

# Effects of Faulty Design Phase on School Buildings Maintenance in Gaza Strip

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**Abstract** The aim of this paper is to identify and rank the design phase faults/errors affecting on the maintenance of the United Nations Relief and Works Agency (UNRWA)'s school's buildings in Gaza Strip, and to propose recommendations for minimizing the future maintenance problem related to the school buildings at Gaza Strip. A survey was conducted to collect the required data were adopted in this study. This study reveals the important factors that leading to defects in the design stage which includes: lack of workshops to discuss construction problems between project parts, Inadequate QA/QC programs during design stage, Lack of auditing and archiving of approved as-built drawing documents electronically after the completion the project. The study recommends several actions to improve maintenance performance of UNRWA's schools in Gaza Strip. The designer must take into account maintenance considerations during the design and supervision stages by choosing of durable materials. The UNRWA should conduct workshops or training courses for designers, supervisor, and maintenance engineers.

**Keywords:** construction industry, construction problems, design phase, faults/errors, gaza strip, maintenance, palestine, schools buildings, UNRWA schools

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## 1. Introduction

Due to the fast developing in Gaza Strip and the increasing in the population every year, many building construction project have been built to overcome the demand of both the public and private sectors. In order to meet the high demand of both the public and private sectors in new building constructions in a short space of time, it is anticipated that many defects and errors will arise, especially during design and construction phase. This will unavoidably result in high maintenance costs.

Similar problem with UNRWA schools the needed of Palestine refugee students for free education and due to population growth and increased rate of transfers from Palestinian Authority schools, where the quality of education and infrastructure is suffering significantly as a result of ongoing conflict and closure, as well as political turmoil, many UNRWA school buildings have been built to overcome the phenomenon of both increase and transfer the number of students in a short space of time, it is expected that many faults will happen, especially during design and construction phase. this will lead to increase the high maintenance costs [1].

Maintenance issue often arises when the building performance is not meeting the standards and quality designed [2]. As a result of the growth of school building with the lack of building standards, more maintenance, rehabilitation, and renovation work have become necessary to ensure the serviceability and safety of the

constructed schools. In addition, the existing schools need to be sustained as long as possible. Therefore, ways must be found to reduce the maintenance cost works due to ageing of the buildings while keeping the same quality.

Maintenance costs of a building during their functional lifetime could easily exceed the initial outlay of a new building. Therefore, it's important to consider maintenance aspects at the very outset of the life cycle of a building because decisions made at planning, design and construction stages have a large effect on the maintenance costs and works incur later in the life cycle of a building. Aged building doesn't necessary have to be associated with high maintenance cost as a new building with numerous defects from faulty design and construction could easily equal or surpass the maintenance cost of an aged building [3].

Gaza Strip is considered a densely populated area that made construction industry and number of buildings increased rapidly after the establishment of the Palestinian Authority in 1994. As known, Gaza Strip has a costal location which makes many reinforced concrete structures susceptible to aggressive actions due to the high relative humidity and high salts concentration [4].

Many concrete structures in Gaza Strip suffer from serious defects/errors that increase maintenance costs and decrease the life span of the structure. Abu Hamam [4] stated that structures in the Gaza Strip may face several defecting criteria in their life, starting from their design stage to the service stage; these normally include faults in design, faults in the construction process, defects in

materials, chemical attacks, etc. Therefore, any design or construction faults/errors may affect negatively on maintenance performance of the residential buildings. As a result, buildings should be designed and constructed to meet higher building standards which demand longer life span and control of the decaying processes.

The aim of this research is to identify the main types of defects/errors in design stage that affecting maintenance of UNRWA school's buildings in Gaza Strip. Improving the maintenance performance of UNRWA's schools, by minimizing the defects of design phase to increase the lifespan of UNRWA school's buildings.

### 1.1. Maintenance Definition

Oxford Dictionary defined the verb maintain' as cause to continue. Maintenance, therefore, is ensuring that physical assets continue to fulfill their intended functions [5]. Maintenance is defined as the combination of all the technical and administrative actions, including supervision, intended to retain an item, or restore it to a state in which it can perform a required function [6].

