PROCEEBING OF
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Introduction

The International Conference on Civil Engineering (ICCE) is organized by Palestine Engineers Association (PEA). It comes as part of PEA role in developing the engineering works in the country and providing local engineers with the opportunity to exchange knowledge with their peers from other countries. This conference is the first international conference in civil engineering to be held in Palestine.
ICCE also aims at allowing for development of the civil engineering practice, upgrading the quality of work, enhancing research and creativity and attracting new investments and technologies in the field of civil engineering.

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FOREWORD

Colleagues and Peers
Greetings

The Engineers Association -Jerusalem Center is considered the largest and most developed association compared to other trade unions and professional associations. The Engineers Association-Jerusalem center was founded in 1958; it began its work with dozens of engineers, ending up in 2010 with more than 16,000 member male and female engineers in the West Bank in all engineering disciplines. The Engineers Association and over the past years was and still keen to achieve its noble objectives and advance the society in addition to improve skills of Palestinian Engineers through the development of the engineering and consultancy field, while adopting the community needs and concerns in parallel with the important national role of the association along the years of suffering incurred by the Palestinian people. There is no doubt that the engineers association has witnessed large and rapid developments depicted in quality of services and facilities provided by the association across all West Bank's branches for engineers colleagues. This evolution emerged through the recruitment of competent staff and expertise necessary for this institution to provide the best quality and service levels parallel to this exponential increase in number of engineers.

In the midst of talk about the development of the engineering work, the association has adopted a set of initiatives aimed to raise the level of scientific and professional skills for engineers and improve their economic and social circumstances through organizing a number of scientific events such as workshops, seminars and other social events and athletic activities, along with conducting capacity building and training courses through the Engineers Training Center, in addition to sponsoring a number of partnership agreements with local and international organizations aimed at providing job opportunities for fellow engineers in all disciplines, in an endeavor to contribute towards supporting the fellow engineers and put them on the track of their professional careers.
The association spared no efforts to provide its utmost services for fellow engineers despite the tremendous growth in its work. it has adopted a set of initiatives and concrete steps towards the development and upgrading of the engineering work, this includes the establishment of the Palestinian Higher Council for Green Building, and the Engineers Accreditation Commission, which is acknowledged on the level of all Engineering Unions and Associations in the whole Arab world, as well as the establishment of the Engineers Training Center, where the association is seeking to raise capacities of this edifice, to compete with other similar international and regional centers.

Regarding the exchange of experiences between fellow engineers with all countries of the world, the
Association has held several local and international conferences like the 4th International Conference of Energy 2011 in order to put fellow engineers in picture of latest developments regarding the engineering work, where over the past years, these conferences addressed many important and central issues on the road of building the State and organization of engineering work in Palestine. To this end, the idea of holding this international event emerged to mainly address one of the most important issues of the Palestinian Work "the Civil Engineering" due to its importance and the high cost of construction in Palestine, landmarks of this event became more clear as it will be held under the rubric of " the International Conference on Civil Engineering - Palestine", which is held under the auspices and blessing of Mr. President Mahmoud Abbas Excellency - Chairman of PLO, the President of Palestine State.

This conference presents some 30 working papers in various areas related to the Civil Engineering themes, presented by participants from 5 countries, namely, "Palestine, Jordan, Italy, USA, and Turkey" while on the margin of this conference number of Palestinian universities student will present their Graduation Projects many Arab and international delegations interested in this sector are also attending this important conference.
Finally, the Engineers Association welcomes all guests and speakers from all countries, in the same time, wishes all success for this important event through bringing up a number of important recommendations that will improve reality of the Palestinian Civil Engineering sector as part of the engineering work in Palestine, which will certainly help the association to ensure achieving its noble mission.

Eng. Ahmad E'daily
Chairman - PEA

PREFACE

During the preparation for the International Conference for Civil Engineering-Palestine, the organizing committee and the scientific committee discussed the way of issuance of this important conference proceedings which is held for the first time in Palestine. It is important as it covers many aspects of the civil engineering profession. Among the suggestion, were to have the proceedings on stick memory, CD or in the form of a book as you see it now. The decision was made to print the proceedings in a book which can be used by the engineers any time they need. They can have it for months or years on the shelf of their libraries.

This is also to save them the time of taking notes during the conference sessions.

The time was running and many details have to be finished before the beginning of the conference. We did succeed in getting this book on time.

This book includes the papers of all authors. The conference was enriched by several Key-note speakers from several countries.

Finally I would like to thank all people who participated in the issuance of this book. First, the very respected authors of their valuable papers. Second, the Association of Engineers' crew who exerted a big effort to make the timely issuance of this book possible.

Dr. Mohammad T. Alsayyed
Chairman of Organizing Committee

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Deterioration, Modelling and Repair of Concrete Bridges
INTRODUCTION

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ABSTRACT

Reinforced concrete bridges are designed to perform satisfactorily for their service life. In early 70's, premature deterioration of concrete bridge was recognized as a serious problem by highway agencies which has been a major concern to the authorities responsible for their running and maintenance. A significant number of interests have been shown by the highway agencies around the world to predict service life of bridges as bridge is a major part of their road system and unanimously, a road is a key factor of development of country. mIt is very important to identify durability of the existing bridges to calculate the deterioration rate which helps to develop a mathematical model. These models can be used in performance prediction, service life prediction and life cycle costing. Hence a good study of the deterioration and development of mathematical modelling can be a useful tool for the analysis of the deterioration of concrete structures which helps in planning maintenance and management strategies of the deteriorated structures.

In past decade more studies have been carried out in Factor method which has been considered as simple and general method. This method has been used to model the service life of the bridges from the database of 439 concrete bridges collected over the period of 50 years which has been remained unused for several years. A simple spreadsheet program based on the principle of factor method with probabilistic approach has been used to estimate the service life of various structures and its members based on structure type and member type only. This model requires further development to include additional factors mainly exposure conditions which is a significant factor leading to bridge deterioration. This study extends the model developed including the structure type, member type and exposure conditions. The developed model in this study provides information whether the structure needs maintenance or not and predicts service life of concrete bridges.

Practical Shoring Systems

By: Dr. Amjad Barghouthi

ABSTRACT

Shoring systems (Earth Support Structures) are required in several situations in construction. The construction of deep basements requires shoring systems to retain the top soil / fill materials down to the competent rock depth.

One problem that appears always is that the designer utilizes the full area of the lot without allowing any space for the shoring system.

This is usually because of the high cost of land or lack of consideration of the necessity of a shoring system.

ACES (Arab Center for Engineering Studies) have designed and utilized shoring systems that will not take significant space from the land area and have proved very feasible systems for fill / top soil heights from 3–15m.

The systems are:

1. Soldier Piles and Rock Nails. The soldier piles are constructed at an angle of 7o – 9o with the vertical.
2. Soil Nailing.

Towards Sustainable Transportation System

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ABSTRACT

Sustainability is a significant topic across all fields in present times, and transportation is no exception. One of the many definitions of sustainability is: "A system of policies, beliefs, and best practices that will protect the diversity and richness of the planet's ecosystems, foster economic vitality and opportunity, and create a high quality of life for people[1]." Indeed, sustainable transportation is vital to ensure a future that preserves all three aspects of the triple bottom line: environment, economy, and society. In 2004, the transportation sector contributed 23% of global greenhouse gases, with a predicted annual increase of 2% thereafter[2]. An enormous amount of work is doubtlessly needed to halt these trends, and significant effort is already being made towards achieving a more sustainable system.

In terms of highways, major issues include congestion and fuel usage, as well as pavement construction. In 2008, congestion cost Europe around 200 billion Euros, 1-2% of the GDP[3]. Sustainable efforts such as congestion pricing, coordinated signal corridors, and intelligent monitoring measures are being used to reduce the amount of time vehicles spend on the road. Globally, motor vehicles are responsible for 75% of greenhouse gases from the transportation sector[4]. Research and development in flexfuel and alternative energy vehicles is producing more environmentally-friendly vehicles; biofuels could account for 10% of global transport fuel in 2030[5]. In addition, technologies are being used or developed to reduce economic and environmental construction costs. For example, recycled asphalt shingles, reclaimed asphalt pavement, and recycled concrete aggregate are more frequently used in pavements. Other techniques such as warm mix asphalt and roller compacted concrete are becoming more widespread and acknowledged for their sustainable qualities. Innovations such as quiet pavements and energy harvesting in pavements are also being studied.

Various challenges and developments are noticed in the fields of railroads and aviation. Rail transport is recognized as one of the most energy efficiency modes for freight and passenger movement. Ongoing research focuses on improving the sustainability of railroad ties and ballast as well as reducing weight and aerodynamic resistance. In addition, high speed rail, which was successfully introduced by Japan and Germany, can greatly alleviate congestion by increasing speed and capacity when optimally used. Over the next 20 years, aviation transport is expected to increase at a rate of 4.5% for passenger travel and 5.3% for freight traffic[6]. Developments in alternative fuels, engine efficiency, aircraft design, and security are necessary to meet this increasing demand sustainably.

To complement the development within the transportation sector, it is necessary to develop specific metrics to track progress towards sustainability. Qualitative rating systems are used by a number of entities that assess the level of sustainable efforts made at a project or agency level. In addition, life-cycle assessment, a quantitative evaluation method, can provide metrics such as the amount of energy used and the carbon dioxide emitted as a result of pavement production, construction, maintenance, use, and disposal. Both types of evaluation can guide decision-makers, designers, and contractors towards creating a more sustainable transportation system.

Finally, sustainability in transportation must also highlight the importance of the involvement of transportation users. It is necessary that sustainable modes of transportation such as bicycling, walking, ridesharing, and public transportation are made readily available to the public. For example, there has recently been an emerging interest in bus rapid transit and in developing accessible infrastructure for pedestrians and bicyclists in urban areas. In 2050, the global annual travel is predicted to be double that of 2010 levels. This considers an increase in passenger travel (passenger-kilometers) and freight travel (tonne-kilometers) from 55 trillion to 115 trillion, with the former being responsible for 70% of the growth[7]. As the demand for worldwide mobility continues to increase, it is important the transportation system be expanded and maintained with strong considerations to sustainability. Innovative, economical, practical, and implementable transportation sustainability alternatives for developing countries will be presented and discussed.

WASTE MATERIALS USED IN ROAD AND OTHER CONSTRUCTION ACTIVITIES

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ABSTRACT

Solid waste materials have become a major environmental concern all over the world. Huge amounts of waste materials and industrial by-products are generated from manufacturing and other mining processes each year. Utilization of waste materials and by-products is now a necessity for sustainable development and better living environment. Large volumes of earth materials are used in construction each year in Turkey and elsewhere in the world, especially as sub-base filling materials commonly used in highway construction. Large amount of wastes have the potential to be used in the mixtures of the road sub-base filling materials in appropriate proportions.

Worldwide there are many industrial waste and by-product materials generated as a result of the treatment of the natural resources. Since extensive level of coal firing for power generation began in the 1920s, many millions of tons of ash and related by-products have been generated. The current annual production of coal ash worldwide is estimated at around 600 million tons, with fly ash constituting about 500 million tons at 75–80% of the total ash produced.

In many cases, waste materials can be replaced with reclaimed highway paving materials, secondary materials, construction debris that are normally deposited in landfills, and can generate millions of dollars savings to taxpayers. Reuse in construction has several benefits, including reduction in solid waste disposal costs incurred by industry, reduction in landfill requirements, minimization of damage to natural resources caused by excavating earthen materials for construction, obtaining added value from waste materials, conservation of production energy, and ultimately providing sustainable construction and economic growth.

Waste materials may be effectively used for road sub-base construction with natural soils which can be medium and low plasticity soil for the sake of safe disposal. Researchers have investigated different types of waste materials as additive components in soil [2]. Those materials have been used in many civil engineering constructions but the amount of utilization is not enough to decrease the huge waste stockpile. The use of waste materials as a sub-grade chemical additive material in road constructions brings two benefits; (1) Waste materials increase the soil strength, bearing capacity, grain size distribution and also decrease some geotechnical parameters such as compressibility, permeability and swelling capacity and (2) chemical and physical pollution of soil, water and air due to waste materials are reduced in the environment.

There is a wide range of waste materials used in different construction sectors. The case studies range from the use of unprocessed waste as in the case of the utilization of used whole tyres, to cementitious systems using processed industrial by-product materials with the aim of total replacement of the energy intensive Portland Cement (PC) and lime, or of natural materials such as timber for building and construction. Portland Cement (PC) and lime are associated with a wide range of negative environmental effects, from increased carbon dioxide emission into the atmosphere, to significant consumption of precious natural raw material resources and large energy inputs, to the negative impact on landscape. The goal towards zero waste and realization of such big goals as co-generation of power do not come easily or in a short period. It requires the joint efforts from researchers, private and government initiatives to facilitate waste utilisation and help reduce the huge waste stockpiles disfiguring the landscape.

A Case Study on Underpinning of Existing Structure Using Jet Grouting

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INTRODUCTION

Many of the structures problems occur due to weakness of soil supporting them. If the structure was designed carefully in terms of elements sizes and reinforcement, then any problem that may appear in the structure can be related to settlement, differential settlement or bearing capacity deficiency. Conventional methods which include excavation and jacketing of the foundations are sometimes adopted to underpin the structures in order to stop the settlement and increase the bearing capacity. Sometimes these methods stand short due to circumstances related to the site. Accessibility to the foundations and to the soil need to be strengthened is important and risk of failures is a concern.

In this paper, a description of a case where excessive differential settlement took place a year after completion of construction of a stadium in Florida, USA. The settlement occurred before any significant live loading took place. Investigation was made to find the reason behind this settlement and to how to strengthen soil layer/s in order to solve the settlement problem.

The problem was defined as follows: The site was mainly composed of very soft organic soil. The designer elected to use soil replacement in order to adopt shallow foundations; isolated and strip. During soil replacement, in part of the site, the excavation was not extended outside the limits of the edge of the foundations. The stress distribution zone was not fully improved. This caused excessive settlement in these areas more than other places.

The owner solicited proposals for solving the problem and stopping the continuous settlement. The hired a company named Hayward Baker, who are a specialty contractor to do the job using jet grouting technique.

The idea was to construct underground wall sufficient to stand the pressure from the foundations which was affecting the soft soils. The wall was constructed at the border line of each of the footings which encountered the problem. No excavation was made. Drilling using triple-rod jet grouting technique was used to carry out the task.

In this method new pre-engineered material replaced the existing soft material creating Soilcrete masses at several locations as per the designer requirement.

The jet grouting method is described hereafter.

Jet grouting is “the simultaneous controlled injection of cement-based grouts to replace soils eroded by high pressure water jets”.

Two main methods are used in the jet grouting process the first is the mixed-in-place method and the second is the excavation and replacement method. The second one was used for this particular project.

Excavation and replacement method: The excavation and replacement method of jet grouting is performed in an oversize borehole that has been advanced to the bottom elevation of the area to be strengthened. Some kinds of admixtures may be added to the cement according to the application needed. The behavior of the grout, once it is in the ground, is the same regardless of how it was placed.

The process is achieved according to the requirement. In case of existing structure underpinning, columns may be installed under the foundations. In case of seepage control, walls may be installed. Other cases may imply installation of gravity walls inside the ground. Design of any of these systems depends on the structure loads and soil parameters. This system is the most reliable as it is giving a pre-engineered material. This means that you can make your design according to the existing subsurface

conditions to produce a new subsurface material. For such applications, usually either bearing capacity has to be increased to the value enough to carry the superstructure load and to reduce the settlement as well, or the permeability has to be reduced to the minimum permitted value.

Using this method enabled increase of the unconfined compressive strength of the material to more than 30kg/cm^2.

The paper presents a description of the use of the method and a description for the methodology along with the some mixes used. Lab results of tests performed on the resulted material are also presented.

SYSTEM DESCRIPTION:

- The system is composed of the following components:
- Drilling rig.
- Air compressor of more than 350 bars.
- Grout mixer.
- Grout pump.
- Drilling rods group of length sufficient for the needed depth.
- Cutting tools to be fitted at the lower end of the first rod.
- Nozzle of 1.8 to 2.2 mm diameter of super hard alloyed material.

METHOD DESCRIPTION:

Jet grouting is used to construct a series of secant or tangential columns at the targeted area regardless of its elevation below ground.

1. The target area is determined and the size as well as the depth is made clear through geotechnical investigations.
2. Based on the soil properties, trial mixes are made in the lab to determine the proportions of mixing and the type of material to be used.
3. After deciding the proportions and the type of materials to be used, design is made to determine the element dimensions.
4. Once this is determined, the specialized contractor can move into the site.
5. Drilling mud is used if there is a concern of the boreholes' sides collapse.
6. The drilling assembly is lowered to the bottom of the second hole and the construction process starts.
7. The nozzle attached in the assembly is directed towards the first guide hole.
8. The parameters used in the drilling process are selected according to the design recommendations and are subject to change during the application in the field.
9. Water jet encircled with air is operated to start cutting the soil between the first and the second holes. The first hole is a guide to assure that cutting reached it and so all the soil between the two holes is broken.
10. Water jet is operated while the drilling rods are being lifted at a specific speed.
11. At the same time, grout is applied through the hole at the bottom of the drilling rod.
12. This process continues until all columns are finished taking into account the sequence of drilling so not to create a weak zone under or next to the foundation.

MIX COMPONENTS:

MIX COMPONENTS:

The following materials were used in the grout trial mixes:

- Cement.
- Bentonite: This is made of montmorillonite clays. It contains about 3/8 lb/ton sodium polyacroid. It is added to reduce the setting time of the mix. It was used in the baseline mix.
- Water Reducer: This is a water reducing agent which was used to enable reducing the W/C ratio and producing a practical level of workability and pumpability of the mix. It was used with and without fly ash in mix (FAWR and FA respectively.
- Silica Fume: This is a dry mineral admixture used to produce concrete with special performance. It is used to produce high strength and low permeability (SFHR).

Table 1) Proportions (%) of the Grout Mixes

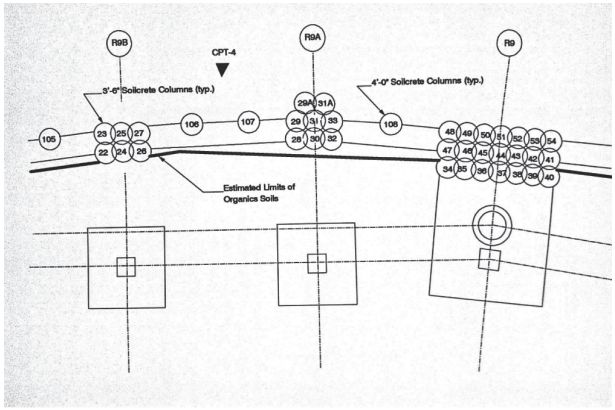
Mix ID	Water	Type II cement	Bentonite	Silica Fume	Fly Ash	Water Reducer
Baseline	39.35	59.67	0.98	---	---	---
WR	27.7	72.03	---	---	---	0.27
SFHR	34.29	57.14		8.57	---	---
FAWR	27.61	60.1	---	---	12.03	0.22

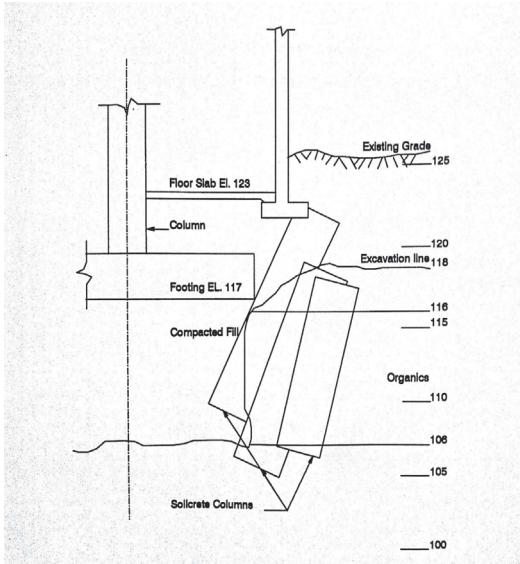
PROCEDURE OF WORK:

The jet grouting method was chosen for stopping the settlement. The idea was to install a series of columns in groups at the boundary between the new fill and the remaining organcs. Some of the columns and their layout are shown in the next figure. The columns are overlapped to ensure that each group forms continuous soilcrete mass. A total of 115 soilcrete columns were constructed. The length, depth and orientation varied to match the limits of the organic layer.

The sequence in which the columns were installed was chosen so that no two adjacent sslots would be grouted in the same shift. This was done in order to reduce the settlement during construction which was not to exceed 12mm.

Test columns were constructed in the site in order to verify the parameters used for construction. Adjustment was made according to the tests results. Verification of the dimensions was made in order to ensure that the design was achieved.





LAB TESTS AND RESULTS:

The following tests were performed on the mixes and the hardened product.

1. ASTM C138 Standard Test Method for Unit Weight, Yield, and Air Content of Concrete.
2. ASTM C939 Standard Test Method for Flow of Grout for Preplaced-Aggregate Concrete.
3. ASTM C873 Standard Test Method for Compressive Strength of Concrete Cylinders Test Cast in Place in Cylindrical Molds.
4. Change in Volume due to bleeding.
5. Permeability.

The results of tests performed on samples from these mixes are summarized in the table 3.

Table 2) Results of Unconfined Compressive Strength Grout and Grout-Soil Mixes

	Unconfined Comp. Strength (MPa)	
		Soilcrete
	Grout	CL
Baseline	20.2	2.9
SFHR	23.4	2.8
FWR	42.8	2.8
FAWR	40.5	5.7

The results of the shrinkage due to bleeding were an important factor that may influence the choice of admixture which is to be used in the grouting process. Table 4 shows the

Table 3) Change of Volume due to Bleeding of Grout and Grout-Soil Mixes

	Change of Volume (%)	
		Soilcrete
	Grout	CL
Baseline	1.2	0.70
SFHR	1.35	0.45
FWR	1.4	0.60
FAWR	1.3	0.50

CONCLUSIONS:

The project was done successfully and the settlement was stopped. Doring construction process settlement was less than 5 mm. From the results of testing the following general conclusions were drawn:

1. Jet grouting could be the most beneficial method of underpinning in case of high depths underground.
2. For underpinning problems, dealing with this method can be useful for soft soils.
3. In general, no need to stop using the subject part of structure for more than the number of days needed for construction.
4. No need for excavation and shoring is needed.
5. No need to remove the tiles and rune any finishing works.

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A DECISION TREE MODEL TO ESTIMATE THE VALUE OF INFORMATION PROVIDED BY A GROUNDWATER QUALITY MONITORING NETWORK

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ABSTRACT— Groundwater contaminated with nitrate poses a serious health risk to infants when this contaminated water is used for culinary purposes. To avoid this health risk, people need to know whether their culinary water is contaminated or not. Therefore, there is a need to design an effective groundwater monitoring network, acquire information on groundwater conditions, and use acquired information to inform management options. These actions require time, money, and effort. This paper presents a method to estimate the value of information (VOI) provided by a groundwater quality monitoring network located in an aquifer whose water poses a spatially heterogeneous and uncertain health risk. A decision tree model describes the structure of the decision alternatives facing the decision maker and the expected outcomes from these alternatives. The alternatives include: (i) ignore the health risk of nitrate contaminated water, (ii) switch to alternative water sources such as bottled water, or (iii) implement a previously designed groundwater quality monitoring network that takes into account uncertainties in aquifer properties, contaminant transport processes, and climate (Khader 2012). The VOI is estimated as the difference between the expected costs of implementing the monitoring network and the lowest-cost uninformed alternative. We illustrate the method for the Eocene Aquifer, West Bank, Palestine where methemoglobinemia (blue baby syndrome) is the main health problem associated with the principal contaminant nitrate. The expected cost of each alternative is estimated as the weighted sum of the costs and probabilities (likelihoods) associated with the uncertain outcomes resulting from the alternative. Uncertain outcomes include actual nitrate concentrations in the aquifer, concentrations reported by the monitoring system, whether people abide by manager recommendations to use/not-use aquifer water, and whether people get sick from drinking contaminated water. Outcome costs include healthcare for methemoglobinemia, purchase of bottled water, and installation and maintenance of the groundwater monitoring system. At current methemoglobinemia and bottled water costs of $150/person and $0.6/baby/day, the decision tree results show that the expected cost of establishing the proposed groundwater quality monitoring network exceeds the expected costs of the uninformed alternatives and there is not value to the information the monitoring system provides. However, the monitoring system will be preferred to ignoring the health risk or using alternative sources if the methemoglobinemia cost rises to $300/person or the bottled water cost increases to $2.3/baby/day. Similarly, the monitoring system has value if the system can more accurately report actual aquifer concentrations and the public more fully abides by managers' recommendations to use/not use the aquifer. The system also has value if it will serve a larger population or if its installation costs can be reduced, for example using a smaller number of monitoring wells. The VOI analysis shows how monitoring system design, accuracy, installation and operating costs, public awareness of health risks, costs of alternatives, and demographics together affect the value of implementing a system to monitor groundwater quality.

INTRODUCTION

In many places throughout the world, groundwater is the sole drinking water source but is contaminated by nitrate (NO3-) and other constituents generated from human activities such as agriculture, industry, municipal waste, septic tanks, cesspits, and dairy lagoons (Almasri and Kaluarachchi 2005). When ingested, nitrate decreases the ability of human blood to carry oxygen, which can result in oxygen deficiency and cause methemoglobinemia (blue baby syndrome) and other health problems including dizziness, headache, loss of muscular strength, hemolysis, seizures, or in the most extreme cases, death (Majumdar 2003). Infants are more susceptible than adults (Lorna 2004), with susceptibility depending on the NO3- concentration in contaminated water (Walton 1951). For example, infants who drink water with NO3- concentrations less than 45 mg/l are unlikely to get the disease. On the other hand, 57% of infants who drink water with NO3- concentrations between 45 and 225 mg/l will experience methemoglobinemia, and almost all infants who drink water with NO3- concentrations greater than 225 mg/l will be affected. These health risks create a need to intensively monitor and manage groundwater resources that might be susceptible to nitrate contamination.

Effective groundwater monitoring and management must provide reliable information about groundwater quality, likelihood of different groundwater quality outcomes, and the costs and consequences of potential outcomes and actions. However, information is not free; it requires money and time to acquire (Sakalaki and Kazi 2006). Thus when deciding whether to ignore a contamination problem, use alternative sources of water, or design and implement a groundwater quality monitoring network, it is important to consider the value of information (VOI) provided by the monitoring network. The VOI compares the present-value, the expected net benefits of collecting additional information to reduce or eliminate uncertainty associated with the outcomes of a decision to the present-value, and the expected net benefits of a preferred uninformed alternative (Alfonso and Price 2012; Chia-Yu Lin et al. 1999; Dakins 1999; Dakins et al. 1994; Dakins et al. 1996; Delquié 2008; Rajagopal 1986; Repo 1989; Sakalaki and Kazi 2006; Yokota and Thompson 2004a; Yokota and Thompson 2004b). VOI makes explicit any expected losses from errors in decision-making due to uncertainty and identifies the preferred information collection strategy as one that leads to the greatest expected net benefit to the decision-maker (Yokota and Thompson 2004a).

To estimate net benefits, managers and decision makers can use expected utility (EU) theory (Delquié 2008). In economics, utility is a set of numerical values that reflect consumer satisfaction from receiving a good or service, such as clean drinking water. EU is calculated by weighting the utility of each potential outcome (such as polluted or clean drinking water) by the outcome probability (Perloff 2008). For public policy decisions where consequences are small compared to the scale of the overall enterprise, we can substitute expected value (EV; measured in value units such as dollars) for EU (Arrow and Lind 1970). Like EU, the EV of each decision is calculated by weighting the value of each potential outcome by the outcome probability.

A decision tree model describes the logical structure of the decisions, uncertainties, and potential outcomes (Figure 1), and can help estimate EU or EV (Lund 2008). In the figure, boxes denote choice nodes where decisions are made. Circles denote chance nodes where information is revealed. Each branch emanating from a choice node represents an alternative, and each branch emanating from a chance node represents an uncertain outcome with a specified probability. Each outcome consequence is shown on a terminal branch at the far right of the tree. In Figure 1, the decision maker has two uninformed alternatives (branches 1 or 2) or may acquire more information about the system to later make a more informed decision (branch 3).

The VOI is measured ex-ante as the difference between the EUs or EVs of the informed and uninformed branches (Delquié 2008; LaValle 1968). When the EV of the informed alternative is larger than the EV of the uninformed alternative, VOI is positive and there will be benefit to acquire more information.

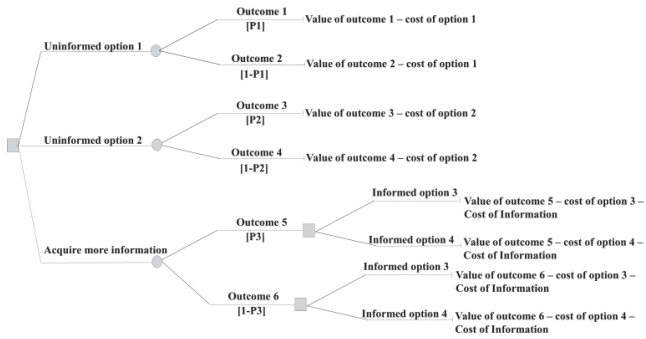

Figure 1. Example decision tree with three alternatives yielding six potential outcomes with probabilities P1, P2, P3, and complements 1-P1, 1-P2, and 1-P3.

Willingness to pay (WTP) is another widely used method to estimate VOI (Alberini et al. 2006; Bouma et al. 2009; DeShazo and Cameron 2005; Dickie and Gerking 2002; Engle-Warnick et al. 2009; Latvala and Jukka 2004; Molin and Timmermans 2006; Roe and Antonovitz; Sakalaki and Kazi 2006) and is defined as the maximum amount a person or a DM is willing to pay to receive a good or to avoid something undesirable (Perloff 2008). Researchers survey individuals and ask them to state how much they are willing to pay for additional information (Alberini et al. 2006; Atkins et al. 2007; Pattanayak et al. 2003). Alternatively, researchers can embed the WTP questions in valuation experiments where participants express their WTP for certain outcomes and then receive rewards/penalties based on their responses and subsequent chance outcomes (Friedman and Sunder, 1994). Both WTP methods require a large number of participants, repeat the method multiple times with individual participants, measure WTP ex-poste from the responses, and assume that participants understand the meanings, outcomes, and likelihoods of the situation posed and are vested in the outcome. For situations where there are only a small number of decision makers, such as a groundwater monitoring system design, the EU method can estimate how rational people should value information and provides an upper bound for WTP that is sufficient for VOI analysis.

