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Development of Maintenance Composite Priority Index for Buildings in Palestine: A Pilot Case Study

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Abstract. The current building maintenance practices in Palestine are not based on scientific systematic methods. Most of the municipalities use one criterion to define the maintenance priorities, which is the "worst-first" criterion. Therefore, the current practices in defining buildings maintenance plans are not dealing with the known phases that are generally followed, including those in establishing building inventories, building condition survey, detailed visual inspection, identification of the proper maintenance and rehabilitation measures, and setting priorities. Accordingly, the recent preparation of the Operation and Maintenance (O&M) Manual for Palestinian municipalities is an important step to guide them towards preparing and implementing their O&M priority-based plans, considering scare resources. During the course of preparation of the Manual, the proposed procedures were applied at ten pilot municipalities. This study aims to explore the outcome of the implementation of the 2014/2015 O&M buildings maintenance priorities at these municipalities through the development of maintenance composite priority index (PI). The new proposed priority index is a scientific tool that will identify the priority of maintenance buildings through using a systematic procedure instead of first worst one. To achieve this, analyses of the outcome of a questionnaire designed to collect relevant information from these municipalities was conducted. The maintenance priority index for buildings is calculated considering different indicators among them building status (condition), classification and importance of the building, number of beneficiaries (users), safety aspects (severity level in the building), and people complaints. The main component of the PI is the building condition index (BCI) which forms about 40% of the total weight. The physical inspection, which is the main input for calculating the BCI, is conducted on two levels; the primary level, and the secondary level. The buildings are ranked in descending order based on the PI values for each public building. The buildings that have the highest values of PI take the most priority till the specified asset maintenance budget for the targeted year is achieved. Finally, the results indicate that most of the maintenance works are funded by municipalities own budgets and not by the government.

INTRODUCTION

The Palestinian National Authority gradually gained control over major cities in the Palestinian territories since 1994 after more than 25 years of Israeli occupation. The urban building sector was one of the major fields which were given priority in the developmental efforts to remedy the deteriorating urban infrastructure in the Palestinian cities after years of negligence [1].

The current building maintenance practices in Palestine are not based on scientific systematic methods. Most of the municipalities use one criterion to define the maintenance priorities, which is the "worst-first" criterion. Therefore, the current practices in defining buildings maintenance plans are not dealing with the known phases that are generally followed, including those in establishing building inventories, building condition survey, detailed visual inspection, identification of the proper maintenance and rehabilitation measures, and setting priorities.

Based on the above, there has been a need to develop and adopt appropriate methods to assist in the decision-making process related to maintaining and upgrading the buildings structures in Palestine. The Ministry of Local

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Government (MoLG), and through the Municipal Development and Lending Fund (MDLF), had hired a local consulting engineering firm for the development of Operation and Maintenance Manual for Municipal Buildings to all municipalities in the West Bank and Gaza Strip of Palestine. The Manual is considered as the first in Palestine in proposing a systematic approach for building maintenance and in identifying a decision-making tool aiming to help the municipalities in creating their operational and maintenance plans, and in prioritizing their annual maintenance activities based on the available budgets. As part of the consultancy, the manual procedures to prepare O&M plans were applied to ten pilot municipalities, and their comments and feedback on the draft Manual were taken into account. The O&M Manual is considered as the reference that guides the municipalities towards the preparation of their O&M plans in the fields of municipal roads and buildings. The Manual has specified the policies, procedures, scope, responsibilities, legal and mandatory requirements, and included flowcharts, tools, and relevant forms and damage catalogue [2].

The procedures identified and outlined in the Manual were proposed after a thorough investigation of the regional and international experience in preparing such manuals, and in developing and implementing building maintenance management practices. Examples of investigated experiences and practices included countries such as Jordan [3], Saudi Arabia [4], South Africa [5], and United Kingdom [6].

Through the literature, various methods were used to prioritize buildings maintenance works. In the beginning, there are no set of rules or systems that determine the priorities of maintenance works. Priorities are determined through subjective judgement of stakeholders and are changed depending on the situation [7]. The most used methods in the literature were Analytical Hierarchy Process, Priority Criterion; Matrix based Priority and Failure Mode and Effect Analysis [8]. Priority index such as Roue's formula were proposed as early as 1986 but it was lacking in flexibility and subsequently abandoned [9]. Priorities settings that are based on weightage of criteria such as Failure Mode and Effect Analysis (FMEA), Analytical Hierarchy Process (AHP), matrix table, Genetic Algorithm (GA) were proposed. The usage of these methods becomes popular as it provides additional justification especially from the quantitative perspective. FMEA is frequently used in industry to prioritize equipments and improving the process of the business. It is usually applied in processes and equipments that cannot afford to have critical breakdowns or downtimes such as equipments for manufacturing semi-conductors [10]. AHP has been applied in maintenance planning for school, hospital, commercial buildings and assets such as critical equipments [11, 12]. However, in this paper a simple and practical approach is proposed here in order to identify the public buildings maintenance priorities through the calculation of the maintenance priority index (PI).

