Water Authority "PWA", etc.) and relevant local NGOs.

c. The analysts, including researchers, research centers, universities and consultants.

Other parties can be classified according to their roles. The funding agencies, in general, can be grouped as stakeholder player, but they may play more important role as a decision maker in some projects. Table 3.2 shows the decision makers in the studied municipalities in Gaza strip. The mayor and councilors are binding decision makers in all municipalities. In some municipalities the decision makers include other staff like heads of project departments and other directors.

Table 3.2: Decision Makers in Gaza Strip Municipalities

Municipality	Decision Makers*
Gaza	The municipality Mayor and Councilors. (department directors, section heads and municipality general director implement the decisions). The development committee consists of ▪ Councilors (selected) ▪ Mayor assistant for urban planning ▪ Director of the supervision department ▪ Director of the projects preparation department ▪ Director of water and wastewater department
Jabalia	Municipality mayor Councilors Projects department
Deir al Balah	Project department Final word is for the municipality mayor
Khan Younis	Municipality mayor Councilors Project department (sometimes the implementing agency or donors)
Rafah	Councilors

* As identified by the municipal representatives at the structured meetings.

3.5.3 Selection Criteria

The decision makers in Gaza Strip municipalities consider some criteria to compare the alternatives. Almost the same criteria are considered in all municipalities. Some specific conditions may be considered in some municipalities and neglected in others such as capacity of the municipality and integration between services. However, the method of dealing with the criteria and how to prioritize the projects based on the criteria vary. They depend mainly on the capacity of the staff, future vision, decision maker preferences, councilors' opinions and master plans.

3.5.3.1 Procedures to Derive Criteria

The number of criteria should be kept as low as is consistent with making a well-founded decision. There is no 'rule' to guide this judgment and it will certainly vary from application to application [Dodgson et al, 1998]. The researcher has followed the following process in order to elicit the decision criteria of prioritization of MIP:

- Background reading.
- Summary of the main criteria and prepare a draft set of criteria.
- Discuss the identified criteria with the municipal representatives and other decision makers, stakeholders and analysts. And prepare the second draft list.
- Finalize the set of criteria after consulting infrastructure experts in Gaza Strip from Governmental Institutions and Private Sector.

The potential sources of evaluation criteria are diverse and include values, goals and objectives, laws and regulations, scientific theories and data, aspirations and concerns of individuals and social groups. Often, criteria can be derived by critically examining the hierarchy; values -then- goals -then- objectives –then- criteria [Malczewski, 1999].

3.5.3.2 Current Selection Criteria

The municipalities determine the selection criteria depending on their understanding of the local conditions or as discussed with the funding agencies and local communities. Investigating the selection criteria in the local municipalities shows the following as the main groups [IUG, 2002 – Enshassi et al, 2004 – Kuhail, 1997];

1- Project Cost.

2- Political Conditions.

3- Risk related criteria.

4- Project impact (social, environmental, etc.).

5- Municipal development and services integration.

6- Project life cycle and component.

7- Contract type, experience of contractors and availability of equipment.

In some cases, the municipalities identify projects according to the special selection criteria defined by the funding agencies. Also, some funding agencies restrict the proposed projects to some areas that have been targeted before in previous funds in order to ensure integration of services. Sometimes they fund specific sectors.

3.5.3.3 General Remarks on the Current Selection Criteria

According to the discussion with the municipal representatives and reviewing relevant available documents, the following remarks could be made:

a. The investigated municipalities use the same criteria with some modifications. No software and no written criteria lists are available.

b. Each funding agency has its own criteria, and sometimes asks the municipalities to identify a specific sector of projects. The municipalities almost do not have the capacity to negotiate with the funding agencies to change their restrictions. In order to ensure implementation of projects, the municipalities accept the funding agencies' criteria.

c. Investigating the decision making criteria in Gaza Strip shows that there are several factors that influence the decisions. If one of these factors exists, the aforementioned list of criteria may be changed or becomes less important. These factors are mainly related to politics as follows:
   i. According to the political and security agreements between the Palestinians and Israelis, the projects that have a transboundary impacts should negotiated and accepted. This includes both the national and municipal level such as, airport and seaport at the national level and wastewater treatment plants and solid waste landfills on the municipal level.
   ii. Political decision from the chairman of the Palestinian National Authority, Ministers Cabinet or the Palestinian Legislative Council. Such decisions include construction a part of regional road or part of wastewater network.

Ch 4 STRENGTHENING THE DECISION MAKING ENVIRONMENT

4 STRENGTHENING THE DECISION MAKING ENVIRONMENT

This chapter addresses the decision making components in Gaza Strip Environment that are in need for strengthening. The recommendations of this chapter and subsequent actions have been carried out based on the discussion of decision making components and practices. The whole decision making process in Gaza Strip is in need for improvement. The Decision Making Approach (DMAP), which is described in the following chapter, is intended to overcome all the limitations and weaknesses of the existing decision making process. The areas and components that are in need for strengthening are outlined as follows:

4.1 Identification Process

The identification process is in need for development. The use of elicitation technique and transparent methodology to ensure the involvement of all the decision stakeholders is necessary [Kebede, 2001]. Also the technique should have the ability to deal with all relevant data, reports, documents, plans, laws and regulations. The different organizational structures and identification channels in Gaza Strip municipalities need to be considered.

4.2 Prioritization Process

The current process of projects prioritization is a diligence process. A transparent, programmable and accountable process should be used to overcome the limitations of the exiting situation. The use of a systematic technique enables the decision makers to prepare ture plans and explain their priorities to the donors and to the public. Following a comprehensive process is essential to enhance the performance of the municipal staff to report detailed information about the different options and consult with all stakeholders.

4.3 Cooperation with Local Community and Community Committees

The level of community participation in the decision process is still weak in most municipalities in Gaza Strip. Rafah municipality in cooperation with the local community has achieved, to some extent, a desired level of community participation in Gaza Strip. The municipality director reports that, all the municipality projects are community-based projects. A methodology should be proposed to increase the level of community or community committee involvement during the different phases of decision. Future plans and methodologies for implementing community-based projects are necessary. The involvement of community in the project development ensures smooth implementation and

facilitates the coordination with individual during construction as well as it helps to achieve the objectives and proposed outputs of the projects. Community-based projects enhance the cooperation amongst people, ensure the collection of community contribution, protect the systems and indirectly improve the short term and long term maintenance as well as sustainability.

Implementing some examples of community-based or semi-community-based projects indicates successful stories as reported during implementing water and wastewater projects in Jabalia and Rafah municipalities which have been funded by Save the children Federation that enforces the community participation [Enshassi and Taha 2004]. The implantation of public awareness workshops and campaigns has introduced the public to the objectives and encouraged them to protect the services and maintain them periodically.

4.4 Negotiation with the Funding Agencies

Some funding agencies or donors require the municipality to implement specific sector projects such as wastewater or water projects. In order to get the funds, the municipalities propose projects according to the funding agencies' willingness. The using of the DMAP will provide the decision makers with a tool to negotiate with donors and explain the municipal plans and justifications. Appraisals of projects based on a comprehensive decision making tool will be more satisfactory.

4.5 Crisis Management

All the municipalities are in need for policies or strategic plans to manage and operate the municipal facilities during crises as reported during the period between 2001 and 2004. The financial resources have been sharply decreasing. Some municipalities follow coping strategies to overcome the crises, increase the municipal revenues and minimize the expenses during Al Aqsa Intifada [EMCC, 2004].

4.6 Decision Making Criteria

It can be helpful to group together criteria into a series of sets that relate to separate and distinguishable components of the overall objective for the decision. Primarily, the decision criteria are categorized as main criteria and sub criteria. The draft set of criteria has been discussed with the decision makers and municipal representatives (in the grade "A" municipalities). Annex (II) shows the list of conducted meetings. According to the

discussion with municipal representatives and decision makers, the following is the modified set of criteria.

1. ***Budget and Funds Availability***

2. ***Integration between Services***
   - ***Master Plan Availability***
   - ***Dependency on other projects***

3. ***Socio-economical Values***
   - ***Beneficiaries***
   - ***Employment Generation***
   - ***Community Participation and financial contribution***
   - ***Availability of Community committee***
   - ***Community Satisfaction***

4. ***Risks***
   - ***Availability of Construction Materials***
   - ***Project Duration***

5. ***Politics (Decision Makers Preferences)***

6. ***Environment and Public Health***

7. ***Municipality Capacity***
   - ***Technology Requirements***
   - ***Staff Capacity***

8. ***Sustainability***
   - ***Maintenance Requirements***
   - ***Availability of Operational Expertise***
   - ***Project Life Time***

Each one of the aforementioned criteria has several options. The classification of options and their weights are discussed in the developed decision making approach. The weight of each criterion in relationship with the other criteria is identified according to the algorithms of the decision making approach. The following remarks have been raised during the discussion with the decision makers, municipal representatives and infrastructure experts in Gaza Strip:

1. ***Budget:*** all the municipalities agree that the budget and availability of funds is the most important criteria. Jabalia Municipality adds that the good relationship of the municipality with the funding agencies is very important in this regard.

2. ***Resources:*** within the decision making approach the decision maker can identify, based on his knowledge, the level of materials, labor, equipment, and capital that are available. The decision maker is responsible to manage using all the resources at their disposal without exceeding the amount available. All the municipal representatives consider financial resources as the most important issue and all other constraints can be discussed if the funds are available.

3. ***Integration between services:*** it is a very important criterion. The municipalities look for implementing their master plans and implementing complementary projects. Also the projects should be implemented according to their significance importance, water, wastewater and then road pavement. The details of the alternatives; components and scale of the project as well as targeted sector of development are important to the decision maker. Mandatory project start and finish dates are also very important. The project manager also knows the geographic constraints imposed by the physical dimensions of the infrastructure and facilities that are proposed. The Decision maker also would like the crews to complete projects in the same facility or in the same neighborhoods in order to ensure master plan compatibility or projects integration. For the importance of the project details and related issues, the approach discusses the project phases and details.

4. ***Risks:*** this criterion is less important; mainly it depends on the level of the implemented or proposed projects. The municipalities have a long list of alternatives and the projects are under the risk of materials unavailability. They directly change some items and add others according to the materials availability. The municipalities transfer this risk to the contractors. It is the responsibility of the contractor to store the required raw/ construction materials for the project.

   The risk of duration is not a critical issue as most of the municipal projects are short and small scale projects. The municipalities usually give the priority for small duration projects. They divide large projects into smaller parts. The minimum duration helps in

reduction of claims, disputes and variations in currency rate of exchange especially in unstable political environment and a weak economy like Gaza Strip conditions.

Other risks factors such as political decision for large projects, e.g. treatment plants and solid waste landfills are discussed under the influencing factors.

5. ***Socio-economical values:*** the number of beneficiaries, direct or in direct is the most important sub criterion. The unemployment level is the second. The beneficiary groups; children, male, female, youth or elderly some times are considered in specific projects like cultural centers. Also during Al Aqsa Intifada, the municipalities have implemented intensive employment projects and the number of employment "skilled and unskilled" realization has been one of the main criteria. The community participation is less important, but if the community is willing to contribute financially in the project it will be a more important criterion.

   The formulation of the community committee is very important. The committees expedite the municipality efforts and help the municipal staff to identify the community requests and urgent needs. The methodology adopted by several funding agencies regarding the cooperation with the community through the community committee in implementation of the community-based projects should be enhanced.

6. ***Sustainability:*** less concern is given for sustainability issues and the municipalities are looking for implementing new projects rather than to maintain the old ones. Some municipalities have joined together and established joint services councils to operate and maintain the infrastructure services which transfer the responsibility of maintenance from the municipality.

7. ***Politics:*** some municipalities have asked to minimize the weight of this criterion as the mayor or other politics may only ask to implement a project if it is only included in the municipality priorities. Others asked to make it one of the most important criteria and classify it as the second criterion. Rafah municipality reports that, politics preferences are considered in sometimes and for special cases. Usually, the priority is assessed according to the need for the project and available resources. Political uncertainty increases the risk factor, frustrates private sector efforts and discourages both local and foreign investors [PDP, 1998].

8. ***Environmental and public health:*** all the municipalities agree that it is an important criteria and each project should conform to environmental regulations and should not cause any major negative impact on the environmental resources during construction or operation. The environmental components that are listed and considered within the DMAP are:
    - Air quality.
    - Noise pollution.
    - Water quality and quantity.
    - Public health.
    - Fauna, Flora and marine life.
    - Land use and aesthetic features.
    - Soil.
    - Transboundary impacts.

9. ***Municipality capacity:*** it is a less important criterion, as the municipalities depend mainly on the contractors and their equipment. The capacity of the staff is important and in need for more training and capacity building programs and it is required for monitoring and supervision activities. The capacity of a municipality to plan, design, implement and manage the project is considered in the approach as one of the issues that control the decision process. In order to increase their managerial efficiency, some municipalities have joined with other municipalities to form managerial bodies to manage the infrastructure facilities. This has enabled the municipalities to overcome this constraint. The availability of software and computer applications can help the staff for design and follow up the implementation and operation activities more professionally.

The aforementioned criteria can be altered depending on the special conditions of each project.

4.7 Decision Analysis

The DMAP is needed to help the decision maker in Gaza Strip municipalities to prioritize and implement infrastructure projects among several options, i.e. decision analysis. According to the stated objectives and importance of prioritization, the following are the specific objectives that are intended to be achieved from the DMAP:

a. Develop the selection criteria of infrastructure projects that are suitable for Gaza environment and utilize a powerful multi-criteria decision-making technique.

b. Reduce excessive expenditures of time and effort by the decision makers.

c. Increase the quality and effectiveness of the selection process of municipal infrastructure projects.

d. Improve the level of transparency and accountability in the planning and implementation of policies and projects.

e. Ensure and permit the participation of stakeholders.

All types of projects are proposed to be screened using a systematic decision making approach, which enables the municipal decision makers to outline their priorities and promote them to donors. The special conditions of Gaza municipalities regarding the data soliciting technique, decision making technique and selection criteria are included in the different stages of the approach. The approach should account for the following issues:

1- The implemented projects vary in terms of their size, physical components, environmental impacts, community satisfaction, standards and specifications.

2- The implementing agencies vary in terms of their capacities, resources and objectives.

3- Ministries, municipalities and non-governmental organizations as well as donor agencies have all dealt with infrastructure projects, and that in some cases has resulted in overlapping of responsibilities.

4- The decision makers are in general not experts with the decision making techniques and software algorithms. So, the approach should be designed to be user friendly without discussing mathematical issues.