This paper uses a decision tree model to estimate the value of information provided by a proposed nitrate groundwater quality monitoring network for the Eocene Aquifer, West Bank, Palestine. The proposed monitoring network and placement of observation wells consider uncertainties in aquifer properties, contaminant transport processes, and climate (Khader 2012). At present, Eocene aquifer managers must decide whether to: (i) ignore the nitrate contamination problem (and face the risk of methemoglobinemia); (ii) recommend households switch to alternative culinary water sources such as bottled water; or (iii) implement the proposed groundwater quality monitoring system then use monitoring results to recommend whether households should either continue to use the aquifer for culinary purposes or switch to alternative water sources. These options differ in their implementation costs, outcomes, likelihood that babies will get sick with methemoglobinemia, and associated consequences. These costs, outcomes, and likelihoods are further affected by whether the public will abide by managers' recommendations to use or not use water from the aquifer for in-home consumption. These costs and uncertainties challenge the decision maker and identify the need for a decision tool that can identify the expected values of the options, determine the value of information provided by the monitoring system, and help decision makers choose a preferred alternative.

Past VOI research in fields like general environmental health, water contamination, and toxicology applications has focused on demonstrating the usefulness of the VOI approach (Yokota and Thompson 2004b). Here, our main contribution is to use the decision tree framework to estimate the value of implementing a groundwater quality monitoring network. Other contributions include applying the approach to help inform aquifer monitoring and management decisions, and showing how the VOI is influenced by a multitude of design, public awareness, financial, demographic, and demographic-hydrogeological factors, such as monitoring system design and accuracy, public abidance with manager recommendations, costs of alternatives, size of the population, and location of the population in relation to areas that pose a health risk.

The next section briefly describes the study area and proposed monitoring network. Sections 3 and 4 present the decision tree components and results from the VOI calculations and sensitivity analyses. Section 5 concludes.

II. STUDY AREA AND PROPOSED MONITORING NETWORK

The methodology of this research is demonstrated using the Eocene Aquifer, which is an unconfined aquifer located in the northern part of the West Bank, Palestine (Figure 2). Nitrate is the main contaminant in the Eocene Aquifer. The main reasons for nitrate contamination in the aquifer are the excessive use of nitrogen-rich fertilizers and the lack of sewer networks (Najem 2008). Nitrate contamination may cause methemoglobinemia for people who live in the area and use the aquifer for culinary purposes.

The Eocene Aquifer is used to meet domestic and agricultural demands for more than 207,000 Palestinians living in 66 communities, including 53,000 people in the City of Jenin (PCBS 2009). Annual population growth in the area is 3.0% and the average household size is 5.5 (PCBS 2008).

In prior work, Khader (2012) used a groundwater flow model, nitrate fate and transport model, and 10,000 Monte Carlo (MC) simulations to capture the effects of uncertainties in aquifer recharge, hydraulic conductivity, and nitrate reaction processes on nitrate concentrations throughout the Eocene

Aquifer. The results were estimates of the spatial distribution of nitrate concentrations across 519 active 1,000 m by 1,000 m aquifer model cells in a finite difference grid that represents the aquifer (Figure 2, right); within each cell there is also a probability distribution of nitrate concentration.

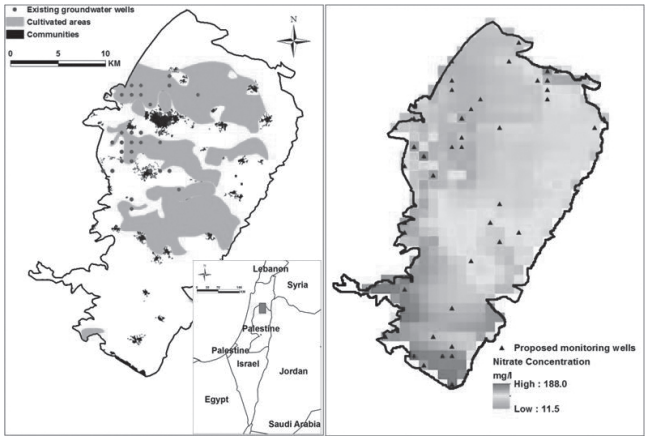

Figure 2. Eocene Aquifer study area. (Left) Palestinian communities, abstraction wells, and cultivated areas. (Right) Average nitrate concentrations predicted by Monte Carlo simulations and proposed monitoring well locations (Khader 2012).

Khader (2012) also used uncertainties revealed through the Monte Carlo simulations to design a groundwater nitrate monitoring network for the Eocene Aquifer. The design shows the proposed locations of 49 monitoring wells and takes into account uncertainties in climate, aquifer properties, and expected nitrate concentrations. To design the network, Khader (2012) used a relevance vector machine (RVM) to build a best-fit model of nitrate concentration distribution everywhere in the aquifer for each Monte Carlo subset. The Monte Carlo simulations yield 10,000 nitrate concentration values for each aquifer water model cell. However, available RVM modeling tools cannot handle a problem of this size, so Khader (2012) performed 100 RVM model runs where in each run, 100 nitrate concentration targets for each cell were randomly but conditionally sampled from the total Monte Carlo population to preserve the spatial correlation of concentrations between cells. The RVM model outputs include the spatial distribution of nitrate concentration everywhere in the aquifer, the uncertainty in the characterization of those concentrations, and the number and locations of "relevance vectors" (RVs). The RVs form the basis of the optimal characterization of nitrate throughout the aquifer and can be used to determine the optimal locations of monitoring wells, predict nitrate concentrations throughout the aquifer, and characterize the uncertainties associated with those predictions. Here, we use all these outputs to calculate the value of information associated with the monitoring network.

III. DECISION TREE ANALYSIS

The decision tree depicts the structure of the problem of how to respond to uncertain outcomes like potential aquifer contamination. We consider three alternatives: (i) do nothing (ignore the nitrate contamination problem), (ii) switch to alternative sources of water, or (iii) implement a groundwater quality monitoring network that reduces uncertainty about groundwater quality and informs subsequent manager recommendations such as to continue to use the aquifer or switch to alternative sources (Figure 3). The decision tree can also be used to calculate the value of information associated with the alternative to monitor to reduce uncertainty.

Ignoring the problem and not testing for nitrate contamination is one uninformed option in which the decision maker will encourage people to use the aquifer for culinary purposes and face a health risk if the aquifer water is contaminated (nitrate concentration greater than 45 mg/l). If the water in an aquifer model cell is contaminated and people who use that water get sick, there will be a cost associated with methemoglobinemia treatment in the form of Methylene blue. Methylene blue converts MHb to hemoglobin, gives immediate relief, but costs about $150 per case (http://www.revolutionhealth.com/drugs-treatments/methylene-blue), which is considered a high cost by the people living in the West Bank (Majumdar 2003). This cost will be considered as a one-time cost and it will be further analyzed in the sensitivity analysis in section 4. As a second uninformed alternative, the decision maker can immediately recommend that people not use water from the aquifer to prepare baby formula and instead switch to alternative sources, such as bottled water. In this case, the supply costs are higher; however, everyone will stay healthy. As a third option, the decision maker can acquire more information about the groundwater quality and the spatial distribution of nitrate concentration. There will be capital costs to design the monitoring network and drill and finish monitoring wells, as well as on-going costs to regularly collect and analyze groundwater samples and operate and maintain the wells. The decision maker can use monitoring results to estimate groundwater quality throughout the aquifer and then, based on the monitoring results, recommend whether people should (i) continue to use the aquifer, or (ii) switch to alternative sources. However, monitoring and estimation of nitrate concentrations are imperfect, so when people continue to use the aquifer there is still a possibility that estimated concentration in their water will differ from the actual concentration. For example, if the monitored/estimated concentration is less than 45 mg/l, the actual concentration might be larger than 45 mg/l. In this

situation, people still face a health risk: they could get sick and require methemoglobinemia treatment even though they followed the decision maker's recommendation to continue to use water from the aquifer. Thus, with monitoring, there are also additional recourse costs that depend on the monitoring results and whether managers subsequently advise households to continue to use the aquifer or use alternative sources. Figure 3 shows this decision tree structure for the case when people fully abide by decision makers' recommendations.

The decision tree structure changes for a second case where only some people abide by decision makers' recommendations (Figure 4). In this case, there are additional branches from each node where a decision maker recommends what people should do; these branches represent people who (i) abide by and (ii) ignore decision maker recommendations. Probabilities A1, A2, A3, A4, 1-A1, 1-A2, 1-A3, and 1-A4 define the likelihoods that people will abide by and ignore the recommendations and are not found in Figure 3 (for the case of full abidance). The additional outcomes represent public awareness and acceptance of decision maker recommendations and ultimately affect the value of information provided by the monitoring system.

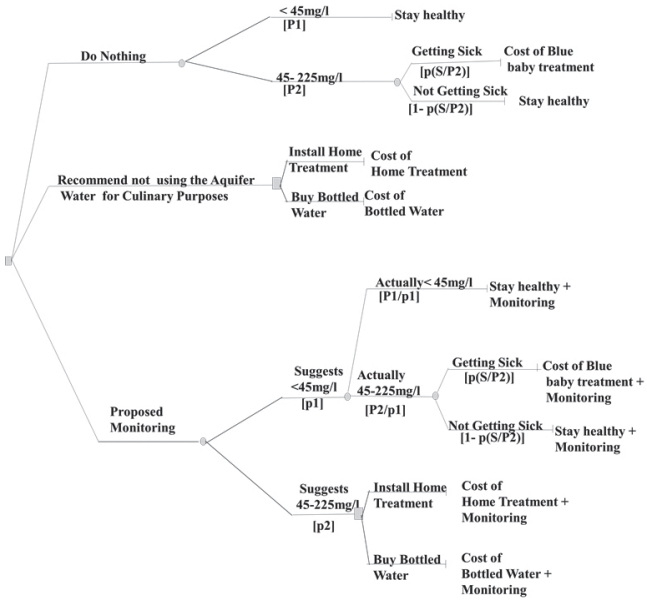

Figure 3. Decision tree model for the scenario where people fully abide by decision maker recommendations.

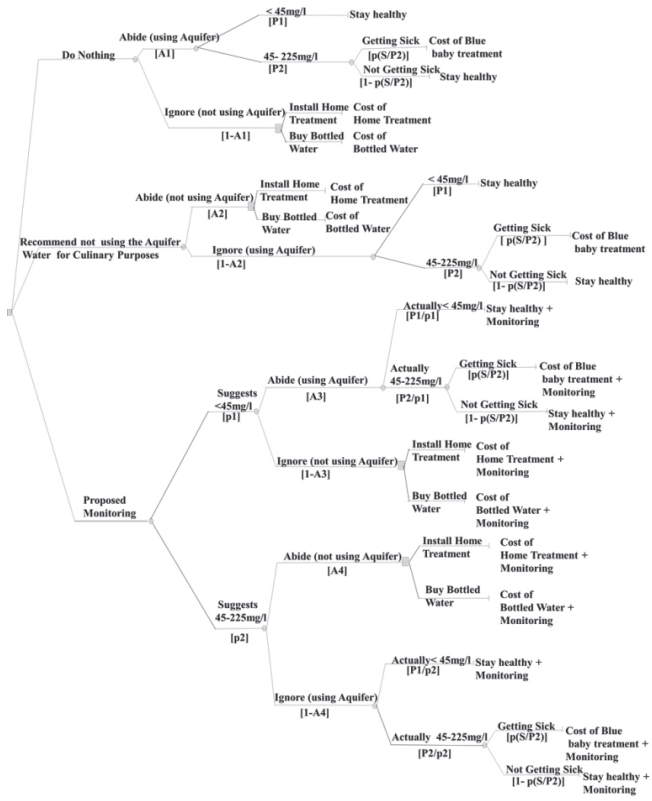

Figure 4. Decision tree model for the scenario where some people abide by and others ignore decision makers' recommendations.

Since outcome costs listed in the decision tree occur both immediately and in future years, we use a common 30-year time horizon (equivalent to the life of the monitoring system) and an interest rate of 5% to bring all future costs to their present value. We also assume that aquifer nitrate concentrations are temporally static over the 30-year analysis period and people face the same health risk each year. Below we present our methods to estimate the various outcome costs and outcome probabilities listed in the decision tree. Then we describe how we use the outcome costs and probabilities to compute an expected cost for each alternative and the value of information for the groundwater quality monitoring system. The decision tree model and the outcome costs were implemented using Excel spreadsheets.

A. Outcome Costs

As shown in the decision tree (Figure 3), there are costs associated with the outcomes resulting from each alternative. These outcome costs include:

1. Methemoglobinemia treatment. When aquifer water is contaminated with nitrate and an individual contracts methemoglobinemia, the most common treatment is methylene blue (Majumdar 2003). The estimated cost of

methylene blue treatment for an infant is $150 (http://www.revolutionhealth.com/drugs-treatments/methylene-blue). Additionally, we assume that both parents work, so when an infant gets sick, at least one parent will stay home for 6 work days to care for the infant, as is common in the West Bank. West Bank wages are typically $50/day. Thus, there is an additional cost of $300 in lost salary associated with the outcome of getting sick.

To estimate community-wide costs, we scale the individual costs per family by the number of households served by the pumping well and the 30% fraction of households that use formula rather than breast milk (Ammar et al. 2008). Absent detailed data on the water distribution system in the study area, we assume that the number of households served by a pumping well is proportional to the pumping rate from the well (Khader 2012). Additionally, the population in the study area is growing by 3% per year, so the number of people affected and costs in future years also increase.

2. Switch to alternative sources. In this option people use alternate water sources to make infant formula rather than polluted groundwater. One alternative water source is bottled water, which costs about $0.6/infant/day or $220/infant/year. Other alternatives include home distillation, reverse osmosis (RO), or ion exchange units (Jennings and Sneed 1996). These units are much more expensive than bottled water, and our analysis assumes households will choose the cheaper bottled water option. We use the same methods as for methemoglobinemia treatment to scale the household cost for bottled water to a community cost.

3. Monitoring system. The costs to install and operate the 49 wells comprising the monitoring system include three components (CDLE 2001):

- Drilling cost ($53.89/m for a well <15 m deep or $60.45/m for a well >15 m deep)
- Finishing cost ($49.72/m), and
- Nitrate sampling cost ($12/well/year), considering only one sample per year for simplicity.

The depth to ground water at each well is estimated using the groundwater flow model developed in Khader (2012). The total present value cost to install and operate the monitoring system are $US 0.6 million, which includes drilling, finishing, and sampling costs.

There are also additional costs associated with further decisions and outcomes taken in response to the monitoring results. For example, if monitoring suggests the water in an aquifer model cell is not contaminated (nitrate concentration < 45 mg/l), decision makers will recommend people to continue to use that water. But the monitoring system is imperfect and there are still possibilities that the actual nitrate concentration will be above 45 mg/l and some people will get sick. In this progression of events, these people will require methemoglobinemia treatment at costs described in cost item #1 above. Similarly, if monitoring suggests the water in an aquifer model cell supplying a pump is contaminated (nitrate concentration > 45 mg/l), decision makers will recommend people who use that water to switch to an alternative source. In this case, these people will incur the costs described in cost item #2 above. Together, the expected cost of the monitoring system includes the present value costs of installing and operating the system plus the present value expected costs of recourse actions and outcomes that occur in response to the monitoring results.

B. Probability Estimation

Probabilities quantify the likelihood of uncertain outcomes such as groundwater quality and public response to decision maker recommendations. We use probabilities to weigh outcome costs and determine the expected cost for the set of outcomes associated with an alternative. Below we describe the methods used to estimate the probabilities associated with uncertain groundwater quality and public responses.

Groundwater Quality: Here, we use prior Monte Carlo simulation and RVM model results derived from uncertainties in climate, aquifer properties, and expected nitrate concentrations (Khader 2012) to estimate the outcome probabilities listed in the decision tree (Figures 3 and 4). We define each probability and present the method to estimate it.

- [P1] is the probability that the actual nitrate concentration in an aquifer model cell is less than 45 mg/l. We estimate this probability by dividing the number of MC simulations where concentration in the aquifer model cell was less than 45mg/l by the total number of MC simulations (10,000 for the current study).
- [P2] is the probability that the actual nitrate concentration in an aquifer model cell is in the range 45225- mg/l. We also estimate this probability from the MC simulations.
- [P3] is the probability that the actual nitrate concentration in an aquifer model cell is greater than 225 mg/l. MC results show that nitrate concentration did not exceed 225 mg/l in any aquifer model cell in any MC simulations. Thus, P3 is zero and we do not consider this outcome in the decision tree.
- [S/P1] is the probability that an infant will get sick with methemoglobinemia given the nitrate concentration in an

aquifer model cell is less than 45 mg/l. This probability is zero (Walton 1951).

- [S/P2] is the probability that an infant will get sick with methemoglobinemia given the nitrateconcentration is in the range 45225- mg/l. This probability is 57% (Walton 1951).
- [p1] is the probability that the monitoring network will suggest nitrate concentration in an aquifer model cell is less than 45 mg/l. We estimate this probability from the RVM model (Khader 2012) by dividing the number of RVM runs where concentration in the aquifer model cell was less than 45mg/l by the total number of runs (100 in this study).
- [p2] is the probability that the monitoring network will suggest nitrate concentration in an aquifer model cell will be in the range 45225- mg/l. This probability is also estimated from the RVM model like for [p1].
- [P1/p1] is a posterior probability and is the probability that the actual nitrate concentration in an aquifer model cell will be less than 45mg/l when the monitoring network suggests the aquifer concentration is less than 45 mg/l. In this circumstance, the monitoring system predicts the correct outcome and we can use Bayes Theorem to calculate this posterior probability from the prior probability [p1/P1] and probabilities [P1] and [p1] that we already know:

$$[P1/p1]=\frac{[P1][p1/P1]}{[p1]} \qquad (1)$$

- [P2/p1] is the probability that the actual concentration in an aquifer model cell will be in the range 45225- mg/l when the monitoring network suggests the concentration is less than 45 mg/l. This case is the complement to [P1/p1] and also represents a Type II error: the monitoring system suggests the aquifer water is safe when in fact the water actually poses a risk. Together, the probabilities for the correct outcome ([P1/p1]) and Type II error ([P2/p1]) sum to 1 and comprise all possible outcomes for the situation when the monitoring system suggests nitrate concentration in an aquifer model cell will be less than 45 mg/l. Thus, we use the law of probabilities to estimate [P2/p1] as:

$$[P2/p1]=1-[P1/p1] \qquad (2)$$

- We use similar methods to estimate [P2/p2] and [P1/p2] as the probabilities that the actual nitrate concentration in an aquifer model cell will be in the ranges of, respectively, 45-225 or 045- mg/l when the monitoring network suggests the concentration will be in the range 45225- mg/l. The probability [P2/p2] also represents a true outcome while [P1/p2] represents a Type I error: the monitoring system suggests the water poses a risk when the water is actually safe.

The above probability estimates are for an individual aquifer model cell. Since the aquifer is heterogeneous, the probability values may also differ by aquifer model cell. In the analysis of alternatives, we use probabilities associated with aquifer model cells that have a withdrawal well and supply people with water.

Public Response: People's responses to a decision maker's recommendation are an important factor that determines the structure of the decision tree and likelihood of outcomes, as shown in Fig.4. To estimate the likelihood that people will abide by decision maker recommendations, we invited two hundred fifty people living in the area of the Eocene Aquifer to participate in a survey that asked them their perceptions of the current water quality and quantity situation and how they would respond in four hypothetical scenarios where decision makers recommend they use/not use aquifer water. The study was approved by the institutional review board at Utah State University, and surveys were administered directly to participants in summer 2011 at centers throughout the study area where they also pay their water bills. One hundred and ninety-six people living in 26 communities responded. Kader (2012) provides a full description of the survey method and results; here, we focus on the portion of the survey that probes how participants may respond to manager recommendations to use or not use water from the Eocene Aquifer. In the first two hypothetical scenarios, the government simply declared the groundwater is either (i) safe or (ii) not safe to drink. In the third and fourth scenarios, the government monitored and tested the aquifer water then declared the water either (iii) safe or (iv) not safe (Khader 2012).

Statistical analysis of the responses to the four questions associated with these four scenarios provides estimates of the abidance probabilities A1-A4 (Table 1). Absent monitoring, less than 30% of participants would abide by recommendations to use the aquifer. However, 96% of participants would abide by a decision maker's recommendation if the recommendation is to not use the aquifer. With monitoring in place, more people will abide by the recommendations to use or not to use the

aquifer (62% and 97%). Across all the scenarios, people are more likely to abide by a decision maker's recommendation when the recommendation is to not use the aquifer. Together, he survey responses suggest which types of messages people will follow and characterize the probabilities people will abide by decision maker recommendations.

Table 1 Probabilities participants will abide by decision maker recommendations

Recommendation		Probability of abidance			
		Label	Mean value	Standard deviation	95% C.I
Without monitoring	Use the aquifer	[A1]	0.294	0.457	0.230-0.358
	Use other sources	[A2]	0.959	0.199	0.931-0.987
With monitoring	Use the aquifer	[A3]	0.624	0.486	0.556-0.692
	Use other sources	[A4]	0.969	0.174	0.945-0.993

C. Expected Costs of Alternatives and Value of Information

We convert all outcome costs to their present values then calculate the expected cost of an alternative as a weighted average of all outcome costs associated with the alternative. We use the outcome probabilities (p1, p2, P1, P2, A1, A2, A3, and A4 in Figures 3 and 4) as the weights. In the Eocene Aquifer study, present-value expected costs incurred by decision makers and the public serve as an adequate proxy for expected value since these costs are the principal factors affecting the expected value of each alternative. A probability-weighted expected-cost metric is risk-neutral and is appropriate for the case when the magnitudes of outcome costs are small, there are similar types of outcomes across the alternatives, and the decision maker does not have strong preferences among outcomes with large and small magnitudes.

We then use the present-value expected costs to estimate the value of information of the monitoring network. This value is the difference between the expected costs of implementing the monitoring network and the lowest-cost, uninformed alternative.

IV. RESULTS AND DESCUSSION

The present-value expected costs of the options to do nothing (continue to use the aquifer), switch to alternative sources, and install and use the monitoring system range between $6 and 7 million (Figure 5). The two uninformed options (do nothing and switch to alternative sources) have nearly equivalent expected costs; the expected cost to switch to alternative sources is slightly smaller, which identifies the use alternative sources option as the preferred response to potential nitrate contamination in the Eocene Aquifer. The expected cost for the monitoring system is larger than either of the uninformed options, which suggests that information provided by the monitoring system does not have value under the modeled assumptions. The monitoring system does not have value because implementing an uninformed option gives a lower expected cost.

When the abidance ratio was relaxed to the values of probabilities A1 – A4 estimated from the survey results (i.e., some people will ignore decision makers' recommendations), the expected cost of the monitoring system slightly increases (purple bars in Figure 5). Expected costs only increase slightly due to the results of the survey which showed that the abidance rate is high in 3 out of 4 scenarios (the values of A2, A3, and A4 are 0.96, 0.62, 0.97, respectively, as shown in table 1). Importantly, this result shows how public awareness, acceptance, and compliance with health safety messages affect the value of information provided by a monitoring network. The result suggests that public outreach to local communities through town hall meetings, media advertising, education campaigns in schools, and the like should be part of monitoring programs since more people abiding with decision maker recommendations reduces overall costs and increases the value of information provided by monitoring.

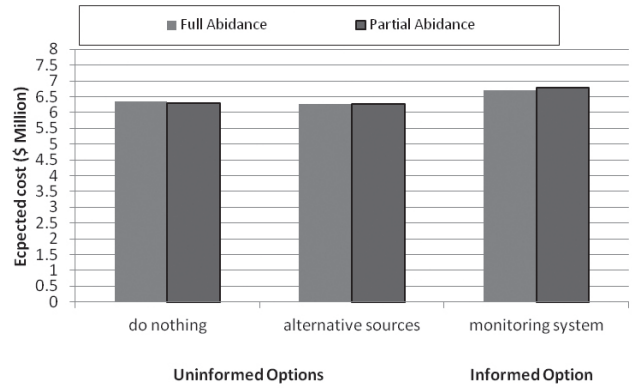

Figure ٥. Present-value, expected costs of alternatives.

We estimate the upper bound on WTP for the monitoring system as the difference in expected costs associated with (i) recourse actions taken after implementing the monitoring system", and (ii) the best uninformed option to not use the aquifer. Fig. 6 shows that this WTP, which is measured ex-ante, is below the expected costs to install and operate the monitoring system. This result shows that the proposed monitoring system does not have value.

However, this ex-ante approach to estimate WTP allows us to further study monitoring systems with unknown installation

and operation costs such as a hypothetically perfect monitoring system that always estimates nitrate concentrations in their actual ranges. In the decision tree model, we represent a perfect monitoring system by changing the values of the posterior probabilities [P1/p1] and [P2/p2] to 1 and the probabilities associated with type I and II errors ([P1/p2] and [P2/p1]) to 0. Model results for the perfect monitoring system show that WTP increases (Figure 6). Should people fully abide by decision maker recommendations, WTP for perfect monitoring exceeds the present value costs to install and operate the proposed (imperfect) monitoring system. For the case of partial abidance with decision maker recommendations, WTP for perfect monitoring is below the costs of the proposed system. When WTP for a perfect system is below the actual system cost, analysts often suggest that decision makers should not invest in monitoring (Yokota and Thompson 2004b). However, lowering the monitoring system capital and operating costs (red line in Figure 6) to $0.2 million (in the case of full abidance) or $0.1 million (with partial abidance) would make the monitoring system investment worthwhile. Decision makers could lower the monitoring system capital costs by reducing the number of monitoring wells or moving wells to locations where it is less expensive to install them. Alternatively, decision makers could improve monitoring system accuracy by including other sources of uncertainty like human activities and on-ground nitrate loading, and considering temporal variations in nitrate concentrations (Khader 2012). The WTP results show how monitoring system size, design, accuracy, public abidance with decision maker recommendations, and capital and operating costs together influence the value of information provided by the monitoring system.

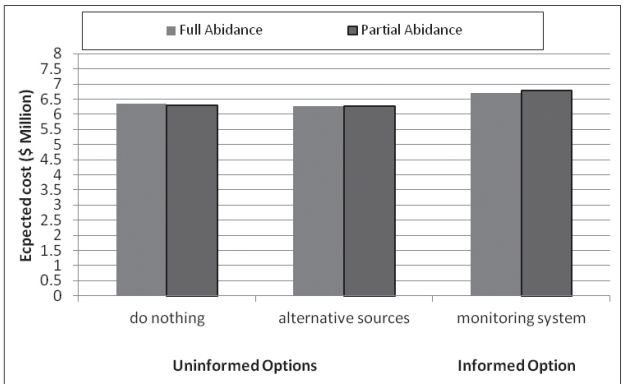

Figure 6. Upper bounds on willingness-to-pay for monitoring systems.

Sensitivity analysis further shows how the value of information provided by the monitoring system is affected by financial, demographic, and demographic-hydrogeological factors. For example, when the cost of methylene blue treatment rises above $300 per person, the expected cost for the do nothing option surpasses the expected costs for the monitoring system and monitoring becomes preferable to doing nothing (results not shown). Similarly, the monitoring system is preferable to the bottled water option when the bottled water cost rises to $2.3/baby/day. When the population using the aquifer increases to 1.2 million, the expected costs for both uninformed options surpass the expected cost for the monitoring system, in which case the monitoring system has value. These results show that financial characteristics of the uninformed alternatives, as well as demographics, affect the value of information.

Beyond the demographic factor of the number of people using the aquifer, monitoring system VOI is also influenced by where people are located relative to aquifer hydrogeological characteristics such as nitrate-contaminated areas. To study this effect, we first noted that in the prior results, 86% of the population is served by wells that draw from locations in the aquifer where the expected nitrate concentration is greater than 45 mg/l and may pose a health risk. (Similarly, 14% of the population is served by wells that pose little health risk.) These results stem from the prior assumption that the number of households served by a pumping well is proportional to the well pumping rate. Second, we varied the percent of the population served by wells that pose a health risk from 0 to 100% and calculated the expected costs for each alternative with partial abidance. These scenarios can be interpreted to represent either demographic (i) proximity to wells where nitrate concentration is greater than 45 mg/l, or (ii) migration towards or away from such wells. As anticipated, results show that do nothing is the low-cost, clearly-preferred option when 0% of the population is at risk (Figure 7, far right). Similarly, switch to alternative sources is the low-cost, preferred option when 100% of the population is served by wells where nitrate poses a health risk (Figure 7, far left). Interestingly, expected costs increase for all options as more of the population is served by wells that pose a risk. However, expected costs increase fastest for the do nothing option and slowest for the alternative sources option, so alternative sources become preferable when 86% or more of the population is served by wells that pose a health risk. Across the scenarios, the expected costs for the monitoring system are always greater than costs for one of the uninformed options. However, the gap narrows between the expected costs of the monitoring system and the least-cost uninformed option as more of the population is served by wells that pose a health risk. This gap, representing the value of information of the monitoring system, is less than the $0.6 million capital and operating cost of the monitoring system in scenarios where more than 86% of the population is served by wells that pose a health risk, which suggests, as discussed

previously, that there is value to a monitoring system with lower capital and operating costs. This value is also affirmed by noting that the decision maker does not presently know what percentage of the population faces a health risk. Thus, should s/he recommend do nothing or switch to alternative sources? To answer this question, the decision maker will need to monitor, and the $0.3 million gap between monitoring and the expected costs of the do nothing and switch to alternative sources options when 100% of the population is at risk represents an upper bound on a decision maker's WTP to monitor. The decision maker's actual WTP may be less and will depend on his/her prior information regarding aquifer contamination and the likelihood s/he associates with the outcome that the entire population will be at risk. These scenarios show that monitoring system VOI is also influenced by where people are located relative to aquifer hydrogeological characteristics such as nitrate-contaminated areas.