In the developed O&M Manual for the Palestinian municipalities, the regional and international experience had been considered. The criteria adopted for buildings maintenance prioritization were composed of five indicators: building condition (status), classification and importance of building, number of beneficiaries (users), safety of building (level of severity), and citizens' complaints [13]. The weight of each indicator was identified considering the regional and international experiences and practices, and the feedback of the MDLF and municipalities' representatives.

The consultant's duties had included as well coaching the targeted ten municipalities in West Bank and Gaza Strip engineering staff on the use of O&M Manual towards the systematic preparation of their annual O&M plans related to municipal buildings. The consultant team had provided the municipalities' relevant staff with hands-on on-the-job training. The consultant team then conducted frequent field visits to all the pilot municipalities and verified their prepared buildings inventories databases, and examined samples of the building condition surveys outputs. In addition, the consultant team discussed with the relevant municipalities' representatives the steps and practical preparations for the development of the O&M Plans, through step-by-step implementation of the procedures of the O&M Manual. Moreover, the municipalities were assisted in the formulation and the final preparations towards the production of their 2014 O&M plan with all relevant documentation [2].

STUDY LOCATION

As mentioned before, the MDLF selected ten pilot municipalities for the development and application of the O&M Manual. The ten municipalities are distributed between West Bank (seven municipalities) and three in Gaza Strip (three municipalities), where the locations of these municipalities are illustrated in Fig. 1. Table 1 presents basic information on the pilot municipalities, including the population, area, and the number of buildings including all categories such as (educational, recreational, operational, etc). Figure 2 illustrates the number of buildings in each municipality based on the data presented in Table 1. It is worth to mention here that the number of municipal buildings is less in Gaza Strip municipalities as the educational buildings belong to the UNRWA.

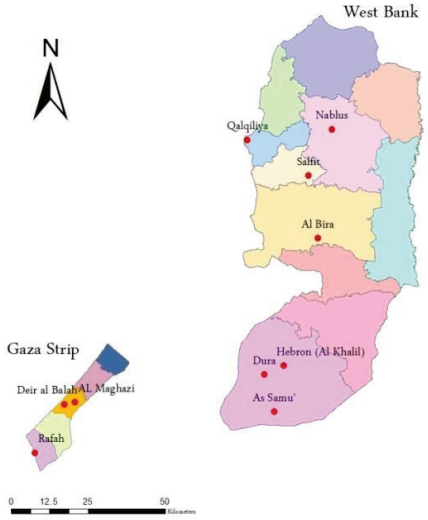

FIGURE 1. Location of targeted pilot municipalities

TABLE 1. The targeted pilot municipalities in the West Bank and Gaza Strip

No	Municipality	Population	Area (km^2)	Number of Public Buildings
	West Bank			
1	Nablus	146,493	29.0	102
2	Qalqilia	49,441	27.9	30
3	Salfit	10,215	4.0	22
4	Al-Bireh	46,212	22.4	39
5	Hebron	202,172	22.8	70
6	Dura	35,030	17.6	15
7	Al Samou	24,349	13.8	5
	Gaza Strip			
8	Al-Maghazi	28,000	3.0	8
9	Deir Al-Balah	67,727	27.0	3
1.	Rafah	152,950	55.0	7