4.8 Computerized Decision Making Approach

Computerizing the decision making process has several advantages [Ahmad, 1990]. Decisions will be obtained rather quickly. Also, the user will be able to change the value of any input variable to see the effect on the output (decision). Thus "what-if" and sensitivity

analyses can be performed easily and quickly. Any decision maker who does not have special knowledge of the analytical tools will still be able to use them.

There are several computer applications or software available for solving LP problems, e.g. LINDO and Solver. LINDO; Linear Interactive Discrete Optimizer was developed by Linus Schrage in 1986. It is a user friendly computer package that can be used to solve LP problems [Winston, 1995]. Solver was developed by Frontline Systems for Microsoft. The standard Solver comes bundled with Microsoft Excel. It includes basic Solver engines for nonlinear optimization problems, linear programming problems and integer programming [Frontlines, 2003]. Investigating the solution of simple sample problems using LINDO and Solver shows that:

1. LINDO requires an expert to deal with the decision problems. It is difficult to formulate the decision problems without previous experience.
2. Solver works with excel application. It is easy to build up the basic formulation by the expert and use it by the decision analyst or decision maker with no experience of how the Solver works.
3. It is easy to furnish raw data to the spreadsheets and Solver computes the weights and selects the necessary data.
4. Solver is very simple compared with LINDO regarding, formulation, finding errors, changing cells (factors or variables), supporting applications.
5. It is easy to create Solver models that contain discontinuous functions or even nonnumeric values. These models usually cannot be solved with classical optimization methods. The Solver's formula language is designed for general computations and not just for optimization [Fylstra, 1998].

According to the above-mentioned advantages, Solver is selected to develop the DMT, i.e. LP for prioritization of MIP. LP problems using Solver are generally solved via the simplex method. Annex (III) includes more details about the solution of LP problems via the simplex method. The Solver proceeds by first finding a feasible solution, and then seeking to improve upon it, changing the decision variables to move from one feasible solution to another feasible solution until the objective function has reached its maximum or minimum, which is called an optimal solution [Fylstra, 1998].

4.9 Prioritization Schedule

The DMAP is to prioritize the MIP. The use of the DMAP cannot be restricted to time bases. It may be used according to the following two cases:

1- Availability of specific amounts of funds and the funding agency asks the municipality to propose a list of projects, prioritized projects.

2- If the municipalities have a list of identified projects and they are looking for funds from the donors or other ministries.

Ch 5 THE DEVELOPED DECISION MAKING APPROACH

5 THE DEVELOPED DECISION MAKING APPROACH

A set of complex steps is required in order to analytically prioritize the alternative projects considering the classification of projects, selection criteria, decision making technique and data elicitation technique. Based on the intensive investigation and discussion of these issues and correlated current practices in Gaza Strip municipalities, a comprehensive Decision Making Approach (DMAP) for prioritization of MIP is developed. User friendly software has also been developed to overcome all the difficulties of alternatives processing and complexity of decision making technique and to reduce excessive expenditures of time and effort by the public sector. The different decision steps of the approach and software are discussed in the following sections. The DMAP consists of three phases shown in **Error! Reference source not found.**. These are:

1. **Input Phase:** where the data, initial ideas and facts are treated.
2. **Process Phase:** it is the decision analysis phase and includes all process to make the decision.
3. **Output Phase:** it is the final decision phase.

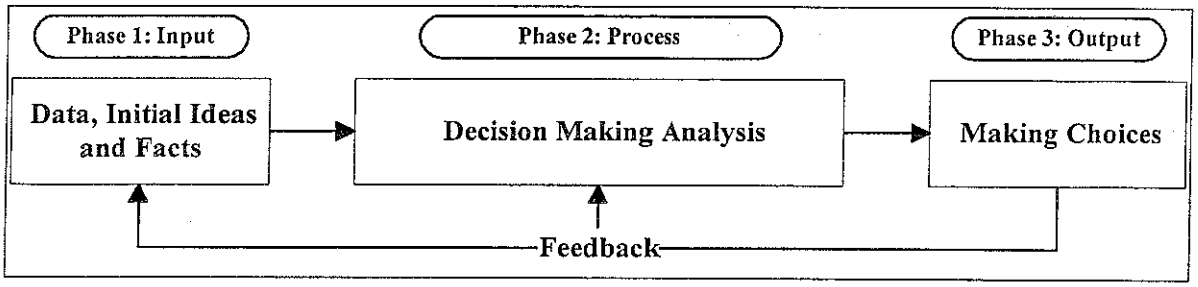

Figure 5.1: Phases of the DMAP

Each of the three decision making phases comprises a number of steps as follows:

1- Identifying objectives

2- Identifying options

3- Identifying the criteria

4- Analysis of the options

5- Making Choices

6- Feedback

According to the decision making technique and data elicitation method, the decision making steps may also include examining the results, sensitivity analysis and risk

assessment. The decision making steps are incorporated within the decision making phases as detailed in the following sections. Figure 5.2 shows the decision making steps.

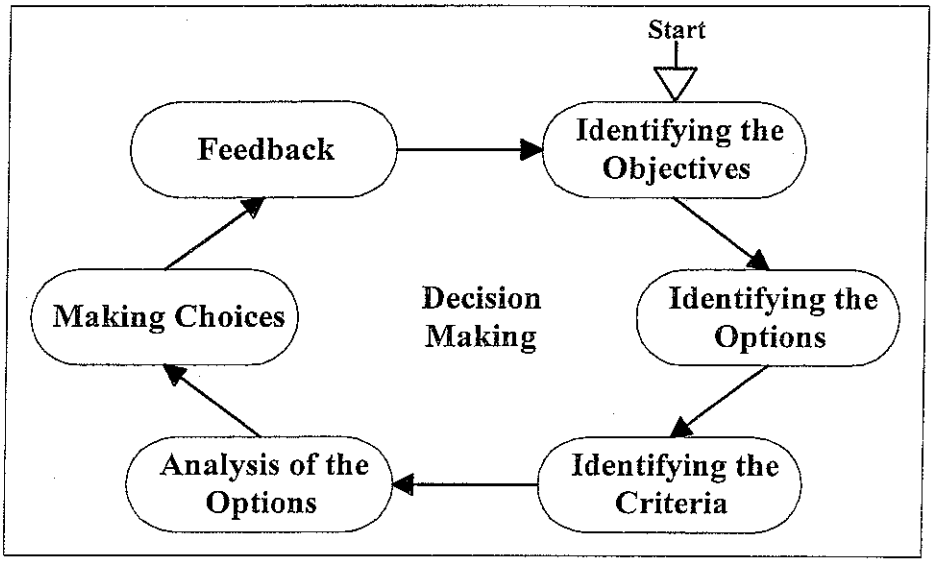

Figure 5.2: Steps of the DMAP

Some of the decision steps are conducted during the first phase, others in the second phase and making choices is the last phase. Feedback is a continuous process between all phases. Each decision phase and step includes sub steps. **Figure 5.3** illustrates the details of the DMAP, phases, steps and all other sub-steps. The developed Data Elicitation Technique (DET) is an essential component of the DMAP. DET can be used at different stages of the technique, i.e. phase I, phase II and phase III.

5.1 Phase I: Input of Data and Facts

The most important issue in the developed decision making process is to understand and establish the decision context or defining the decision problem. The decision context means the aim of the decision process, it includes the identifying of the decision making players, i.e. decision makers, stakeholders and analysts, and preparation of related documents. The phase is the beginning of the decision making process, it starts from the formulation of the idea for proposing or implementing a project. The input phase consists of two steps of the decision making; identifying the objectives and identifying the options for achieving the objectives.

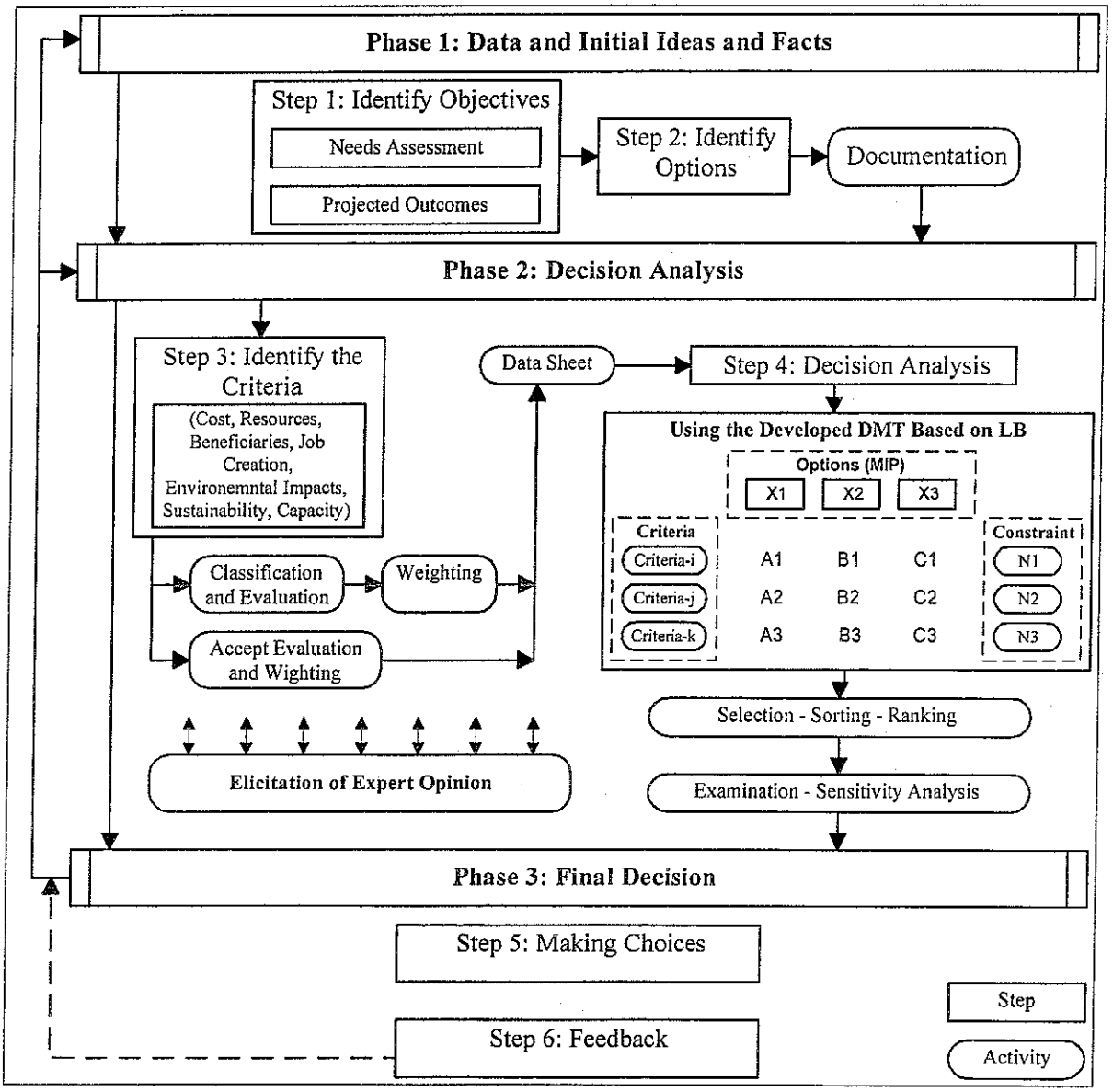

Figure 5.3: DMAP Phases and Decision Making Steps

5.1.1 Phase I – Step 1: Identify Objectives

The first step in decision making is identifying the objectives. The decision makers receive general information from three different channels about the need for a project in a specific area to serve a specific objective. These channels are; municipality identification, donors willingness and petitions from local communities. The information about projects can be processed and reported. However, achieving the requests for projects and processing the information is an objective. Clear objectives are necessary to make decisions. These should be specific, measurable, agreed, realistic and time-dependent. The objectives may be identified according to:

i. Needs assessment: the responsible employee should carry out a needs assessment study in the area of question. The study helps to outlines the necessary services in the area, then the objectives.

ii. Projected outcomes and deliverables: implementation of MIP helps to achieve some developmental objectives with different outcomes. The municipality studies the proposed projects and their projected outcomes to identify the targeted project.

5.1.2 Phase I – Step 2: Identify Options

Once the objectives have been defined, the next step is to identify options that may contribute to the achievement of these objectives. The options in the DMAP are the MIP. The data collected from the community requests, engineering studies and needs assessment should be reported. For decision making purposes, the data about a project are summarized and recorded in a special data sheet. The technique incorporates these issues in order to deal with the needs assessment, proposed/expected project objectives and the expected outcomes or deliverables of the alternative projects. As a result of this phase of decision, the decision maker will be able to prepare the initial list of priority projects.

Table **5.1** shows some examples of objectives and options.

Table 5.1: Examples of Objectives and Options

Objectives	Options
Providing the community in a specific street with proper wastewater facilities.	Construction of wastewater network (main pipes, manholes, house connections and pumping station).
Facilitating the movement of cars and pedestrians in the same area.	Paving the street using interlock.
Increasing the pumped water quantity for the whole city.	Rehabilitation of the existing water wells

Sometimes more than one option can achieve the objective. It is the responsibility of the technical staff to identify the best option. The developed DET can be used to mange the discussion about objectives and options. In this process mainly the technical and engineering perspectives draw the picture of final accepted options.

5.2 Phase II: Decision Analysis

This is the main phase and called the processing phase. The decision environment consists of several issues, selection criteria, data elicitation technique, decision making techniques and the project life cycle. These issues are used to evaluate the alternatives.

Using the approach, the available alternatives are screened using the outlined hierarchy of the DMAP. The final decision can be achieved based on the understanding and incorporating all the other decision components. Two techniques are developed to be used in this phase of the approach; one for the Decision Making Technique (DMT), i.e. LP technique and the other one for Data Elicitation Technique (DET). The phase starts from checking the proposed criteria, and ends with a list of prioritized options. The decision players may check the options and check the processing method based on the developed data elicitation technique. This phase consists of the following two steps:

5.2.1 Phase II – Step 3: Identifying the Criteria

The next step of decision making after identifying the objectives and options is to decide on how to compare different options. This requires the selection of criteria to reflect performance of options in meeting the objectives. Using the developed approach, the decision maker will be responsible to establish the relationship between the decision criteria and alternatives of the decision making problem and to determine how much the criteria are sensitive for each single criterion. The evaluation of selection criteria will enable the decision maker to choose among several alternative projects and prioritize the list of identified projects.