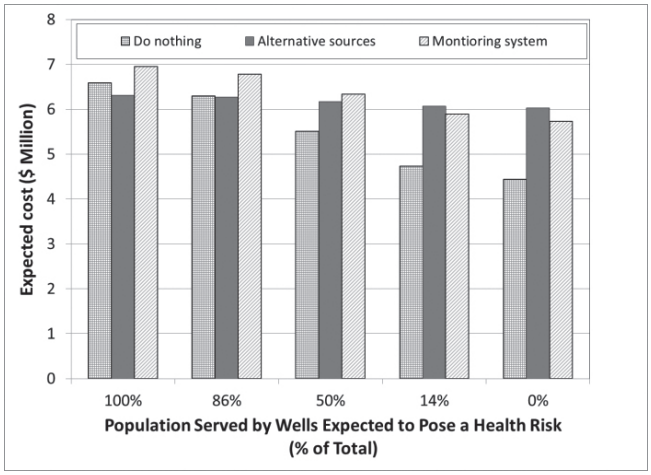

Figure 7. Expected costs for alternatives with partial abidance under population redistribution scenarios where more/less people use nitratecontaminated aquifer water.

Together, the decision tree model, VOI results, and sensitivity analyses show that the proposed monitoring system for the Eocene aquifer does not have value and that uninformed options like switch to alternative sources are lower-cost. However, the VOI provided by the monitoring system is affected by important public acceptance, system design, financial, demographic, and demographic-hydrogeological factors such as whether people abide by decision maker recommendations, accuracy of the monitoring system, installation and operation costs, costs of uninformed alternatives, the number of people served by the aquifer, and where people live in relation to areas with nitrate concentrations that pose health risks. These results indicate that there is WTP for a monitoring system but the system installation and operating costs for the proposed system will need to decrease by half to $0.3 million or less for the system to have value. Besides using fewer monitoring wells (with potentially some loss in concentration prediction ability), decision makers could alternatively lower the monitoring system cost by including costs to drill and finish wells as additional criteria in the RVM design and selection of monitoring well locations. This latter approach identifies the potential benefit to embed value of information methods directly in the monitoring network design process.

V. CONCLUSIONS

This paper presents a decision tree method to estimate the value of information provided by a groundwater quality monitoring network located in an aquifer whose water poses a spatially heterogeneous and uncertain health risk. We use the decision tree to describe the structure of the decision alternatives facing the decision maker, as well as likelihoods and expected outcomes of these alternatives. The alternatives include: (i) do nothing (continue to use the aquifer and ignore the health risk of nitrate contaminated water), (ii) switch to alternative water sources, or (iii) implement a previously designed groundwater quality monitoring network that takes into account uncertainties in aquifer properties, contaminant transport processes, and climate. We estimate the value of information provided by the monitoring network as the difference between the present-value expected costs of the monitoring network and the lowest-cost uninformed alternative.

We illustrated the method for the Eocene Aquifer, West Bank, Palestine where methemoglobinemia is the main health risk associated with nitrate contamination. We estimated the expected costs of each alternative as the weighted sum of the costs and probabilities (likelihoods) associated with the potential outcomes resulting from the alternative. Potential outcomes included contaminant concentrations in individual aquifer model cells, concentrations reported by the monitoring system, whether people abide by manager recommendations to use/not-use aquifer water, and whether people get sick from drinking contaminated water. The likelihoods of these outcomes were derived from Monte Carlo simulations of uncertain aquifer properties, RVM results, surveys of people's likely responses to official pronouncements regarding aquifer water quality, and prior heath studies. Outcome costs included healthcare for methemoglobinemia, purchasing bottled water, and installing and maintaining the groundwater monitoring system.

Decision tree results show that the expected cost of establishing the proposed monitoring network exceeds the expected costs of the uninformed alternatives and there is not value in the information the system provides. Eocene Aquifer managers

should instead recommend that families use alternative sources like bottled water to make baby formula.

The value of information provided by the monitoring system is further diminished when only part of the affected population abides by decision maker recommendations to use/not use the aquifer. However, should bottled water costs increase to $2.3/baby/day, methemoglobinemia costs rise to $300/person, or the population served by aquifer increase above 1.2 million persons, decision makers should prefer the monitoring system to switching to alternative sources or ignoring the health risk. A monitoring system with lower installation and operating costs or that more accurately reported actual aquifer concentrations would likewise have value. Designers could lower system costs by either (i) using fewer monitoring wells, or (ii) including the costs to drill and finish wells as additional criteria in the RVM to select monitoring well locations.

The VOI analysis offers Eocene Aquifer managers specific recommendations to respond to the nitrate contamination in the West Bank, Palestine. The analysis also shows how the value of information provided by a monitoring system is affected by important system design, public acceptance, financial, demographic, and demographic-hydrogeological factors like monitoring system accuracy, installation and operation costs, whether people abide by decision maker recommendations, costs of uninformed alternatives, the number of people served by the aquifer, and where people live in relation to areas with nitrate concentrations that pose health risks. Monitoring groundwater quality in the Eocene Aquifer has value, but most likely using a modified version of the proposed monitoring system.

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A Proposal for Sustainable Water Use in the West Bank

By Dima Nazer*

ABSTRACT

Water in the West Bank in Palestine is a key issue due to its limited availability resulting from arid climate conditions as well as the Israeli control over the water resources available in the area. Since 1967, when Israel occupied the West Bank, Israel severely restricts the amount of water for the Palestinians. For example, the Palestinians have no access to the water from the River Jordan. As a consequence, there is unequal distribution of the water resources in the area between Palestinians and Israelis (50 m3/cap/year versus 300 m3/cap/year). The Israelis are using more than 80% of the groundwater available in the West Bank and 60% of the water flow from River Jordan. However, the current water use in the area is unsustainable because aquifers are being overexploited while deterioration of the quality of the water resources will further reduce the available quantity of good quality water. The water sector in Palestine is facing problems of water scarcity, unequal distribution of water and inadequate use of the scarce water resources and sanitation systems, in addition to the population growth and economic development which is expected to increase the pressure on the scarce resource. Therefore, there is a need for a completely new approach towards water management in the area, whereby return flows are viewed as a resource and the focus is on the conservation-oriented approach of "use, treat and reuse'.

After considering two initial scenarios, the "do-nothing" and the "water stress", this study develops a strategy for sustainable management of water in the West Bank that can be used to guide the development of the Palestinian water sector. Analysis of the existing situation of the water sector as well as the expected availability and demand projections for the year 2025 were conducted. It was concluded that striving for equitable water rights to the existing water resources in the area is essential to satisfy the basic water needs for all Palestinians. However, until then sustainability can gradually be achieved by the staged introduction of a combination of water management alternatives in the domestic, agricultural and industrial sectors.

Key words*: *Palestine, strategy, sustainability, water management, West Bank.

1. Introduction

The demand for high quality water is increasing all over the world because of growing populations and increasing demands from the industrial and agricultural sector. With finite resources, countries are, therefore, increasingly forced to device plans for the efficient utilization of the available water. The West Bank in Palestine is, in that sense, no exception. However, the arid climate of the West Bank region as well as the Israeli control over the water available for Palestinians living in the West Bank emphasize even more the need to be careful with available water.

The total average water use in the West Bank is 123 million m3/year. With a population 2.5 million, this amounted to 50 m3/cap.year. Since 2004, the water availability has remained constant while the population has increased. The Oslo II Agreement of 1995 include a paragraph stating that the West Bank will be provided with an additional 75 million m3/year of groundwater, to be provided from "new resources" (Oslo II Agreement, 1995). According to Oslo II promise, although this agreement seems not realistic but as a best case, we can assume that the theoretical water availability for Palestinians in the West Bank is 198 million m3/year equal to 80 m3/cap/year. The latter is expected to drop to 45 m3/cap/year by the year 2025 because of population growth and industrial development (Nazer et al., 2008). These are still very low figures by any standards, including the definition of water scarcity of less than 1,000 m3/cap/year proposed by Falkenmark (1986). It can, therefore, be stated that the West Bank is in a situation of extreme water scarcity.

The scarce water resources are facing threats of water pollution due to the disposal of untreated wastewater. This pollutes water resources and further decreases water quality and, therefore, availability (Nazer et al., 2008). In most cases wastewater is discharged directly into wadis without any type of treatment increasing the environmental problems (MOPIC, 1998 b; ADA and ADC, 2007). Depletion of water resources and deterioration of water quality are key environmental challenges that require urgent action.

Although the water resources are shared between Israel and Palestine, there is unequal allocation of the water. The per capita water use, for all purposes (domestic, industrial and agricultural), of the Israelis is 324 m3/cap/year (adapted from Adin et al., 2004) while the Palestinians water use is 50 m3/cap/year (PWA, 2004).

A shift in thinking is needed, in terms of both water and sanitation systems, to solve the problem of water scarcity and the problem of environmental deterioration. For water systems, the attitude of dealing with water as a resource with no value needs to change. Water is to be looked at as a scarce and valuable good for which there often is no substitute. Water should be conserved whenever possible and water conservation methods must be introduced at the domestic, industrial and agricultural levels. Also a new sanitation approach is needed, one focusing on the use of the least amount of water while ensuring the improvement of public and environmental health. This is possible through a sanitation system that treats the waste on site or even derives benefits from what is considered waste by reusing it or recovering some of its components.

In order to improve the water situation in the West Bank, new ways should be traveled which change the current trend of once-through water use and identify the path towards water sustainability in the West Bank in Palestine.
In 2000 the Palestinian Water Authority (PWA) formulated its National Water Plan that outlines the direction in which the Palestinian water sector is proposed to develop until the year 2020. The main goal of the National Water Plan is to achieve the equitable and sustainable management of water resources in Palestine where everyone has access to 150 liters of water/day to satisfy his/her domestic needs and where enough water is available for the development in agriculture and industry. However, the National Water Plan relies on achieving the Palestinians' water rights, through negotiations with Israel, from the existing groundwater aquifers and surface water from the River Jordan. As the political situation is complicated and the permanent status negotiations have not been accomplished and it may take ages to achieve the water rights through negotiations, the promise of the National Water Plan is unrealistic.

The objective of this paper is to develop a proposal for future water use that allows the Palestinians living in the West Bank to access an adequate volume of water per day of sufficient quality for domestic, agricultural and industrial purposes and that leads, after a transition period, to a situation of water sustainability by 2025.

2 Background

2.1 Study area

This study focuses on the West Bank. The West Bank is situated on the central highlands of Palestine; the area is bordered by the River Jordan and the Dead Sea in the east and the 1948 cease-fire line in the north, west and south. The total area of the West Bank is 5,800 km2 including the area of the Dead Sea that falls within the West Bank boundaries. The results of the 2007 census show that in 2007 the total Palestinian population living in the West Bank was 2.4 million (PCBS, 2008). The population predictions indicated that the projected population of the West Bank in 2025 is 4.4 million (PCBS, 1999).

2.2 Available water resources

The water resources available in the area are groundwater and surface water from the River Jordan. Groundwater is the main source of fresh water for Palestinians in the West Bank as it accounts for 95% of the total water consumption. In addition, Palestinians harvest rainwater from roofs or rock catchments and store it in cisterns, to meet part of their household needs (WRAP, 1994; Haddad, 1998; Nazer et al., 2008).

Groundwater in the aquifer system flows in three main drainage basins: the Western, the Northeastern and the Eastern basins. The first two basins are shared between the West Bank and Israel, the eastern basin falls entirely within the West Bank (WRAP, 1994; MOPIC, 1998 a; SUSMAQ and PWA, 2000). The annual average recharge of the three basins is 679 million m3/year. However,

the total groundwater abstraction (fresh and brackish) by both Palestinians and Israelis amounts to 770 million m3/year, out of which 85% is abstracted by Israelis and the rest 15% is abstracted by Palestinians. This means that the aquifers are being overused (Nazer et al., 2008).

The River Jordan is the only source of surface water in the area. The natural flow of the river in the absence of extraction is estimated at 1250- 1600 million m3/year (Mimi and Sawalhi, 2003). Abed and Wishahi (1999) stated that the most famous agreement regarding water allocation in this river is the Johnston Plan developed by Erick Johnston in 1953. According to this agreement the Palestinians share of water is included in the Jordanian share because the West Bank was part of Jordan at that time and is between 257 and 320 million m3/year (Abed and Wishahi,1999). In spite of this, the Palestinians are not allowed to use water from River Jordan as a result of the Israeli control over the flow of the river.

2.3 Water use

Table 1 presents the water use for Palestinians in the West Bank. The overall water use has remained more or less stable, while population has grown which causes the per capita water use to decrease. The water use decreased from 139 m3/cap/year in 1991 (Eckstein and Eckstein, 2003) to 50 m3/cap/year in 2005 (Nazer et al., 2008). This number will continue to decrease because of the population growth and limited amount of extra water being made available for Palestinians.

numbers [a] 1991		numbers [b] 1995		numbers [c] 2003	
Total *Mm^3/year	Per capita (m^3/c/year)	Total Mm^3/year	Per capita (m^3/c/year)	Total Mm^3/year	Per capita (m^3/c/year)
125	139	139	72	123	50

Mm^3/year stands for million m^3 per year *

[a] Based on Eckstein and Eckstein (2003)1991 numbers

[b] Based on Fisher et al. (2005) based on 1995 numbers

[c] Based on (Nazer et al. , 2008) 1988-2003 numbers

2.4 Palestinian rights to water

According to Wolf (1999) water is the only scarce resource over which the international law is poorly developed and there are no internationally accepted criteria for allocating shared water resources or their benefits. However, in 1966 the International Law Association (ILA) adopted the Helsinki Rules which were further developed by the International Law Commission (ILC), an organization created by the United Nations. In 1991, the ILC completed the draft of the "Convention of the law of non-navigational uses of international watercourses" which has been approved by the United Nations General Assembly in 1997 (Wolf 1999; UN, 2005). According to article 5 of the convention, the right to use part of shared water resources by riparian states is recognized as it indicates that all parties that share an international water basin should be entitled to a reasonable and equitable share of water with the obligation of not causing significant harm to another user (article 7 of the convention). Additionally, the human right to water has been guaranteed in human rights law. The general comment # 15 released by the UN Committee on Economic, Social and Cultural Rights in November 2002 stated that "The human right to water entitles everyone to sufficient, safe, acceptable, physically accessible and affordable water for personal and domestic uses". Accordingly, both Palestinians and Israelis have the right to use the surface water coming from the River Jordan as well as the groundwater available in the area because they are sharing these water resources.

In the basin of the River Jordan, over the years many management plans and attempts to reach agreements over water resources have been proposed such as Main Plan (1953), Johnston Plan (1953), Cotton Plan (1954) and Arab Plan (1954). Nevertheless, countries in the region have continued to develop their water resources, often at the expense of other countries (Mimi and Sawalhi, 2003). For example, Israel constructed the National Water Carrier which brings some 500 million m3/ year from Lake Teberias to the south and central region of Israel and Jordan developed the east Ghore Canal for irrigation. Historically, the Palestinians in the West Bank enjoyed using part of the water from River Jordan before the Israeli occupation of the West Bank in 1967 (Weinthal and Marei, 2001). Moreover, their right to water from river Jordan has been recognized in the Johnston Plan (1953). However, the Israelis banned the Palestinians from using the water from this river after the occupation in 1967, ignoring the Palestinians‘ right to the water.

Rights to surface water

In the context of surface water allocation in the area Mimi and Sawalhi (2003) developed a methodology for allocating the water from the River Jordan between the riparian parties. In their study they considered nine factors listed by the International Law Association as the factors associated with equitable water: population size, hydrology, climate, past and existing use, availability of other resources, geography of the basin, comparative costs of alternatives and economic and social needs. According to this methodology, the Palestinians would have the right to use 14% of the total flow of the river (12001600- million m3/year). This amounts to some 200 million m3 /year.

Rights to groundwater,

With regard to ground water, Eckstein and Eckstein (2003) stated that the international law constitutes the rules and norms by which states conduct their actions in relation to other states. Historically, the focus of international water law was on surface water such as shared lakes and rivers. The use, management and conservation of shared groundwater resources received little attention in international legal discourse and political circles and generally was absent from bilateral and multilateral agreements. The International Law Associations' Helsinki Rules of 1966 and Seul Rules in 1986 were among the few international documents to directly address the status of groundwater under international law (Eckstein and Eckstein, 2003). However, in the case of groundwater shared by Palestine and Israel, there is no agreement that shows the share of each party or even guarantees the water rights for both parties. Mimi and Aliewi (2005) proposed a methodology for shared groundwater allocation between Palestinians and Israelis similar to that developed by Mimi and Sawalhi (2003) for distributing water of the River Jordan. The results of their study suggested that the Palestinians have the right to 60% and the Israelis 40% of the groundwater available in the West Bank aquifers. This would give the Palestinians the right to use some 400 million m3 /year of the groundwater available in the area.

Accordingly, if we follow Mimi and Sawalhi (2003) and Mimi and Aliewi (2005), some 600 million m3/year of water would be available for the Palestinians in the West Bank from both the River Jordan and groundwater, a number that could satisfy the needs of the Palestinians until 2025 and beyond. However, in the existing political situation of Israel's continued denial of the Palestinian water rights, water scarcity will not decrease but, in contrast, will continue to increase.

Many ways have been proposed to confront the increasing water scarcity in the area such as desalination plants, the construction of the Red and Dead Seas canal and the peace pipeline from Turkey (Eckstein and Eckstein, 2003). All these proposals focus on finding new water resources to fill in the gap between water demand and water availability. However, re-allocation of water resources between both parties, based on equitable water use for all, is an important step towards approaching water scarcity in the area. Moreover, water management is of great importance for both Palestinians and Israelis. The focus of this paper is to reduce water demand to match water availability. The demand management methods suggested in this paper can be applied in both Israel and Palestine and will result in a decrease of the pressure on the scarce water resources. However, this paper will focus on the West Bank only.

2.5 SWOT analysis of the water sector in the West Bank

In 2000 the Palestinian Water Authority (PWA) developed a National Water Plan (PWA, 2000). The vision of the National Water Plan is "to ensure equitable use, sustainable management and development of Palestine's water resources." The main goals of the plan are:

1. To optimally manage, protect and conserve existing water resources and enhance new resources to meet present and future demands.
2. To guarantee the right of access to water of good quality for both the present population and future generations at costs that they can afford.
3.

Figure 1 shows the overall strategy proposed by PWA in its National Water Plan (PWA, 2000). The strategy consists of three main areas where action is proposed.

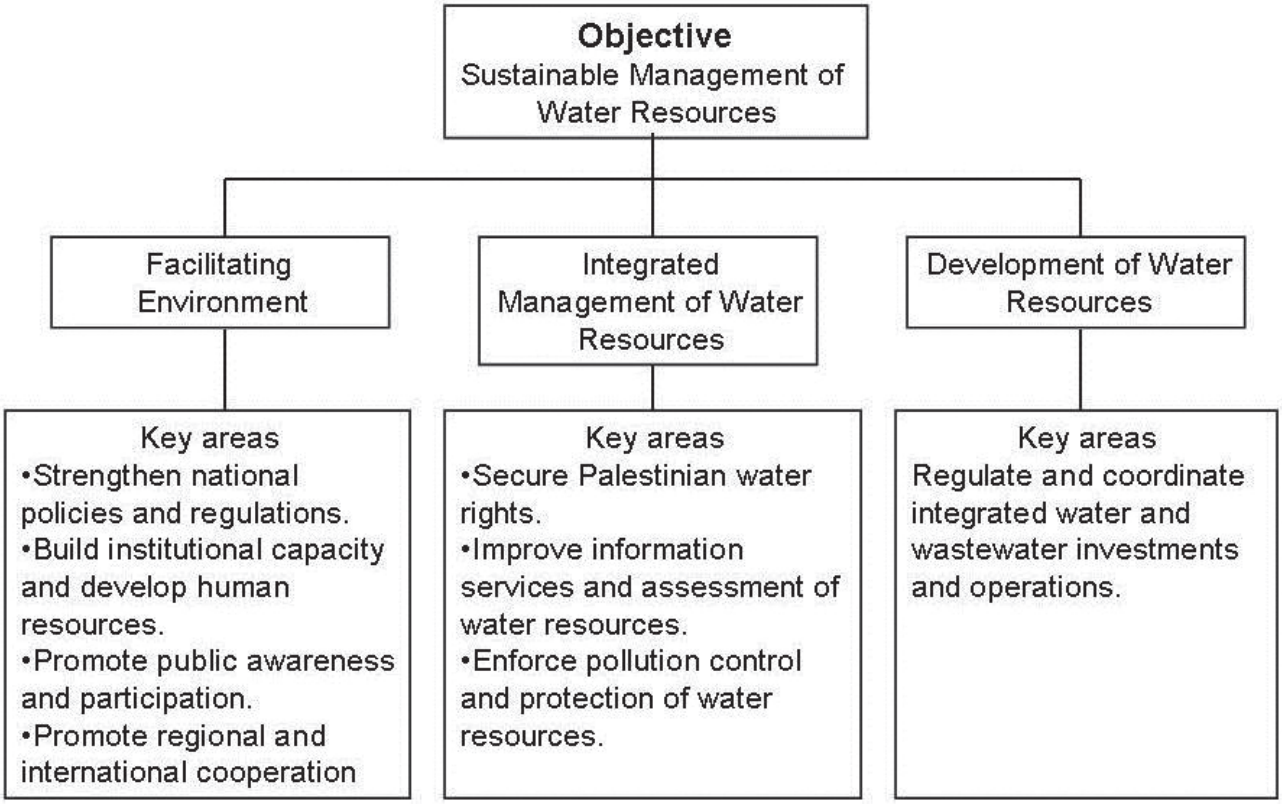


Figure 1: Main principles of the overall strategy of National Water Plan (PWA, 2000)

In general, a strategy builds on the existing situation, strengthening the strong elements and addressing the existing weaknesses while taking advantage of opportunities and addressing potential threats. SWOT, sometimes referred to as TOWS (Weihrich, 1982 and 1999), stands for Strengths, Weaknesses, Opportunities and Threats. SWOT analysis is a tool that helps in formulating strategic alternatives from situation analysis (Weihrich, 1982 and 1999). Weinhrich (1982) modified the SWOT (or what he called TOWS) into a matrix format that matches the internal factors (strengths and weaknesses) and the external factors (opportunities and threats).

The TOWS provides a framework for developing alternative strategies by analyzing strengths, weaknesses and integrating them with opportunities and threats. It provides four sets of strategic alternatives (Weihrich, 1982 and 1999). The most favorable alternative is using strengths to take advantage of opportunities (SO), another alternative is to use strengths in order of overcome threats (ST), the third is to overcome weaknesses in order to take advantage of opportunities in an attempt to turn weaknesses into strengths (WO), the fourth one, which is the least favorable situation, is facing threats in light of existing weaknesses and trying to minimize both (WT) (Weihrich, 1982 and 1999).

In this study, the TOWS Matrix was used to analyze the existing situation of the water sector in the West Bank in order to develop a strategy for the water sector. First a list of strengths, weaknesses, opportunities and threats were given after which the TOWS Matrix was developed (Figure 2). In light of the listed strengths, weaknesses, opportunities and threats the TOWS Matrix, adapted from Weihrich (1982 and 1999), was developed for the water sector in the West Bank. It presents the basis for developing a strategy for improving the water sector (Figure 2).

Internal Factors External Factors	Strengths (S) .S1. Adaptation water scarcity .S2.The NWC and PWA S3. The water law of 2002 .S4.The awareness on water scarcity S5. The existence of NGOs S6. The challenge of providing 150 l/ .cap/day for domestic users	Weaknesses (W) W1. Low water availability. W2. Insufficient and inefficient water services W3. The fragmented of institutional status. W4. Low cost recovery. W5. Insufficient. Awareness. W6. Lack of community participation.
Opportunities (O) O1. Potential water management alternatives and technologies. O2. Donor community. O3. Potential pricing systems that ensures cost recovery. O4. Palestinian water rights O5. The existence of community societies. O6. Research in water management. O7. Well qualified professionals.	strengths and opportunities (SO) 1. Using S1, S 4 to benefit from O1, O2, O4, O6 to introduce new technologies for water saving. 2. Establish regulations using S3 to support point 1 and to improve the pricing system O3. 3. Activate NWC S2 in order to acquire water rights O4.	weaknesses and opportunities (WO) 1. Using O1, O2, O4 to overcome W1, W2 by introducing emerging new technologies. 2. Using O3 to alleviate W4 by introducing a new pricing system. 3. Using O5 to overcome W6. 4. Using O7 to overcome W3 and W5.
Threats (T) T1. The Israeli control over the water .resources. T2. There is no clear agreement regarding water allocation. T3. Pollution of the water resources. T4. Population growth.	strengths and threats (ST) 1. Using S2 to overcome T1 and T2 by making use NWC to help in the negotiations with regard to the water issues. 2. S3 can be used to overcome T3 by applying and enforcing the laws regarding pollution.	weaknesses and threats (WT) 1. The threats T1, T2 regarding Israeli control over water can only be overcome through negotiations and pushing the world community to support this issue.

Figure 2: TOWS Matrix adapted to the West Bank water sector

2.6 Scenarios building

To determine how the water sector is going to develop over the period to 2025, two scenarios are considered. In the first, "do-nothing" scenario, it is assumed that the current political situation will, relative to the water availability issue, remain effectively unchanged. Accordingly, the water available for Palestinian use will remain under the Israeli control and will be limited to the present 123 million m3/year. It is also assumed that the current trends in the water demand will encounter no change leaving the overall (domestic, industrial and agriculture) per capita water demand at around 50 m3/cap/year. With the increasing population, this will mean an increasing gap between availability and expected demand which will reach some 100 million m3/year in 2025 under the do-nothing scenario (Figure 3).

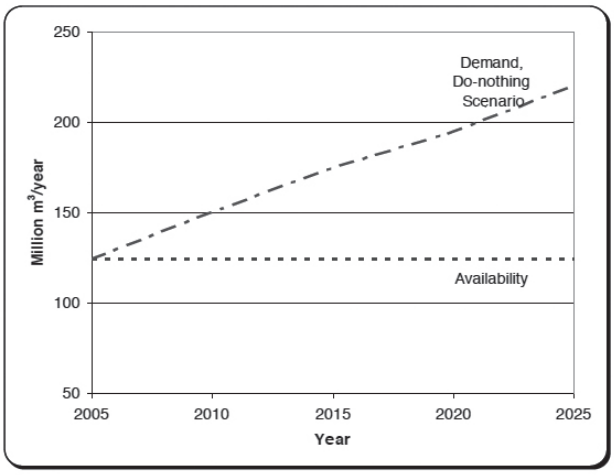


Figure 3: Water availability and expected demand in the "do-nothing" scenario

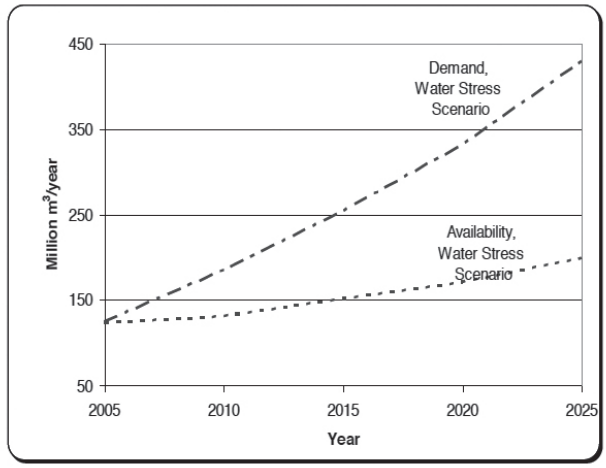


Figure 4: Water availability and demand under "water stress" scenario

In the second "water stress" scenario, it is assumed that there will be some progress in the negotiations with Israelis, as a result of which the water availability will rise to 198 million m3/year, being the existing water consumption of 123 million m3/year plus 75 million m3/year as agreed upon in the Oslo II agreement (1995). However, due to political, technical and financial reasons this quantity can not be made available directly so the availability will increase by some 4 million m3 each year from the existing 123 million m3 to 198 million m3 by 2025. It is also assumed that the West Bank will undergo some development and improvements in the social, commercial, industrial and environmental sectors which will increase the water use. The development in the water sector will be geared towards increasing the domestic per capita water consumption to 150 liter/cap/day (this number is the target of the PWA in its national plan) to all users by 2025 (PWA,2000). For the sake of calculations, it is assumed that the population will be provided by 70 liter/cap/day in 2010 and this will increase by 5 liter/cap/day each year until 150 liter/cap/day in 2025 . The water allocated for industry is taken as percentage of the domestic water use and the expected water demand for agriculture is assumed constant as the existing per capita agricultural consumption of 30 m3/cap/year. On the basis of these assumptions, the total water demand will reach 430 million m3/year by 2025 (Figure 4). This will increase the gap between availability and expected demand in scenario 2 to some 230 million m3/year.

3. Preparing for the future

Although water availability is very low, the Palestinian Water Authority, in its National Water Plan, promises 150 l/cap/day for all domestic uses by 2020. This means that some 210 million m3/year should be available by then for domestic purposes only, a number exceeding the existing water availability through the Oslo II Agreement of 1995 (198 million m3/year). The National Water Plan's promise amounts to some 500 million m3/year, from ground and surface water, for all purposes (domestic, industrial and agriculture) in the West Bank. This policy target would only be possible if the Palestinians succeed in claiming equitable rights from the existing water resources, the Jordan River and the aquifers. It may be questioned whether this target consumption is realistic and desirable, given the limited water resources in the area and the politically complicated situation which makes the achievement of the water rights rather difficult.

However, the Palestinians, in parallel with striving for their water rights, can travel an alternative path to confront the water scarcity and achieve sustainability. This can be done by applying the strategic alternatives proposed in Figure 6.6, that is, integrating strengths and weaknesses with opportunities and threats. Going this way requires: (a) technical, institutional improvements or changes; this could not be achieved without setting the needed laws and legislation to support these improvements or changes, (b) education for those who are going to implement or use them and (c) finance for the required investments in infrastructure. In the following, an approach is presented to reach water sustainability in the West Bank by the year 2025.