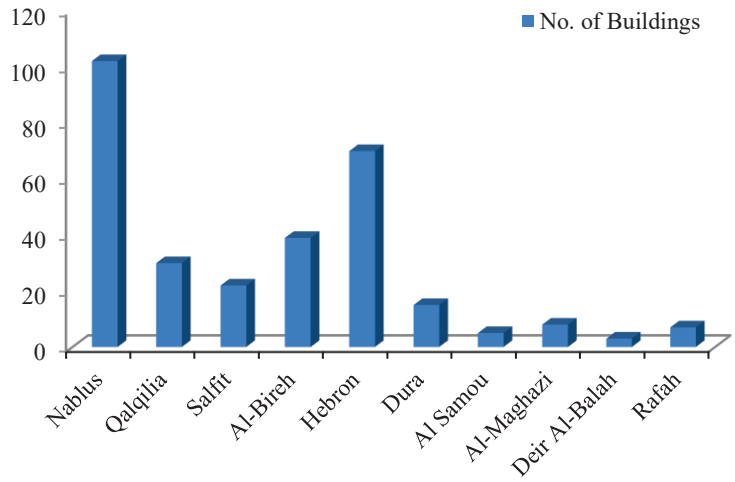

FIGURE 2. The number of public buildings in the ten municipalities

METHODOLOGY

In order to achieve the objective of the paper, a questionnaire was developed to investigate the implementation of the O&M Manual utilized towards the preparation of the municipalities O&M plans in the building sector. The study sample included all the ten pilot municipalities. The questionnaire was designed to be composed of several parts covering issues related to the preparation and implementation aspects of the O&M plans for buildings. These include mainly the criteria used in the prioritization of buildings maintenance works compared with that proposed in the O&M Manual as well as the level of benefit from the Manual and the coaching sessions. The main queries (items) in the questionnaire were; population, area, number and classification of existing public buildings, the criteria and indicators used for prioritization of buildings maintenance works, the weight for each indicator, the value of the factors corresponding to the indicators and included in the PI equation such as building condition index, building classification and importance, number of people using the building, the severity level, and local citizens complaints. Moreover, the questionnaire include questions about the main obstacles that they faced in applying their maintenance plans, financial resources for applying the maintenance works, the existing and the qualification of the municipal technical staff responsible for the maintenance works, their satisfaction from the O&M Manual and the training sessions on using the Manual.

The questionnaire was sent to the Municipal Engineer of each of the considered municipalities. This was followed by a telephone call with each Municipal Engineer to ensure clarification of questions and to encourage timely response. The results of the questionnaires were then analyzed for each item using excel to assess achievements, examine the degree of satisfaction of the Municipal Engineers in the procedures followed, assess the implementation aspects of the prepared O&M plans related to maintenance of buildings, and draw proper conclusions and recommendations.

RESULTS AND DISCUSSION

The results of the ten municipalities on the criteria for prioritization of buildings maintenance works are shown in Table 2. Moreover, Figure 3 illustrates the weights of the five indicators based on the Operational and Maintenance Manual as presented in Table 2. All of the ten targeted municipalities agreed with the prioritization indicators and relevant weights listed in the O&M Manual.

TABLE 2. Buildings maintenance prioritization criteria in the O&M Manual and corresponding targeted municipalities

All Municipalities	O&M Manual Criteria for Prioritization of Buildings Maintenance Works (Weights)				
	Building Condition Index	**Classification and Importance of Building**	**Number of Beneficiaries**	**Severity in the Building**	**Citizens' complaints**
	0.40	0.35	0.05	0.15	0.05
Municipality	**Used Criteria for Prioritization Buildings Maintenance Works (Weights)**				
	Building Condition	**Classification and Importance of Building**	**Number of Beneficiaries**	**Severity in the Building**	**Citizens' complaints**
1. Nablus	0.40	0.35	0.05	0.15	0.05
2. Qalqilia	0.40	0.35	0.05	0.15	0.05
3. Salfit	0.40	0.35	0.05	0.15	0.05
4. Al Bireh	0.40	0.35	0.05	0.15	0.05
5. Hebron	0.40	0.35	0.05	0.15	0.05
6. Dura	0.40	0.35	0.05	0.15	0.05
7. Al Samou	0.40	0.35	0.05	0.15	0.05
8. Al Maghazi	0.40	0.35	0.05	0.15	0.05
9. Deir Al Balah	0.40	0.35	0.05	0.15	0.05
10. Rafah	0.40	0.35	0.05	0.15	0.05

The final five indicators and their weights were identified and approved by the Municipal engineers after a thorough literature review and several meetings and discussions with the targeted municipalities' representatives.