As the research assesses the evaluation criteria in Gaza Strip municipalities, the decision making players should test the validity of criteria and developed them. Some criteria may be included or excluded or their evaluation may be modified. However, the decision making process relies on two essential elements; a correct identification of relevant criteria, and a correct measurement of these criteria. The selection criteria of MIP are:

1. ***Budget and Funds Availability***

2. ***Integration between Services***
   - ***Master Plan Availability***
   - ***Dependency on other projects***

3. ***Socio-economical Values***
   - ***Beneficiaries***

- *Employment Generation*
- *Community Participation and financial contribution*
- *Availability of Community committee*
- *Community Satisfaction*

4. *Risks*
   - *Availability of Construction Materials*
   - *Project Duration*

5. *Politics (Decision Makers Preferences)*

6. *Environment and Public Health*

7. *Municipality Capacity*
   - *Technology Requirements*
   - *Staff Capacity*

8. *Sustainability*
   - *Maintenance Requirements*
   - *Availability of Operational Expertise*
   - *Project Life Time*

5.2.1.1 Standardization and Evaluation

One of the major challenges of decision making is how to evaluate a specific criterion among the proposed options. Taking the cost of options as an example, what is the difference between two projects one of a cost of 1,000 and another one of a cost of 5,000?. The option that has the lesser cost is preferable. According to the algorithms of the developed DMT, the evaluation should be a range from 1.0 to 2.0. For research purposes, the researcher in cooperation with the research supervisor have developed the methodology of evaluation. The methodology has been discussed with the municipality of Rafah (case study) and some of the local experts. The methodology is compatible with the selected DMT, LP. All information is totally computed by the developed software based on the data sheets. The evaluation details (weight of criteria and their sensitivity) can be modified by a group of decision players following the developed DET. The following example describes how the proposed methodology can be used to evaluate the cost criterion.

- For cost of US$ 30,000 or less, the project will have 2 points
- Up to US$60,000 =1.8,

- Up to US$90,000 =1.6,
- Up to US$140,000 =1.4,
- Up to US$200,000 =1.2,
- More than US$200,000 =1.0.

Table 5.2 shows the possible options of each decision criterion. The table contains the possible options and their weights, which can be checked and modified by experts only as proposed by the developed DET.

Table 5.2: Classification of Decision Criteria

No.	Criteria	Options of Criteria					
1	**Cost (Fund Availability)**	Less than 30,000	60,000	90,000	140,000	200,000	More than 200,000
		2.00*	1.80*	1.60*	1.40*	1.20*	1.00*
2	**Integration between Services**						
	Master Plan	Yes			No		
		2.00			1.00		
	Dependency on other projects	Before		After		With	
3	**Socio-economical Values**						
	Beneficiaries	Cost / beneficiaries					
		Less than 2	5	10	20	50	More than 50
		2	1.8	1.6	1.4	1.2	1
	Employment Generation	% of Employment					
		More than 30%	25%	20%	15%	10%	Less than 10%
		2	1.8	1.6	1.4	1.2	1
	Community Financial Contribution	% of community participation on the project cost					
		More than 40%	30%	20%	15%	10%	Less than 10%
		2	1.8	1.6	1.4	1.2	1
	Availability of Community committee	Active Community Committees		Inactive Community Committees		Only Community Representatives	No Community Committees
		2		1.6		1.3	1
	Community Satisfaction	Highly Satisfied	Satisfied	No Opinion	Un Satisfied		
		2	1.7	1.35	1		
4	**Risks**						
	Availability of Construction Materials	100% Local		Partially Local		Imported	
		2		1.5		1	
	Project Duration	3 months		6 months	12 months		More than 12 months

		2	1.7	1.4	1		
5	**Politics (Decision Makers Preferences)**	Highly needed	Needed	No opinion	Not needed		
		2	1.7	1.4	1		
6	**Environment and Public Health**	More than 4.5	4	3.25	2.5	1.5	Less than 1.5
		2	1.8	1.6	1.4	1.2	1
7	**Municipality Capacity**						
	Technology Requirements	Available Tech.	Semi-available	Not Available			
		2	1.5	1			
	Staff Capacity	High Level	Acceptable Level	Low Level			
		2	1.5	1			
8	**Sustainability**						
	Maintenance Requirements	Maintenance / cost					
		Less than 0.02	0.04	0.06	0.08	0.1	More than 0.1
		2	1.8	1.6	1.4	1.2	1
	Availability of Operational Expertise	High Level	Acceptable Level	Low Level			
		2	1.5	1			
	Project Service Time	more than 30	20	10	5	1	less than 1
		2	1.8	1.6	1.4	1.2	1

* (2) points is the maximum weight and (1) point is the minimum.

The decision players may have some comments on these suggestions and they have the responsibility to make modifications on the range (classification of each criterion) and the evaluation. The DMAP provide this advantage. Using the DMAP software, the decision player will enter the total cost of the project only. The software is designed to calculate the weight of the entered cost according to the previous example if it is accepted by the experts before processing. The question here is, what is the weight of the cost as a criterion in relationship with other criteria?. This is because the preceding discussion covers only the evaluation methodology of options regarding the criteria.

5.2.1.2 Criteria Weights

Assigning a constant weight of criteria without differentiating or giving the right of change to the decision maker is a disadvantage. Also, it is difficult to determine criteria weights without human intervention and this is the advantage of LP. The research provides a developed weighing system depends on the sensitivity of each criterion. The developed method has been subjected to detailed investigation and testing using the DMAP and software and some modifications have been included. The weighing methodology overcomes the disadvantage of decision maker preferences. This methodology was developed based on the following assumptions:

1- The methodology calculates the weight of criteria without the intervention of decision maker.

2- The methodology of adaptive weight approach overcomes the weakness of conventional aggregation approaches, in which the weights are the constant determined through a prior knowledge about the problem.

3- The methodology represents the relative importance of each criterion.

The criteria in the developed approach are weighed as follows:

C_{max} = Maximum class value of any criterion,

C_{min} = Minimum class value of any criterion,

v_i = value for the criterion (i),

W = total weight of criteria (=1.0).

w_i = Adaptive weight for the criterion (i).

$vi = C_{min} /(C_{max} - C_{min})$

$W = v_1 + v_2 + v_3 + v_4 + ... + v_i$

$W = 1.0$

$w_i = v_i / W$

Table 5.3 shows an example for evaluation the criterion of cost of four options and the methodology for calculation of the weight of the criteria.

Table 5.3: Evaluation of Criteria and Weight Calculations

	Option 1 (X1)	Option 2 (X2)	Option 3 (X3)	Option 4 (X4)
Cost	35,000	40,000	80,000	160,000
Evaluation	1.8	1.8	1.6	1.0
v_i	$= C_{min} /(C_{max} - C_{min}) = 1.0 /(1.8 - 1.0) = 1.2$			

The following comments can be drawn regarding the weighing methodology:

1- When the difference between the maximum and minimum values of any criterion is small, it means that this criterion is very sensitive and should have high weight. If $C_{max} = 2$ and $C_{min} = 1.2$, vi equal 1.5. If $C_{max} = 2$ and $C_{min} = 1.8$ vi equal 9. The value of 9/W

is more than the value of 1.5/W. In other words, if the range of one criterion (for all options) is not as wide as another criterion, it will receive a higher weight.

2- When the difference between C_{max} and C_{min} is constant for two criteria but the values of C_{max} and C_{min} are varied, the weight of the criteria is more sensitive when C_{min} have higher values. This means that the difference is 0.2 and vi equal 9 if C_{min} = 1.8, and vi equal 6 if C_{min} = 1.2.

3- The weighting methodology become invalid if $C_{max} = C_{min}$. The researcher developed a methodology for weighing the criteria when $C_{max} = C_{min}$ as presented in Figure 5.4 to avoid division by zero. The figure shows the relationships between C_{max} and vi for all possible values of C_{min}. The continuous line which presents the equation (10 . C_{max} – 1.0) shows the maximum possible values of vi. These maximum values are realized when the value of C_{max} and C_{min} are very closed to each other.

In order to overcome the limitation of the methodology when the two values are the same, the developed DMAP and its supporting software are designed to test the values before doing the calculations. If there is a difference between values of C_{max} and C_{min}, the value of vi will be calculated as above and if the two values are equal, the software will calculate the weight according to the equation of the continuous line as shown in Figure 5.4 which is ($vi = 10.C_{max} - 1.0$) when $C_{max} = C_{min}$.

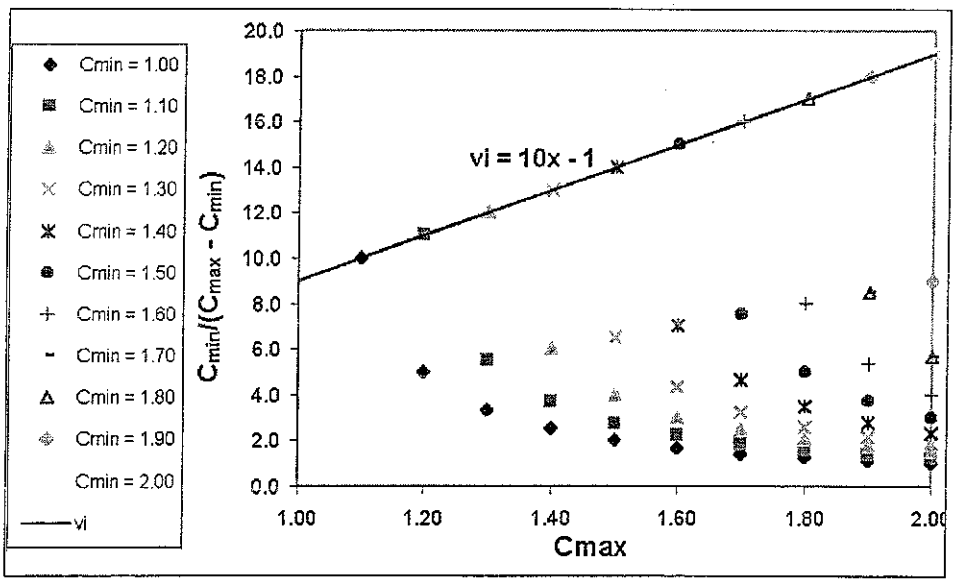

Figure 5.4: A Methodology for Weighting of Criteria

Table 5.4 shows examples for weighting the criteria. The table shows that, the weight of a criterion increases and the difference between the maximum and minimum values decreases.

Table 5.4: Criteria Weighting Methodology

Criteria	X1	X2	X3	Max.	Min.	max-min	vi = min/max-min	Wi = vi / W
Criterion 1	1.2	1.6	1	1.6	1	0.6	1.667	0.07
Criterion 2	2	2	2	2	2	0	#DIV/0! (10max.-1) = 19	0.798
Criterion 3	1.3	1.45	1.1	1.45	1.1	0.35	3.143	0.132
W (v1 + v2 +v3)							23.81	

5.2.1.3 Accept Evaluation and Weighing

If the proposed evaluation and weighing methodologies is accepted for the user of the DMAP, he can go to the next step, i.e. data sheet. If there is any objection or doubt about the methodologies, the developed DET should be used to make the necessary changes.

5.2.1.4 Data Sheet

The data sheet can be used to archive the projects for different objectives. It is designed mainly to be consistent with the approach and its components. Using the LP allows the decision player to consider the following issues:

a. Extra criteria, for specific purposes the decision maker may need more criteria to evaluate the options. For example, in prioritization of internal roads that are connecting the city center to another municipal facility, the decision maker may consider the time of trip as one of the evaluation criteria. The data elicitation technique shows the procedure for identifying new criteria as well as a decision making technique with an open structure to allow adding or removing criteria. Some experience on how to deal with LP is necessary as well as the understanding of the DMAP algorithms.

b. Project life cycle, the decision maker should be familiar with the project life cycle and its impacts. Some projects need experience with design, time limitations, or relationship with other projects for starting of operation.

Table 5.5: Data Sheet

Project Name	Upgrading of Sewerage Network	
Project Code	X1	
Location	Block 86A Tal Sultan, Rafah	
Reporting Date		
Sector	Wastewater	
Complement with Master Plan	Yes	
Dependancy on other projects	Independent	Project
Socio-economical Values		
Beneficiaries	Direct Beneficiaries	Cost / beneficiaries
	3500	43.57 ($ / Person)
Employment Generation	Total Labors	Daily Rate
	3177	$ 12
	Total Value	38124 US$
Community Financial Contribution	Community Contribution	
	0	
Availability of Community committee	Active Community Committees	
Community Satisfaction	Highly Satisfied	
Risks		
Availability of Construction Materials	100% Local	
Project Duration (months)	5.0 Months	
Politics (Decision Makers Preference)	Needed	

Environment and Public Health	Component	5, 4, 3, 2, 1
	Air Quality	5
	Noise	5
	Water Quantity	2
	Water Quality	2
	Public Health	5
	Fauna	5
	Flora	5
	Marine Life	5
	Lan use	5
	Aesthetic Features	5
	Soil	5
	Tranboundary	4
	Total	53
	Average	4.42

Municipality Capacity		
Technology Requirements	Semi-available	
Staff Capacity	Acceptable Level	
Sustainability		
Maintenance Requirements (US$)	Yearly Maintenance Requirements	
Availability of Operational Expertise	High Level	
Project Life Time (Years)	25 Years	

Table 5.5 shows a typical data sheet. The data sheet will be used by assistants of the decision makers; design engineers, supervision engineers, environmental and social auditors and financial managers. The sheet covers all the necessary information which is

required to complete the data entry for the DMAP. The data sheet has been designed considering the selection criteria of projects and the possible classification of criteria. It includes other information about the project name, code, location and sector. The data sheet has been designed based on two methodologies:

1- Specific options: if the options of a specific criterion can be limited and are already known. For example, the criteria of availability of community committees has four specific options; availability of experienced community committees, availability of inexperienced community committees, only availability of community representatives, and no community committees are available. The design of data sheet provides simplicity for the user to use the arrows and choose one option from the box.

2- Vague (unspecific) options: where it is difficult to limit and identify the options. for example the criteria of employment generation.

5.2.2 Phase II – Step 4: Decision Analysis

After the options and their data and criteria have been identified, the next stage in the process is analysis. The software provides the decision maker with a tool to analyze the data about options and compute the weights of criteria. The LP relies on the assumptions that:

1) The objective must be represented by a linear function.
2) Each constraint must be represented by a linear inequality.
3) Each variable must be non-negative.
4) The objective function is optimized and other functions are addressed as conjunctive constraints.
5) An open system is one that allows user modification, extensibility, and integration with other systems.
6) The model computes the weights from the data furnished to the model.