3.1 Balancing water availability and demand

In order to improve the water sector and reduce the gap between water demand and availability, presented in the water stress scenario, the developments in the water sector in the West Bank should be geared towards sustainable water use. A simple solution to achieve this is not possible. What is needed is an integrated water resources management (IWRM) approach, intelligently combining available water management

alternatives in the domestic, agricultural and industrial sectors by using strengths and making advantage of opportunities and minimizing weaknesses and threats. The "sustainable water use" scenario is proposed as an alternative to the do-nothing and water stress scenarios and aims to achieve water sustainability. This scenario suggests the following interventions in the domestic, agricultural and industrial sectors:

Domestic sector, the domestic water sector in the West Bank can use its strengths and take advantages of opportunities (SO) alternative in TOWS Matrix of Figure 6.6: in this approach the water sector can benefit from the fact that the Palestinians are well aware of the existing water scarcity and are already using water management alternatives such as rainwater harvesting systems in order to expand these alternatives and to take advantage of the existing new technologies for water saving available in the market and the willingness of donors to sponsor water management projects. In light of this, the sustainable water use scenario focuses on the reduction of the domestic water demand, through introducing water saving alternatives such as dry toilets, dual flush toilets, low-flow shower heads and faucet aerators and enhancing water reuse such as graywater systems. Moreover, rain water harvesting, which is already widely practiced, is an option to further increase alternative water resources that can substantially reduce the demand for groundwater, thus minimizing the weakness of insufficient water availability.

Demand management through introducing such alternatives has been used in several projects. For example, within a pilot project on ecological sanitation in Palestine implemented by the Palestinian Hydrology Group (PHG) and Swedish International Development Cooperation Agency (Sida), 30 units of dry toilets have been installed in Beni Naim village near Hebron city in the West Bank (Subuh, 2003; Winblad et al., 2004). The project was rated as successful because it was socially accepted by the people who are using the toilets, a 25-30% reduction of water consumption and well operation of the system that prevents smell and fly breeding (Subuh, 2003). Winblad et al. (2004) described the project as well-conceived high standard project which showed that ecological sanitation could be an alternative for Palestine. Dry toilets have been implemented in several places such as Vietnam, China Mexico, Sweden and South Africa (Winblad et al., 2004; Jönsson and Vinnerås, 2007; Mels et al., 2007). These systems reduce water use and pollutant emission while increasing nutrient recovery. These systems also experienced some problems such as bad smell and clogging in the piping system which can be overcome by improved technology (Jönsson and Vinnerås, 2007; Mels et al., 2007). Gray-water systems were used in the Netherlands (Het Groene Dak in Utrecht and Polderdrift in Arnhem); these cases have the potential to reduce water consumption up to 40% although partial system failures, due to lack of operation and maintenance by inhabitants, were recorded (Mels et al., 2007). In Australia, the reuse scheme implemented in Sydney managed to provide 36,000 households with treated used-water for toilet flushing, garden watering and other uses, thereby reducing the demand for water from these households by 4.7 million m3/year in 2007 (NSW, 2007).

The selection of the appropriate combination of these alternatives depends largely on the specific conditions of the location where they are proposed to be introduced. In the West Bank, there are different categories of housing locations with regard to the availability of water and sanitation services according to which the appropriate combination can be chosen. Some locations are enjoying good quality services in both water and sanitation. Other locations do not enjoy any type of good quality services and are neither connected to water distribution network nor to a sewage collection system. Most locations find themselves in between these two extremes.

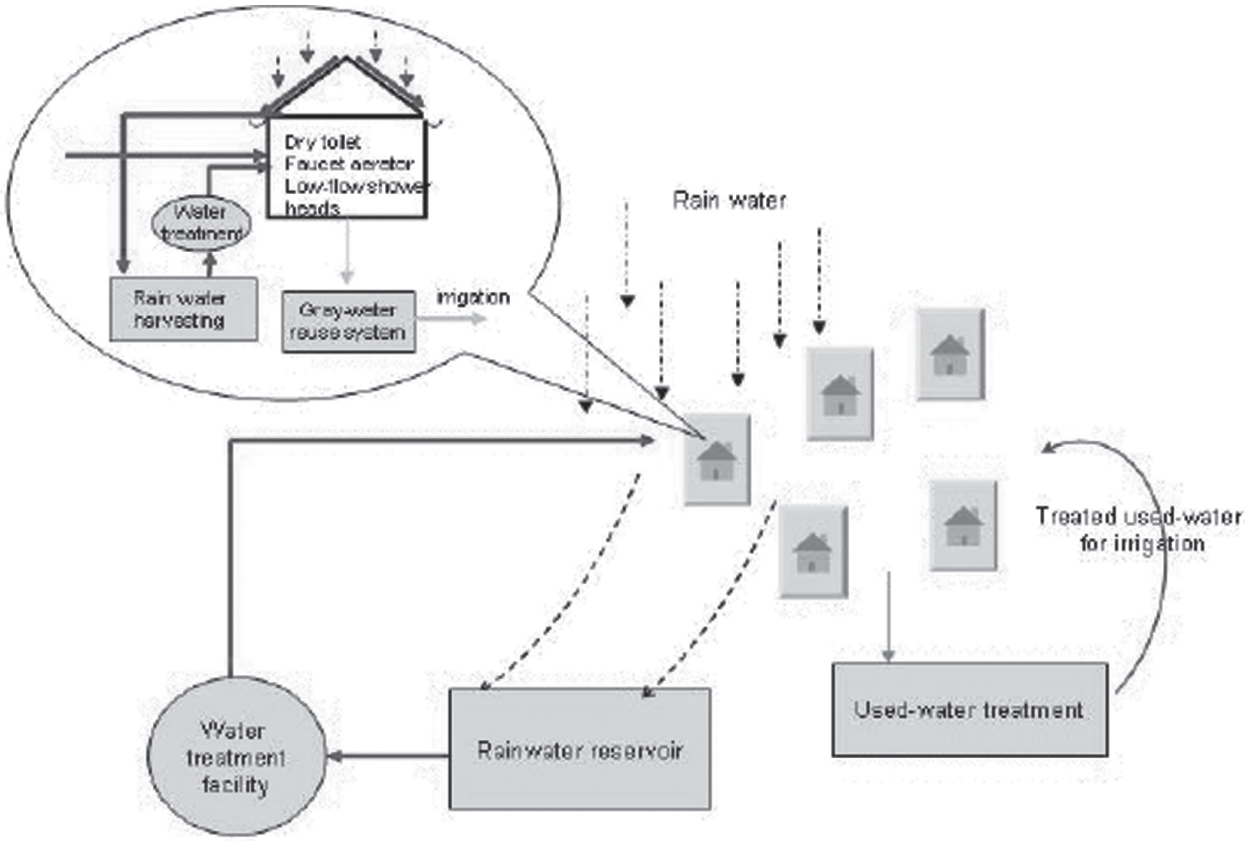
A potential opportunity exists for increasing water availability and improving water services by introducing water and sanitation systems, in locations without these systems, while at the same time reducing overall water use (see Box 1). In locations with an existing water and sewer network, there exists a potential for reducing water use by introducing certain options without too much reconstruction requirements such as the installation of faucet aerators, low-flow shower heads and dual flush toilets. People living in these areas should be encouraged to install such fixtures. Expanding the already used alternative, rainwater harvesting systems, can be helpful in overcoming the low water availability and improve the water services. Leakage reduction is another, obvious priority activity.

Palestine is one of countries with extremely low per capita water availability. It, should therefore consider orienting the introduction of these water management options towards a situation in which each future property (separate houses, housing complexes or buildings) can be largely independent in terms of water and sanitation systems. i.e., each property has its own water resource (rainwater harvesting system) and its own wastewater treatment system (graywater treatment system in case of dry toilet use). However, this may not be possible

in some places where the rainwater harvesting does not yield sufficient water. In such places part of the water needed can be supplemented with other sources which will be relatively easy due to the reduced demand in other areas. At the same time these areas can still reduce the consumption by using other water management options.

Box 1 Example of introducing water management options

According to ADA and ADC (2007), there are 211 localities accounting for 10% of the population in the West Bank that are neither connected to water distribution network nor to a sewerage collection system. At present, these localities depend on rainwater collected in cisterns at house level and tankers. It is proposed that these localities are made independent in terms of water and sanitation. The figure below presents a schematic of the water and sanitation systems proposed. With regard to the water system, these localities would continue using the rainwater harvesting cisterns available to cover parts of their needs. The rest of the locality water needs can be covered through a rainwater harvesting reservoir which can be constructed on the locality level combined with a water treatment plant and a local distribution system where needed. For improvement of in-house water use fixtures, the installation of low water saving fixtures such as faucet aerators (FA) and low-flow shower heads (LFSH) is proposed.



As to sanitation, a new sanitation system is proposed which is oriented towards material recovery. For toilets, there are several types of ecological sanitation systems emerging ranging from urine diversion toilets to completely dry toilets. By using dry toilets with urine diversion, the urine can be stored, collected and transferred to a facility where nitrogen and phosphorus can be recovered and used as fertilizers (Matsui et al., 2001). Solid excreta can be composted and used to produce energy; the compost can also be used as fertilizer. The collection of compost can be arranged via trucks such as those used in collecting solid waste. For other water uses in the house-hold, the remaining used-water is now graywater and can be treated on site and reused for lower water quality needs such as irrigation. This will need a local used-water collection system with a treatment plant. By doing so, less water is used, less used-water needs to be treated; and fewer pollutants need to be removed.

Agricultural sector, Agriculture is the biggest water consumer in the West Bank as it accounts for 70% of total water consumption. Therefore, effective agricultural water management is key to achieving water sustainability. The water sector can use the opportunities of water management in order to overcome the low water availability. Potential water reduction options include:

1. Treated used-water reuse: using opportunity of applying re-use options and the to overcome low water availability weakness, it is proposed that 10% of the domestic treated used-water will be reused for irrigation in 2010, 20%, 40% and 60% of the domestic treated used-water will be available for reuse in irrigation in 2015, 2020 and 2025 respectively. Although expensive in terms of investment, treated used-water reuse for agriculture has been implemented in several countries (Jordan, Tunisia and Israel), Jordan is re-using 28% of its produced used-water, Tunisia is using 13% and Israel is using 54% (Abu-Madi, 2004).
2. Expanding rain-fed agriculture: to overcome low water availability the West Bank can use the fact that agriculture in the Palestine is largely depending on rainfall, 92% of the area cultivated in the West Bank being rain-fed (PCBS, 2006); 44% of the water footprint of the Palestinians in the West Bank is from consuming rain-fed crops (Nazer et al., 2008). Therefore, it is suggested to further promote this notion by gradually reducing the area cultivated by crops that are currently irrigated but that can be cultivated under rain-fed conditions. Such crops include olives, grapes, squash, wheat and dry onion (PCBS, 2006). This approach is consistent with Falkenmark (2007), who stated that future food production will have to benefit maximally from rainfall rather than from irrigation. She maintains that climate data show that there is, also in semiarid regions, generally enough rainwater during the rainy season to meet consumptive water requirements. Yang et al. (2006) argued that rain-fed agriculture has lower opportunity costs and environmental impacts in terms of water use than irrigated agriculture. Water stored in soil moisture, or what is called green water, which is used for rain-fed crops is a free good in terms of supply. Other land uses and plants are the only major competitive users of this water. This makes rain-fed agriculture attractive in terms of cost and environmental impact although the yield of rain-fed crops is less than that of irrigated crops. With increasing water scarcity, more efforts are needed to improve rain-fed agriculture in terms of improving the yield of rain-fed crops and the efficient use of rain-fed agriculture (Yang et al., 2006; Falkenmark and Rockström, 2004).
3. Virtual water: Palestinians are already depending on virtual water through importing crops; 52% of the Palestinians water footprint is virtual water imported through in the form of crops. It is proposed that decision makers should consider increasing virtual water imports through planning the cropping patterns in a way that can reduce water use, increase the profitability of agricultural activities and ensure an acceptable level of self-sufficiency in terms of food production. That is, importing water intensive and low value crops and exporting high value crops. Many studies (Allan, J.A, 1997; WWC, 2004; Al-Weshah 2000; Hoekstra and Hung, 2005; Hoekstra and Chapagain, 2007) support the concept of virtual water trade, through food trade, as an option towards dealing with water scarcity in countries with scarce water resources. For example, Jordan has formulated policies to enable water saving by reducing export of water intensive crops (WWC, 2004). Al-Weshah (2000) argued that although virtual water trade is a means of water saving in water scarce countries, it poses the risk of creating job loss in the agricultural sector. Planners and policy makers should consider projects to shift activities in the same area. Al-Weshah (2000) added that many voices in all the countries sharing the Jordan River are calling for better water resources management in the agriculture sector. The calls of experts from Jordan and Israel suggest that importing some agricultural products may be more rational than producing them locally in terms of their water use. One may argue that it may be unfair to call for reducing the exports of some crops from the West Bank while at the same time Israel, which is sharing the same water resources, is exporting these crops at the expense of Palestine's water share from existing water resources. According to Chapagain and Hoekstra (2004), the agriculture water use in Israel is 1290 million m3/year out of which some 370 million m3/year is used for producing low value wheat which can be imported from other countries. The water used to produce wheat in Israel is more than half the 600 million m3/year proposed by Mimi and Sawalhi (2003) and Mimi and Aliewi (2005) as Palestine's water rights from the existing water resources, and is nearly double the total quantity recognized by Oslo II Agreement as the West Bank water share (198 million m3/year).
4. The ongoing research with regard to the appropriate cropping patterns can be used to overcome the low water availability. For example Nazer et al. (Accepted) stated that a 4% water saving can be achieved from changing the cropping patterns according to their water use.
5. Efficient irrigation systems, there are several ways to enhance the efficiency of irrigation ranging from choosing the appropriate time for irrigation to using drip irrigation.

In the industrial sector, industry can take the opportunity of the ongoing research in re-use and recycling to overcome the weakness of low water availability and the threat of pollution. In line with this, it is proposed to enhance onsite reuse and recycling and to employ cleaner production principles in order to reduce water consumption and environmental impact. Several studies proved the feasibility of applying cleaner production principles in reducing water use in industrial activities (Carawan, 1996 a, b; Carawan and Merka, 1996; Wenzel and Knudsen, 2005; Nazer et al., 2006; Fresner et al., 2007). Figure 5 presents a schematic of how an industrial activity can be designed such that consumptive water use is minimized; water is provided for each process, the amount of water consumptively used (evaporated or incorporated into the product) as well as the amount and quality of return flows (used-water) from each process is to be evaluated and according to this evaluation it will be decided whether this used-water can be reused directly in another process or the type of treatment it will need in order to be reused.

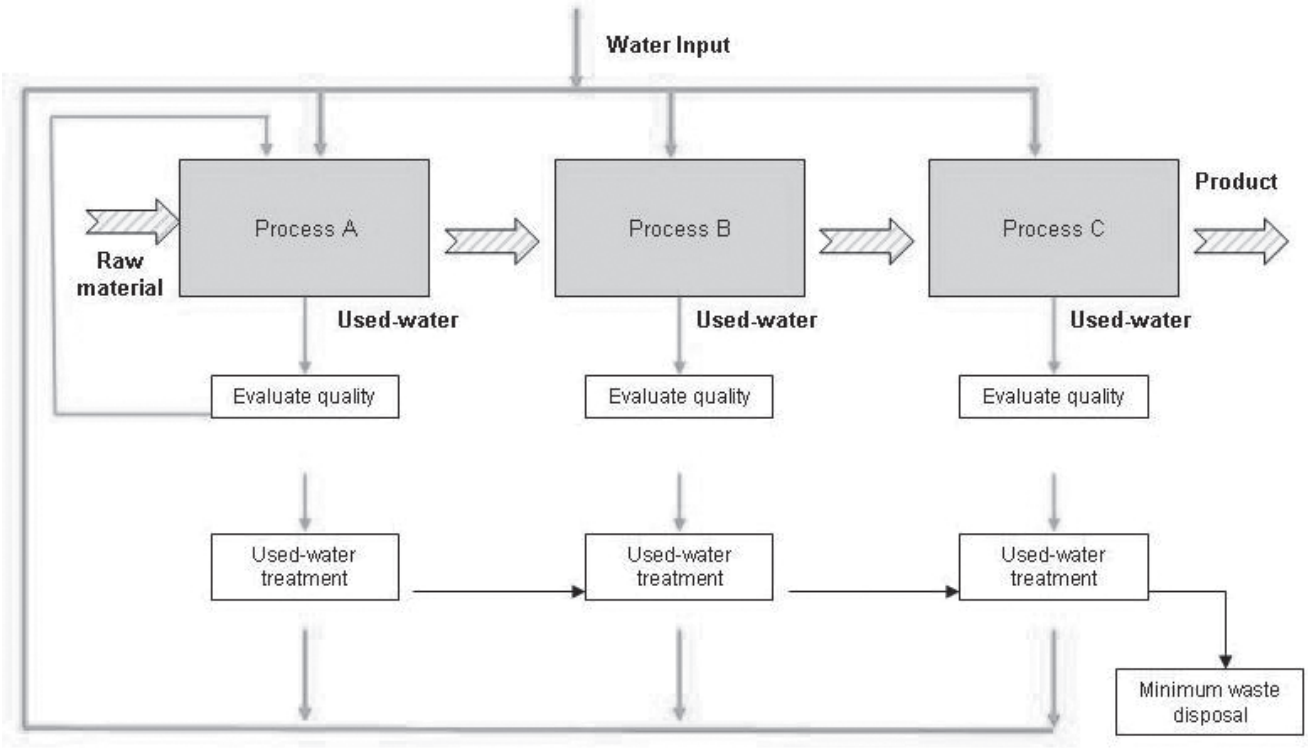


Figure 5: Schematic for proposed water use in an industrial activity

In line with the above strategy, the "sustainable water use" scenario was defined. In this scenario, a combination of water management alternatives was proposed in order to close the gap between availability and demand in domestic, agricultural and industrial sectors. Figure 6 shows that the availability of water is gradually increasing due to the use of rainwater harvesting systems while the future water demand is decreasing due to implementation of water management programs in the domestic, industrial and agricultural sectors (detailed calculations are presented in the Appendix). It can be seen that by implementing water management options the gap between availability and demand is gradually reduced through the years until it is eliminated by 2025 (Figure 6).

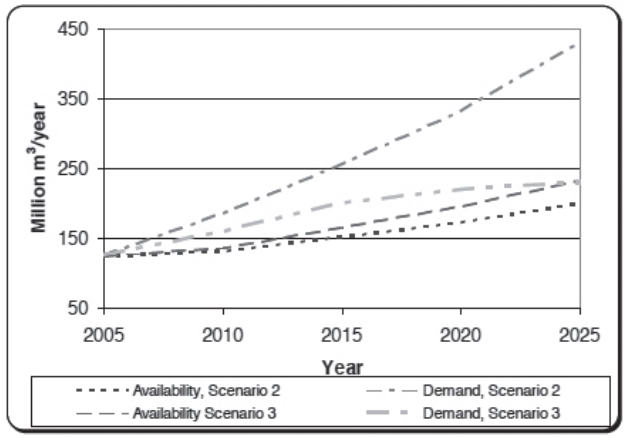


Figure 6: Water availability and demand under "sustainable water use" scenario

6.3.2 The needed awareness

Although there is some awareness of water scarcity, this awareness is considered insufficient because of the severe water scarcity condition facing the West Bank which needs expansion of awareness to cover all segments of the society. The West Bank can take advantage of the experience of already existing NGOs which have the potential in terms of professional human resources who can help in designing and implementing awareness campaigns. Moreover, the existing local community societies can provide logistic support for such campaigns.

There is growing recognition of the importance of social norms and attitudes in the management of water. Recent main policy documents recognize the importance of awareness raising to influence these norms and values towards a more sustainable use of water resources (Schaap and Van Steenbergen, 2001). Without changes in the way consumers use water, safe, wise and ecologically sustainable water resources management is impossible. The aim of awareness campaigns is to change the behavior of target groups towards new social norms and attitudes related to water use (Schaap and Van Steenbergen, 2001). Target groups are school children, the general public and other stakeholders. Several programs regarding water awareness have been implemented in different countries, a long list can be found in Schaap and Van Steenbergen (2001).

6.3.3 The needed regulations

Educational programs and awareness campaigns are necessary but insufficient conditions to motivate everyone to use water wisely. Therefore, establishing administrative and regulatory mechanisms at appropriate levels is a complementary tool to implement policy, and, if effectively executed, can enforce the policy (Gleick et al., 1995; GWP, 2009). In this context, the Water Law of 2002, considered as strength, can be used as the basis for these regulations and their enforcement. The regulations may emphasise principles to support water management, such as: polluter pays principle, public participation, ecological protection and equitable access to water resources.

4 Conclusions

Within the limitations of the study on making water use in the West Bank sustainable, the following conclusions may be drawn:

1. Under both the "do-nothing" and "water stress" scenarios there is an increasing gap between water availability and water demand.
2. The gap between water availability and water demand in the West Bank can be closed by gradually introducing water management alternatives that increase the availability (through rain-water harvesting) and reduce the demand through water conservation options as well as re-use options.
3. Legislation and regulations regarding the introduction of these alternatives is an important supporting tool. Awareness and education about water scarcity and potential methods for dealing with it is crucial to achieve effective management.

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Alternatives to Solve Traffic Problems on Faisal/Haifa Street in Nablus CBD

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ABSTRACT—This paper presents recent efforts made for developing solutions to the mounting traffic congestion problems along Faisal/Haifa Street in Nablus which passes through the city center. The paper shows how recent data collection efforts for the study corridor have been used in the analysis of traffic conditions. The paper then proposes and examines two major alternate capital projects for carrying through traffic; a tunnel and a bridge connecting east to west serving the through traffic. These are compared with an arterial development and management alternative, which implies reallocation of space in the street space. The results illustrate clearly that although applying the arterial management and development systems costs less than constructing a tunnel or a bridge, but it isn't an effective solution in the long-term. Building a tunnel or a bridge will be more expensive but will significantly reduce traffic congestions and the related costs.

Abstract—This paper presents recent efforts made for developing solutions to the mounting traffic congestion problems along Faisal/Haifa Street in Nablus which passes through the city center. The paper shows how recent data collection efforts for the study corridor have been used in the analysis of traffic conditions. The paper then proposes and examines two major alternate capital projects for carrying through traffic; a tunnel and a bridge connecting east to west serving the through traffic. These are compared with an arterial development and management alternative, which implies reallocation of space in the street space. The results illustrate clearly that although applying the arterial management and development systems costs less than constructing a tunnel or a bridge, but it isn't an effective solution in the long-term. Building a tunnel or a bridge will be more expensive but will significantly reduce traffic congestions and the related costs.

I. INTRODUCTION

Palestinian cities are getting more crowded, where increasing traffic flows use the already congested road networks, especially in the cities Central Business Districts (CBDs), causing traffic jams and leading to longer trip times, slower speeds, and disturbance to the urban environment. Traffic Systems Management (TSM) approaches have been used by Palestinian city planners and traffic engineers for making smarter use of road capacities which consequently improve the road users' conditions as well as reduce the negative impacts to the environment. However, such approaches which could have an overall positive impact on the short- or medium-term at reasonable costs, have to be dealt with along with the long-term solutions where no much improvement can be attained by further application of TSM approaches.

Nablus Governorate has a central location connecting the northern governorates with the governorates in the middle and the south of the West Bank. Nablus city is the heart of the governorate and had been designated as the economic capital of Palestine. Traffic that passes through the city is relatively high.

Faisal Street with its branched parallel Al-Ghazali Street, along with its western extension Haifa Street, is the main arterial that passes through the center of the city. The street accommodates high traffic volumes, with heavy volumes of pedestrian crossing the street in the CBD area. The street currently faces considerable challenges in terms of traffic volumes and congestion, where it carries about 50,000 vehicles per day, resulting in considerable delay, tangible accidents problems, along with a conflict between local traffic, through traffic and pedestrian crossing the street. In addition, the street serves several key locations in the area, such as Al-Watani Hospital, Nablus Municipality, the Police Department, the Palestinian Telecommunications

Company, and several commercial compounds which increase the crowdedness in the area.

Traffic signals and several traffic management plans have been implemented at various locations within the corridor. However, the corridor requires further examination in order to optimize the street operation for the users who share the corridor, more precisely, the through traffic and local vehicular traffic, and the pedestrians. This paper is based on the outcome of the graduation projects of Abdulhaq and Qamhieh (2009) and Herzallah et al. (2012), which dealt with these issues.
The paper first describes the prevailing traffic problems. Next, the steps considering the methodological approach followed are presented, which include data collection, data analysis, alternatives development, and evaluation and assessment. Finally, the paper ends with summary and conclusions.

II. PROBLEM DESCRIPTION

Many problems which are facing Faisal/Haifa corridor are expected to continue to intensify in the future, as a result of the anticipated growth in population and economic activities, and the resulting continued increase in car ownership and travel demand. Such reasons will lead to a considerable growth of through and local traffic along the corridor, which is anticipated to lead to the following major problems:

- Congestion problems are major problems clearly observed on the corridor, which will intensify in the future due to the continued increase in the traffic flow compared with the limited capacity.
- Delay problems are problems that result mainly from congestion along the corridor, due to local traffic that conflicts with other traffic through traffic at intersections and when changing lanes to go to/leave the CBD area or any local street intersecting with Faisal/Haifa Street, in addition to the traffic signals for vehicular or pedestrian crossing control.
- Safety problems noticed along the corridor as local traffic conflicts with through traffic when changing lanes to enter the CBD area or at intersections with other local streets. This is in addition to interference between vehicular and pedestrians crossing the corridor at its sections within the crowded CDB area, especially near Al-WataniHospital, despite the existence of pedestrian traffic signals and pedestrian barrier rails.
- Geometry problems which exist due to the changing right-of-way width of Faisal Street. This is most clear near Zafer Al-Masri building and in the vicinity of Nablus Municipality, since Faisal Street at these two locations is narrow and where traffic volumes are high.

III. DATA COLLECTION

Data collection sources varied between maps and previous traffic studies Nablus Municipality, Universal Group of Engineering and Consulting, and the Transportation Engineering Laboratory at An-Najah National University, to conducted traffic counts and studies along the corridor.

The collected traffic-related data are categorized in the following groups:

- Vehicular intersection traffic counts: Intersection counts were conducted at eight major critical intersections along the corridor to determine the volumes of turning movements and the design hour volumes (DHV). The counts were conducted manually during typical workday peak periods.
- Vehicle classification counts: These counts were collected from the Universal Group of Engineering and Consulting which were conducted to determine the percentage of the presence of each class of vehicles, ranging from the passenger car to the trailer/semi-trailer combinations. These counts were conducted manually during the peak periods on typical workdays at the middle of the corridor.
- License plate studies: These studies were manually collected at two different sets of locations at two different periods. Vehicle license plates were recorded at the beginning and end of the specified sections, which were selected to be first at the start and end of the study corridor (i.e., from Al-Salam Mosque to Al- Haj Mazoz intersections), and later at middle part of the corridor (i.e., from its intersection with Sufian Street to Heteen Street), in order to capture the through traffic volumes for the longer and shorter sections of the corridor. A combination of video camera and mobile, as well as manual recording techniques were used to record the license numbers for further analysis.
- Pedestrian volume counts: These counts were collected from the Universal Group of Engineering and Consulting. The counts were mainly collected on the sidewalks of Faisal Street close to Al-Watani Hospital and Al-Medina Taxi Office, and on pedestrian crosswalks on Faisal Street in front of Al-Watani Hospital. The counts were conducted manually during from the start of the morning peak period until the end of the afternoon perk period on a typical workday, capturing the midday peak pedestrian flow.
- Accidents studies: These studies were performed through collecting relevant data from the Traffic Police Department in Nablus, taking all the accidents occurred on the study corridor during the period 20082010-. Accident specific

location, severity, cause, as well as the day and timing, for each accident were collected.

IV. DATA ANALYSIS

The data collected were thoroughly studied and analyzed. The analyses were steered to find relevant indicators, assess current conditions, and forecast future traffic volumes and the severity of traffic congestion problems as follows:

A. Relevant Traffic Indicators

The vehicular traffic volumes, whether for the a.m. or p.m. peak hours, or the average daily traffic volumes were calculated from the traffic date collected. Pedestrian peak hour traffic volumes were calculated. The frequencies and average values of traffic accidents causes and locations were calculated. Moreover, the traffic volumes of through traffic were calculated after inputting the recorded data into a notepad and then analyzing them utilizing a computer program developed especially for this project using Java language, which compares the license plates numbers for vehicles entering and exiting each section during a maximum pre-determined travel time to match the vehicles license plates numbers which represent the through traffic between the stations.

Peak hour 2011 traffic volumes show a total of 2,796 veh/hr at Al-Salam Mosque intersection at the west, while they reach 3,546 veh/hr at Omar Al-Moktar intersection in the middle, and 4,051 veh/hr at Al-Ballor intersection in the east.

Analysis of matched license plate numbers show that, for example, the 2011 peak hour through traffic in the central part of Faisal/Haifa Corridor, extending from Al-Kendy intersection to Hetten intersection that there is a total of 720 veh/hr.

Traffic accident data analysis show that Al-Watany Hospital spot represents the most critical place, accounting for 10% of the average annual 110 accidents which occurred along the corridor, including two fatal accidents.

B. Assess Current Traffic Conditions

The analyses were framed under the varied traffic problems along the corridor. Street geometric limitations and side obstacles were firstly examined at different locations of the study area and the most problematic locations were highlighted. Congestion problems were secondly inspected, assessing the identified level of service through finding the travel delays at intersections or volume/capacity ratios using the Highway Capacity Software. Reasons behind congestion were identified and sized. Safety and traffic accidents were assessed and locations and causes were ranked and highlighted, where the reasons behind each were identified in several spots.

C. Forecasting future traffic volumes and congestion

The directional traffic volumes, whether the overall traffic volumes on the corridor or the through traffic volumes on it, were forecasted for the next 20 years, considering 5-year increments, and utilizing growth rates that depend on the past trends for the last few years. Based on this, an annual traffic growth rate of 2.53% was adopted.,

growth rate of 2.53% was adopted.