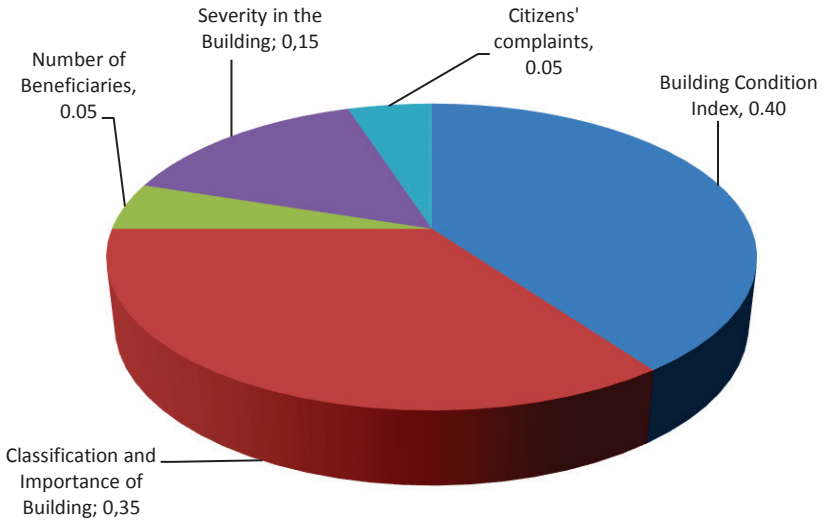

FIGURE 3. The distibution of weights for the five indicators

The maintenance composite priority index (PI) for buildings is calculated using the following equation:

$$PI=0.4\_BCI+0.35\_CI+0.05\_UF+0.15\_S+0.05\_CC \quad (1)$$

where,
BCI: Building Condition Index,
CI: Classification and Importance of building,
UF: User Factor of no. of Beneficiaries,
S: Severity level of the building, and
CC: Citizens' Complaints.

The Building condition (BC) is the most important indicator in the equation as shown from the weights. The building condition index (BCI) is usually used to express the condition of the building. Table 3 illustrates the BCI values based on the O&M Manual. The BCI forms about 40% of the total weight of PI equation. The physical inspection, which is the main input for calculating the BCI is conducted on two levels; the primary level, and the secondary level.

The primary level includes general inventory for the basic building components through performing the Building Condition Survey (BCS). The output of the BCI gives the general rating of the building by using five scale rating. The secondary level assesses building sub-elements through using the detailed visual inspection (DVI). The results show that all the targeted municipalities used the prioritization criteria proposed in the O&M Manual. The rating value of the BCI is used in identifying the proper maintenance treatment and actions (routine maintenance, preventive maintenance, corrective maintenance, and reconstruction), and accordingly calculating the corresponding maintenance cost.

This process should be repeated annually to identify the defects in early stages and accordingly apply the proper maintenance treatment. This policy will enhance the application of the preventive maintenance in the future which consequently contributes in saving the maintenance costs.

TABLE 3. Building Condition Index (BCI) Values [13]

No.	Building Evaluation	BCI Value
1	4 (Good)	25
2	3 (Fair)	50
3	2 (Weak)	75
4	1(Unacceptable)	100

The classification and importance of the building factor is considered based on the type of service supplied by the building. It is the second important factor. Table 4 shows the relevant priority factor based on O&M Manual.

TABLE 4. Classification and Importance (CI) Values [13]

No.	Building Type	CI Value
1	Educational	100
2	Health	100
3	Social/Cultural/Women	90
4	Institutional	90
5	Recreational/Tourism	80
6	Commercial	80
7	Heritage/Museum/Library/Sport	70
8	Slaughterhouse/Cemetery	60
9	Garages/Operational/Maintenance	50

The number of beneficiaries' factor in terms of users factor (UF) is calculated using equation 2.

$$UF = 100x\sqrt{\frac{AUN}{MaxAUN}} \quad (2)$$

Where,
AUN : Average users number per one year, and
Max. AUN : Max. daily number of users.

The severity level (S) of the building factor is expressed the general safety in the building. Table 5 presents the values of the severity factor based on the O&M Manual.

TABLE 5. Severity Level Factor [13]

No.	Level of Severity	S Value
1	High Severity	100
2	Medium Severity	65
3	Low Severity (Safe)	35

People (citizens') complaints (CC) are the fifth and last factor. The factor expresses the satisfaction of the people towards the services provided by the building. Table 6 illustrates the priority factor values of the CC based on O&M Manual.

TABLE 6. Priority Factor for Citizens' Complaints (CC) [13]

No.	Element	CC Value
1	High complaints	100
2	Medium complaints	65
3	Low complaints	35
4	No complaints	0

The relative weights for the before mentioned indicators are shown in Table 2. It is clear that all pilot municipalities adopted the proposed weights. Moreover, the building condition indicator has the maximum weight among others followed by the classification and importance of the building. On the other hand, all municipalities agreed that the number of users and the citizens' complaints has the lowest equal weights of 0.05.