According to the aforementioned assumptions, the followings are the main concepts of the proposed LP model for prioritizing the MIP:

a. The objective function of the proposed model is to rank the options; MIP projects, assuming that the number of projects is (n). The solution of the model is designed to provide the decision maker with a list of ranked projects according to priority from the maximum priority to the minimum.

b. The decision variables are the options, MIP. Assuming that the decision maker has three options, X1, X2 and X3, (Option 1 = X1, Option 2 = X2 and Option3 = X3). The objective function is (aX1 + bX2 + cX3), where a, b, and c are factors and their values in this model is =1, so they were ignored.

c. (AX1 + BX2 + CX3 + . . .) less than, greater than or equal to (N), is the general form of constraints. The factor, A, B and C are the value of decision criteria and they are multiplied by the decision variables. Each criterion is compared with the maximum and minimum accepted value (RHS), 2 as maximum value and 1 as minimum value.

The model building of LP revolves around deciding which aspects of a real-world problem should be included and which should not. Also, it decides the priorities of options. The formulation of a problem to be used by solver is outlined in Table 5.6

Table 5.6: Formulation of Solver Sample Problem

Items	Option 1	Option 2	Option 3	Target Cell	Calculated RHS	Required RHS
Objective Function, factors	a	b	c			
Decision Variables	X1	X2	X3			
Constraint 1	A1	B1	C1		n1	N1
Constraint 2	A2	B2	C2	.....	n2	N2
Constraint 3	A3	B3	C3		n3	N3

Where:

Target Cell	=(aX1 + bX2 + cX3)
a, b, c	Given Factors, For MIP their values assumed as 1.0 to give equal preferences.
X1, X2, X3	Decision variables
A1, A2, A3	Given Factors, for MIP, they are the weight of the first criteria for all options.
B1, B2, B3	Given Factors, for MIP, they are the weight of the Second criteria for all options.

C1, C2, C3	Given Factors, for MIP, they are the weight of the Third criteria for all options.
N1, N2, N3	Values of Constraints, the constraints for the MIP are the maximum or minimum allowable value.
n1, n2, n3	Calculated values in order to compare the solution with the constraints and their values =AX1 + BX2 + CX3.

Formulating and running the solver will give the value of the hatched cells in Table 5.6. The required values are the values of options, X1, X2 and X3. The user must check that all constraints are achieved, by comparing the values of constraints with those calculated by Solver. Solving the aforementioned example using solver is outlined in Table 5.7.

Table 5.7: Solver Formulation and Solution

Items	Option 1	Option 2	Option 3	Target Cell	Calculated RHS	Required RHS
Objective Function, factors	1	1	1			
Decision Variables	2250	0.0	1250			
Constraint 1	0.53	0.55	0.56		1892.5	1850
Constraint 2	25	30	35	3500	100000	100000
Constraint 3	2	2	2		7000	7000

a. Solver Dialogs

The following are some parameters, dialogs and commands of Solver [MS Excel, 1998 and Fylstra et al, 1998].

b. How to Operate Solver

- If the Solver command is not on the Tools menu, install the Solver add-in.
- On the Tools menu, click Add-Ins
- In the Add-Ins dialog box, select the Solver Add-in check box, and then click OK
- On the Tools menu, click Solver.

Figure 5.5 shows the solver parameters dialog.

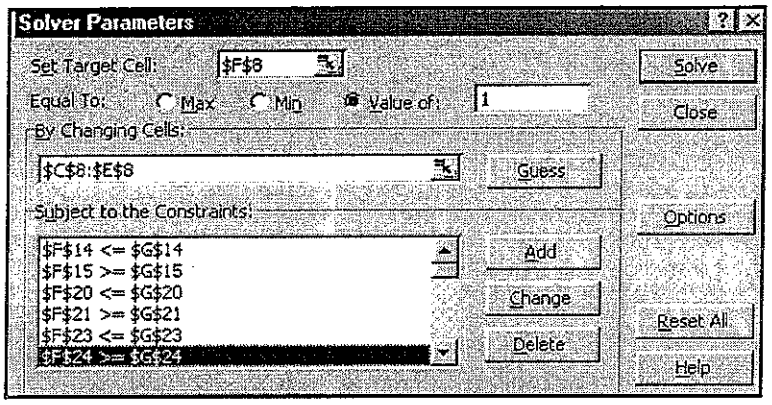

Figure 5.5: Solver Parameter Dialog

c. Solver Parameters Dialog

First: **Set Target Cell**

In the Set Target Cell box, enter a cell reference or name for the target cell. The target cell must contain a formula; (aX1 + bX2 + cX3).

Second: **Equal to**

Select one of the following:

- To have the value of the target cell be as large as possible, click Max.
- To have the value of the target cell be as small as possible, click Min.
- To have the target cell be a certain value, click Value of, and then type the value in the box.

Third: **By Changing Cells**

In the By Changing Cells box, enter a name or reference for each adjustable cell, separating nonadjacent references with commas. The adjustable cells must be related directly or indirectly to the target cell.

Fourth: **Subject to the Constraints**

Specify a restriction on the contents of the Cell reference box. Select the relationship you want to add or change (<=, = and >=) between the referenced cell and the constraint. Then enter the constraint — a number, cell or range reference, or formula — in the box to the right. Using the add, change and delete icons, the decision maker can play between the decision constraints. Clicking the Solve icon start finding the feasible and/or optimal solution.

Fifth: **Click Solve.**

To keep the solution values on the worksheet, click Keep Solver Solution in the Solver Results dialog box.

Sixth: **Reports**

Creates the type of report you specify, and places each report on a separate sheet in the workbook. Figure 5.6 shows Solver results dialog box.

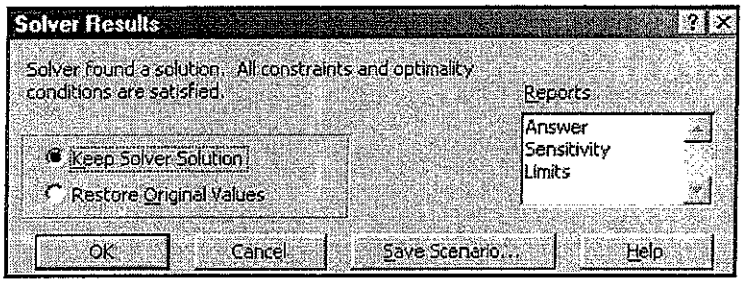

Figure 5.6: Solver Results Dialog Box.

- **Answer;** Lists the target cell and the adjustable cells with their original and final values, constraints, and information about the constraints.
- **Sensitivity;** Provides information about how sensitive the solution is to small changes in the formula in the Set Target Cell box in the Solver Parameters dialog box or the constraints.
- **Limits;** Lists the target cell and the adjustable cells with their respective values, lower and upper limits, and target values. This report is not generated for models that have integer constraints. The lower limit is the smallest value that the adjustable cell can take while holding all other adjustable cells fixed and still satisfying the constraints. The upper limit is the greatest value.

Within this stage, the decision player will have a summary sheet for all alternatives which shows the options and their criteria evaluation. The decision player only completes the data sheet. The software provides the decision player with a summary sheet showing the criteria and their weights as shown in Table 5.8.

Table 5.8: Evaluation of Criteria

Criteria	From Data Sheet	Evaluation
Cost (Budget Availability)	152,500.0	1.2
Integration with Services		
Complement with the Master Plan	Yes	2
Dependency on other Projects	Independent	
Socio-economical Values		
Beneficiaries (Direct)	43.57142857	1.2
Job Creation	25.00%	1.6
Community Participation	0.00%	1
Community Committees	Active Community Committees	2
Community Satisfaction	Highly Satisfied	2
Risk		
Construction Materials	100% Local	2
Duration (months)	5	1.7
Decision Makers Preferences	Needed	1.7
Environmental and Health	4.42	1.8
Municipality Capacity		
Technology Requirements	Semi-available	1.5
Staff Capacity	Acceptable Level	1.5
Sustainability		
Maintenance Requirements	0.00%	2
Operation Expertise	High Level	2
Project Service Time	25.00	1.8

After completing the data sheet of all options and accepting the summary sheet, the software calculates the weight of criteria based on the weighing methodology. The constraint of each criterion is computed based on the maximum and minimum evaluation of criteria; 2 and 1, assuming the following:

i. The weight of a specific criterion, Wx = 0.126 as calculated by the weighing methodology.

ii. The total weight of criteria, W = 1.0

iii. The maximum RHS value = (Wx) . (Cmax) = (2) . (0.126) = 0.252

iv. The minimum RHS value = (Wx) . (Cmin) = (1) . (0.126) = 0.126

The computed value of the RHS value after running the software should be value within the range between the maximum and minimum. Table 5.9 illustrates an example of the DMAP results. To start processing, assume the target value of the objective function is 1.0. This

means that; X1 + X2 + X3 = 1.0. The table shows that each criterion is represented by two constraints; maximum and minimum.

Table 5.9: DMAP Example

Constraints	Weight of Criteria	Options			1.000	RHS
		Project1	Project2	Project3		
		X1	X2	X3		
		0.346	0.338	0.315		
Budget and Funds Availability	0.051	2	1.5	1	0.078	0.10256
		2	1.5	1	0.078	0.05128
Integration between Services						
Socio-economical Values						
Beneficiaries	0.01	2	1.8	1.8	0.019	0.02051
		2	1.8	1.8	0.019	0.01846
Unemployment Level (Job Creation)	0.026	2	1.8	1.5	0.046	0.05128
		2	1.8	1.5	0.046	0.03846
Community Participation and fin.cont.	0.01	1.2	1.2	1	0.012	0.01230
		1.2	1.2	1	0.012	0.01025
Availability of Community committee	0.513	1	1	1	0.513	0.51282
		1	1	1	0.513	0.51282
Risks						
Availability of Construction Materials	0.051	1.5	1	2	0.076	0.10256
		1.5	1	2	0.076	0.05128
Project Duration	0.051	2	1.5	1	0.078	0.10256
		2	1.5	1	0.078	0.05128
Politics (Decision Makers Preferences)	0.051	2	1.5	1	0.078	0.10256
		2	1.5	1	0.078	0.05128
Environment and Public Health	0.041	2	1.8	1.2	0.069	0.08205
		2	1.8	1.2	0.069	0.04923
Municipality Capacity						
Technology Requirements	0.051	1	2	1.5	0.077	0.10256
		1	2	1.5	0.077	0.05128
Staff Capacity	0.051	1	2	1.5	0.077	0.10256
		1	2	1.5	0.077	0.05128
Sustainability						
Maintenance Requirements	0.041	1.8	1.5	1	0.059	0.07384
		1.8	1.5	1	0.059	0.04102
Availability of Operational Expertise	0.051	2	1.5	1	0.078	0.10256
		2	1.5	1	0.078	0.05128

From the above example it can be concluded that the three alternatives have the following prioritization order:

X1 = 0.346

X2 = 0.338

X3 = 0.315

The total value is one (1) and the first option (X1) has the highest priority. The decision maker can use any value instead of 1.0 for the total value of all decision variables, the formulation of RHS values is in need for modification in this case. However, the case study which is presented in Chapter 7 illustrates an example.

5.2.2.1 Selection, Sorting and Ranking

The result of data processing would include:

i. Selection Procedure; helps the decision maker to choose the best action or option amongst those studied. The highest weight is the highest priority.

ii. Sorting or Segmentation Procedure (Classification): helps to sort out options that seem good among a set of alternatives studied, i.e. the options that have the higher values.

iii. Ordering or Ranking procedure; help to rank the options in decreasing order of preference. The ranking operation involves establishing a preference pre-order on the set of options. This gives the decision maker an indication of the relative importance of alternatives.

5.2.2.2 Examination and Sensitivity Analysis

The decision maker can examine the prioritized list of options whether it is meaningful or not. The examination is necessary to check that the result is achieving all decision constraints. This step includes testing the software report and sensitivity analysis report.

Sensitivity analysis is a procedure, in which weights (representing preferences) and criterion evaluations are varied in order to test the stability of assessment measure of each decision alternative. The solution (ranking of decision alternatives) is said to be sensitive if small changes in weights or criterion scores produce significant changes in the order of ranked decision alternatives. After making judgments about the relative importance of options, the sensitivity analysis report of the DMAP software enables the decision maker to test the sensitivity of the decision to changes in priorities. These what-if scenarios are useful for decision making.

5.3 Phase III: Final Decision

This phase consists of two steps:

5.3.1 Phase III – Step 5: Making Choices

The final step of the decision making process is the actual choice of options and it is the computer work. After examining the results and their sensitivity, the decision players decide to accept the results. The final decisions should be discussed with all other stakeholders to ensure acceptance. If any doubt is reported, they may go to the feedback step.

5.3.2 Phase III – Step 6: Feedback

The decision making requires a continuous reassessment of choices made in the past. Individual decision makers may learn from their own mistakes, but it is important that lessons be learned in a more formal and systematic way, and communicated to others, so that they can inform future decisions. Also, it is important to reassess the decisions according to the data sheet to be sure the results are right and satisfactory. It is necessary to place heavy emphasis on the importance of thinking about the feedback and control aspects of a decision problem. During the course of work after identification of options input data may be changed due to external and internal factors, which requires reanalysis of the problem to account for these changes.

5.4 Strengths of the DMAP

The DMAP has been developed to strengthen some areas of the MIP decision making environment. The following is a summary of the strengths provided by the DMAP.

a. Identification Process

Availability of a comprehensive DMAP will encourage the municipalities to increase their efforts regarding needs assessment and brainstorming about options that can achieve developmental objectives. This requires in-depth dealing with possible options and their projected outcomes as well as consultation with the local community. On the long run, this will introduce the strategic planning to the municipalities and enhance their staff to state clearly their objectives and missions.

b. Prioritization Process

The developed approach, i.e. the DET and DMT will improve the level of transparency and accountability in the planning and implementation of MIP projects. The projects will be prioritized on scientific and analytical basis.

c. Cooperation with Local Community

Using a transparent system for project selection will build the trust among people and strengthen their relationship with the municipalities.

d. Negotiation with Funding Agencies

The analytical approach provided by the developed DMAP will help the municipalities to state their objectives and necessary options. The donors will be more comfortable when they provide donations for MIP. The donors will adopt the municipal justifications, which are determined based on the DMAP. The analysis will support the appraisal reports and fund requests.

e. Crisis Management

Special attention is paid for emergency projects during crisis, i.e. job creation projects and municipal support projects. These are different in their objectives and outcomes. However, the DMAP can handle this group of projects. This will help the municipalities manage their resources.

f. Decision Criteria

The decision criteria were intensively investigated. The DMAP uses all criteria to solve any prioritization problem of MIP. The decision criteria reflect performance of options in meeting the objectives of MIP. Highlighting all relevant criteria for MIP was strengthening by proposing a methodology for evaluation of each criterion among options and another methodology for weighting the criteria.

g. Computerized DMAP

The developed software has the following strengths:

a. Solver is one of several software that are using LP principles in optimizations. It depends on Windows and MS Excel, they can be used friendly.

b. Easy in formulation rather than writing the inequalities with risk for mistakes and it is possible to change any variable or factor to test the variations.

c. Reporting of Solver results is simple and comprehensive.

d. Solver could be developed easily by constructing macros using excel or Visual Basic Software.