Maintenance includes the costs of regular custodial care and repair, annual maintenance contracts, and salaries of facility staff performing maintenance tasks. Replacement items of minor value or having a life of less than five years are included as a part of maintenance i.e. replacing light bulbs and repainting are normally included under the maintenance category [7]. it may be more descriptive to describe the latter work as "running maintenance",

together with other work such as cleaning floors and windows, replacing broken tiles, etc. Various definitions of maintenance exist among maintenance managers, as defined by various authors and institutions, some of these definition are summarized below at Table 1.

The issue of building maintenance is a universal issue and is highly considered in the early process of the construction (design) to assure the quality of the building [8]. Maintenance issue often arises when the building performance is not meeting the standards and quality designed [2]. Building maintenance follows a specific set of objectives including repair, replacement, renewals, modification, protection that protects the basic materials (i.e. external painting and thin coating), decoration that protects of the internal surface of the building (i.e. painting and etc.), and cleaning for maintaining the internal face of the building [9].

The other's objectives of building maintenance were summarized by [10], among of these were: to ensure that the buildings and their associated services are in a safe, to ensure that the building are fit for use, to ensure that the condition of the building meets all statutory requirements, to carry out the maintenance works necessary to maintain the value of the physical assets of the building stock and to carry out the work necessary to maintain the quality of the building. In summary, building maintenance is to ensure the building and its services are in a safe condition; fit for use; to meets all statutory requirements; and to maintain the value and quality of the building [11].

**Table 1. Definition of maintenance building**

Term	Definition	Quoted source
Maintenance	Work undertaken in order to keep, restore or improve every facility, i.e. every part of the building, its services and surrounds, to a currently acceptable standard and to sustain the utility and value of the facility	[12]
Maintenance	the combination of technical and administrative actions to ensure the items and elements of a building in an acceptable standard to perform its required foundation	[2]
Maintenance of a building	the process of restoration activity of the structure and components of a building. It covers the whole building which includes toilets, rooms, walls, roofs, drains, doors, windows, floors and also the fix furniture	[11]
Building maintenance	work undertaken in order to keep, restore, or improve every part of the building, its services and surrounds, to currently accepted standards, and to sustain the utility and value of the building.	[13]
Building maintenance	effort undertaken so as to keep, refurbish or improve every element that is every part of a building, its services and surroundings to a currently acceptable condition and to maintain the utility and value of the facility.	[3]
Maintenance	the work that is carried out to preserve an asset in order to enable its continuous use and function, above a minimum acceptable level of performance, over its design service life, without unforeseen renewal or major repair activities.	[14]
Maintenance	Actions undertaken in order to reduce the adverse effects of breakdown and maximize the facility at minimum cost.	[15]

### 1.2. Literature Review

Buildings cannot remain new throughout their entire life. All buildings start to deteriorate from the moment they are completed, and at that time the need for maintenance begins. A newly completed building, also requires maintenance. Moreover, it is not possible to replace or rebuild all buildings at one time. The value of a building decreases unless maintenance is carried out on the building [16,17]. Maintenance works are the only way to maintain and increase the value of the property. Therefore, the need for maintenance will only intensify. Building maintenance and the performance of the building constantly affect people's comfort and productivity.

With the increasing costs of new construction, the effective maintenance of the existing building stock has become even more important. Increasingly, building

owners are beginning to accept that it is not in their best interest to carry out maintenance in a purely reactive manner, but that it should be planned and managed as efficiently as any other corporate activity [18]. Knowing that, it is impossible to produce buildings that are maintenance free, but maintenance work can be minimized by good design and proper workmanship carried out by skilled experts or competent craftsmen using suitable codes of installation and requisite building materials and methods [19].

Al-Shiha [20] conducted a research discussing the effect of faulty design and construction factors on building maintenance. As a result, the most severe factors which affect the maintenance works and causes the high maintenance cost are determined as: inadequate structural design such as foundation, hiring unqualified designers, not complying with specification, not relating exterior

materials selection to climate conditions, inadequate waterproofing and drainage, unqualified workplace, inability to read the drawing's.

Assaf et al. [21] identified eleven groups of defects which are affects in building maintenance. these group were defects in civil design, architectural defects in design, design defects in maintenance practicality and adequacy, defects due to consultant firm administration and staff, defects due to construction drawing, defects due to construction inspection, defects due to civil construction, defects due to contractor administration, defects due to construction materials, defects due to construction equipment and defects due to specification.

Bin Hashem [22] listed some factors that influence maintenance in the design stage for building maintenance such as: deterioration, future needs and faulty of choice materials.