The following example illustrates the calculation of the maintenance composite priority index for three buildings: Educational, Recreational, and Operational. Table 7 shows the input data for the applied example. Moreover, Table 8 depicts the calculation of the PI considering the weights for the five indicators and the corresponding priority factor.

TABLE 7. Input data for the applied example

Indicator	Ed	Re	Op	Calculation of Priority	Factor
Building Condition	75	75	75	Based on Table 3	
Classification and Importance of Building	100	80	50	Based on Table 4	
Users Number	500	200	50	Average Users Number	
	500/500	500/200	500/50	UF=100*(AUN/Max. AUN)	
Severity Level	35	35	35	Based on Table 5	
Citizens' Complaints	0	0	0	Based on Table 6	

Ed: Educational, Re: Recreational, Op: Operational

TABLE 8. Applied example for calculating building maintenance priority index (PI)

Indicator	Fi			Weight (Wi)	Wi*Fi		
	Ed	Re	Op		Ed	Re	Op
Building Condition	75	75	75	0.40	30	30	30
Classification and Importance of Building	100	80	50	0.35	35	28	17.5
Users Number	100	40	10	0.05	5	2	0.5
Severity Level	35	35	35	0.15	5.25	5.25	5.25
Citizens' Complaints	0	0	0	0.05	0	0	0
Priority Index (PI)					**75.25**	**65.25**	**53.25**

Ed: Educational, Re: Recreational, Op: Operational

From Table 7 it is obvious that the first building (educational) type has the first maintenance priority, followed by the second and third buildings (recreational and operational), respectively. The same procedure is applied on all buildings in each municipality. The PI is calculated for each type and after that the PI values are then arranged in descending order. The corresponding type of treatment (routine, preventive, corrective, etc.) and related cost are then identified for each building. Consequently, the annual selected buildings for maintenance are chosen based on PI values till the allocated budget is finished for the specified year. The remaining buildings are postponed to the next years.

The results of the questionnaire analysis indicated also that the lack of the external financial resources specified for maintenance of buildings (which is the main obstacle faced the municipalities) led to not executing all annual planned maintenance works as the local maintenance budgets are usually limited. In addition, all municipalities assured that they have the qualified technical staff responsible for buildings maintenance works. Finally, the level of benefit from the O&M Manual and the coaching sessions about how to use it was rated as good and very good.

CONCLUSIONS

It is evident from the survey results that the preparation and application of the O&M Manual had a positive impact on the pilot ten municipalities. The level of benefit from the Manual was rated as very high. Likewise, the level of benefit from the conducted capacity building and training workshops ranked as high, which was reflected on the capability of the municipal staff in all buildings maintenance phases. Both results express the high confidence of the Municipal Engineers in the prepared Manual in terms of applicability and its guidance in the identification of their maintenance priorities.

The criteria used by the municipalities for prioritization maintenance works were generally in line with the criteria specified in the O&M Manual. All the ten municipalities applied the same indicators and weights as per the Manual. The developed O&M Manual has exhibited flexibility to allow tailoring the weights of the indicators according to the needs and realities.

It is well understood that not all the proposed works in the maintenance plans were implemented. The main reason behind that was the lack of funds (internal and external). Other factors that contributed to this include the experience of local Municipal staff, and lack of equipment and materials used in maintenance works. Moreover, the

war against Gaza Strip in the summer of 2014 contributed significantly to the destruction of considerable public buildings in Gaza Strip, and the municipalities there, consequently, had changed the priorities.

The study showed also the real need for establishing a new unit in the municipalities concerned with maintenance works, taking into consideration assigning the required staff and allocating the demanded budgets, equipment and materials. This corresponds well with the proposed establishment of such units as recommended in the O&M Manual.

Based on the relative successful implementation of the O&M Manual in the ten pilot municipalities, it is recommended to extend and disseminate the experience to the rest of the municipalities in the Palestinian territories, and to include other infrastructure assets in the Manual such as water and wastewater networks, storm water drainage systems, electricity grids, etc. Moreover, it is recommended to apply similar maintenance prioritization procedures outside municipalities' boundaries by the Ministry of Public Works and Housing (MoPWH).

The MDLF is recommended to pursue its plans to develop a special software package which implies the transformation of the O&M Manual into a computerized user-friendly O&M System as and to be tested on the pilot municipalities.

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