Ch 6 IMPLEMENTATION OF THE PROPOSED APPROACH

6 IMPLEMENTATION OF THE PROPOSED APPROACH

6.1 Case Study Selection

The developed DM approach has been implemented using a real-life decision making environment in order to test its validity and applicability. One of the investigated five municipalities; i.e. Jabalia, Gaza, Deir Al Balah, Khan Younis and Rafah is proposed. During the course of research, the Municipality of Rafah representatives showed their willingness to demonstrate the developed DMAP and provided the necessary assistance. Rafah municipality was selected for the case study demonstration. Characteristics of implemented projects, proposed projects, capacity of the municipality staff, organization of the municipality, availability of a master plan and three year investment plan, and willingness of the municipality for cooperation are issues that strengthened the selection of Rafah Municipality.

6.1.1 Rafah Municipality

Rafah is one of the oldest cities in Palestine. Rafah is located to the south of the Gaza Strip and it is the main link between Gaza Strip and Egypt and the outside world. Rafah gained the status of a municipality only recently (1972), and prior to that, it was governed by a village council. The area of Rafah city that is covered by the master plan of 1999 is approximately 26,000 donums. There are ten populated districts in Rafah city [IUG, 2002 – PCBS, 2000]. Population is about 164,370 people (year 2004 updated figures) [PCBS, 2004], 85% of whom are refugees living in refugee camps.

The city was occupied in 1967 and suffered significant destruction during Al Aqsa Intifada. Several neighborhoods were demolished including buildings as well as infrastructure facilities. 1,636 homes were totally destroyed and 2,850 homes were partially destroyed [MOR & RG, 2004]. Also workshops and small business activities were destroyed. Several water networks, wastewater network and roads were either fully or partially destroyed during the attacks. The revenues of the municipality were dramatically reduced during Al Aqsa Intifada [IUG, 2002 and EMCC, 2004]. During the demonstration of the case study, Rafah city and its camp were subjected to the most violent demolishing.

6.1.2 Decision Making in Rafah Municipality

The decision making related to infrastructure projects is characterized by the following:

a. The municipality has a master plan that was prepared in 1999.

b. The municipality has a three years investment plan prepared in 2000. The proposed projects of the plan were identified by the municipality staff or by petitions from the local conditions. All proposed projects comply with the master plan and have the community acceptance.

c. The municipality has an acceptable organizational structure and employees cover all the necessary areas.

d. The municipal staff received capacity building, training programs and supporting from the Canadian Program to support the Palestinian municipalities.

e. The municipality works effectively with the local community. The local community committees are active and experienced in how to deal with municipality, community and funding agencies.

6.2 Demonstration of the DMAP on the Case Study

The demonstration of the developed DMAP on the case study, i.e. Municipality of Rafah, is shown accordingly, in step-by-step compliance to the DMAP.

6.3 Case Study - Phase I: Input of Data and Facts

The demonstration started by formulating the decision making context which means the decision problem and decision players. The decision problem is to prioritize some of projects in order to achieve development in some neighborhoods in Rafah. The decision players are:

1. Decision Maker: a group from the municipality served as the decision makers. The group included the municipality General Director and three municipal engineers. However, in Rafah Municipality, the decision makers are the councilors.

2. Analysts: the researcher played the role of the analysts.

3. Stakeholders: for the research purposes, the decision makers and analysts played this role for time constraints. Also Rafah as mentioned earlier was subjected to sieges and curfews, which prevented the coordination for structured meetings with stakeholders.

6.3.1 Case Study - Phase I – Step 1: Identify Objectives

The objective was the development of several neighborhoods in infrastructure services. The objective was already achieved but was studied to demonstrate the case study.

6.3.2 Case Study - Phase I – Step 2: Identify Options

The options that achieve the objectives were implemented. Nine options (projects) of infrastructure projects (implemented) were selected in close cooperation between the municipality representatives and the researcher. Table 6.1 shows the identified objectives and projects for the case study purposes. The decision players agreed on the objectives and projects.

Table 6.1: Case Study – Objectives and Projects

No.	Projects	Objective	Location
1.	Upgrading of Sewerage Network	Improving the wastewater system	Block 86A Tal Sultan, Rafah
2.	Upgrading of Sewerage Network	Improving the wastewater system	Block 88 Tal Sultan, Rafah
3.	Construction of Sewerage Network	Provide the community with proper wastewater system	Amer Neighbourhood, Rafah
4.	Construction of Sewerage Network	Provide the community with proper wastewater system	Block A, Junainah, Rafah
5.	Construction of Wastewater Trunk Line	Provide the community with proper wastewater system	Block A, Junainah, Rafah
6.	Omar Ben Al Khattab Road	Provide the community with complete infrastructure facility	City Center, Rafah
7.	Deir Yaseen School Road	Facilitate the movement and increase the accessibility	Al Junainah Area, Rafah
8.	Al Badeel Road - No 35	Provide the community with complete infrastructure facility	Tal Al Sultan, Rafah
9.	Imam Ali road No 9	Provide the community with complete infrastructure facility	West Rafah

6.4 Case Study - Phase II: Decision Analysis

6.4.1 Case Study - Phase II – Step 3: Identifying the Criteria

A set of meetings were conducted with the municipal staff in Rafah Municipality in order to discuss the proposed criteria for prioritization of MIP, evaluation methodology, weighting methodology and the data sheet. Several comments, suggestions and inquiries were raised and discussed. The municipal staff completed the data sheets for the selected nine projects. Annex (IV) shows the data of each project and the weight of each criterion according to the proposed classification and evaluation methodology. The developed DET should be used if the decision players have any comments about the criteria, evaluation and weighting methodology.

6.4.2 Case Study - Phase II – Step 4: Decision Analysis

After completing the data sheets and translating the data furnished into values ranged between 1.0 and 2.0, the processing of software starts. The selected DMT, LP was demonstrated using the developed software. The furnished data of all projects were transformed to the main page of software. Table 6.2 shows the final evaluation of criteria, weight of criteria, values of the RHS (upper and lower limits) and the final ranking of projects. To start the processing of the selected nine projects, the following issues were assumed:

i. The problem is Linear

ii. Total value of the decision variables is 1.0 (target cell value is = 1.0), it means that all projects (decision variables have values less than 1.0; i.e. 0.2, 0.123, etc.

iii. Maximum value of RHS of each criterion is (2 x Weight of criterion) and the minimum is (1 x Weight of criterion).

Table 6.2: Ranking of Projects

Constraints	Weight of Criteria	Alternatives									1.000	RHS
		Project 1	Project 2	Project 3	Project 4	Project 5	Project 6	Project 7	Project 8	Project 9		
		X1	X2	X3	X4	X5	X6	X7	X8	X9		
		0.111127	0.111171	0.111136	0.111042	0.111206	0.110793	0.111159	0.111230	0.111136		
		1.2	1.6	1	1	1	1	1	1.4	1	0.008	0.0147601
Cost	0.007	1.2	1.6	1	1	1	1	1	1.4	1	0.008	0.0073801
Integration between Services												
		2	2	2	2	2	2	2	2	2	0.467	0.4674047
Master Plan	0.234	2	2	2	2	2	2	2	2	2	0.467	0.2337023
Dependency on other projects												
Socio-economical Values												
		1.2	1.2	1.4	1	1.8	1.6	1.8	1.8	1.6	0.015	0.0196802
Beneficiaries	0.01	1.2	1.2	1.4	1	1.8	1.6	1.8	1.8	1.6	0.015	0.0098401
		1.6	1.6	1.8	1.8	1.6	1.4	1.4	1.4	1.6	0.008	0.0098401
Job Creation	0.005	1.6	1.6	1.8	1.8	1.6	1.4	1.4	1.4	1.6	0.008	0.00492
		1	1	1	1	1	1	1	1	1	0.111	0.2214022
Community Participation and fin.cont.	0.111	1	1	1	1	1	1	1	1	1	0.111	0.1107011
		2	2	2	2	2	1	2	2	2	0.023	0.0246002
Availability of Community committee	0.012	2	2	2	2	2	1	2	2	2	0.023	0.0123001
		2	2	2	2	2	2	2	2	2	0.467	0.4674047
Community Satisfaction	0.234	2	2	2	2	2	2	2	2	2	0.467	0.2337023
Risks												
		2	2	2	2	2	2	2	2	2	0.467	0.4674047
Availability of Construction Materials	0.234	2	2	2	2	2	2	2	2	2	0.467	0.2337023

Constraints	Weight of Criteria	Alternatives										RHS
		Project 1	Project 2	Project 3	Project 4	Project 5	Project 6	Project 7	Project 8	Project 9		
		X1	X2	X3	X4	X5	X6	X7	X8	X9		
		0.111127	0.111171	0.111136	0.111042	0.111206	0.110793	0.111159	0.111230	0.111136		
		1.7	1.4	1.4	1.4	1.4	1.4	1.7	1.7	1.7	0.006	0.0073801
Project Duration (Months)	0.004	1.7	1.4	1.4	1.4	1.4	1.4	1.7	1.7	1.7	0.006	0.00369
		1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	0.335	0.3936039
Politics (Decision Makers Preferences)	0.197	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	0.335	0.196802
		1.8	1.8	1.8	1.8	1.8	2	2	2	2	0.005	0.00492
Environment and Public Health	0.002	1.8	1.8	1.8	1.8	1.8	2	2	2	2	0.005	0.00246
Municipality Capacity												
		1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	0.258	0.3444034
Technology Requirements	0.172	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	0.258	0.1722017
		1.5	2	2	2	2	1.5	1.5	1.5	1.5	0.011	0.0123001
Staff Capacity	0.006	1.5	2	2	2	2	1.5	1.5	1.5	1.5	0.011	0.0061501
Sustainability												
		2	2	2	2	2	2	2	2	2	0.467	0.4674047
Maintenance	0.234	2	2	2	2	2	2	2	2	2	0.467	0.2337023
		2	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	0.010	0.0123001
Availability of Operational Expertise	0.006	2	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	0.010	0.0061501
		1.8	1.8	1.8	1.8	1.8	2	2	2	2	0.005	0.00492
Project Life Time	0.002	1.8	1.8	1.8	1.8	1.8	2	2	2	2	0.005	0.00246

The following conclusions can be drawn from the above results:

a. The problem is solved mainly as a nonlinear problem. When the box that restricts the solution to linear. The results were all projects having zero value and one is selected as optimal solution with value of 1.0 (project 8).

b. The values are very close to each other, which means that the solution is very sensitive and it is difficult to rank the alternatives.

In order to overcome the aforementioned limitations, several alternatives were studied:

a. Considering new constraints, such as (all decision variables should be more than 1.0)

b. Considering the cost constraint always as a binding constraint.

c. Drawing a relationship between the cost and beneficiaries and decision variables and consider it as a binding constraint. This issue was highlighted by Mr. Nolberto Munier, Senior Consultant from Teamic International – Canada. Mr. Munier was consulted during the research activities.

d. Using the (COUNTIF) function in excel to avoid the repetition of values.

e. Multiplying the upper limit and lower limit of the RHS by 45 (Sum of 9, 8, 7, 6, 5, 4, 3, 2 and 1) and using the (integer) property. This issue provides a semi-acceptable solution but about six projects have the same value.

f. Solving the problem by dividing the criteria into groups; i.e. without employment generation criterion as an example or using stages in processing. This gives different results (more acceptable), but it is time consuming and difficult to be understood and justified. This issue was highlighted by Dr. Rifat Rustom, LP Expert, Islamic University of Gaza during the consultation by the resercher.

All of these suggestions are very difficult in formulation and their results contain errors or unjustified solutions. Also they were very difficult regarding the generalization of the software to future problems. In addition, Solver provided infeasible solutions.

The researcher consulted the Solver developers in this regard (Frontline Systems, Inc.). They agreed that the solver has a limitation in how to avoid the repletion of the same value. Fortunately, they developed new supporting software to be used with Solver to help in ranking of projects. The supporting software includes a property called (alldifferent) which ensures that the projects have different values.

Using (alldifferent) property ensures integer values of the decision variables. So it was necessary to add a factor to ensure that the values will be a range from 9.0 to 1.0, where 9.0 is the number of projects.

Several alternatives were studied, and the results were either infeasible, leading to extra sub-problems, or were unjustifiable. The final trial was as follows:

1. Insert the number of alternatives (9.0).
2. Calculate the sum of projects numbers. (45).
3. Multiply the RHS of each criterion by (45).
4. Add a new constraint to restrict the total value of projects to (45).
5. Add new two constraints to ensure all results are more than 1.0 and less than 9.0.
6. All projects have integer values.
7. Solve the problem as maximization problem.

Figure 6.1 shows the modified Solver dialog after considering the supporting file.

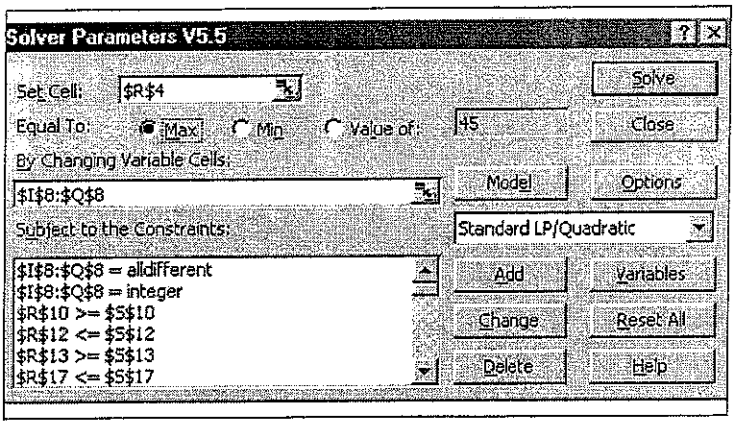

Figure 6.1: The Modified Solver Dialog

6.4.2.1 Selection, Sorting and Ranking

Table 6.3 illustrates the final results.