Cooper and Jones [23] defined the key factors that contributed to high levels of dissatisfaction of the approach to maintenance programs poor specification of initial requirements; unclear aims and objectives and inappropriate frameworks; an inability to predict long term cost requirements; variations in levels of experience of those conducting surveys; unrealistic claims by consultants selling survey services; inappropriate or unusable data; poor links to organizational objectives; and a lack of fit of survey data.

Hoe [3] studied 37 (thirty – seven) different defects were identified in four groups, these group were design defects, construction defects, defects due to consultant firm administration and staff, defects due to contractor administration and staff. He concluded that there are three important effects on maintenance due to the defects. These are increased maintenance works, increased maintenance time/duration and Increased maintenance budget.

Ali et al [17] conducted a survey of 200 building managers on the factors affecting the cost of building maintenance. These factors include existing building condition, building age, complaints received regarding building performance, client's request, availability of funding, safety and health requirements. The study concluded that the cost of maintenance is affected mainly by condition of building and complaints received about building performance.

While Cobbinah [24] showed another type of factors as being responsible for the poor maintenance of public buildings: The age of the buildings, lack of maintenance culture, inadequate funds and high maintenance cost, pressure on building facilities by number of users and poor construction work and maintenance work done by maintenance personnel of the institution.

AL-Farra [25] studied and investigated the defects of the residential buildings in GS which appear mainly due to faults in design or construction phases which lead to the need for maintenance of those buildings. The survey showed that the dampness, cracks between walls and structural elements, and corrosion of reinforcement are the main defects which negatively affect the need for building maintenance. Based on his investigation improvements on tender documents were proposed in order to minimize maintenance requirements in future construction projects in Gaza. Also, the study showed the importance of applying the lessons learned concept as a tool to determine the building defects and to ensure they are not repeated in future projects.

Ali et al. [2] identified types of design defects that contributed to high maintenance cost for school building in Malaysia. These types include failure to follow well-established design criteria in the choice of structural system and selection of materials; ignorance of the basic physical properties of the materials; use of new materials or innovative forms of construction which have not been properly tested in use; misjudgment of user and climatic conditions under which the materials have to perform; difficulty in executing the design due to impractical issues; and poor communication between members of the design and construction teams. Therefore, it is important that the earlier decisions and initiatives are taken into consideration during the design phase to ensure the proposed building design is maintenance-friendly and sustainable throughout the whole life cycle of a building.

Olanrewaju and Abdul-Aziz [26] identified the factors leading to maintenance building. These factors were: poor design, poor workmanship, defective materials and components usage and age, climatic and environmental factor, and nature of users.

Enshassi and El-Shorafa [27] studied the maintenance performance indicators in order to control the operation of hospital building maintenance in the Gaza Strip. Also, the survey studied the operational conditions and factors that carried out and affect the maintenance management and deriving a suitable framework for the minimum requirements. The study recommended developing a team vision for hospital maintenance department, changing the work style and culture towards maintenance, making certified periodic maintenance checklists, developing and implementing adequate key performance indicators for the Gaza strip hospital status.

## 2. Methodology

In this research, questionnaire survey (a quantitative approach) was used to collect the factual, perceptive, and attitudes of the respondents [28,29]. Two populations were targeted in this research. The first population is UNRWA engineering department, which include around 80 of engineers; site/office, maintenance, and designers in different unit's in ICIP, among of these unit (maintenance unit, construction unit and design unit). These categories of staff will be considered in this study to assist in improving the maintenance performance of UNRWA school buildings in GS by minimizing the defects of design and construction phase to increase the lifespan of UNRWA schools buildings. The second population is Palestinian Contractors Union (PCU) categories that are classified under the maintenance of building categories in Gaza Strip. These categories are "1st, 2nd, and 3rd, maintenance of building categories" that have valid registration. The small categories (4th and 5th) were neglected due to the low practical and administrative experience of their companies in construction works and the low experience of their subcontractors specially in maintenance works. Based on the list of registered contractors at the PCU in December 2014, the size of population for the 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup>, maintenance building categories was 50 companies. Most of these company have been worked with maintenance of UNRWA school buildings.

To determine the sample size for each population of UNRWA Engineering staff and maintenance of contractors, Kish [30] equation was used.

$$n = \frac{n'}{1 + \frac{n'}{N}} \tag{1}$$

n' is the sample size from infinite population, which can be calculated from this formula [n' = S<sup>2</sup>/V<sup>2</sup>]. The definitions of all variable can be defined as the following:

n: sample size from finite population.