With the consideration of the indicated annual traffic growth rate, traffic volumes were predicted after 20 years to reach a total peak hour volume of 6,677 veh/hr at the most critical location, including a total through traffic volume of 1,187 veh/hr for the peak hour. However, a more detailed forecast would be needed to predict the additional diverted traffic to any proposed new facility, which is expected to demonstrate relatively higher speed and no interference of local traffic.

These volumes were used to assess the severity of future traffic congestion problems, considering the forecasted traffic volumes and comparing them with the capacities using the Highway Capacity Manual (2000). Such assessment will guide towards the selection of the proper solutions and the identification of the facility type to be proposed to accommodate the through traffic, and for specifying the related number of lanes for accommodating both the through traffic and the local traffic.

V. ALATERNATIVE DEVELOPMENT

Three different alternate solutions were suggested and examined to deal with the traffic-related problems along Faisal/Haifa Street. These proposed solutions include arterial development and management considering the reallocation and optimal utilization of right-of-way, a tunnel (underpass) or a bridge (overpass) connecting the eastern and the western ends of proposed the middle sections of the corridor to serve as a route for through traffic.

Design Criteria was set considering AASHTO (2004) guidelines, including those for cross sections, horizontal and vertical alignment. Preliminary design was conducted utilizing state-of-the-art software, such as the latest version of Softdesk Land Desktop Companion and Civil 3D design programs.

The basic preliminary design development features, including the typical cross section and the layout for each of the alternatives, are presented hereafter.

A. Arterial Development and Management Alternative

At the beginning the whole system of street and its extensions were studied to try to figure out a solution that can alleviate traffic problems. The idea was to provide a total of four lanes for through traffic, two per each direction, separated from two other lanes in each direction dedicated for local and turning traffic, bringing the total number of lanes to eight. This resembles an inner/outer arterial management concept where the inner arterial is used for the through traffic, separated by separation strips from the outer arterial which is used for the slow local traffic.

While adopting this strategy, right-of-way limitations had been identified. The study area was divided into three parts; the first starts from Al-Salam Mosque west till Al-Kendy School, the second is the central part of corridor, where most of the problems occur, and the third starts from Nablus Municipality to Al-Ballor Hall east.

The concept of arterial development and management was ideally applied in the second part of the corridor. A cross section with a minimum width of 35 meters was considered. Widths of lanes were taken to be consistent with AASHTO (2004) standards. Four lanes were dedicated to through traffic, with a width of 3.3 m each, four other lanes were dedicated to local traffic with a width of 3 m each, in addition to designing a 2 m median in the middle, and two separation strips with a width of 1 m each. The sidewalks were secured with a minimum width of 2.9 m each. Fig. 1 shows a typical cross section, while Fig. 2 illustrates the layout.

B. Tunnel Alternative

This alternative is applied over almost the whole study area, which extends from Al-Salam Mosque (Haifa Street), where the western terminal (entrance/exit) of the tunnel is proposed, till the old Municipality building, where the western terminal (entrance/exit) of the tunnel is proposed.

The tunnel cross section dimensions and elements consider the design guidelines of the AASHTO (2004). A cross section of the tunnel's preliminary design is shown in Fig. 3, which includes two-way four lanes total for through traffic having a width of 3.3 m each, a median having a width of 1 m, and two emergency sidewalks, having a width of 0.5 m each. Fig. 4 illustrates the layout of the tunnel.

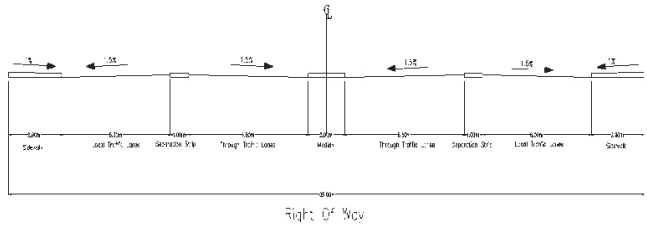

Figure 1. the cross section for the arterial management alternative

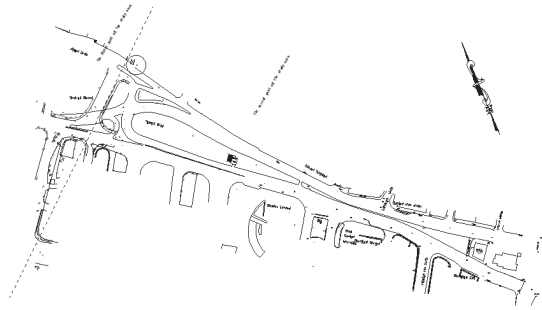

Figure 2. The layout of the middle part of the arterial management alternative

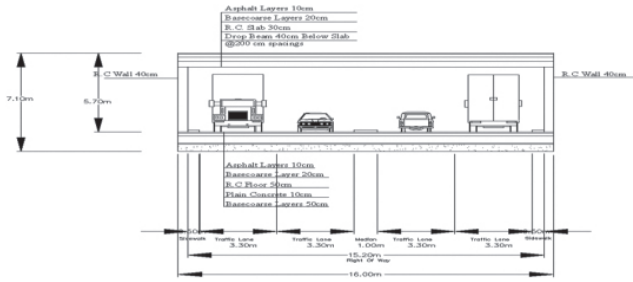

Figure 3. The cross section for the tunnel alternative

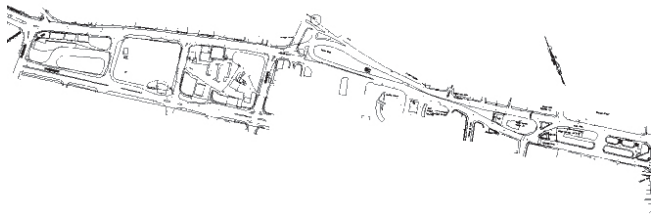

Figure 4. The layout of the middle part of the tunnel alternative

C. Bridge Alternative

The third proposed alternative is a bridge which begins from Al-Kendy School intersection west with four lanes (two lanes each direction), then the bridge continues east where it is separated in front of Omar Al-Mokhtar Street into two segment, one for each direction composed of two lanes. Finally, the two separated bridge sections end approximately 70 m before Al-Ballor Hall east. The bridge will serve the through traffic that passes from Al-Kendy intersection to Al-Ballor Hall intersection over the existing road, considering the ground streets' grades. The local traffic will remain below the bridge with some modifications resulting from introducing the bridge, and securing enough height clearances.

The bridge cross section dimensions consider the design guidelines of the AASHTO (2004). Fig. 5 shows a typical cross section, while Fig. 6 illustrates the general layout.

VI. EVALUATION AND ASSESSMENT

In order to evaluate the alternatives, an initial assessment is made considering proposed criteria. These take into account the cost, potential for solving traffic problems on the long-term, disruption of traffic during construction, existing utilities impact during construction, impact on pedestrians impact on nearby buildings, and visual impact. Table I shows a comparison among the alternatives.

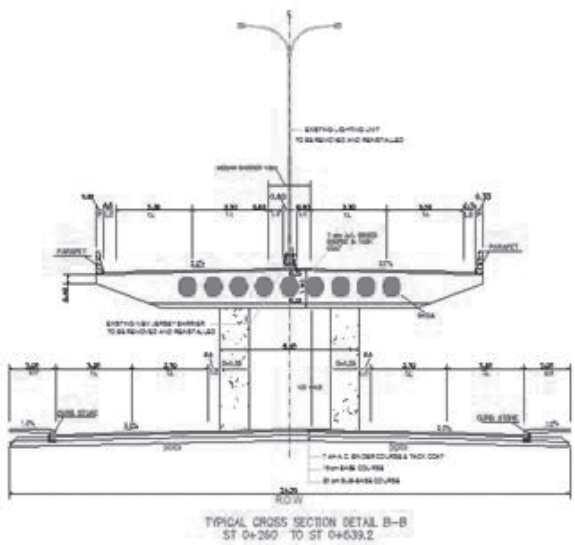

Figure 5. Bridge alternative typical cross section

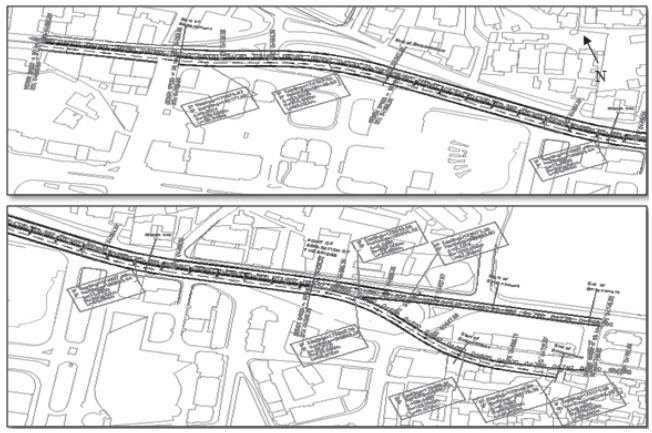

Figure 6. Bridge alternative general layout

TABLE I. A COMPARISON BETWEEN THE THREE ALTERNATIVES

.No	Criterion	Alternatives		
		Arterial Management	Tunnel	Bridge
1	Initial cost consideration	Low	High	High
2	Disruption of traffic	Low	High	High
3	Visual impact	Medium	Low	High
4	Impact on nearby buildings	Low	High	High
5	Existing utilities impact	Low	High	Medium
6	Potential for solving traffic problems on the long-term	Low	High	High
7	Impact on pedestrians	Medium	Medium	High

From the table, it is concluded that although applying the arterial management and development systems costs less than constructing a tunnel or a bridge, but it has no potential for solving traffic problems on the long-term. Building a tunnel or a bridge will be more expensive but will significantly reduce traffic congestions, despite the higher impacts on the nearby environment.

VII. SUMMARY AND CONCLUSIONS

The paper presented how alternative solutions were developed aiming to solve congestion along a major corridor (Faisal/Haifa corridor) crossing a Palestinian city (Nablus) which carries considerable through traffic. Proper traffic data were collected and analyzed, leading to the consideration of the proposed solutions. After assessing the three alternatives, it can be concluded that although applying the arterial management

and development system costs considerably less than constructing a Tunnel (١٠٠٠ $/m^2) or a bridge (١٢٠٠ $/m^2), it can be only capable of solving short-term problems, and can be considered only as a step towards longer-term capital cost effective solutions.

The study provides the basis for more in-depth economic and environmental impact assessment studies and for detailed design for each of the alternatives. A more detailed traffic demand study is needed to predicted the additional diverted traffic. Furthermore, simulation methods are proposed to be implemented in order to resemble the operational aspects and to better assess the alternatives.

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Assessment of Retrofit Strategies for a Multi-Story RC Building againsit Seismic Loading

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ABSTRACT—The better understanding of the dynamic behavior and seismic performance of structures has led to advances in earthquake engineering in the recent years. For instance, the development of performance-based design approach that allows the selection of a specific performance objective based on different parameters, including the functional utility of the structure, the seismic risk, and the potential economic losses. Such an approach plays pivotal role in the design and retrofitting projects. To improve the seismic performance of systems that are found to be deficient, practitioners use various seismic retrofit strategies depending on the performance level needed.

I. INTRODUCTION

Typical reinforced concrete buildings in the West Bank are not adequately designed for seismic resistance. Therefore, it is important to assess these structures and improve the seismic performance for several seismic retrofit strategies. To assess the global and member structural behavior; nonlinear static (push-over) analysis and nonlinear dynamic (time history) analysis are to be conducted for the RC structure, For the (push-over) analysis, the distribution of lateral loads over the building height will be of two types; one to follow the first mode of the building and the other of a uniform pattern. For(time history) analysis Sources of synthetic ground motion data are to be found for moderate intensity earthquakes. Based on the analytical analysis results, seismic assessments are conducted using Federal Emergency Management Agency (FEMA-356) performance criteria. (FEMA-356) suggests the seismic evaluation to be performed on the global-level and member-level of the structural system using three performance levels (Immediate Occupancy, Life Safety and Collapse Prevention). For global-level assessment, the maximum interstory drifts for each floor level are to be determined. The member-level assessment is performed using plastic rotation limits to obtain detailed information regarding the structural behavior and seismic performance. The case study building is assessed to determine if the expected seismic response is acceptable for the different performance levels.

II. METHOD USED

A. Pushover analysis

It is a technique by which a structure is subjected to an incremental lateral load or displacement of certain shape as shown in figure 1.1. The sequence of cracks, yielding, plastic hinge formation and failure of various structural components are noted. The structural deficiencies are observed and then repaired. Pushover analysis gives an estimate of seismic capacity of the structural system and its components based on its material characteristics and detailing of member dimensions. However, the analysis cannot predict accurately the higher mode responses of a flexible building.

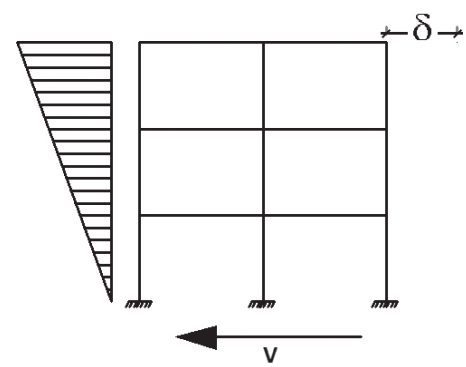


Figure 1.1 (pushover analysis)

Pushover procedure is described below:

1. Make two or three dimensional analytical model for the structure which includes all the important linear and nonlinear behavior of the structure.
2. Apply lateral displacement or load in a pattern that represents approximately the relative inertial forces generated at each floor.
3. Push the structure to a displacement that is larger than the maximum displacement expected under a design earthquake or push until complete failure occurs.

B. Plastic hinge formation and moment rotation curve :

The nonlinearity of structural elements is expressed as plastic hinges which are assigned at where flexural yielding is expected to firstly occur .For example, in concrete moment resisting frame(MRF) the plastic hinges are expected to form at the joints as the moment is maximum at the joint under lateral displacement or load. To reflect the behavior of the members in the structure, it is important to define the cross section properties, which can be done by drawing the moment-curvature relationship which can be converted into moment-rotation relationship (figure 1.2)

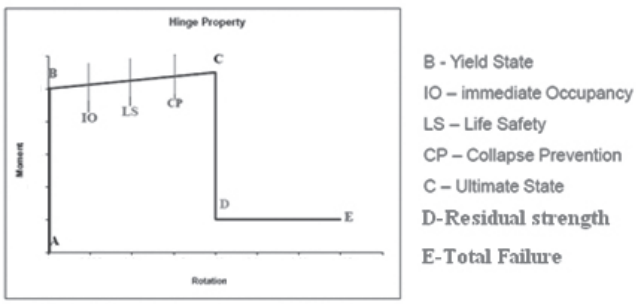


Figure 1.2 (moment rotation curve with performance levels)

III. CAPACTY CURVE

Pushover analysis provide a capacity curve that is the relation of base shear against roof displacement(Figure2.3), the change of slope of the curve indicates start of yielding of structural element and plastic . Pushover curve can be converted into capacity spectrum curve of spectral acceleration against spectral displacement (Capacity ADRS).

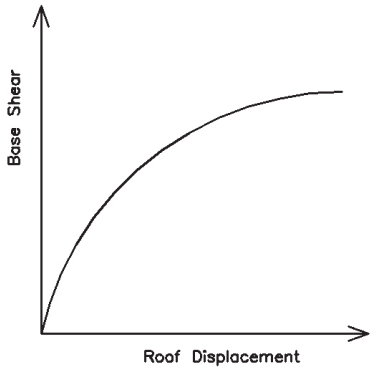


Figure III.3: Pushover Curve

IV. DEMAND RESPONSE SPECTRUM

Demand response spectrum is a representation of an earthquake ground motion. Due to the unavailable ground motion records and the difficulty to generalize the demand curve from an earthquake, seismic codes suggest methods for drawing the demand curve as a function of building period with an assigned damping ratio of 5 % (which consider as the inherent damping in the structure).A method of constructing a demand response spectrum using UBC97 or ATC40. This curve can be converted into acceleration displacement response spectrum (Demand ADRS). (Figure 1.3) demand response spectrum

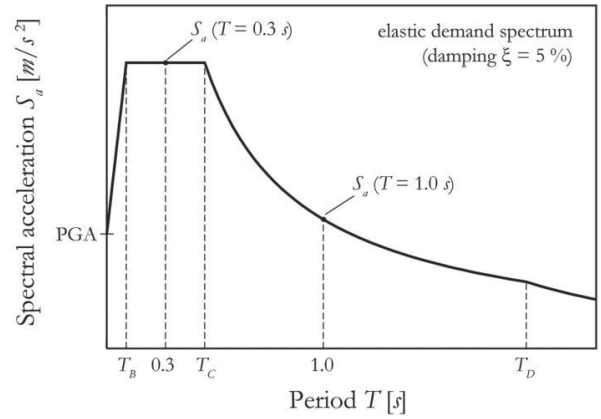


Figure 1.3 (Demand Response spectrum)

A. Performance point

A performance point of the analyzed building is the point at which demand and capacity spectrum curves (in the ADRS format) intersect as shown in (figure 1.4). It is used to

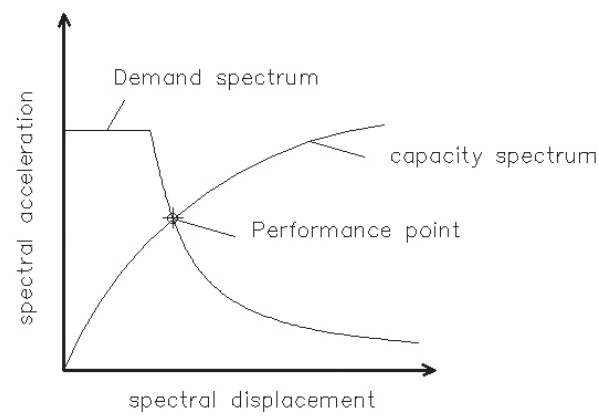


Figure 1.4(performance point)

determine the performance level of the structure under a prescribed earthquake and then comparing this level with the required performance objective under such earthquake. determine the performance level of the structure under a prescribed earthquake and then comparing this level with the required performance objective under such earthquake.

V. CASE STUDY AND NUMARICAL MODELING

The case study building represent a typical RC building which is usually found in most cities of West Bank like East of Jerusalem, Nablus, Ramallah, Bethlehem and Jenin. It represents 30% to 40% of the housing stock in these cities. This type of housing construction is commonly found in both rural

and urban areas. In this type of construction, the lower floor is usually use as parking with no infill walls which expected to form a soft story action under seismic load.

For the purpose of nonlinear analysis, the material and geometrical nonlinearity should be defined; the P-Δ effect was neglected.

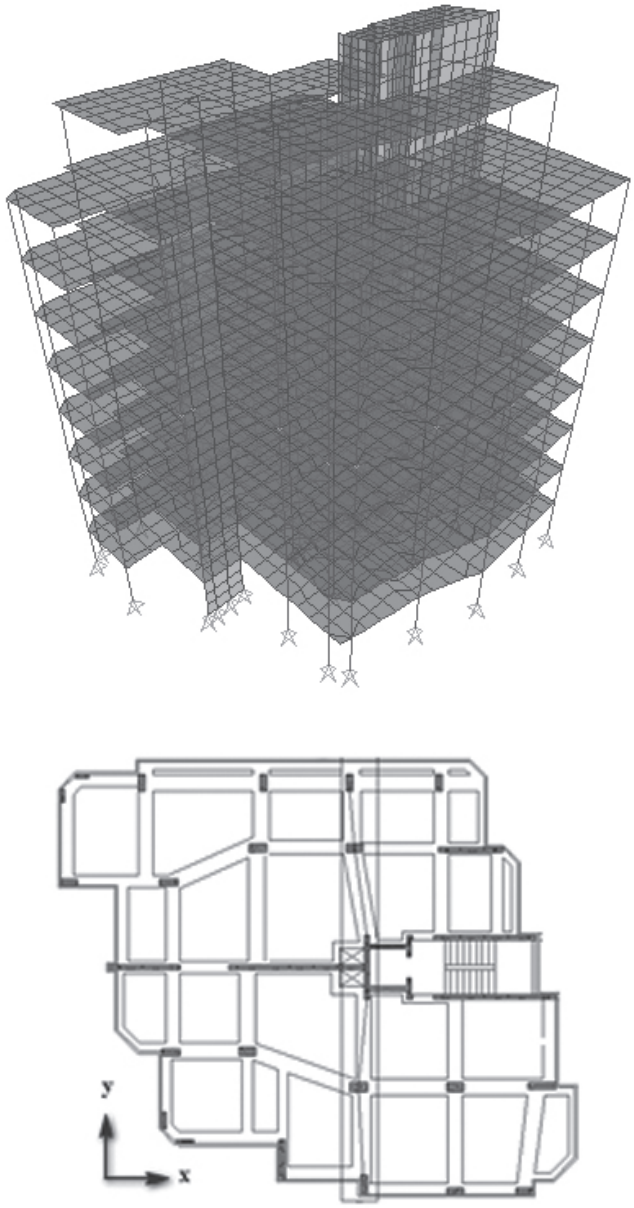


Figure 1.5(3D model and plan veiw)

The material nonlinearity is defined for concrete and steel by defining the stress strain curve for both materials.

VI. SHEAR WALL MODELING

The shear wall is modeled using a fine mesh of smeared multi-layer shell elements. The multi-layer shell element is based on the principles of composite material mechanics and it can simulate the coupled in-plane/out-plane bending and the coupled in-plane bending-shear nonlinear behaviors of RC shear walls. The shell element is made up of many layers with different thickness and different material properties are assigned to various layers (Figure 1.6). This means that the reinforcement rebar's are smeared into one layer or more. During the finite element calculation, the axial strain and curvature of the middle layer can be obtained in one element. Then according to the assumption that plane remains plane, the strains and the curvatures of the other layers can be calculated. In the case study building, the behavior of shear walls is dominated by flexure as the ratio of height to length is larger than 3. Therefore, the nonlinear behavior is considered for the analysis of in-plane bending (membrane action) of the concrete and vertical steel layers.

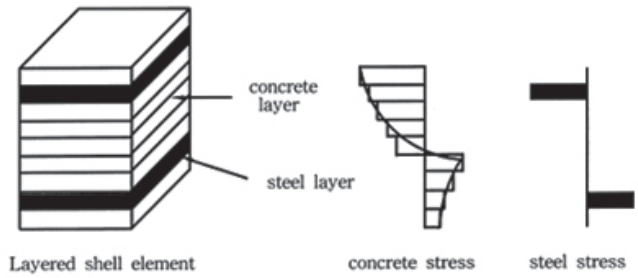


Figure 1.6(shear wall modeling)

VII. FRAME ELEMENT MODELING

For pushover analysis the nonlinear behavior of beams and columns is simulated by assigning lumped plastic hinges at member ends where flexural yielding is assumed to occur. Flexural characteristics of beams are defined by moment-rotation relationships assigned as moment hinges at beam ends, where as in columns coupled axial and moment hinges which are defined using moment-curvature and axial-bending interaction curves, are assigned at columns ends. The hinges are assigned at relative distance of (2% of member length) from the member ends.

VIII. MODAL ANALYSIS RESULTS

Modal analysis is performed for the numerical model of the case study building. (Figure 1.7) shows the first three mode shapes. Modal data of the first six mode shapes are shown in

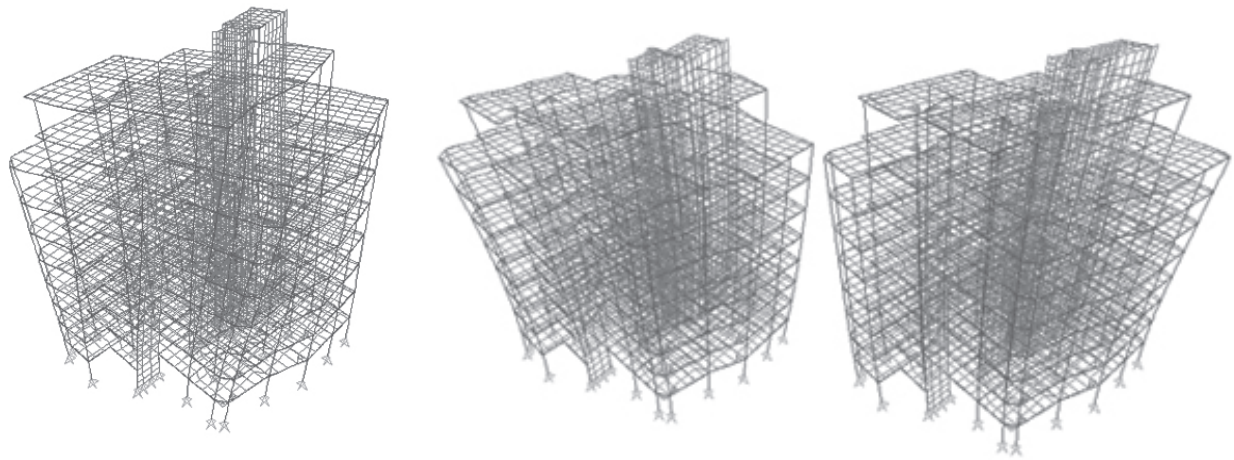


Table 1.1:Modal Data

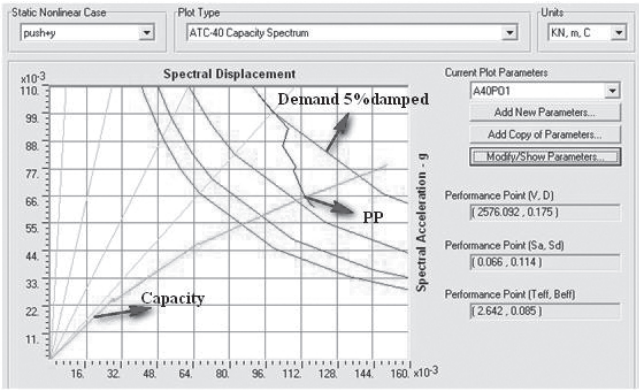
Modal Periods And Frequencies				Modal participation factor	
Mode	Period Sec	Frequency Hz	UX KN-s2	UY KN-s2	UZ KN-s2
Mode1	2.45	0.40	-1.28	11.76	-0.18
(Mode2 (translation in Ydir	2.19	0.45	-0.10	-65.05	0.21
(Mode3 (translation in Xdir	0.89	1.11	-65.07	-0.56	-0.49
Mode4	0.67	1.49	3.30	-3.00	-0.21
Mode5	0.54	1.85	-0.05	-33.47	-0.23
Mode 6	0.37	2.64	0.87	-0.11	-4.64

- It is observed that major modes for Y and X-directions are the second and third respectively mode shapes. This is observed from the values of modal participation factors.
- The first mode is the primary torsional mode as the distribution of the shear walls induces a large eccentricity between centre of regidity and center of mass, which cause high torsional effects.
- The vibrational mode shape of translation in Y-direction has lower frequancy than the one of translation in X-direction because the main lateral resisting system is the shear walls and there are multible shear walls working in the X-direction which make it stiffer when compared to Y-direction, which has only one shear wall.

IX. PUSHOVER AND PERFORMANCE POINT RESULT

According to the seismic hazard map of Palestine, the site may be classified as 2B region so the Z factor can be taken 0.2, for the project zone, values of 0.2 for both Ca, Cv is considered in constructing demand curve for the design earthquake. The performance objective under the design earthquake is Life safety (LS) .

The demand represented by the elastic spectrum is drawn with the capacity curve in the ADRS. The performance point is found by the intersection of these two curves. Capacity spectrum method suggested by ATC40 for finding the performance point is used. The Bilinear representation of capacity spectrum method of ATC40 is used in estimating the effective damping and reduction of the elastic demand spectrum. figure 1.8(performance point and pushover results)



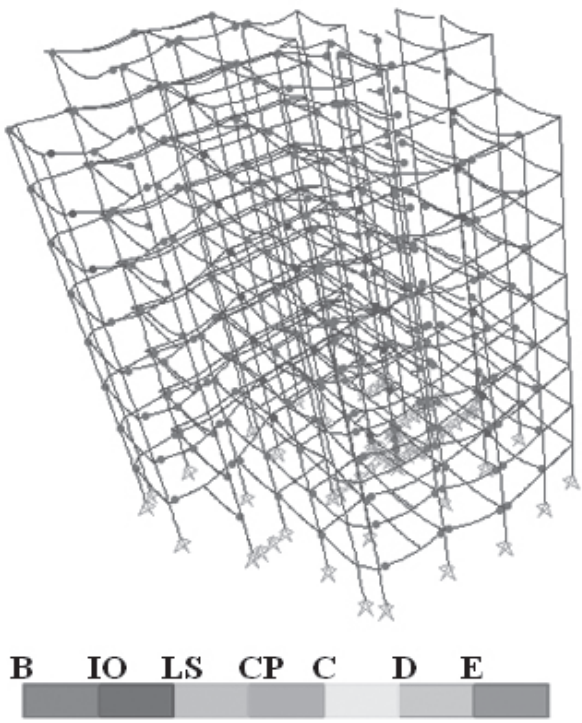


Figure 1.8(performance point and pushover results)

At the performance point, 27 beam elements undergo inelastic deformation under IO to LS performance levels. While 2 columns reach their ultimate capacity and fails, the both column are boundary columns at the first floor.

At the performance point, there are no severe plastic hinges at beams and columns except that formed in boundary columns of SW1 at the base of the building as shown in (figure 1.9). While SW1 which is the main lateral resisting system in Y direction undergoes high stresses in the compression zone. The concrete in membrane action (MC) undergo high stresses at the compression side that exceeds the ultimate compression strength of concrete (=24000 KN/m2) and, therefore, cause the crushing of concrete and a brittle failure occurs. The vertical steel reinforcement in membrane action (MS) of the shear wall yields and undergoes high stresses; however, these stresses are below the ultimate capacity as shown in (figure

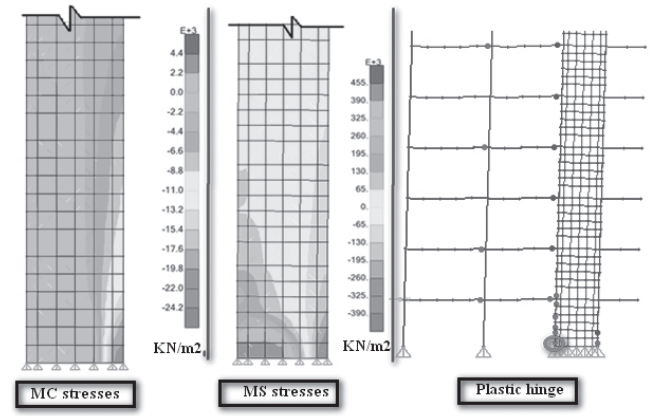


Figure 1.9(concrete and steel stress in shear wall)

Therefore, the main retrofitting objective is to enhance the lateral resistance in Y direction by adding shear wall or bracing element to enhance the building performance in a global level. Moreover, there is a need to enhance the ductility and failure mode of the columns of collapse prevention performance level to achieve strong column-weak beam connection.