Table 6.3: Final Results

Constraints	Weight of Criteria	Projects										
		Project 1	Project 2	Project 3	Project 4	Project 5	Project 6	Project 7	Project 8	Project 9	40.0	RHS
		X1	X2	X3	X4	X5	X6	X7	X8	X9		
		7	4	1	2	3	5	6	8	9		
Rank		3	6	9	8	7	5	4	2	1		
		1.2	1.6	1	1	1	1	1	1.4	1	0.833	1.1529223
Cost	0.007	1.2	1.6	1	1	1	1	1	1.4	1	0.833	0.7205765
Integration between Services												
		2	2	2	2	2	2	2	2	2	16.429	16.429143
Master Plan	0.234	2	2	2	2	2	2	2	2	2	16.429	16.429143
Dependency on other projects												
Socio-economical-Values												
		1.2	1.2	1.4	1	1.8	1.6	1.8	1.8	1.6	0.836	0.9727782
Beneficiaries	0.01	1.2	1.2	1.4	1	1.8	1.6	1.8	1.8	1.6	0.836	0.5404323
		1.6	1.6	1.8	1.8	1.6	1.4	1.4	1.4	1.6	2.314	2.723779
Job Creation	0.005	1.6	1.6	1.8	1.8	1.6	1.4	1.4	1.4	1.6	2.314	2.1184948
		1	1	1	1	1	1	1	1	1	3.891	3.8911129
Community Participation and fin.cont.	0.111	1	1	1	1	1	1	1	1	1	3.891	3.8911129
		2	2	2	2	2	1	2	2	2	0.817	0.8646918
Availability of Community committee	0.012	2	2	2	2	2	1	2	2	2	0.817	0.4323459
		2	2	2	2	2	2	2	2	2	16.429	16.429143
Community Satisfaction	0.234	2	2	2	2	2	2	2	2	2	16.429	16.429143
Risks												
		2	2	2	2	2	2	2	2	2	16.429	16.429143
Availability of Construction Materials	0.234	2	2	2	2	2	2	2	2	2	16.429	16.429143

Constraints	Weight of Criteria	Projects										
		Project 1	Project 2	Project 3	Project 4	Project 5	Project 6	Project 7	Project 8	Project 9		
		X1	X2	X3	X4	X5	X6	X7	X8	X9		
		7	4	1	2	3	5	6	8	9		
		1.7	1.4	1.4	1.4	1.4	1.4	1.7	1.7	1.7	3.228	3.429944
Project Duration (Months)	0.004	1.7	1.4	1.4	1.4	1.4	1.4	1.7	1.7	1.7	3.228	2.8246597
		1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	11.760	11.759808
Politics (Decision Makers Preferences)	0.197	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	11.760	11.759808
		1.8	1.8	1.8	1.8	1.8	2	2	2	2	7.488	7.7822258
Environment and Public Health	0.002	1.8	1.8	1.8	1.8	1.8	2	2	2	2	7.488	7.0040032
Municipality Capacity												
		1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	9.079	9.0792634
Technology Requirements	0.172	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	9.079	9.0792634
		1.5	2	2	2	2	1.5	1.5	1.5	1.5	2.090	2.5940753
Staff Capacity	0.006	1.5	2	2	2	2	1.5	1.5	1.5	1.5	2.090	1.9455564
Sustainability												
		2	2	2	2	2	2	2	2	2	16.429	16.429143
Maintenance	0.234	2	2	2	2	2	2	2	2	2	16.429	16.429143
		2	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	2.046	2.5940753
Availability of Operational Expertise	0.006	2	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	2.046	1.9455564
		1.8	1.8	1.8	1.8	1.8	2	2	2	2	7.488	7.7822258
Project Life Time	0.002	1.8	1.8	1.8	1.8	1.8	2	2	2	2	7.488	7.0040032

Discussing the results with the municipality of Rafah staff shows that the results are acceptable and justified. They indicate that the ranking is acceptable for most of projects. Only project (X6) must have a higher priority compared with X7, X8 and X9. The high cost of the project, unavailability of community committees and the long implementation period contributed in this result. In order to solve such unsatisfactory results, the municipality is recommended to follow the following measures which increase the opportunity of this project:

1. Dividing the project into phases, this will minimize the cost of each phase and minimize the implementation period.
2. Strengthening the community by formulating community committees.
3. Increasing the job creation and enhancing the community to participate financially.

6.4.2.2 Examination and Sensitivity Analysis

Sensitivity analysis is used to test the robustness of the results provided by the DMAP. In particular, changing the upper and lower limits, changing the weighting methodology and changing the evaluation of some criteria have been investigated. Five solutions were investigated as follows:

Solution (1): It is the original solution of the case study based on the furnished data.

Solution (2): Linked the upper and lower limits to the maximum and minimum criteria evaluation instead of using 1 and 2 for all criteria.

Solution (3): Linked the upper and lower limits to the maximum and minimum criteria evaluation instead of using 1 and 2 for all criteria with minimizing the range by increasing the lower limits by 0.1 for criteria that have differences between the upper and lower evaluation values.

Solution (4): All criteria have the same weight =1.0.

Solution (5): Changing the evaluation of criteria for one project (X2) by assigning 2 for most of criterion.

Solution (6): Similar to solution (1) but use the range of 1-10 for criteria evaluation.

Table 6.4 shows the priorities of projects in each solution. The following points were raised:

i. The results show that the first two solutions are very similar. This is obvious and make the optimal solution very closed to the limits of criteria. This solution increases the number of binding criteria and dropping-down their slack values to zero. In general, all slack values of criteria in solution 2 have values less than or equal the slack values for the same criteria in solution 1 as shown in Table 6.5. Table 6.5 shows sample for some criteria and their slack values as ratio of the total calculated value of each criteria.

ii. In principle, solution 2 is similar to solution 3 but solution 3 has more critical range for evaluation of criteria. This increases the number of binding criteria and gives different results. However, this practice is not recommended as it allows the decision maker interventions.

iii. Solution 4, which gives all criteria the same weight with ignorance of the proposed weighting methodology, the results were different. This solution gives all criteria the same weight without any preference to the more sensitive criterion. The results are different and the slack values also are different.

iv. Solution 5, every one can expect that project (X2) should have the first priority, the results is not consistent with the expectation. This resulted from that, assigning 2 for most of criterion increases the range between limits. However, this is considering as a weak point in the software and in need for further investigation. The thesis investigated several issues to solve it but all were unfeasible.

v. Solution 6 has the same results of solution 1. This means that, the range of evaluation is not a matter.

Table 6.4: Results of Prioritization for Different Solutions

Project	Priority					
	Solution 1	Solution 2	Solution 3	Solution 4	Solution 5	Solution 6
X1	3	4	1	9	9	3
X2	6	9	9	4	4	6
X3	9	8	8	8	8	9
X4	8	7	7	7	7	8
X5	7	6	6	2	6	7
X6	5	5	3	6	2	5
X7	4	3	5	5	5	4
X8	2	2	2	3	3	2
X9	1	1	4	1	1	1

Table 6.5: Examples of Slack Values of criteria

Criteria		Slack Ratio					
		Solution 1	Solution 2	Solution 3	Solution 4	Solution 5	Solution 6
Cost	Upper	73.1%*	44.0%*	42.3%*	39.5%*	66.7%*	73.1%*
	Lower	13.5%	10.0%	2.2%	12.8%	16.7%	13.5%
Master Plan	Upper	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Lower	50.0%	0.0%	0.0%	0.0%	0.0%	50.0%
Beneficiaries	Upper	29.3%	14.4%	17.1%	14.1%	20.0%	29.3%
	Lower	35.3%	36.4%	28.5%	36.6%	40.0%	35.3%
Number of binding Criteria		**6**	**15**	**16**	**15**	**9**	**6**

* Slack ratio calculated as (slack value / criteria value of all projects), this ratio calculated by the software. If the slack value = 0.0 this criterion is binding criterion.

6.5 Case Study - Phase III: Final Decision

6.5.1 Case Study - Phase III – Step 5: Making Choices

The results of the software were accepted. The following are the main strengths of the software:

a. The linear programming-using Solver is implemented successfully.

b. The software provides a prioritization (ranking) of all projects.

c. The software can be used successfully to prioritize small as well as large number of projects.

d. The results are very coinciding with the preferences of decision makers and technical experts about the prioritized projects.

6.5.2 Case Study - Phase III – Step 6: Feedback

This step was effectively utilized during the case study demonstration. The complaints about the initial results of the software were studied several times.

6.6 Conclusion

The linear programming can be implemented successfully using Solver as a user-friendly application. The experimental results through the case study, show that the overall performance of the proposed algorithm is acceptable. The Excel based solver was poor to solve the problems MIP properly; it was in need for other supporting applications. The Premium Solver Platform Version 5.5 was useful in this regard.

One of the limitations of the Solver is how to build the dependency among the projects. For the case study purposes, this problem was solved by a simple algorithm, which was difficult to generalize. The researcher consulted Solver Developer regarding this limitation. They agreed and declare that they do not have any supporting materials in this regard.

Ch 7 GENERAL REMARKS, CONCLUSIONS AND RECOMMENDATIONS

7 GENERAL REMARKS, CONCLUSIONS AND RECOMMENDATIONS

7.1 Difficulties of the Study

Conducting this research was subject to some limitations. In addition to the limited available resources, the main limitations were the lack of detailed and accurate information about the current practices of decision making within the local municipalities. Also, the local libraries are poor in scientific references in the fields of decision making, decision making techniques, data elicitation techniques as well as the prioritization software. No previous studies at the local level have discussed this issue. Also, the prevailing political constraints; closures, siege, curfew in the Palestinians communities and areas have prevented the researcher to travel several times to the municipalities. The prevention of travel for Palestinians from Gaza Strip to the West Bank has also limited the study to Gaza Strip municipalities.

A set of measures were adopted to overcome the obstacles such as using the internet and email to contact international experts in the field of decision making. They were cooperative and sent some of their research works and papers. Tens of papers were collected from the websites of international conferences and through corresponding with decision making specialists.

Several visits were paid to the municipalities to collect the data. Previous experience of the researcher and supervisor helped to achieve the thesis objectives.

Unavailability of computer programs and limited LP applications in Gaza Strip was a constraint. Only two programs were available; Lindo and Solver.

7.2 Summary of Contributions

The thesis has addressed the fundamentals and algorithm of a Linear Programming decision making technique to be used as tool for prioritization of Municipal Infrastructure Projects. The Linear Programming Technique is part of a proposed Decision Making Approach, which is the main objective of this thesis. To conclude the contributions of the thesis, the following issues can be emphasized:

a. The planning of alternatives is essential and it becomes more important if it deals with development of socio-economic conditions and life of people, i.e. infrastructure projects.

b. The decision players in MIP projects are the decision maker, analyst and stakeholders. The stakeholders may be institutions or individuals.

c. Investigating the decision making criteria in the world shows that the developed countries consider mainly; cost, time and environment in planning of alternatives. In the developing countries the criteria include risk and experience. In general, the decision criteria should be comprehensive and measurable. The criteria in Gaza environment are, cost, integration between services, socio-economical values, risks, politics, environment, municipal capacity and sustainability. Some of these main groups are branched to sub-criteria.

d. Several decision making techniques are available. Most of them have been developed from the practical experience based on some mathematical formulas. There were doubts about the mathematical background of some DMT. However, they were effectively utilized for different purposes. The research proves that the LP is the a suitable technique in planning of MIP in the Palestinian environment.

e. A framework of the Data Elicitation Technique has been suggested based on the Scenario Analysis and Delphi Technique to help the decision players in data collection and processing.

f. The local decision making practices are not comprehensive or transparent and in need for development. A comprehensive decision making approach has been proposed for planning of municipal infrastructure projects. The approach consists of three phases and six steps. The phases are input: data and initial ideas, Process: decision making analysis, and output: making choices. The decision steps are identifying objectives, identifying projects, identifying the criteria, analysis of the projects, making choices and feedback.

g. The developed DMAP is proposed to strengthening some areas of local decision making environment. These areas would include, identification practices,

prioritization practices, cooperation with local community, negotiation with funding agencies and crises management.

h. The linear programming can be implemented successfully using Solver as a user-friendly application. The experimental results, case study, show that the overall performance of the proposed algorithm is acceptable. The Excel based solver was poor in solving the problems properly; it was in need for other supporting applications. The Premium Solver Platform Version 5.5 was useful in this regard.

7.3 Directions for Future Works

The following issues are recommended:

a. Recommendations for the Municipalities and Ministry of Local Government

1- Using the developed DMAP for municipal infrastructure identification and prioritization is recommended in order to increase the quality, effectiveness and transparency of the selection process.

2- The Ministry of Local Government should become involved and participate in planning of any development activity. This is to ensure that the proposed projects are priorities. The ministry can play an effective role in the relationship with donors, allocation of developmental budgets, coordination with other ministries and the reshaping of the donors' selection criteria to suit the local situation and planning methodologies. In future work, representatives from the ministry of local government should participate in DET.

3- The municipalities should reshape the people's understanding and develop new mechanisms to build up trust and transparency in relation with the community. This can be achieved by public meeting with the community or committees. Implementing community-based projects is an excellent vision in this regard.

4- Capacity building and training for the municipal staff is needed in areas such as; planning of priorities, evaluation of project impacts, strategic planning, preparing proposals and negotiation with donors.

5- It is recommended to restructure the whole decision making situation in the municipalities, i.e. projects identification, projects prioritizations, and expert opinion elicitation. The decision makers will be able to make more sustainable decisions.

b. Recommendations for the DMAP

1- Further work will integrate the developed approach and software. Further development of the developed software using more simple windows application like Visual Basic is recommended.

2- The developed software fulfilled the general requirements of the DMAP. Some particular requirements may be points for further investigation, i.e. dependency between projects.

c. Recommendations for Future Work

1- Research work should be encouraged in the areas of evaluation of implementation of projects, cost recovery plans, community-based projects and how to draw the attention of donors to invest in development.

2- Development of methodologies for evaluation and weighting the environmental, health, socio-economical impacts is needed.