N: Total population (80 UNRWA engineers and 50 maintenance contractors)

V: Standard error of sample population equal 0.05 for the confidence level 95%, t= 1.96.

S<sup>2</sup>: Standard error variance of population elements, S<sup>2</sup>= P (1-P); maximum at P= 0.5

The sample size for UNRWA engineering staff and maintenance contractors' population can be calculated from the previous equations as follows:

$$n' = S^2 / V^2 = (0.5)^2 / (0.05)^2 = 100$$

n UNRWA engineering staff □

$$= \frac{100}{1 + 100 / 80} = 45 \text{ UNRWA engineering staff}$$

n maintenance contractors

$$= \frac{100}{1 + 100 / 50} = 34 \text{ maintenance contractors.}$$

Although the calculated sample size for UNRWA engineering staff is 45, the questionnaire was distributed to 60 of UNRWA engineering staff to overcome the risk of not responding from the respondents and to reflect higher reliability and benefits for the study. For the same reason, 44 questionnaires were distributed for the maintenance contractors.

Fortunately, the response rate was 75% for UNRWA engineering staff and 77% for maintenance contractors as shown in Table 2.

**Table 2. Sample size and response rate of the study populations**

Population Category	Total Population	Calculated Sample Size	Distributed questionnaire	No of respondents	Response Rate
UNRWA Eng. staff	80	45	60	45	75%
Maintenance contractors	50	34	44	34	77%

According to Moser and Kalton [31], the obtained response rates of 75% and 77% are reasonable and will reflect good results and outputs.

For the first population of UNRWA engineering staff, the selected sample represented all engineering units, which include maintenance, design and construction units. For the second population of maintenance contractors, the

selected sample represented all classification categories of the maintenance contractors in GS.

The study was carried out in Gaza Strip and targeted the UNRWA engineering department and maintenance contractors distributed all over Gaza Strip as shown in Table 3 below:

**Table 3. Geographical distribution of the sample**

Group	North	Gaza	Middle Area	South	Total
UNRWA Eng. staff	11	20	6	8	45
Maintenance contractors	9	14	4	7	34

Based on literature review Hoe [3], Buys & Le Roux (2014), Razak&Jaafar [35], Al-Shiha [20], Al-Khatam (2003), Assaf et al. [21], and Al-Hammad et al. [37]. 41 main types of defects/errors in design phase that affecting maintenance of UNRWA school buildings were considered in this study. The factors were categorized under 5 groups, according to the pilot study.

The ten experts were asked to review the questionnaire and verify the validity of the questionnaire topics and its relevance to the research objective and give their advice. In general, they agreed that the questionnaire is suitable to achieve the goals of the study.

Their valuable comments and suggestions were used to revise the questionnaire. All suggested comments and modifications were taking into consideration. Minor changes, modifications, and additions were accommodated based on pilot study findings to develop the final questionnaire. The questionnaire was validated by the criterion-related reliability test that measures the correlation coefficients between the factors selected for in each group and for all groups as one entity, and structure validity test (Spearman test). Cornbach's a coefficient of

internal consistency reliability tests for level of frequency responses was also used. The RII technique has been widely used in construction research for measuring attitudes with respect to surveyed variables. Several researches [32,33,34] used the RII in their analysis. The respondents were asked to rate the identified interface problems on a five-point Likert scale (1 for the strongly disagree to 5 for the strongly agree). Based on the survey response, a RII was tabulated using the following equation:

Relative Importance Index

$$= \frac{\sum w}{AN} = \frac{5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1}{5N}$$

Where W is the weighting given to each factor by the respondent, ranging from 1 to 5, (n1 = number of respondents for strongly disagree, n2 = number of respondents for disagree, n3 = number of respondents for neutral, n4 = number of respondents for agree, n5 = number of respondents for strongly agree). "A" is the highest weight (i.e 5 in the study) and N is the total number of samples. The relative importance index ranges from 0 to 1.

### 3. Results and Discussion

#### 3.1. Factors Related to Defects/Errors in Civil /Structural Design (Group1)

Table 4 shows the opinion of respondents about the factors related to defects/errors in civil /structural design according to relative importance index ranked from high to low.