XI. RETROFITTING TECHNIQUES

After seismic evaluation of the structure, the structural deficiencies location is determined, and a seismic retrofitting of the structure to enhance the seismic performance is required. The methods that increase the resistant capacity of structures by various techniques are called retrofitting.

The basic concept of retrofitting aims to the followings separately or collectively:

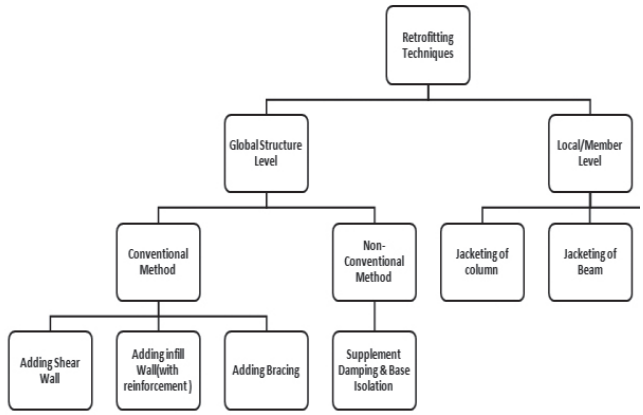
- Upgrade the lateral strength of the structure.
- Increase the ductility of the building.
- Increase of the strength and the ductility.
- In general the selection of the best retrofitting technique depends on the technical and financial factors. The cost of the retrofitting is often over 25% of the value of the building.

FEMA 356 standard can be used to choose the best retrofitting technique; this standard applies to the seismic rehabilitation of both the overall structural system of a building and its non-structural components including ceilings, partitions, mechanical, electrical, and plumbing systems. For this project the focus is on the rehabilitation of the structural system by two techniques global structure level (adding bracing element) and local level (column jacketing).

A. Global (Structural) level retrofitting:

Global level of retrofitting mainly used to control the global lateral drift and reduced the damage of the frame member by promoting the lateral resistance of the existing structure; steel bracing elements.

As the shear wall is the main structural system in resisting the lateral loading. And it's observed that the north south direction needs for strengthening. In this project adding bracing element is chosen to enhance the lateral resistance as it is less invasive technique.



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Collapse of the Physical Education Building at Birzeit University
A Case Study on Forensic Engineering

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1. INTRODUCTION

The collapse of the Physical Education Building (PEB) occurred around mid day on Tuesday, February 25, 2003 after a snow fall that started in the evening of the previous day. Luckily, the incident resulted only in loss of property due to the fact that university campus was closed on the that day. According to the Meteorological Office of the Palestinian National Authority's Ministry of Transportation, snow accumulation over Birzeit area was sighted to be ranging between 20 and 30 cm. Wind speed was insignificant to account for. Eye witnesses remarked that the collapse was both sudden and swift bringing most of the steel structure down in seconds.

Although ten years have passed since this incident for which numerous theories and speculations where presented by various committees and professional individuals to explain the cause of collapse, no scientifically rationalized account was presented to the public or to the professional society of engineers.

This paper1 uses scientific approach and methodology to explain what exactly went wrong, and how the sequence of events lead to its building collapse. Failure theory is outlined and structural analysis is performed to support it. Visual and material evidence, which pointed to course of events are also presented.

Figure 1.1 Overall view of the collapsed structure.

The observations, calculations, and conclusions presented in this paper are based on the following activities undertaken by the investigators:

a. Collecting and reviewing design, fabrication, and erection data.

b. Interviewing eye witnesses.

c. Conducting site inspection of the steel structure and documenting the findings.

d. Conducting in-house structural analysis of the steel frame to check its load-carrying capacity.

2. DESCRIPTION OF THE PEB BUILDING AND STRUCTURE

The Physical Education Building, a two-story building for the Department of Physical Education at Birzeit University, has plan dimensions of 36.57m by 44.7m. The structure is built in reinforced concrete with the exception of the roofing to the column-free multi-purpose sports hall on the ground floor. For the latter, seven identical steel gable frames were employed to support the roof, connected at their column ends to the main concrete frame at one end (along axis 7, Fig 2.1) and to the ground at the other end (along axis 1).

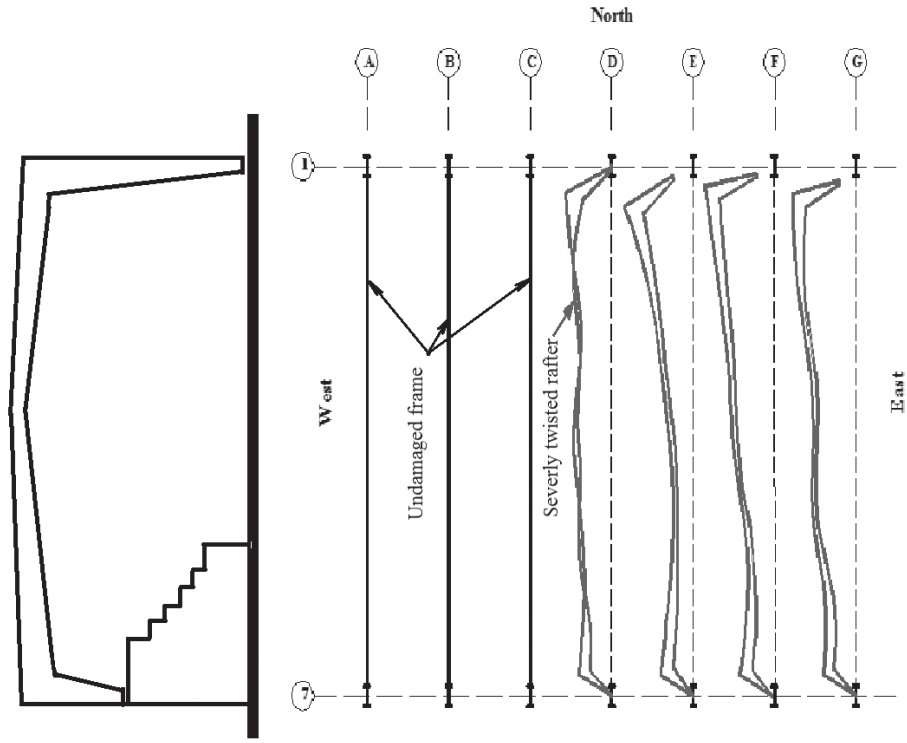

Figure 2.1 Schematic layout of collapsed frames D, E, F, and G.

The single-bay gable frames span in the north-south direction across the width of the building of 36.55m and are placed at equal spacing of 7.35m. The eaves of the frames are at 8.77m. The slope of the rafter is 0.5:10. The columns at either end of the frame vary in height; the south-end columns being 2.3m high while the north-end ones are 7.93m high. All frames consist of tapered built-up I-sections for the rafter and the column. Plates used for the built-up sections are ASTM A572 Grade 50 with yield strength of 50 ksi (34.5 kN/cm2). Roof covering consists of 200mm-deep cold formed Z- section purlins with the insulation between double-skin sheeting. A fascia of 1.12m high is provided all around the roof.

Cross-bracing is provided at roof and side walls every other bay. Wall cross-bracing consists of 24mm-diameter steel rods, while roof cross-bracing is 16mm diameter. Bracing rods are ASTM A36 steel with yield strength of 36 ksi (24.82 kN/cm2). This bracing system is intended to resist lateral (wind) forces acting in the East-West direction. The frame is unbraced in its own plane (North-South) and resists lateral forces in this direction by frame action alone. Lateral-torsional restraints of the rafter are employed using single angle links which form a V-shape (Fig 4.1) connecting the bottom flange of the rafter to the purlins which, along with the roof sheeting and X-bracing, form a horizontal diaphragm at roof level.

3. COLLAPSE CIRCUMSTANCES AND DESCRIPTION

The building structure collapsed one day before its duly commissioning date. This implies that all works should have been duly completed and certified by both the contractor and the consulting engineer.

At the time of collapse snow accumulation over the slightly sloped roof was sighted between 20 and 30 cm producing an average snow load of 0.625 kN/m2, well below both the assumed design snow load of 1.0 kN/m2 and the assumed live load of 0.75 kN/

m2. These facts alone lead to an early but reasonable conclusion that service loads (or overloads), individual or combined, did not play a major or direct role in the structure failure. And thus, their effect on the investigation may be given a lower priority against other probable factors.

Eye witnesses reported that the collapse was both sudden and swift. The structure went down in very few seconds. It culminated in the total collapse of 4 frames in the eastern part of the structure (frames along axes D, E, F, and G) leaving the remaining 3 frames along axes A,B, and C undamaged (Fig 2.1 and Fig.3.1). The rafter of only one of the frames, namely the one along axis D, was visibly and severely twisted. The other three laid on the floor with considerably less deformations. It will be noted later on that such observations deserve appropriate attention and not let go without thorough comparison and examination.

The long columns showed virtually no damage or deformations. The short columns also showed no deformations. This observation, reasonably leads to another early conclusion that the strength, or lack of strength, of columns was not a probable cause of the failure.

Figure 3.1 Uprooted, but virtually undamaged long columns along axis 1 in failed frames D, E, F, and G

Inspecting the rafters in all failed frames revealed a distinguishing extent of damage and twist in the rafter of frame D (Fig 3.2) which resembled the mode of lateral torsional buckling of beams (Fig.3.3). The nature and extent of the collapse and the overwhelming damage to the structure as a whole indicated that the failure was initiated by loss of stability. Strong evidence pointed to the likelihood that collapse was specifically triggered by loss of lateral stability of the central frame D causing it to snap to the west and inwards pulling in the same direction the rest of the frames E, F, and G. A more thorough investigation of this scenario of events is presented in the following sections.

4. CAUSE AND SEQUENCE OF COLLAPSE

Steel structures are composed of thin elements (plates) they necessitate special attention to stability requirements (overall member stability as well as local component stability) in addition to other member strength requirements such as bending and shear. When acting forces are compressive or flexural or both, as the case in the frames at hand, the stability issue becomes of vital importance. The potential problems caused by instability are further emphasized when member slenderness becomes relatively large.

In this case both the long columns along axis1 (length = 7.5 m.) and all rafters (span = 36 m.) require special attention to stability requirements both at the analysis/design stage and during construction. Elements that are meant to provide or insure stability may seem insignificant but they sure are crucial to the whole structure strength and its overall carrying capacity. These elements are generally provided in the form of braces of various shapes and configurations.

Long Columns Along Axis 1

For the built-up long columns along axis 1 the designer assumed no bracing, which was reflected both in his calculations and in the construction drawings. Material evidence on the ground, namely conditions of the columns, both fallen and still standing, reflected no apparent member deformations or failure. Thus they were excluded as instigators of collapse.

Rafter stability assessment

The rafters were built-up members which comprised of 6 segments of varying depth and plate properties in the web and flanges. Rafters are subjected to bending moments which vary both in magnitude and sign along the span. Thus, flange compression occurs in the top flange at some locations and in the bottom flange at other locations along the rafter. Compressed flanges tend

to buckle out of plane (sideways in this case) causing the rafter to twist and to fail by what is termed as lateral torsional buckling (LTB). To prevent this mode of failure bracing arrangements are usually required to hold the flanges in place and to prevent them from lateral movement when compression forces reach critical values. The top flange is normally adequately braced by the roofing system consisting of purlins, double skin sheeting, and horizontal bracing. As for the bottom flange, the designer provided for a V-shaped brace (Fig. 4.1) linking the bottom flange of rafters to the purlins and, consequently, to the relatively stiff roofing system.

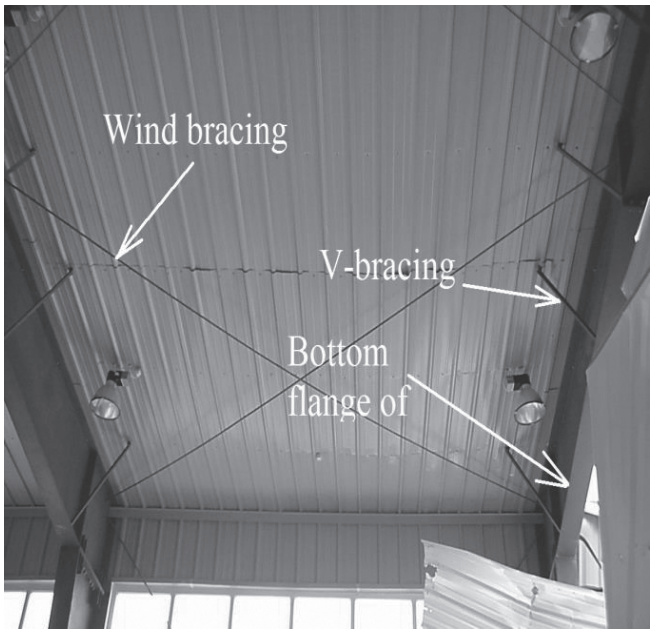

Figure 4.1 Roof wind bracing and the V-bracing of the bottom flanges of rafters.

Figure 4.2 Looking upwards, the twisted rafter in frame D.

Unfortunately, inspection of the collapsed structure revealed that neither the contractor, subcontractor nor the field representative of the consulting engineer realized the crucial role of these elements in structure soundness. It is evident that they (the V-braces) were treated with negligence. In many instances they were left unconnected completely loose, or temporarily held in place by steel wires and left as such, and when connected many were not sufficiently tightened to provide the required stiff link (Fig.4.3). Apparently, exceeding erection tolerances prevented alignment of bolt holes and no action was taken to remedy such a problem. The critical flaw with regard to the V-bracing occurred in Frame D where all braces along the entire length of the rafter on its west side were completely left out, while on the other eastern side some were attached and others were let loose (Figs. 4.4). Apparently this was done to allow for electrical installations in which a cable tray interfered with the inclined link of the V-brace.

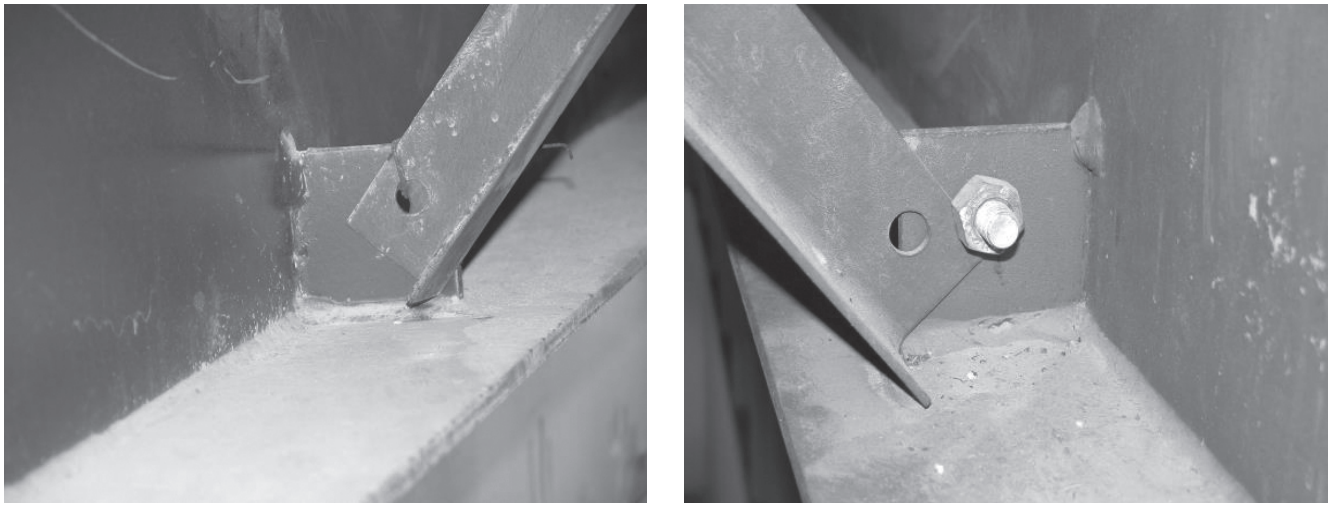

Figure 4.3 Unconnected rafter flange bracing angles (V-brace) in the undamaged frames.

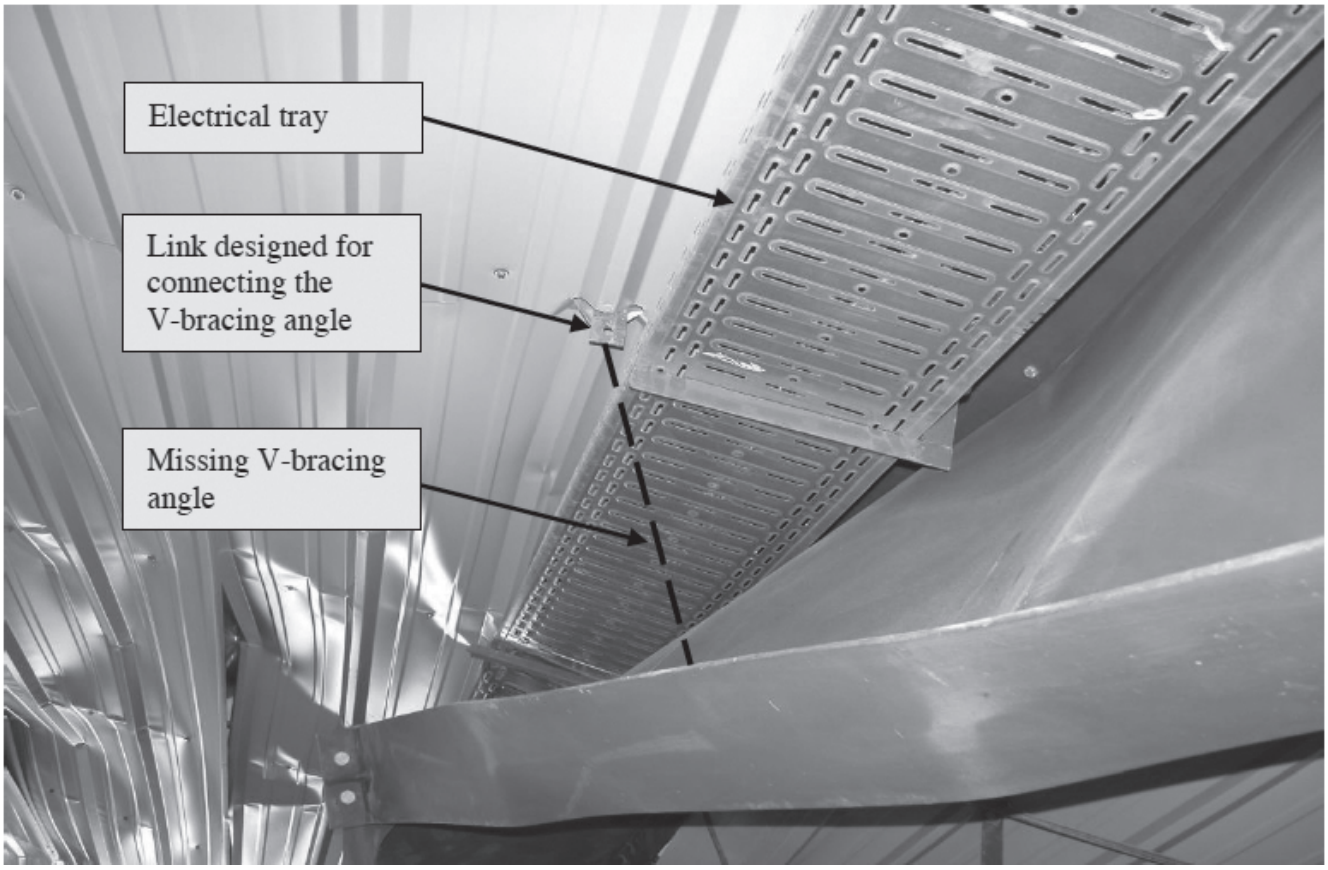

Figure 4.4 Interference of electrical installations with the V-brace prevented its installation on the west side of rafter D

The situation illustrated above (absence of all braces on the west side of rafter, and with long segments unbraced due to loose braces on its east side) rendered the rafter of frame D insufficiently braced over its entire span of 36 m. It caused it to be greatly susceptible to lateral torsional buckling under marginal loads well below the design loads. The presence of a bolted end plate connection in the suspected rafter segment (Fig .4.2, and 4.4) accelerated failure and caused it to commence in that specific location. The violent twist of this specific rafter compared to the others' is a clear evidence of this phenomenon. The direction of twist and the consequent collapse mechanism of this frame lea to the conclusion that failure of the structure started with this frame which, consequently, pulled the rest of the frames westward in the direction of its out-of-plane lateral torsional buckling.

5. ANALYTICAL ASSESSMENT OF "FRAME D"

To illustrate how, why, and at precisely what stage of loading the structure collapsed, analytical evaluation of the "as-built" steel frame was carried out. Based on the observations and conclusions drawn in the previous sections, the following assessment focuses on frame D with an unbraced 9 m.-long rafter segment in the vicinity of the short column at axis 7. This segment represents the stretch in rafter D over which the V-bracing angles were not present on both sides of the rafter.

Numerous runs on STAADpro were performed with incremental loading to reach the failure load. Examination of the computer output revealed the following:

1. The moment diagram showed that the unbraced 9 m.-segment of rafter D was subjected to negative bending moment, meaning that its bottom flange is under compression, and hence bracing against lateral-torsional buckling was vital to the stability of this segment.
2. The failure diagram (Fig. 5.1) shows that frame failure started at this very segment, and that computer output indicated that failure was controlled by AISC equations H1-H3, which express member strength under combined bending and compression.
3. Analytically, failure occurred under a load of 0.325 KN/m2, which resembles a load resulting from snow accumulation of 15 cm.
4. The inherent safety factors in the AISC design specifications allowed the frame to carry the estimated 20 to 30 cm. accumulation at the time of collapse.

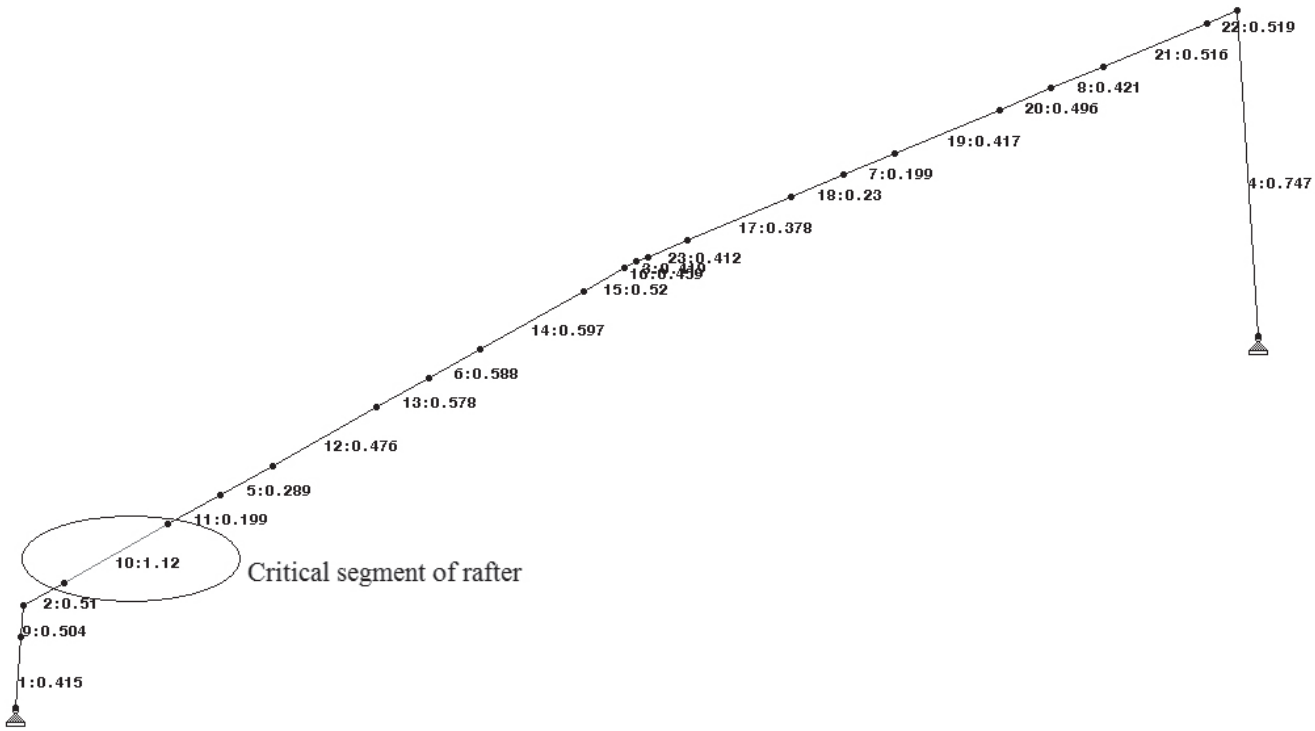

Figure 5.1 Failure diagram (Unity Check). Note the predicted failure of member 10 (with ratio 1.12) adjacent to the short column on the left.

6. SUMMARY AND CONCLUSIONS

This paper presents a comprehensive appraisal of the collapse of the steel frame of the Physical Education Building at Birzeit University. Investigation of the collapse was conducted along four main tracks:

The first was to document the "as-built" failed structure and collect site date and observations relevant to probable fabrication and erection flaws, the second was review of calculation sheets and drawings submitted for construction. The third was performing analytical assessment to draw conclusions and substantiate

judgments on causes of structure collapse, its failure mechanism scenario and sequence.

The following conclusions are made:

1. Numerous construction flaws were observed. The recurrence of these flaws point to a degree of insufficient experience and/or negligence on behalf of both the contractor/subcontractor and the supervising site engineer.
2. The most serious construction flaw occurred in Frame D where elements of the lateral torsional bracing of the rafter were completely eliminated on one side of the rafter, and a number of the installed braces on its other side were not bolted to their respective gussets on the rafter. Consequently, rafter D was left with at least 9 m.-long segment of the compressed flange laterally unbraced causing it snap sideways in a lateral torsional buckling mode setting off collapse of the larger portion of the structure under a marginal snow load well below the assumed design value of 1.0 KN/m2.

Decision Making in the Selection of the Exterior Walls Techniques in Affordable Housing Buildings in Palestine

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ABSTRACT- Housing is considered the most important challenge facing the Palestinian National Authority, where the housing problem in Palestine is increasing day after day in light of the steady rise in population and returnees in the face of limited land and high prices of them, rising construction costs and relatively low income level. Success in providing affordable housing depends on several factors including the reduction of construction costs, which in turn depends on the construction techniques. Construction technique is a key tool to reduce the cost of the buildings but the reduction in cost should not be on the account of the efficiency of construction, durability, and resistance to natural and geological factors, and other than that the idea of getting the house of a low-cost, regardless of the expected age and quality of construction is a short sighted idea and a cheap solution in the present but a complex problem in the future. Therefore, there is a great need for a decision making process to select the optimum technique during the preliminary engineering study to reach to cut down the construction cost with the higher efficiency of the housing unit.

1. Introduction:

Housing is a major concern of every country, society, and household. For the country it has a political and economical effect, and plays a significant role in developing the economy and creating new jobs.

The Palestinian National Authority is initiating a new endeavor to stimulate economic development and improve the housing stock through infrastructure development within the housing sector. There is high demand for housing in the Palestinian Territories (approximately 400,000 to 450,000 housing units in the next 10 years) and limited supply (about16,000 units per year) according to the Ministry of Public Works and Housing. Purchasing housing is increasingly unaffordable due to high prices and low - per capita income. This research aims mainly to work to improve the level of housing projects in Palestine through the selection of the proper construction techniques in terms of cost of construction, strength and durability, aesthetics, etc. This research is conducted on the construction techniques in order to evaluate them and make decision in the selection of the proper construction techniques in order to obtain affordable quality housing.

2. Building and Construction Sector:

Building and construction constitutes the backbone of the various development policies which have either a negative or positive impact on the different development sectors. At the Arab level, the building and construction industry has achieved high development rates. Yet, in spite of such development, the economic and technical importance of this industry has not received the due attention due to the absence of any link within the Arab market, and the lack of integration and unity in the industry per se, being scattered in small country-based frameworks. Therefore; it can't properly contribute to development unless it becomes an integrated system.

The building and construction sector is vital to the economy, as it is diversified and covers several fields that are interrelated with the various sectors of economy. Building materials constitute the major elements in the buildings costs, ranging between 64% and 67% of the basic cost of any building. Thus the increase in its cost consequently leads to the increase in the cost of buildings.

Building and construction technologies represent the effective solution to meet the ever increasing demand on quality, together with finalizing major projects on time, increasing the productivity of these materials, and maintaining high levels of vocational

safety at the construction sites. The decision to use advanced building and construction technologies is affected by feasibility studies, which are manifested in the comparisons in the cost of employing highly skilled labor, modern technologies and equipment that require more or less intensive capital; particularly at the early stages of application of these technologies and the specific requirements of the project.

3. Building and construction Sector in Palestine:

The building and construction industry is one of the leading economic sectors in the West Bank and Gaza, not only for its substantial contribution in the Palestinian Gross Domestic Product and in employment, but also for its strong interrelations with other economic activities. The construction of buildings, in particular, comprises a significant part of construction activities as a whole. Residential buildings make up the bulk of investments. Housing has been considered the most important challenge facing the Palestinian National Authority. Where the housing problem in Palestine is increasing day after day, Palestinian National Authority is trying to find solutions to this problem through the establishment of urban communities, but the availability of housing in it is inadequate in terms of quantity.

Building materials industry in Palestinian Territories still doesn't cover all the requirements of local market and imports make up the balance. In general, the main materials used in construction in Palestine are concrete, stone, hollow concrete blocks, steel, aluminum, wood and other complementary materials. These kinds of building materials can be used individually or together with each other to form the structure of buildings.