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Annexes

Annex I: **MCDM Techniques based on the Prior Articulation of Preferences.**

Annex II: **List of Meeting with Municipal Representatives, Decision Makers and Experts.**

Annex III: **Solution of LP Problems with Simplex Method.**

Annex IV: **Case Study - Summary of Data Sheets and Weight of Criteria.**

Annex – I: Methods based on the Prior Articulation of Preferences.

[Mollaghasimi, 1997 – Dodgson, 1998 - Moeffaert, 2003 – Mendoza, 1999 - Triantaphyllou, 1998, Winston, 1995]

Method	Description	Advantages and Disadvantages
- **Scoring Methods (Linear Additive Model) (weighted sum model - WSM)** - **weighted product model (WPM)** (multi-attribute, deterministic and the output is based on ordinal ranking)	The methods assign weights to the criteria and then rate the alternatives against each criterion. - The criteria should be independent and uncertainty not to be formally built into the decision process. - decide the range of weighing scale of the criteria (1-10 for example) and decide the range of weighing scale of alternatives (0-10 for example) - The value of the scores of each alternative is calculated by multiply weight of each alternative by the relevant criteria and calculate the total value for each alternative. - The alternative with the highest value is selected as the best option. - weighted product model (WPM): The WPM is very similar to the WSM. The main difference is that instead of addition in the model there is multiplication. Each alternative is compared with the others by multiplying a number of ratios, one for each criterion. Each ratio is raised to the power equivalent to the relative weight of the corresponding criterion.	**Advantages:** - Easy and simple - Help the decision-maker to structure and analyze the decision problem. - Models of this type have a well-established record of providing robust and effective support to decision-makers working on a range of problems and in various circumstances. **Disadvantages:** - It tend to be rather ad hoc because the interpretation of the scales is not pre-specified and the scales are often misinterpreted as a ranking rather than as a relative importance. - The scores on attributes are not truly weights - The use of linear weighted sum to compute the values of the alternatives has little theoretical foundation to support it. - However, this simple arithmetic is only appropriate if the criteria are mutually preference independent.
Performance Matrix (Consequence Table)	- each row describes an option and each column describes the performance of the options against each criterion - numerical, bullet point scores or color coding. - It is similar to the scoring method and including qualitative terms and binary terms.	**Advantages:** - It is an intuitive processing of the data can be speedy and effective **Disadvantages** - it may lead to the use of unjustified assumptions, causing incorrect ranking of options - some of these criteria are measured in cardinal numbers (price), some in binary terms (a tick indicates presence of a particular feature), and one in qualitative terms. - The information in the basic matrix is usually converted into consistent numerical values. - The decision maker is in need to establish scores for each option to evaluate the options.

Method	Description	Advantages and Disadvantages
Preference Based Methods (MAV is a multi-attribute and multi-objective, deterministic and the output is based on cardinal ranking) (MAUT is a multi-attribute and multi-objective, uncertain outcomes and the output is based on cardinal ranking)	- Used to solve multi-attribute and multi-objective decision problems to rank a set of alternatives. - Characterized mathematically the decision maker preferences over a set of attributes in the form of a real-valued function. - Multi-attribute Value Function (MAV) function can be used in decision situations where no uncertainty is involved. - Multi-attribute Utility Function (MAUT) aids the decision-maker in selecting the best option from among a set of 'n' alternatives in the presence of uncertainty. - -	**Advantages:** - MAV and MAUT have strong theoretical foundations. - MAUT can incorporate uncertainty in the process. - MAUT allows attributes to interact with each other in other than a simple, additive fashion - MAUT does not assume mutual independence of preferences. **Disadvantages:** - MAV, for large number of alternatives and attributes, this would be virtually impossible to do in an objective and consistent fashion. - Assessment the components of MAV and MAUT requires information that is difficult for the decision maker to provide. - Difficulties of assessing scaling constants for MAV and MAUT and in ensuring that the underlying assumptions. - In MAUT, the including of uncertainty results in additional complexities in both the assessment and computational process. - MAUT [UTLR, 2000] In subsequent years some limitations have become apparent in the ability of this line of theory to express the preferences of individuals. However it remains relevant to most areas of government decision making about marginal impacts on community welfare - MAUT, in its most general form it is relatively complex and best implemented by specialists on major projects where time and expertise are both necessary and available. - MAUT does not directly help decision makers in undertaking complex multi-criteria decision tasks. it is relatively complex and best implemented by specialists on major projects where time and expertise are both necessary and available
The Analytical Hierarchy Process (multi-attribute, deterministic and the output is based on cardinal ranking – ratio scale)	- (AHP) also develops a linear additive model, but, in its standard format, uses procedures for deriving the weights and the scores achieved by alternatives which are based, respectively, on pair-wise comparisons between criteria and between options - Allows the consideration of both objective and subjective factors is selecting the best alternative. - Used to arrive at a ratio-scale cardinal ranking alternatives for multi-attribute decision problems. - AHP is based on three principles; decomposition, comparative	**Advantages:** - The pair-wise comparison form of data input straightforward and convenient - One of the key strengths of AHP is that it uses ratio scale measurements, which allows the decision maker to make direct comparisons among the celebrities. - AHP is one of the most popular multi-criteria decision making methodologies. - Flexible and easy for use.

Method	Description	Advantages and Disadvantages
	judgment and synthesis of priorities. - The AHP is applicable to decision situations involving subjective judgment.	- Commercial software packages are available. - It uses quantitative and qualitative data **Disadvantages:** - Rank Reversal: the reversal of the preference order of the alternatives when new options are introduced in the problem. The ranking of AHP is produced by a subjective opinion. - The ambiguity in the meaning of the relative importance of one factor when it is compared to another factor. - The type of questions asked during pair-wise comparisons are meaningless. - On the other hand, serious doubts have been raised about the theoretical foundations of the AHP and about some of its properties. In particular, the rank reversal phenomenon has caused concern. This is the possibility that, simply by adding another option to the list of options being evaluated, the ranking of two other options, not related in any way to the new one, can be reversed. This is seen by many as inconsistent with rational evaluation of options and thus questions the underlying theoretical basis of the AHP. - Time consuming and tedious if there are many levels in the decision hierarchy.
Goal Programming (Multi-objective, deterministic and the output identifies the best compromise solution)	- The method facilitates the consideration of multiple conflicting objectives by assigning each priority. - The method is used when the relationship between the objectives and decisions variables can be expected mathematically.	**Advantages:** - Much easier than MAUT and MAV functions. **Disadvantages:** - Applicable only for multi-objective programming problems. - The resulting solution to a goal program may be dominated. (there is may exist a solution that is better in terms of some or all objectives than the solution obtained through goal programming.
methods based on fuzzy sets	- Methods of this type are not yet widely applied (developed by Zadeh in 1960s). - Options are 'fairly attractive' from a particular point of view or 'rather expensive', not simply 'attractive' or 'expensive'. Fuzzy arithmetic then tries to capture these qualified assessments using the idea of a membership function, $\mu(x)$, through which an option would belong to the set of, say, 'attractive' options with a given degree of membership, lying between 0 and 1. (e.g. $\mu = 0.8$ suggests quite a strong degree of belief that the problem is a	**Advantages:** - it recognizes the reality that many of the concepts involved in decision making are far from clear or precise to those involved. - Fuzzy sets provide an explicit way of representing that vagueness in the decision maker's mind in an explicit way. - **Disadvantages** - difficult for non-specialists to understand - do not have clear theoretical foundations from the perspective of

Method	Description	Advantages and Disadvantages
	major one, but not complete certainty) - Building on assessments expressed in this way, fuzzy MCA models develop procedures for aggregating fuzzy performance levels using weights that are sometimes also represented as fuzzy quantities.	modeling decision makers' preferences - have not yet established that they have any critical advantages that are not available in other, more conventional models. - a lack of convincing arguments that the imprecision captured through fuzzy sets and the mathematical operations that can be carried out on them actually match the real fuzziness of perceptions that humans typically exhibit in relation to the components of decision problems. - doubts as to whether prescriptively trying to model imprecision, which is in some sense a descriptive reflection of the failings of unaided human decision processing, is the right way to provide support to deliver better decisions; - failure to establish ways of calibrating membership functions and manipulating fuzzy values that have a transparent rationale from the point of view of non-specialists.
Simple Multi Attribute Rating Technique (SMART)	- SMART uses simple utility relationships. - SMART allows the use of less scale range, so that alternatives which are not significantly different for a particular criterion can be scored equally. This important when confidence in the differences in data is low.	- SMART method is robust and reproduces decisions made from more complex MAUT analysis with a high degree of confidence.
Outranking Methods (multi-attribute, deterministic and the output is based on partial or complete ordinal ranking)	The method provides ordinal ranking (some times partial ordering) of the alternatives. dominance within the outranking frame of reference uses weights to give more influence to some criteria than others. One option is said to outrank another if it outperforms the other on enough criteria of sufficient importance (as reflected by the sum of the criteria weights) and is not outperformed by the other option in the sense of recording a significantly inferior performance on any one criterion. All options are then assessed in terms of the extent to which they exhibit sufficient outranking with respect to the full set of options being considered as measured against a pair of threshold parameters. ELECTRE methods try to find an outranking relation S between two alternatives. **ELECTRE I** - ELECTRE I for selection problems. - Choose the alternatives that are preferred for most of the criteria and do not cause an unacceptable level of any one criterion. - Examines the non-dominated alternatives and searches for a	**Advantages:** - The method requires less information from the decision maker. - Information is easy to obtain. - it is possible, under certain conditions, for two options to be classified as 'incomparable' ('difficult to compare' is probably a better way to express the idea - it is dependent on some rather arbitrary definitions of what precisely constitutes outranking and how the threshold parameters are set and later manipulated by the decision maker - The outranking concept does, however, indirectly capture some of the political realities of decision making - It can also be an effective tool for exploring how preferences between options come to be formed - It is indirectly capture some of the political realities of decision making - It can also be an effective tool for exploring how preferences between options come to be formed. **Disadvantages:**

Method	Description	Advantages and Disadvantages
	subset of the non-dominated solutions for which a certain degree of dissension or discord is acceptable. **ELECTRE II** - ELECTRE II for Ranking problems. - Develops a complete ordering of the non-dominated solution. **ELECTRE III** - ELECTRE II for Ranking problems	- Under certain conditions, for two options to be classified as 'incomparable'. - it is dependent on some rather arbitrary definitions of what precisely constitutes outranking and how the threshold parameters are set and later manipulated by the decision maker. - In particular it downgrades options that perform badly on any one criterion (which might in turn activate strong lobbying from concerned parties and difficulty in implementing the option in question
Outranking Methods - NAIADE	- Its procedure can be divided in three steps (pair-wise comparison of alternatives, aggregation of all criteria and evaluation of alternatives)	- The method is need for review for internal consistency and logical soundness. - This method can be used for special problems with limited alternatives. Generalization for problems with large numbers of options is difficult.

Annex II: List of Meeting and Correspondents with Municipal Representatives, Decision Makers and Experts

Name	*Institution and Position*	*Time*
▪ Eng. Ishaq Al Bitar Director of Projects Preparation Dep. ▪ Eng. Ata al Siqali Deputy Director of Projects Preparation Dep.	Municipality of Gaza	Sunday 24th August 2003
▪ Mr. Bashir Al Tayeb Municipality General Director ▪ Projects Department Staff	Municipality of Jabalia	Tuesday 26th August 2003
▪ Eng. Abdullah Nasrallah Head of projects Section ▪ Eng. Mohammed Abu Mezied Municipality Engineer	Muicipality Deir al Balah	Sunday 31st August 2003
▪ Eng. Basem Shurrab Head of Projects Department	Municipality of Khan Younis	Wednesday 5th November 2003
▪ Dr. Ali Barhoum Municipality General Director ▪ Eng. Yahya Abu Ebaid Wastewater Department ▪ Eng. Hamza Abu Warda Projects Design Department ▪ Eng. Husam Husam Projects Design Department	Municipality of Rafah	March - April 2004
▪ Eng. Rifat Diab	Palestinian Consultant, Water and Sanitation Engineer, Engineering and Management Consulting Center (EMCC)	March 2004
▪ Eng. Ribhi Al Sheikh	Senior Infrastructure Engineer, Palestinian Water Authority, Gaza	April 2004
▪ Eng. Sufian Abu Samra	Projects Manager, Ministry of Local Government, Gaza.	May 2004
▪ Eng. Tariq Assar	Senior Consultant, Municipal Services Expert, Gaza	May 2004
▪ Dr. Rifat Rustom	LP Expert, Lecturer at the Islamic University of Gaza	January – May 2004
▪ Mr. Nelberto Munier	Senior Consultant, Decision Making Expert, Canada	October 2003 – June 2004
▪ Mr. Denis Moeffaert	Senior consultant, Sweden	November, 2003

Annex III: Solution of LP Problems with Simplex Method.

The Simplex Algorithm starts with an initial basic feasible solution and tests its optimality. If some optimality condition is verified, then the algorithm terminates. Otherwise, the algorithm identifies a basic feasible solution, with a better objective value. The optimality of this new solution is tested again, and the entire scheme is repeated, until an optimal basic feasible solution is found. Since every time a new basic feasible solution is identified the objective value is improved, and the set of basic feasible solutions is finite, it follows that the algorithm will terminate in a finite number of steps (iterations). The basic logic of the algorithm is depicted in Figure III.1. The following points should be considered:

a. Standard Form: convert LP into an equivalent problem in which all constraints are equations and all variables are nonnegative.

b. Slack variables (Si), Si = slack variable for i^{th} constraint, which is the amount of the resource unused in the i^{th} constraint. for example:

$Si = 40 - X1 - X2$ or,

$X1 + X2 + X1 = 40$

$Si \geq 0.0$

c. If constraint (i) of a LP problem is a $\leq$ constraint, convert it to an equality constraint by adding a slack variable Si to the i^{th} constraint and adding the sign restriction $Si \geq 0.0$.

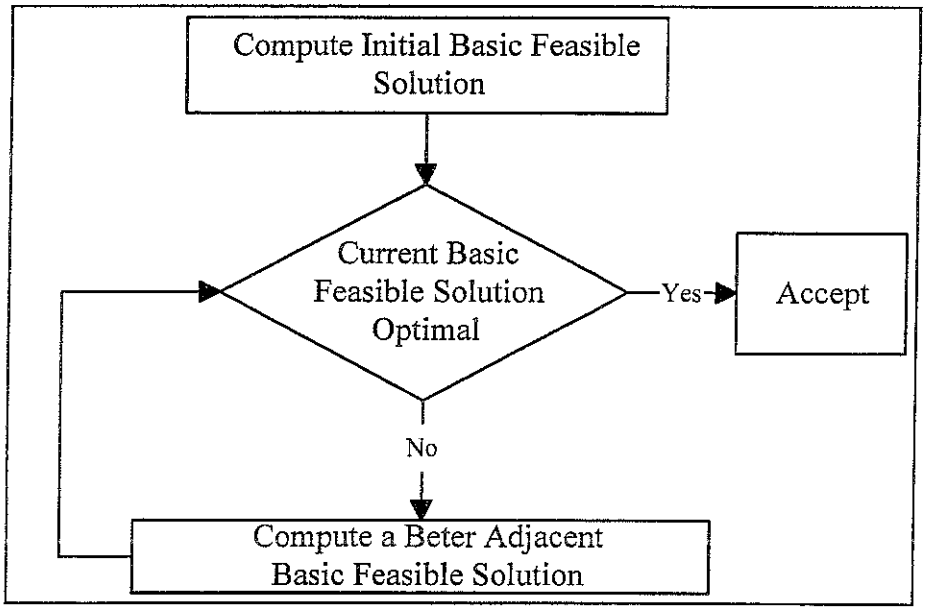

Figure III.1: The basic Simplex logic

The following explains how the Simplex algorithm implements this logic in its computations by appplying it on a simple LP problem.

Example: The basic Simplex logic

1- The simplex method: maximization with ≤ problem constraint.

Maximize:	P	=	50X1	+	80X2			Objective Function
Subject to:			X1	+	2X2	≤	32	
			3X1	+	4X2	≤	84	Problem Constraints
					X2	≤	12	
			X1	,	X2	≥	0.0	Nonnegative constraint

2- Using the nonnegative slack variables; S1, S2 and S3.

Maximize:	P	=	50X1	+	80X2									
Subject to:			X1	+	2X2	+	S1						=	32
			3X1	+	4X2			+	S2				=	84
					X2					+	S3		=	12
			X1	,	X2	,	S1	,	S2	,	S3	≥	0.0	

3- Equivalent Standard Form.

X1	+	2X2	+	S1							=	32
3X1	+	4X2			+	S2					=	84
		X2					+	S3			=	12
-50X1	-	80X2							+	P	=	0.0

4- Obvious basic feasible solution

S1, S2, S3 and P are basic variables

X1 and X2 are non-basic variables

X1	+	2X2	+	S1							=	32
3X1	+	4X2			+	S2					=	84
		X2					+	S3			=	12
-50X1	-	80X2							+	P	=	0.0

X1 = 0.0, X2= 0.0, S1= 32, S2= 84, S3= 12, P= 0.0

The value of P can be improved by increasing the variables of X1 and X2.

5- Increase the decision variables that contributed most to the profit for each unit increase in the variable; P = 50X1 + 80X2

- Each unit increase in X1 → 50$
- Each unit increase in X2 → 80$
- So, increase X2 first
- X1 = 0.0, X2 =??

6- Rewrite the equations

$$\begin{aligned} 2X2 + S1 &= 32 \rightarrow X2 = 16 \text{ "to become negative"} \\ 4X2 + S2 &= 84 \rightarrow X2 = 21 \text{ "to become negative"} \\ X2 + S3 &= 12 \rightarrow X2 = 12 \text{ "to become negative"} \end{aligned}$$

Select the minimum of (16, 21 and 12) which is 12 without causing any of the variables S1, S2, S3 to become negative.

7- Substitute (X2 = 12 – S3)

$$\begin{aligned} X1 + 2(12 - S3) + S1 &= 32 \\ 3X1 + 4(12 - S3) + S2 &= 84 \\ X2 + S3 &= 12 \\ -50X1 - 80(12 - S3) + P &= 0.0 \end{aligned}$$

Which equivalent to

$$\begin{aligned} X1 + S1 - S3 &= 32 \\ 3X1 + S2 - 4S3 &= 84 \\ X2 + S3 &= 12 \\ -50X1 + 80S3 + P &= 960 \end{aligned}$$

Use X1 and S3 as non-basic (zero), the obvious solution is:

X1 = 0.0, X2= 12, S1= 32, S2= 84, S3= 0.0, P= 960

8- Complete the solution following the same concepts and processes until:

P = -20S1 – 10S2 + 1,480

Any increase in S1 or S2 will reduce the value of P

So, P = 1,480 is the optimal solution.

The following table shows the obvious basic feasible solutions,

X1	X2	S1	S2	S3	P
0	0	32	84	12	$0.0
0	12	8	36	0	$960
8	12	0	12	0	$ 1,360
20	6	0	0	6	$1,480

However, the optima; solution shows that there is a slack in equation (X2 ≤ 12), and have value of 6.0 units as shown in the table. (S3 = 6.0).

Annex IV: Case Study - Summary of Data Sheets and Evaluation of Criteria.

Table IV.1: Summary of Data Sheet and Evaluation of Criteria of the First Project

Project Card	
Project Name:	Upgrading of Sewerage Network
Project Code:	X1
Location:	Block 86A Tal Sultan, Rafah
Sector:	Wastewater

Criteria	**(Data Sheet)**	**Evaluation**
Cost (Budget Availability)	152,500.0	1.2
Integration with Services		
Complement with the Master Plan	Yes	2
Dependency on other Projects	Independent	
Socio-economical Values		
Beneficiaries (Direct)	43.57142857	1.2
Job Creation	25.00%	1.6
Community Participation	0.00%	1
Community Committees	Active Community Committees	2
Community Satisfaction	Highly Satisfied	2
Risk		
Construction Materials	100% Local	2
Duration (months)	5	1.7
Decision Makers Preferences	Needed	1.7
Environmental and Health	4.42	1.8
Municipality Capacity		
Technology Requirements	Semi-available	1.5
Staff Capacity	Acceptable Level	1.5
Sustainability		
Maintenance Requirements	0.00%	2
Operation Expertise	High Level	2
Project Life Time	25.00	1.8

Table IV.2: Summary of Data Sheet and Evaluation of Criteria of the Second Project

Project Card	
Project Name:	Upgrading of Sewerage Network
Project Code:	X2
Location:	Block 88 Tal Sultan, Rafah
Sector:	Wastewater

Criteria	(Data Sheet)	Evaluation
Cost (Budget Availability)	82,900.0	1.6
Integration with Services		
Complement with the Master Plan	Yes	2
Dependency on other Projects	Independent	
Socio-economical Values		
Beneficiaries (Direct)	31.88461538	1.2
Job Creation	25.00%	1.6
Community Participation	0.00%	1
Community Committees	Active Community Committees	2
Community Satisfaction	Highly Satisfied	2
Risk		
Construction Materials	100% Local	2
Duration (months)	6	1.4
Decision Makers Preferences	Needed	1.7
Environmental and Health	4.42	1.8
Municipality Capacity		
Technology Requirements	Semi-available	1.5
Staff Capacity	High Level	2
Sustainability		
Maintenance Requirements	0.00%	2
Operation Expertise	Acceptable Level	1.5
Project Life Time	25.00	1.8

Table IV.3: Summary of Data Sheet and Evaluation of Criteria of the Third Project

Project Card	
Project Name:	Construction of Sewerage Network
Project Code:	X3
Location:	Amer Neighbourhood, Rafah
Sector:	Wastewater

Criteria	(Data Sheet)	Evaluation
Cost (Budget Availability)	200,000.0	1
Integration with Services		
Complement with the Master Plan	Yes	2
Dependency on other Projects	Independent	
Socio-economical Values		
Beneficiaries (Direct)	10	1.4
Job Creation	25.00%	1.8
Community Participation	0.00%	1
Community Committees	Active Community Committees	2
Community Satisfaction	Highly Satisfied	2
Risk		
Construction Materials	100% Local	2
Duration (months)	6	1.4
Decision Makers Preferences	Needed	1.7
Environmental and Health	4.42	1.8
Municipality Capacity		
Technology Requirements	Semi-available	1.5
Staff Capacity	High Level	2
Sustainability		
Maintenance Requirements	0.00%	2
Operation Expertise	Acceptable Level	1.5
Project Life Time	25.00	1.8

Table IV.4: Summary of Data Sheet and Evaluation of Criteria of the Fourth Project

Project Card	
Project Name:	Construction of Sewerage Network
Project Code:	X4
Location:	Block A, Junainah, Rafah
Sector:	Wastewater

Criteria	(Data Sheet)	Evaluation
Cost (Budget Availability)	205,000.0	1
Integration with Services		
Complement with the Master Plan	Yes	2
Dependency on other Projects	Independent	
Socio-economical Values		
Beneficiaries (Direct)	51.25	1
Job Creation	25.00%	1.8
Community Participation	0.00%	1
Community Committees	Active Community Committees	2
Community Satisfaction	Highly Satisfied	2
Risk		
Construction Materials	100% Local	2
Duration (months)	6	1.4
Decision Makers Preferences	Needed	1.7
Environmental and Health	4.42	1.8
Municipality Capacity		
Technology Requirements	Semi-available	1.5
Staff Capacity	High Level	2
Sustainability		
Maintenance Requirements	0.00%	2
Operation Expertise	Acceptable Level	1.5
Project Life Time	25.00	1.8

Table IV.5: Summary of Data Sheet and Evaluation of Criteria of the Fifth Project

Project Card	
Project Name:	Construction of Sewerage Network
Project Code:	X5
Location:	Block A, Junainah, Rafah
Sector:	Wastewater

Criteria	**(Data Sheet)**	**Evaluation**
Cost (Budget Availability)	250,000.0	1
Integration with Services		
Complement with the Master Plan	Yes	2
Dependency on other Projects	Independent	
Socio-economical Values		
Beneficiaries (Direct)	2.5	1.8
Job Creation	25.00%	1.6
Community Participation	0.00%	1
Community Committees	Active Community Committees	2
Community Satisfaction	Highly Satisfied	2
Risk		
Construction Materials	100% Local	2
Duration (months)	6	1.4
Decision Makers Preferences	Needed	1.7
Environmental and Health	4.42	1.8
Municipality Capacity		
Technology Requirements	Semi-available	1.5
Staff Capacity	High Level	2
Sustainability		
Maintenance Requirements	0.00%	2
Operation Expertise	Acceptable Level	1.5
Project Life Time	25.00	1.8

Table IV.6: Summary of Data Sheet and Evaluation of Criteria of the Sixth Project

Project Card	
Project Name:	Omar Ben Al Khattab Road
Project Code:	X6
Location:	City Center, Rafah
Sector:	Complete development

Criteria	(Data Sheet)	Evaluation
Cost (Budget Availability)	980,000.0	1
Integration with Services		
Complement with the Master Plan	Yes	2
Dependency on other Projects	Independent	
Socio-economical Values		
Beneficiaries (Direct)	9.8	1.6
Job Creation	18.37%	1.4
Community Participation	0.00%	1
Community Committees	No Community Committees	1
Community Satisfaction	Highly Satisfied	2
Risk		
Construction Materials	100% Local	2
Duration (months)	8	1.4
Decision Makers Preferences	Needed	1.7
Environmental and Health	4.92	2
Municipality Capacity		
Technology Requirements	Semi-available	1.5
Staff Capacity	Acceptable Level	1.5
Sustainability		
Maintenance Requirements	0.51%	2
Operation Expertise	Acceptable Level	1.5
Project Life Time	40.00	2

Table IV.7: Summary of Data Sheet and Evaluation of Criteria of the Seventh Project

Project Card	
Project Name:	Deir Yaseen School Road
Project Code:	X7
Location:	Al Junainah Area, Rafah
Sector:	Asphalt Pavement

Criteria	**(Data Sheet)**	**Evaluation**
Cost (Budget Availability)	240,000.0	1
Integration with Services		
Complement with the Master Plan	Yes	2
Dependency on other Projects	Independent	
Socio-economical Values		
Beneficiaries (Direct)	4	1.8
Job Creation	19.00%	1.4
Community Participation	0.00%	1
Community Committees	Active Community Committees	2
Community Satisfaction	Highly Satisfied	2
Risk		
Construction Materials	100% Local	2
Duration (months)	4	1.7
Decision Makers Preferences	Needed	1.7
Environmental and Health	4.92	2
Municipality Capacity		
Technology Requirements	Semi-available	1.5
Staff Capacity	Acceptable Level	1.5
Sustainability		
Maintenance Requirements	0.83%	2
Operation Expertise	Acceptable Level	1.5
Project Life Time	40.00	2

Table IV.8: Summary of Data Sheet and Evaluation of Criteria of the Eighth Project

Project Card	
Project Name:	Al Badeel Road - No 35
Project Code:	X8
Location:	Tal Al Sultan, Rafah
Sector:	Complete development

Criteria	**(Data Sheet)**	**Evaluation**
Cost (Budget Availability)	90,000.0	1.4
Integration with Services		
Complement with the Master Plan	Yes	2
Dependency on other Projects	Independent	
Socio-economical Values		
Beneficiaries (Direct)	3	1.8
Job Creation	20.00%	1.4
Community Participation	0.00%	1
Community Committees	Active Community Committees	2
Community Satisfaction	Highly Satisfied	2
Risk		
Construction Materials	100% Local	2
Duration (months)	3	1.7
Decision Makers Preferences	Needed	1.7
Environmental and Health	4.92	2
Municipality Capacity		
Technology Requirements	Semi-available	1.5
Staff Capacity	Acceptable Level	1.5
Sustainability		
Maintenance Requirements	1.67%	2
Operation Expertise	Acceptable Level	1.5
Project Life Time	40.00	2

Table IV.9: Summary of Data Sheet and Evaluation of Criteria of the Ninth Project

Project Card	
Project Name:	Imam Ali road No 9
Project Code:	X9
Location:	West Rafah
Sector:	Complete development

Criteria	**(Data Sheet)**	**Evaluation**
Cost (Budget Availability)	280,000.0	1
Integration with Services		
Complement with the Master Plan	Yes	2
Dependency on other Projects	Independent	
Socio-economical Values		
Beneficiaries (Direct)	7	1.6
Job Creation	21.43%	1.6
Community Participation	0.00%	1
Community Committees	Active Community Committees	2
Community Satisfaction	Highly Satisfied	2
Risk		
Construction Materials	100% Local	2
Duration (months)	3	1.7
Decision Makers Preferences	Needed	1.7
Environmental and Health	4.92	2
Municipality Capacity		
Technology Requirements	Semi-available	1.5
Staff Capacity	Acceptable Level	1.5
Sustainability		
Maintenance Requirements	0.71%	2
Operation Expertise	Acceptable Level	1.5
Project Life Time	40.00	2