Building techniques in West Bank and Gaza strip are influenced by the materials available domestically as well as techniques in neighboring countries. The following construction techniques have been evaluated:

1. External reinforced concrete walls with natural stone cladding.
2. External reinforced concrete walls with cast stone cladding.
3. Slab-beam-column system with exterior masonry walls of stone backed by concrete.
4. Slab-beam-column system with exterior walls built from stone, concrete, and concrete blocks.
5. Slab-beam-column system with exterior walls built from concrete, stone and concrete block and insulating material between them.
6. Slab-beam-column system with exterior masonry walls built from light weight units with stone cladding.
7. Slab-beam-column system with concrete blocks exterior walls.
8. Slab-beam-column system with exterior masonry walls built from light weight units "ytong" with stone cladding.
9. Slab-beam-column system using precast concrete facade panels for exterior walls.

IV- Decision Making Process:

The decision making process which is followed in this study is the process of generating decision criteria, and identify the alternatives to select from. In this process the following table will used to:

1. Identify a decision the researcher wish to make and the alternatives considering.
2. Identify the criteria that consider important.
3. Assign each criterion an importance score.
4. Determine the extent to which each alternative possesses criterion.
5. Multiply the criterion scores by the alternative scores to determine which alternative has the highest total points.

V- Methodology:

In this study, a questionnaire was prepared to determine the criteria that influence the decisions for selecting the proper construction technique and to determine their overall importance in the decision making process, and to evaluate the construction techniques by reference to these criteria. In this questionnaire, the construction techniques have been evaluated based on the weighted evaluation method by using a 10-point scale in making judgment in a decision criterion that influence the decisions for ranking and evaluating construction techniques. These criteria were obtained from the literature review, documentation of previously implemented construction projects, a survey and informal interviews with the people who

are responsible for conducting construction projects. Table (1) shows the 10 decision criterions that were considered.

Table (1): Decision criterions that influence the decisions for ranking and evaluating construction techniques

1- Strength and durability	2- Cost of construction
3- Safety during construction	4- Aesthetically
5- Environmental factor resistance	6- Construction speed
7- Cost of future maintenance	8- Thermal insulation
9- Fire resistance	10- Need for specialized skills

A housing unit has been taken as a case study in order to estimate the actual cost for each technique. Some external experts (Four contractors) have been asked to price the same BOQ for each technique and the average has been taken in order to assess the techniques and compare them in terms of the cost of construction.

VI- Data Analysis:

Based on questionnaire results analysis, Table (2) shows the degree of importance of the criterion that influences the decision for selecting the proper construction technique.

Table (2): Evaluation of the factors that are used in evaluating construction techniques

	Decision Criterion	Percentage		Decision Criterion	Percentage
1	Strength and durability (9.87)★	15 %★★	6	Construction speed (7.22)	10%
2	Cost of construction (9.58)	15 %	7	Cost of future maintenance (6.76)	10%
3	Safety during construction (9.07)	15 %	8	Thermal insulation (5.25)	5%
4	Aesthetically (7. 75)	10 %	9	Fire resistance (4.35)	5%
5	Environmental factor resistance (7. 51)	10 %	10	Need for specialized skills (3.80)	5%

The sum of total scores =71.16

The sum of total percentage =100%

*The number between ( ) is the weighted average score for a decision criterion.

★★ The weighted average score was converted to a percentage and rounded to the nearest five.

The construction techniques have been evaluated based on the weighted evaluation method by using a 10-point scale in making judgment in a decision criterion. In the following table the construction techniques were ranked according to the evaluated of the research sample.

Table (3): Ranking the construction techniques

	Construction techniques	Score
1-	Exterior walls built from concrete, stone, concrete block and insulating material between them.	72.6
2-	External reinforced concrete walls with natural stone cladding.	72.3
3-	Exterior walls built from concrete, stone, and concrete block	70.9
4-	Exterior masonry walls of stone backed by concrete.	70.7
5-	Exterior masonry walls built from light weight units with stone cladding.	67.1
6-	External reinforced concrete walls with cast stone cladding.	65.1
7-	Precast concrete facade panels for exterior walls	64.7
8-	Two layers of 20 and 7cm concrete block and insulating material between them.	62.9
9-	20cm concrete block exterior walls.	59.6

According to the results mentioned above, the following techniques have the highest total points:

- Exterior walls built from concrete, stone, concrete block and insulating material between them.
- External reinforced concrete walls with natural stone cladding.

The research sample was asked to determine which one of the previous nine techniques is the proper technique for executing an affordable housing project. The answers are shown in table (3).

Table (4): Selection of the construction technique

	Construction techniques	Repetition	Percent
1-	Exterior walls built from concrete, stone, concrete block and insulating material between them.	31	55.4%
2-	External natural stone cladding.	11	19.6%
3-	Exterior walls built from concrete, stone, and concrete block	3	5.4%
4-	Exterior masonry walls of stone backed by concrete.	5	8.9%
5-	Exterior masonry walls built from light weight units with stone cladding.	1	1.7%
6-	External reinforced concrete walls with cast stone cladding.	0	0.0%
7-	Precast concrete facade panels for exterior walls	0	0.0%
8-	Two layers of 20 and 7cm concrete block and insulating material between them.	3	5.4%
9-	20cm concrete block exterior walls.	2	3.6%
Total Summation		56	100%

VII- Conclusion:

Based on the results mentioned above regarding the selection of the proper construction technique for executing an affordable housing project of the nine surveyed techniques, one can say that there is a matching between the selection and the evaluation of these techniques if one looks to the selection of the proper technique, where most of the research sample (55.4%) selected the technique: Exterior walls built from concrete, stone, concrete block and insulating material between them, which has the highest total points (72.6) as the proper technique for executing an affordable housing project.

Because an optimization must be reached between safety, serviceability, and economy to reach the minimum cost with the higher efficiency of the housing unit, the researcher started the thesis by introducing research objectives which can be summarized by review of construction techniques currently used in research environment (West Bank), then Developed a mechanism to evaluate these techniques and be judged by reference to decision criteria.

Quantitative and qualitative researching approach has been used, and the data was collected using a questionnaire, 81 companies have been surveyed and the response rate was 69 per cent. Another data collection ways have been used also such as interviews, and personal observations. As a result the technique: Exterior walls built from concrete, cast stone, concrete block and insulating material, will enable cheaper housing construction. Other techniques such as precast concrete facade panels for exterior walls helps in developing the methods of construction to cut down the production cost in other countries but in research environment prefer dependence on the available labor to avoid the cost of employing highly skilled labor and reducing investment in modern technologies, so the infrastructure of this technique is not ready. Changing the culture of people to adopt this new technique is also needed. There are building regulations that impact, for example the requirements on using stone in external walls. The techniques that have been selected in this study (Exterior walls built from concrete, cast stone, concrete block and insulating material) have the highest score in the evaluation and meet the demand of the Engineers Association with respect to insulation and reduce the production cost by saving in building materials while maintaining the appearance of the stone that represents the culture and identity of the buildings in the West Bank.

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Engineering Mistakes & Potential Failures in Buildings
A Case study: Dafer Al-Masri Building- Nablus City

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ABSTRACT— Structural evaluation was performed to explore the existing state of commercial building to provide the owner with recommendations for the future treatment of the building. Results of investigation were crucial from structural safety conditions and serious conditions of mostly all columns at basement and GF, and in-adequate foundations. This paper is an extract from the structural evaluation report where only four failures are flashed to show the magnitude of risk which is still existing in the building as a whole. Results are also showing major defaults in design considerations and incompatibility to codes conditions what leads to deteriorations and rapid aging in some bearing members due to overstressing and low strength of used concrete due to low level of quality control at the time of construction. Quick remedial repair and strengthening was done to avoid the inevitable occurrence of sudden failure in the ٦ floors elevation where the failure was in very advanced stage and about to tilting the exterior wall, if not the whole building in a sequence.

Keywords-component; structural Evaluation, safety factors; sudden failures, potentil failure, poor practice, engineering mistakes.

I. INTRODUCTION

Many existing buildings have potential failures caused by poor design, engineer's mistakes and or poor construction practice. Some failures are a result of non-adequate design data on soil mechanical properties where testing was not custom or enforced by regulations. Other reason is the design engineer knowledge and or respect of codes and specifications in situations like in Palestine where no mandatory conditions or limits to be followed during design process.

The investigated building has different potential failures, ongoing deteriorations and actual failures and distresses, if we compare its properties such as strength, bearing capacity, reinforcement ratio…etc. to the allowable limits in building codes. Some failures are revealed after many years in service where deterioration of concrete strength due to aging, poor practice and overstressing, thus increasing the critical state of the building.

Lack of quality control and mistakes in design consideration, mistakes in implementation practice are active participating factors in building deterioration where some code requirements were not met and many defaults and distresses were developed during building service lifetime. Service life time of the building is actually is becoming shorter (35 years since construction) because of the occurred distresses and potential failures where the feasibility of the project at all is in question. The economy factor is jeopardized due to mistakes and in adequate design and detailing of important building.

It is important to note that the building was evaluated twice in different times by other colleagues and some remedial actions were done such as strengthening of foundation by adding ground beams between columns of northern part and partial jacketing of one column was done.

II. PAPER SIGNIFICANCE

This paper is intended to explore an existing case to the awareness and knowledge of Engineers and to disseminate information on cases of inadequate design and or engineering mistakes and their magnitude of risk to the public interest and economy which could occur if code requirements and mandatory regulations are not met. In the other hand, how much important are the safety factors and how much they are useful to save buildings from sudden failures will be flashed here.

III. PROJECT DESCRIPTION

The building is consisting of one basement, five floors and a roof. It was built in the late 1970's from two parts with (5 m) wide space between them starting at ground floor. The two parts are connected at basement and at the top level by sky path.

The structural bearing system is from spread columns with ribbed slabs, where exterior walls are from stone cladding concrete walls suspended on slabs or beams.

Stair cases and elevators walls are also suspended on basement (partially transferred) slab where they are starting. Exterior walls at basement level are R.C retaining walls at the perimeters of the whole plot area, serving only the basement level, discontinued above due to the reduction in the building foot print. See attached drawings.

The foundation soil is different below each part, where one has rock beddings and the other has well stiffened clayey layers. Consequently footing and foundation are different for both parts, where spread footing at Northern part and mat foundation at the other southern part.

IV. FAILURES AND DEFAULTS

For the purpose of this paper, we are concentrating only on four major failures caused by in-adequate design and/or building practice. Those failures are:

- Non adequacy of spread footing area and depth.
- Non adequacy of the columns sectional area at basement and ground floor levels.
- Non adequacy of mat foundation slab depth and reinforcement.
- Sudden reduction in four columns sections at mezzanine level causing very dangerous failure.

V. ILLUSTRATIONS OF STUDIED FAILURES

A. Failure in spread footing bearing capacity:

The footing area for mostly all investigated spread columns in northern part is (1.4 X 1.05 m), where the maximum service loads are between 1950 KN and 2920 KN, thus, loading factor from (3.8 to 5.75) times the allowable bearing capacity which is (350 KN/m2) in our case.

- From calculation, the foundation soil is imposed with about (11.5 Kg/cm2) or (1150 KN/m2) which is not allowed in any building code.

B. Failure in columns bearing capacity:

In the northern part above footings, the columns cross section is (60X30 cm) at ground floor level, where loading from factored loads are from (2516 KN) to (3792 KN) per column, revealing that loading factors ranges from (1.26 to 2.24) times the column capacity with the in-situ concrete strength varying (from 12.3 to 19.1 MPa). Example of five columns is illustrated in the tables below. If we consider the maximum design concrete strength at the time of construction as (≈ 24 MPa), most columns are still in failure conditions, where axial compression resistant is failed.

- If we consider only service loads on the mentioned four columns with the best probable concrete strength at the time of construction (fc' = 24 MPa), the results are still showing failure in most columns as seen for sample of columns in tables (1),(2) and (3) below.

Member Desc-ription	Member Location	Structural Dimention		Dead Loads	Live Loads	Concrte Strength	Columns Reinform nt	Rein.t ratio	Bearing Capacity	Ultim. Imposed loads on Columns		Loading Factor	CHECK RESULT
						F'c		ρ		Serv.	Fact.d		
		cm	cm	KN	KN	Mpa	Cm2	%	KN	KN	KN	%	POINT
C8	Ground	60	30	2056.9	396.4	14.8	12.06	0.67	1301	2453	3102.5	238%	UNSAFE
C9	Ground	60	30	1175.7	283.2	14.03	12.06	0.67	1241	1459	1864.0	150%	UNSAFE
C10	Ground	60	30	1422.6	423.8	14.03	12.06	0.67	1241	1846	2385.2	192%	UNSAFE
C11	Ground	60	30	1424.1	420.4	14.03	12.06	0.67	1241	1845	2381.6	192%	UNSAFE
C12	Ground	60	30	1941.2	403	14.03	12.06	0.67	1241	2344	2974.2	240%	UNSAFE

TABLE I. SAMPLE OF COLUMNS LOADING WITH FACTORED LOADS

Member Desc-ription	Member Location	Structural Dimention		Dead Loads	Live Loads	Concrte Strength	Columns Reinform nt	Rein.t ratio	Bearing Capacity	Ultim. Imposed loads on Columns		Loading Factor	CHECK RESULT
						F'c		ρ		Serv.	Fact.d		
		cm	cm	KN	KN	Mpa	Cm2	%	KN	KN	KN	%	POINT
C8	Ground	60	30	2056.9	396.4	24	12.06	0.67	2028	2453	3102.5	153%	UNSAFE
C9	Ground	60	30	1175.7	283.2	24	12.06	0.67	2028	1459	1864.0	92%	G.COND.
C10	Ground	60	30	1422.6	423.8	24	12.06	0.67	2028	1846	2385.2	118%	SEVERE
C11	Ground	60	30	1424.1	420.4	24	12.06	0.67	2028	1845	2381.6	117%	SEVERE
C12	Ground	60	30	1941.2	403	24	12.06	0.67	2028	2344	2974.2	147%	UNSAFE

TABLE II. SAMPLE OF COLUMNS LOADING WITH FACTORED LOADS USING FC' = 24 MPA

Member Desc-ription	Member Location	Structural Dimention		Dead Loads	Live Loads	Concrte Strength	Columns Reinform nt	Rein.t ratio	Bearing Capacity	Ultim. Imposed loads on Columns		Loading Factor	CHECK RESULT
						F'c		ρ		Serv.	Fact.d		
		cm	cm	KN	KN	Mpa	Cm2	%	KN	KN	KN	%	POINT
C8	Ground	60	30	2056.9	396.4	14.8	12.06	0.67	1301	2453	3102.5	189%	UNSAFE
C9	Ground	60	30	1175.7	283.2	14.03	12.06	0.67	1241	1459	1864.0	118%	SEVERE
C10	Ground	60	30	1422.6	423.8	14.03	12.06	0.67	1241	1846	2385.2	149%	UNSAFE
C11	Ground	60	30	1424.1	420.4	14.03	12.06	0.67	1241	1845	2381.6	149%	UNSAFE
C12	Ground	60	30	1941.2	403	14.03	12.06	0.67	1241	2344	2974.2	189%	UNSAFE

TABLE III. SAMPLE OF COLUMNS LOADING WITH SERVICE LOADS

- Looking at the reinforcement ration in columns we find it less than the minimum allowed ratio in all columns. Here we can conclude that original design for columns and footings was not properly done, or other, un-known considerations were taken by the design Engineer.

C. The Mat foundation distress: The southern part of the building is bearing on mat foundation with (35cm) thickness with concrete fc' of
(40 MPa) as revealed from in-situ concrete core tests. The spans between columns are between (4.0 – 4.50 m). The foundation soil is from well stiffened clay layers with 1.5 Kg/cm2 is the calculated allowable bearing capacity of soil from plate bearing test. Punching shear capacity was checked taking load on column (C10) at axes (M/13) as example. Columns are polygonal in section (204cm) in perimeter, where loading from above is: P service = 2930 KN P factored = 3800 KN SAFE structural software was utilized for analyses of the mat foundation. Soil pressure taken from SAFE software is about (36.2 KN/m2). The punching force is (3340 KN).

$$\tau = \frac{\Phi}{3}\sqrt{fc'} * b * d \text{ , ---------- [1], } \textit{where}$$

b: perimeter of critical section for shear in footing
d: distance from extreme compression fiber to
centroid of longitudinal tension reinforcement.

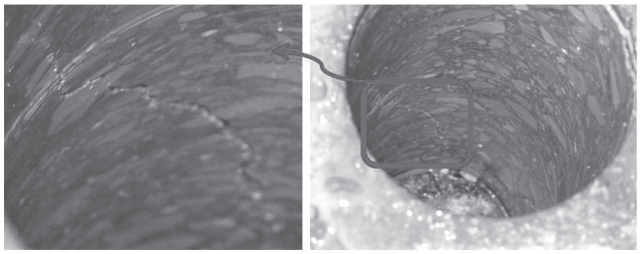
$$\tau = \{0.75 \text{ X } 0.33 \text{ X } \sqrt{40} \text{ X } 421 \text{ X } 30 \text{ X } (10/1000)\}$$

= 1977 KN.

Here the shear capacity is less than the punching force where loading factor is:

$$\frac{3440}{1977} = 1.74 \text{ times,}$$

This explains the cracks around columns in the mat foundation. The simple conclusion here is that the depth of the mat is low and should have been at least (٥٠cm).



D. Reduction in columns section:

At mezzanine level, at east elevation, four columns were reduced from (45X30cm) to (30X30cm), and then transverse beam with (30cm) width & (100cm) depth was constructed to bear the above (five floors) exterior wall, where columns became concealed within wall thickness. The four columns between mezzanine slab top level and the bottom of the perimeter deep beam became short with (1.3 m) height. Reinforcement is (6Φ16) of mild steel bars.

During inspection, the failure was clearly noticed were concrete was cracked and longitudinal bars were clearly buckled, stirrups are already un-tied.

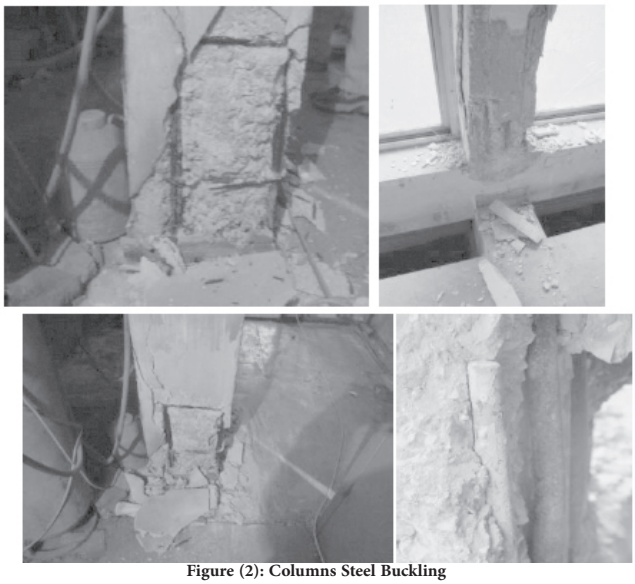


Figure (2): Columns Steel Buckling

From inspection outside, the wall above is shown with defects, cracks and de-bonded stone cladding at columns face, some stone panels are already spelled out.

This case was the most critical where failure is on-going and sudden failure to the whole elevation is expected anytime.

From calculations we found that those four columns were imposed up to (2.3) times in average from their actual capacity because of the change in structural bearing setup above column.

Remedial actions were made directly after inspection and four columns were jacketed with steel plates (10 mm) thick and welded stirrups inside to maintain proper confinement to already failed concrete. The filling is from high performance, self leveling concrete specially mixed with additives where compression strength could reach (60 MPa).

Member Deso-ription	Member Location	Structural Dimention		dead	live	Concrte Strength	Columns Reinforcm nt	Rein.f ratio	Bearing Capacity	Ultim. Imposed loads on Columns		Loading Factor	CHECK RESULT
						Fc		ρ		Serv.	Fact.d		
		cm	cm	KN	KN	Mpa	Cm2	%	KN	KN	KN	%	POINT
C6	FIRST	30	30	1226	121	14	12.06	1.34	682	1347	1664.3	244%	UNSAFE
C8	FIRST	30	30	1147	107	14.03	12.06	1.34	682	1255	1548.4	227%	UNSAFE
C28	FIRST	30	30	1337	103	14.03	12.06	1.34	682	1441	1770.2	259%	UNSAFE
C22	FIRST	30	30	1145	117	14.03	12.06	1.34	682	1441	1770.2	259%	UNSAFE

TABLE IV. SAMPLE OF COLUMNS LOADING WITH FACTORED LOADS

Figure (3): Columns Strengthening Processes

E. Effects of the existing failures on the building future:

As a result of the mentioned and other failures in the building, the owner is now discussing the feasibility of repair and rehabilitation compared to removal and replacement because the existing failures revealed the following:

1. Bowing of stone cladding at all elevations, risking passing people.

Figure (4): Falling Stone Pieces

2. Many columns at basement level and most columns at ground floor level are in distressed, over-stressed conditions, with low concrete strength. Here strengthening is a must to save the building.

3. The foundations of both parts are in potential failure where foundation soil is imposed more than three times its allowable bearing capacity.

4. Because the basement walls are discontinued and the staircase shear walls are suspended on basement floor slab, other walls are also suspending on basement floor slab, and discontinued due to stores openings, the whole structural system above ground level has weak resistance to lateral forces.

Conclusions

- From analyses and calculations, we found that the building was designed in logical sequence, but with inadequacy in conformation to Code requirements, and lack of details which led to some crucial mistakes like in four columns change of orientation.
- Judging by the Codes conditions, the building is theoretically failed, and still expected to fail if strengthening measures not taken on time.
- it is the privilege of safety factors imposed by codes of practice where:

1. Taking the allowable bearing pressure for foundation soil three to five times less than the ultimate bearing pressure.
2. Taking safety factors of (1.61.7-) for live loads and (1.21.4-) for dead loads in strength or limit state design methods is providing a good reserve to help overcoming overloading or mistakes in loads calculations.
3. Considering factors of safety on material strength (a total of 0.65 for concrete in compression, 0.9 for steel bars), or FOS on material as 3.0 for concrete and (1.751.85-) for steel in the allowable strength method in the previous codes are inevitable to help in avoiding overstressing of materials under over -loading conditions and for durability factors.

- Inadequacy and mistakes in design concepts and input data are more dangerous than those in poor practice because they affect the whole system, not certain locations or members.
- The building feasibility is jeopardized as a result of inadequate design and mistakes what is exploring the importance of proper design and its reflection on the service lifetime of building exploitation and income generation.

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Equivalent Lateral Load Method vs. Response Spectrum Analysis Which Way is Forward

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ABSTRACT-In earthquake prone zones like the region in which Palestine is situated, structures have to resist added forces induced on them as a result of member distortions caused by the ground motion on which they rest. The response is attributed to the inherit properties of the structure itself, the nature of the exciting motion as well as the particular foundation system of the structure.

The present study aims at clarifying the prudent technical approach for the structural analysis and design for seismic action in compliance with pertinent code requirement; namely that of the IBC and the UBC. Of the recognized three dimensional standard methods of seismic analysis of multistory structures are the Equivalent Lateral Load method and the more sophisticated Response Spectrum Method. The later is better known as the Modal Analysis procedures both methods form the foci of the present study. Other methods are available but they are beyond the scope of the following discourse. Examples that illustrate the difference and the limitations of the two prime methods are presented in addition to the study of the effect of various seismic parameters that include, inter alias, height, topology and the vertical distribution of stiffness and mass on the overall structural response. Moreover, prevalent structural systems which include the locally popular yet essentially adverse practice of adding unreinforced facade masonry walls to framed reinforced concrete structures is briefly alluded to.

1.Introduction

The Equivalent Lateral Load method is essentially a simplified static approach that involves the judicious application of an equivalent lateral load along the height of the building at the floor levels. the Response Spectrum method is substantially more sophisticated. The fundamental objective is to evaluate the strength demand imposed by the seismic action on structures on one end and to quantify the structure's capacity to counteract those demands on the other end. It is of interest to remember at the onset that the adoption of the Response Spectrum method is hitherto an accepted method of analysis; however it does not relieve the designer from carrying out the obligatory Equivalent Lateral Load method. The necessary parameters for any seismic structural analysis and design undertaking include Zoning, Site Characteristics, Structural Occupancy, Structural Topology, Structural System and Height The popularity of the Equivalent Lateral Load method stems from the fact that it requires modest understanding of the structure being analyzed or the nature of the spectral data or the mathematics involved in the more elaborate mode superposition in the Response Spectrum dynamic analysis. The following study presents a comprehensive numerical comparison between the two methods of analysis. Towards the turn of the century the UBC code was replaced by the IBC; the procedure in each is slightly different albeit the general logic remains virtually unchanged.

2. The Equivalent Lateral Load Method

In seismic analysis loads, are historically taken as equivalent static accelerations modified by certain factors depending on the seismicity of the location, soil properties and the natural frequencies of the structure and the intended use. The formulas are developed for regular structures which enjoy reasonable distribution of mass and stiffness and lead to decoupling of lower modes. The method of analysis is obviously limited by stringent constraints that include but are not limited to height, weight, occupancy and the relevant seismic zone category. In such a procedure, once the base shear is evaluated for a certain structure its vertical distribution along the height of the structure is accomplished in a manner that resembles the first mode of a vertical cantilever. The scenarios where this logic is applicable are limited to the following:

- Structures in design category A
- Structures in Seismic Design category B and C except for light framed structures
- For regular structures that have a period < 3.5 TS and are in design category D, E and F
- For irregular structures in D, E and F but with horizontal irregularity type 2, 3, 4 and 5 and T < 3.5 TS.
- In irregular structures in Seismic Design Category D, E, and F but with vertical irregularities of type 4, 5a and 5b and T < 3.5 TS.
- Light framed construction in occupancy I & II, more than

3 stories high, occupancy III & IV, more than 2 stories high and regular light frame structures with T < 3.5 TS in Seismic Design Category D, E, and F.

In accordance with the IBC, the necessary data pertaining to the seismic action include the Seismic Importance Factor, I and Structural Occupancy, the Mapped Spectral Response Accelerations SS and S1, the Site Class, the Spectral Response Coefficients, SDs and SD1, the Seismic Design Category, Seismic Response Coefficient, Cs and the Response Modification Factor.

Based on UBC97, the base shear is calculated by the following formula

$$V = \frac{C_v I}{RT} W \qquad UBC97 \quad 30-4$$

But the total design base shear shall not exceed the following:

$$V = \frac{2.5 C_a I}{R} W \qquad UBC97 \quad 30-5$$

The total design base shear shall not be less than the following:

$$V = 0.11 C_a I W \qquad UBC97 \quad 30-6$$

In addition, for seismic zone 4, the total base shear shall not also be less than the following:

$$V = \frac{0.8 Z N_v I}{R} W \qquad UBC97 \quad 30-7$$

The period is calculated

$$T = C_t (h_n)^{\frac{3}{4}}$$

Where:

Z= seismic zone factor,

I= importance factor,

R= numerical coefficient representative of the inherent over strength and global ductility capacity of lateral force resisting systems,

Ca=acceleration seismic coefficient,

Cv= velocity seismic coefficient,

Nv= near source factor,

W= the total dead load and portions of other loads

Ct= 0.0731 for reinforced moment resisting frame and hn is the height in meters.

Once the base shear is quantified the lateral distribution follows after determining an additional force applied at the top when certain conditions exist. This addition force, Ft shall be determined from the formula:

$$F_t = 0.07TV \le 0.25V \; for \; T > 0.7 \text{ seconds}$$
$$F_t = 0.0 \; for \; T \le 0.7 \text{ seconds}$$

Therefore the tota

$$V = F_t + \sum_{i=1}^{n} F_i$$

$$F_x = \frac{(V - F_t) w_x h_x}{\sum_{i=1}^{n} w_i h_i}$$

Where:

Fx = design seismic force applied to level x

Wx = that portion of weight, W located at or assigned to level x

Wi = that portion of weight, w located to or assigned to level i

hx, hi = height in meters above the base to level x and i

The storey shear is distributed in proportion of the stiffness of the supporting frames. The rather new IBC code specifies a significantly different procedure. It should be noted that in the static approach the formulations do not accommodate horizontal neither vertical irregularities

3. The Response Spectrum Method

The Response Spectrum method is heavily based on computers and on improved structural analysis techniques. Here the force distribution is based on the natural modes of vibration. It is a more precise method and requires the determination of a Response Spectrum from measured seismic activity data. The Response Spectrum curve is a plot of the maximum spectral value versus period. The data of the seismic activity is reduced to the determination of a plot of seismic action versus natural frequency; this could be displacement; acceleration or velocity; however, the most typical is the acceleration. The plot has two characteristic periods; they are TS and To. Detailed information from the structural model obtained from geometric decomposition gets coupled with the corresponding spectral values for each specific mode of vibration. In order to guarantee that the majority of the structural mass is included in the analysis; the code sets the acceptable mass participation at 90%. Independent results are combined to determine the general response of the overall structure. Since building structures enjoy closely spaced band of frequency values, the Complete Quadratic Combination method is given the edge over the SRSS.

The Response Spectrum is a function of period and damping ratio; it is developed for a single degree of freedom harmonic oscillator in order to develop equations for displacements, velocity and acceleration; the values are the maximum absolute values from the equations. It can be noticed that spectral acceleration drops exponentially with increasing period after leaving the plateau region, this means that for structures with low first frequencies the resulting spectral accelerations can be quite low. Structures with high fundamental frequencies

fall either within the sharp initial linear region or within the plateau region.

The Response Spectrum procedure is obligatory for structures that are high in elevation with vertical or horizontal irregularity of stiffness, mass or geometry. These are some of the conditions that are clearly mentioned in codes of practice.

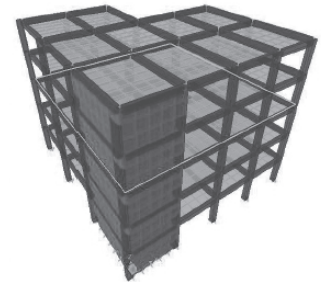
The following is the procedure briefly outlined:

- Determine SS and S1 short period spectral acceleration and 1 second period spectral acceleration
- Determine Site Classification
- Based on SS and S1 Determine site amplification coefficients Fa and Fv from ASCE 705-
- Determine SMS and SM1
- SMS = Fa Ss
- SM1 = Fv S1
- Determine design SDS and SD1
- Maximum considered earthquake spectral acceleration is reduced by 13/
- SDS = 23/ Fa SS
- SD1 = 23/ SM1

Calculation of the Design Response Spectrum follows a standard procedure.

4. The Mathematical Models

Two regular yet common framed reinforced concrete building are selected. Both have a 7 meter span and 3 bays in the Y-direction and a 5 meter span with 4 bays in the X-direction. The isometric view of the models is shown in Figures 1and 2; the structures are assumed to have a total fixity at base. However, one model is comprised of 5 identical floors while the other is comprised of 15. For comparison purposes the plans of the models are structurally modified in order to amplify the irregularity induced. The structures are modeled using Etabs Software of Computers and Structures Incorporation. The seismic data is selected in harmony with local geotechnical conditions. [Soil: soft rock, Sc type in accordance with UBC 97 provisions. Site class C in accordance with IBC 2009. Zone factor Z = 0.2 in UBC 97, Ca= 0.24; Cv= 0.32; Ω= 2.8; R=5.5 Due to lack of a map of spectral accelerations of S1 and SS, the following is assumed S1 = 1.25 Z; Cd = 4.5; SS = 2.5 Z, and a 5% damping ratio [Amendment No. 3 to SI 413 (2009)].



.Figure 1: The Irregular 5-Story Bldg

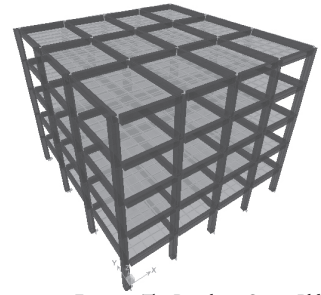


Figure 2: The Regular 5-Storey Bldg

With the above data and in accordance with the UBC procedure the following is obtained:

The period is given by:

The base shear is:

$$T = C_t(h_n)^{\frac{3}{4}} = (0.0731)(5x3.5)^{0.75} = 0.625 \text{ seconds}$$

$$V = \frac{C_v I}{RT} W = \frac{(0.32)(1)}{(5.5)(0.625)} = 0.0931W \qquad UBC\ 97 \quad 30-4$$

V= 3243.7 kN

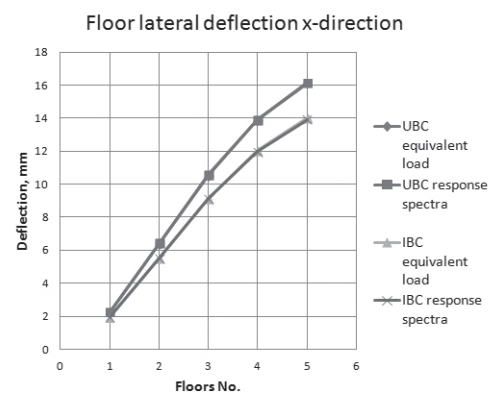


Figure 3: Floor Lateral Deflection, 5-Storey Bldg

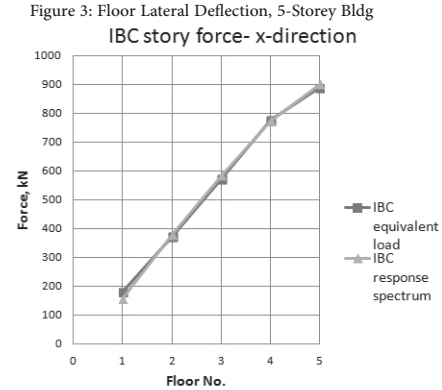


Figure 4: Story Forces, 5-Storey Bldg

For the 15-Storey regular the following and following similar calculations lead to the following in accordance with the UBC 97. The period is given by:

$$T = C_t(h_n)^{\frac{3}{4}} = (0.0731)(15x3.5)^{0.75} = 1.43 \text{ seconds}$$

The base shear is given by:

$$V = \frac{C_v I}{RT} W = \frac{(0.32)(1)}{(5.5)(1.43)} = 0.0407W \qquad UBC\ 97 \quad 30-4$$

$$V = 0.0407 \times 104523.75 = 4254kN$$

However in accordance to the IBC

$$T_a = C_t(h_n)^x = 0.0466(52.5)^{0.9} = 1.65 \text{ seconds} \qquad ASCE\ 7-10\ (12.8-7)$$

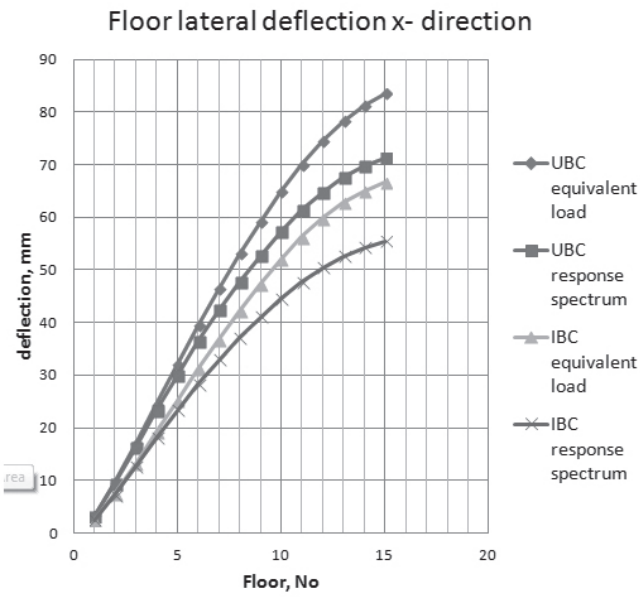


Figure 5: Floor Lateral Deflection 15-Storey Regular Bldg.

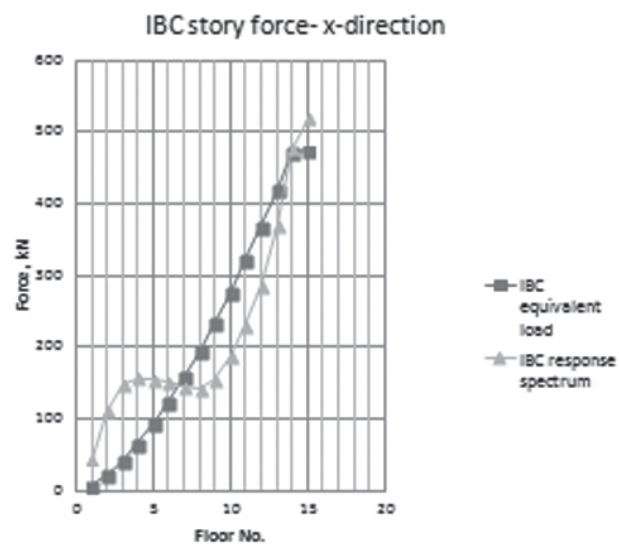


Figure 6: Story Forces 15-Storey Regular Bldg.

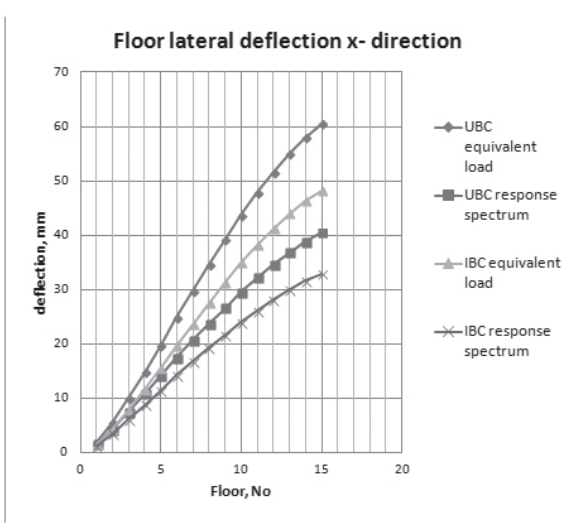


Figure 7: Floor Lateral Deflection, 15-Storey Irregular Bldg.

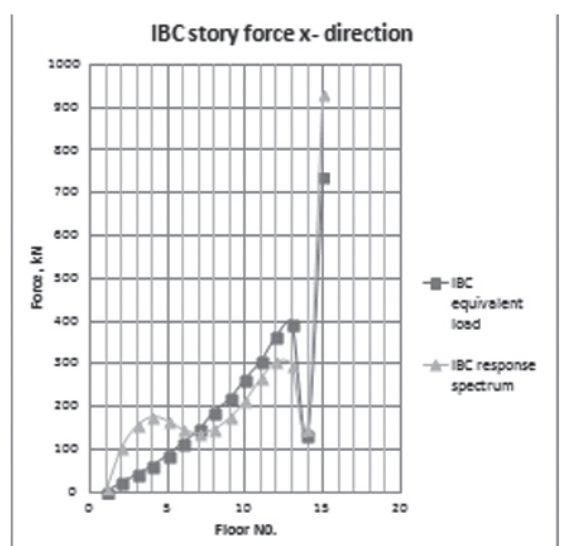


Figure 8: Story Forces, 15-Storey Irregular Bldg

5. Results and Conclusion

Scrutinizing the above figures and focusing on the lateral deflection as an indicator of structural behavior it is easily observed that the equivalent lateral load method gives conservative results results relative to the response spectrum method. This is manifested in both in regular and in irregular buildings albeit that the difference is more pronounced in the later. The order of difference increases substantially with increasing height. This observation is irrespective of irregularity. However the deviation is quickly amplified in the irregularity domain.

Tables 1 to 4 below show the geometric decomposition results for the 4 different structures. Scrutinizing the geometric decomposition results which include mass participation, modal participation as well as the frequency distribution for the four models, it is noticed that in the 5-storey regular structure a 90% of the total mass is secured from the initial very few modes. Torsion modes have no significance. However, for the 5 story irregular structure the situation changes. Frequencies become spaced within a narrower band, more eigenvector are required to guarantee 90% modal mass participation and the torsion modes become of considerable significance. This implies that for irregular structures there is no predominant mode signifying that the inertia force is well distributed over a number of vibration modes.

The question therefore is never which way to go in seismic analysis and design undertakings. Since the static analysis is an obligatory initial step then the question amounts to whether to continue with the elaborate dynamic analysis. This is indeed necessary, as has been shown above, even in the case of symmetric structures but of increased elevation. Furthermore, plan symmetry is not the important matter, because unsymmetrical floor plans may be brought closer to regularity with judicious distribution of shear walls. Another attribute to consider is the closeness of the eigenvalues. For irregular structures these are narrowly spaced. Finally it is to be noted that masonry infill walls have an adverse effect of lowering the fundamental frequency while shear walls wisely located help tone the system to behave closer to a regular one. Masonry walls add mass with little, if an, contribution to stiffness.

Mode	Period	UX	UY	UZ
1	1.193648	0	83.2225	0
2	1.08944	83.945	0	0
3	0.9543	0	0	0
4	0.380425	0	10.3853	0
5	0.352391	10.2205	0	0
6	0.307236	0	0	0
7	0.213645	0	4.0126	0
8	0.20265	3.7436	0	0
9	0.175414	0	0	0
10	0.145962	0	1.8358	0
11	0.142349	1.6315	0	0
12	0.121737	0	0	0

Table 1: The Case of the 5-Storey Regular Structure

Mode	Period	UX	UY	UZ
1	0.986037	27.1231	28.8366	0
2	0.588376	42.4655	28.7159	0
3	0.357902	3.9435	4.0019	0
4	0.250577	6.633	18.7326	0
5	0.198518	1.3068	0.9122	0
6	0.163069	11.9233	9.2425	0
7	0.137487	0.8899	0.9292	0
8	0.111909	0.1754	0.2088	0
9	0.097563	2.053	2.4887	0
10	0.089108	1.9082	3.6474	0
11	0.080365	0.8123	0.7935	0
12	0.070824	0.0393	0.0674	0

Table 2: The Case of the 5-Storey Irregular Structure

Mode	Period	UX	UY	UZ
1	3.463663	0	83.5087	0
2	3.163478	83.4518	0	0
3	2.70096	0	0	0
4	1.088422	0	8.0963	0
5	0.993782	8.4615	0	0
6	0.849938	0	0	0
7	0.623896	0	3.288	0
8	0.566168	3.3069	0	0
9	0.497197	0	0	0
10	0.442182	0	1.7431	0
11	0.403697	1.6881	0	0
12	0.354162	0	0	0

Table 3: The Case of the 15-Storey Regular Structure

Mode	Period	UX	UY	UZ
1	2.758852	25.7397	34.4477	0
2	2.225406	44.9144	26.7901	0
3	1.189814	2.6553	8.4536	0
4	0.983758	5.2725	7.6902	0
5	0.622555	8.3816	6.1001	0
6	0.541208	0.7901	1.2724	0
7	0.398217	0.8633	0.844	0
8	0.289971	0.3117	0.2817	0
9	0.286246	2.8416	3.0861	0
10	0.27288	2.077	3.9307	0
11	0.236729	0.2999	0.329	0
12	0.19334	0.253	0.2074	0

Table 4: The Case of the 15-Storey Irregular Structure

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Generating a geotechnical map for the city of Nablus by comparing two functions of GIS software

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ABSTRACT:
Key words: Geotechnical map, IDW, Kriging, Thiessen polygon, spatial interpolation, ArcGIS, Soil type.

Geotechnical maps is a commonly used to support project and land use planning, It can provide engineers with information about soil type and its bearing capacity and therefore help to know the best location for specific building and the best type of foundation to be used in order to avoid problems that can be caused by soil such as swelling.
In this paper Geographic Information System (GIS) was employed to construct a knowledge base for geotechnical experts. The procedure based on employing the ArcGIS software and its extensions: Geo-statistical and Spatial Analyst in applying interpolation methods and representing results. Soil data for more than 100 boreholes logs distributed within city of Nablus were manipulated through ArcGIS software to test its capability for spatially modelling its types all over the city.

The interpolation procedures were implemented to display the soil type information for any point of the whole area. Kriging, Inverse Distance Weighting (IDW) and Thiessen polygon interpolation procedures were used to predict soil type's distribution. The qualitative description of the soil was turned into quantitative figures that could be interpolated by means of coding. The results of the study showed non realistic distribution for soil types at some places when using IDW and kriging methods, the minimum average error in predicated soil type was achieved when using the Thiessen polygon method.
It can be concluded that GIS techniques through ArcGIS and its extensions could be considered as a good base for developing an expert system for geotechnical investigation for soil types.

Introduction:
"The definition of soil varies depending on the person considering it. To a civil engineer planning a construction site, soil is whatever unconsolidated material happens to be found at the surface. To a miner, it is just some worthless material that must be removed. To a farmer, it is the medium that will nourish and supply water to the crops. So soil may have differing definitions, depending on the area of study. (R. Scharf)

The profile and texture of soil indicate the relative types of rocks and minerals that compose the soil, chief of which are sand, silt, and clay. Soil texture is an important indicator of the ability of soil to absorb and hold both water and plant nutrients. So it is important to develop an appropriate visual and quantitative representation of the soil type which named a Geotechnical maps. (Chris Lundber).

Geotechnical maps are widespread nowadays due to the existence of Geographical Information Systems (GIS) and Global Position Systems (GPS).
Geographic information systems (GIS) and modelling are becoming powerful tools in natural resource management. Spatially distributed estimates of environmental variables are increasingly required for use in GIS and models. (Jin Li and Andrew D. Heap, 2008)

The most obvious use of a geotechnical map is to indicate the types of the soil. This is clearly of great importance to civil engineers who, for example, have to advise on the excavation of road cuttings or to build up on this place or not; to geographers studying

the use of land, and ordering the data in geotechnical maps will save effort, time and provide easier using of data for engineering projects, especially in civil engineering field.

This paper describes two methods used in the production of a geotechnical map for the area of Nablus city using GIS program. The purpose is to use advance program (GIS) to make a geotechnical map for the soil type of Nablus city, based on the bearing capacity of these types, Several methods was used and the results was evaluated in order to select the methods that produce a map similar to the reality. Firstly, it talks about Nablus city and its location, data used in the study, methodologies that were used, and finally the results. The paper ends with a conclusion will and direction for future research.

Location:

Nablus district is located in the Central Highlands of the West Bank, some 63 km north of Jerusalem. Located in a strategic position between Mount Ebal and Mount Gerizim, it is the capital of the Nablus Governorate and a Palestinian commercial and cultural center. It is bounded by Asira alshemaliya from the north, Zwata and biet-iba from the west, Kufr qaleel from the south Wadi-elbadan, Roujeb ,salem and Deer-elhatab villages from the east.

Fig1:Nablus city-west bank

Data:

The required data was collected from geotechnical labs in the city by studying their reports, and some AUTOCAD maps for Nablus city which shows the distribution of soil in it. this map includes the surface soils and extend deep till the pressure from the foundations fades .
(Isam Jerdaneh, 2007)

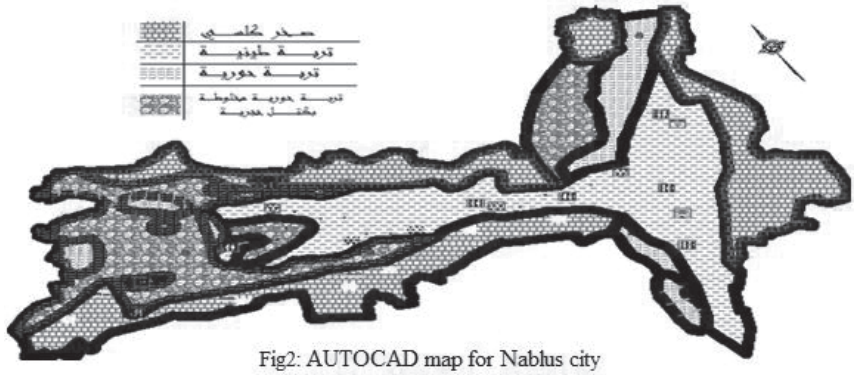
Fig2: AUTOCAD map for Nablus city

Methodology:

The geodatabase described in this work, was made in a way that all the information contained in the database could be easily imported to a Geographical Information System (GIS) and displayed spatially. The database contains information about bearing capacity of many points in different sites.

The data contained in the database, come from lab reports and then the database was linked to the GIS.

By using the GIS functions, we could predict the unknown values by different methods, however these methods are following Tobler second law (Tobler 1970) "Everything is related to everything else, but near things are more related than distant things."

Thiessen polygon:

This method assigns polygons whose boundaries define the area that is closest to each point relative to all other points. They are mathematically defined by the perpendicular bisectors of the lines between all points

In mathematics, it is a way of dividing space into a number of regions. A set of points (called seeds, sites, or generators) is specified beforehand and for each seed there will be a corresponding region consisting of all points closer to that seed than to any other. The regions are called Voronoi cells. It is dual to the Delaunay triangulation.

In the simplest and most familiar case, we are given a finite set of points {p1,...,pn} in the Euclidean plane. In this case each site pk is simply a point and its corresponding Voronoi cell (also called Voronoi region or Dirichlet cell) Rk consisting of every point whose distance to pk is less than or equal to its distance to any other site. Each such cell is obtained from the intersection of half-spaces, and hence it is a convex polygon.

- Inputs: A feature layer (Point, Polyline, Polygon)
- Outputs: New polygon feature class.

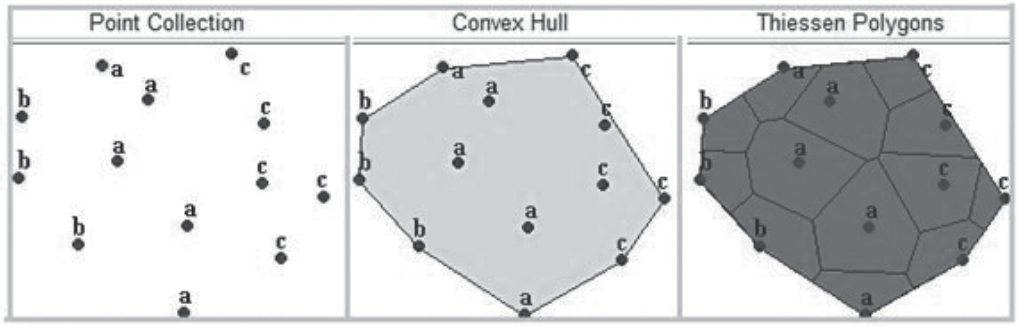

Fig3: Thiessen polygon

Thiessen polygons thus; Consider a set, S, of n labeled points in the plane, where:
S = {P1, P2 … Pn}
With each point, pi, in S we associate all locations, x, in the plane that are closer to Pi than to any other point, pj, in S(j≠ I). The result is to create a Thiessen polygon, Pi. More formally, if d(x, i) is the Euclidean distance from x to Pi then
Pi = {x |d(x, i) ≤ d(x, j); j " S, j ≠ i}
It is possible that x is equidistant from a pair of points, in which case it will lie on the boundary of Pi. In addition, x may be equidistant from three or more points so that it forms one of the vertices of Pi.
If Thiessen polygons are created for all points in S, then the resulting set of polygons
{P1, P2… Pn}, forms a unique, contiguous, space-exhaustive tessellation known as the Thiessen (Voronoi) diagram of S, V(S).
In other words, the area contained in a Thiessen polygon is likely to be more representative of the point on which the polygon is based than of any other point in the set. (Gordon, 2003)

After using this method to interpolate the soil map for the city of Nablus we got the result described in figure (4) below

2- Inverse distance weighting (IDW):

IDW interpolation explicitly implements the assumption that things that are close to one another are more alike than those that are farther apart. To predict a value for any unmeasured location, IDW will use the measured values surrounding the prediction location. Those measured values closest to the prediction location will have more influence on the predicted value than those farther away. Therefore, IDW is the process of assigning values to unknown points by using values from usually scattered set of known points. This requires vectors of coordinates and variable values of known points (x,y,v) and calculated the variable values by means of Inverse Distance Weighting (IDW) multivariate interpolation for a vector or matrix (V int) unknown points described by coordinates (x,y)

$$\frac{\sum_{i=1}^{n} \frac{m_i}{d_i^2}}{\sum_{i-1}^{n} \frac{1}{d_i^2}}$$

Where di is the distance between x0 and xi, (distance from measurement I to the cell center is denoted by di), and n represents the number of sampled points used for the estimation.
(Esri, 19952013-)

For any unknown point, we take some form of weighted average of the values at surrounding points to predict the value at the point where the value is unknown, In other words, we create a continuous surface from a set of points , Figure (5)

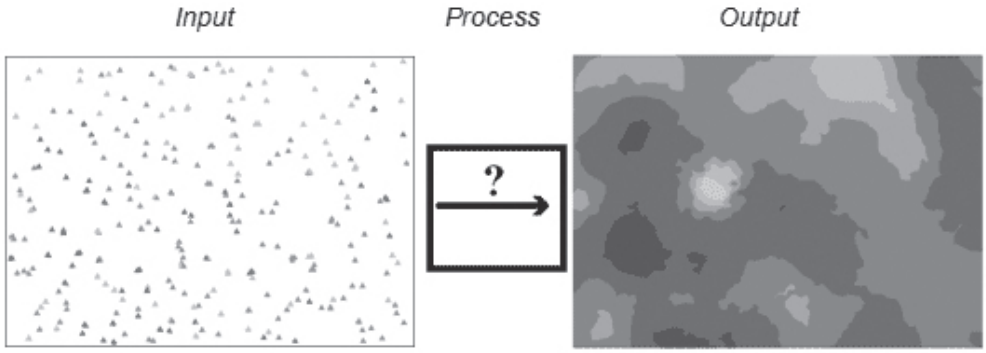

Fig5: Interpolation by Inverse distance weighting

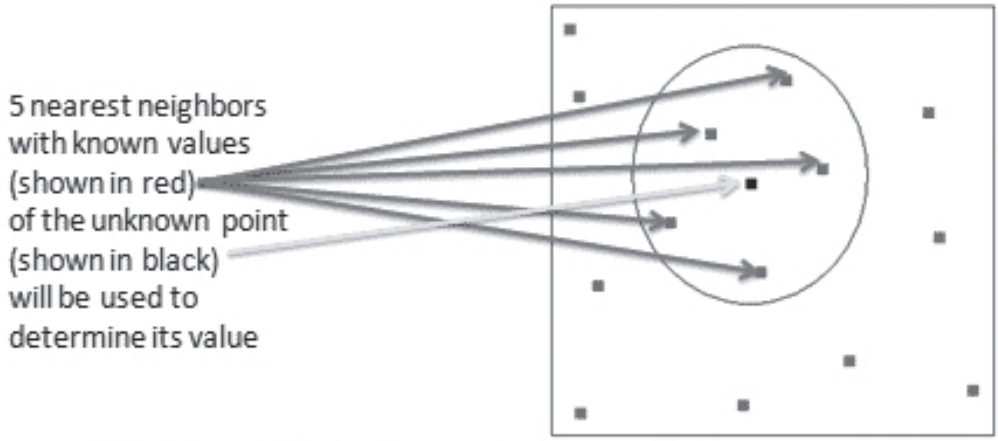

Fig6: Interpolation by Inverse distance weighting process

Figure (7) describe the resulted soil map for Nablus using this method.
The result shown below in fig (7):

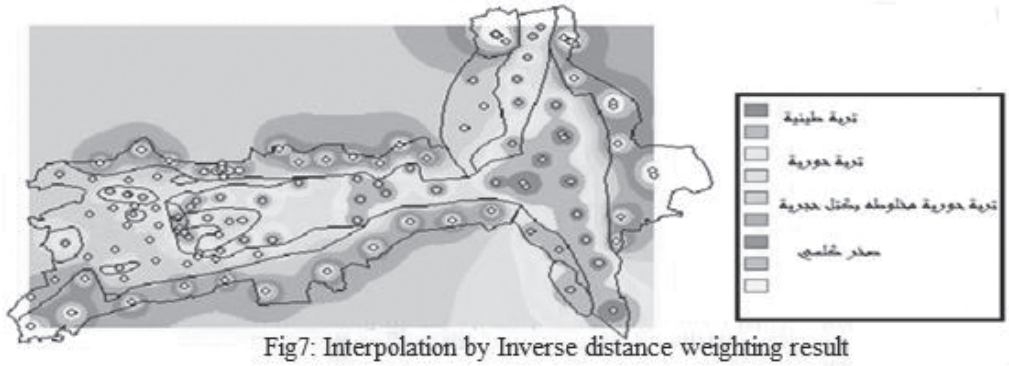

Fig7: Interpolation by Inverse distance weighting result

Results and conclusion:

This work presents some functions that are used in GIS program to generate surfaces. The resulted surface represents a geotechnical map that can be of great help for the planning of the cities.

The functions adopted in this paper are used to determine which one of them is more suitable and recommended to be used in similar geological conditions; here are some reasons that why the Thiessen polygon is more suitable than IDW?

* Firstly, field is a geographic phenomenon which can be discrete or continuous.

- A discrete object has known and definable boundaries: it is easy to define precisely where the object begins and where it ends.
- A continuous surface represents phenomena in which each location on the surface is a measure of the concentration level or its

relationship from a fixed point in space or from an emitting source, another type of continuous surface includes phenomena that progressively vary as they move across a surface from a source.

When the field which we want to construct assumed to be discrete, it is preferable to assume that any unmeasured location has the value of closest measured point by constructing polygon around the measured point so all points inside this polygon will be assigned the value of this measured point; this means generating discrete field representation from point data using Thiessen polygon technique.

But, using interpolation is more common when the data which we are dealing with is considered to be continuous (gradual changing in data), this mean generating continuous field representation from point data.

Soil type is a typical example of discrete field.

* Secondly; if the resulted maps that we have from the two methods are compared with the original map we find that Thiessen polygon gives more accurate map which is closer to the original one, they are shown below. and as it seems from the results of map that IDW needs more measurement points to give better result but may be for Thiessen polygon it was almost enough.

As a result the Thiessen polygon method is preferred.

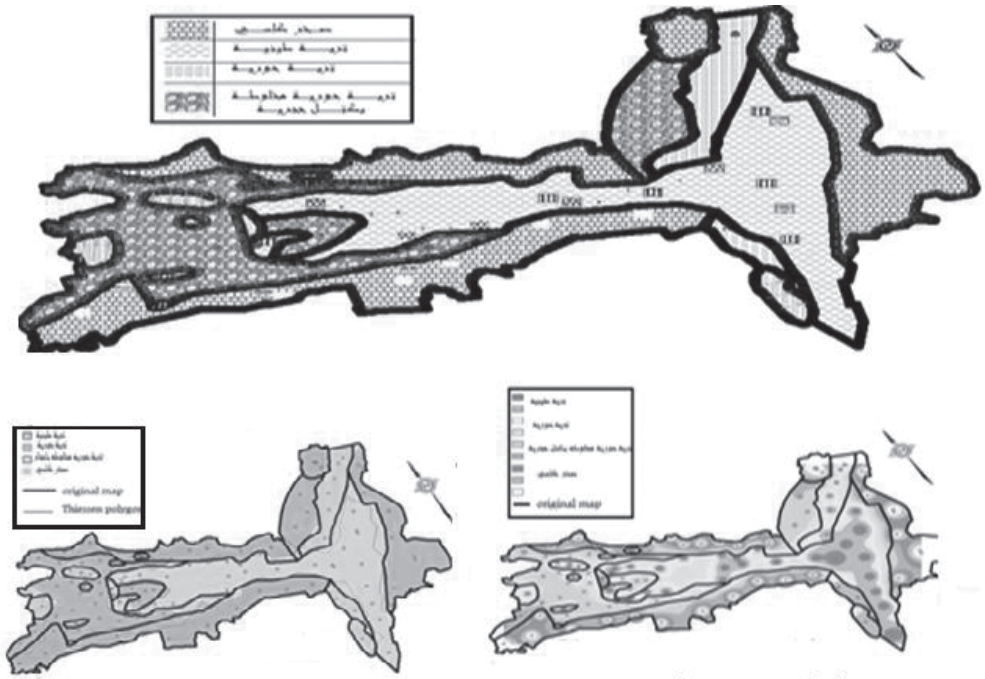

Fig8: why Thiessen polygon method is preferred than IDW method

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