Table 4. Rank and RII of factors related to defects/errors in civil /structural design

Factors	UNRWA Eng.'s		maintenance contractors		All respondents	
	RII	Rank	RII	Rank	RII	Rank
Lack of attention to the design details and the concrete block walls and the intersection with the structural elements	0.778	1	0.743	2	0.763	1
Improperly locating conduits and pipe openings at critical structural locations (sleeves)	0.739	2	0.772	1	0.753	2
Ignore prepare soil tests in the projects and the depending on previous experience	0.589	3	0.500	7	0.551	3
Ignore design of expansion / contraction / settlement joint and special construction joint	0.439	9	0.581	4	0.500	4
Ignore the effects of the environment and the loads on structural elements and weather conditions on the materials used	0.489	5	0.500	6	0.494	5
Inadequate concrete cover on structural elements	0.378	11	0.625	3	0.484	6
Using of type of foundations inappropriate to soil characteristics	0.489	4	0.434	9	0.465	7
Ignoring the dynamic loads effects on the stability of the building (elevators, air conditioners and generators)	0.483	6	0.427	10	0.459	8
Ignoring the design for wind effects and design for earthquakes loads effects on the structure	0.417	10	0.507	5	0.456	9
Ignore the difference in the adjacent soil layers and variation in soil conditions	0.456	8	0.434	8	0.446	10
Exceeding the allowable deflection limits	0.461	7	0.272	11	0.379	11
All factors	0.519		0.527		0.523	

From Table 4, it is shown that, "Lack of attention to the design details between concrete block walls and the intersection with the structural elements" was ranked in the first position by all respondents with RII of (0.763). The responding UNRWA Eng.'s ranked this factor in the first position with RII of (0.778), while the maintenance contractors ranked it in the second position with RII of (0.743). This emphasizes that, this is an important factor used by both UNRWA Eng.'s and maintenance contractors affecting on maintenance school in design stage in this group. There is no clear referring in the design details for most UNRWA schools to leave a distance not less than 15 cm between walls and columns (Infill between columns and block), installation steel bars  $\Phi 8\text{mm}$  each 40cm horizontally and one steel bar  $\Phi 8\text{mm}$  vertically, which should be cast later with a reinforcement concrete (B200), or as the opinion of the supervising engineer. Also, the design in detail drawing ignored identifying the locations of stop beads, angel beads, movement beads and metal latching in plaster works that are required to minimize shrinkage cracks between block and concrete elements. Lack of attention to the design details between concrete block walls and the intersection with the structural elements leading to causes different type of cracks which increase maintenance work. The obtained results agreed with [25].

On the other hand, it is shown that, "Improperly locating conduits and pipe openings at critical structural locations (sleeves)" was ranked in the second position by all respondents with RII of (0.753). The responding UNRWA Eng.'s ranked this factor in the second position with RII of (0.739), while it was ranked in the first position by the responding maintenance contractors with RII of (0.772). This emphasizes that, this is an important factor used by both UNRWA Eng.'s and maintenance contractors affecting on maintenance school in design stage in this group because, when the civil designer does not review the layout of the mechanical or electrical

design, where the electrical or mechanical designer installs the conduits in a very critical structural area which will result in failure or continuous cracking of the structural elements or damage to the mechanical system of the building, e.g. breakage of water pipes or sewer leakage.

Finally, it is shown that, "Exceeding the allowable deflection limits" was ranked in the last position by all respondents with RII of (0.379). Also, maintenance contractors in the last position with RII of (0.272), while UNRWA Eng.'s was ranked in the seventh position with RII of (0.461). Where the UNRWA design engineers aware about importance to avoid exceeds the allowable structural span length. Also, they take care when they evaluate the dead and life load to be correct. And they used drop beam as a good solution to avoid any deflections. The results of this study in the first line of Razak and Jaafar [35] who found that, this factor was in the last position in this group.

#### Spearman Rank Correlation Coefficient

Spearman rank correlation coefficient ( $\rho_{\text{Rho}}$ ) is a non-parametric test for measuring the difference in ranking between target groups (UNRWA Eng.'s and maintenance contractors). For calculation of ( $\rho$ ), the following simple formula is applied:

$$\rho = 1 - \frac{6 \sum d_i^2}{N(N^2 - 1)}, [36]$$

where,  $d_i$  = the difference in ranking between each pair of factors.

$N$  = number of factors.

For the group of factors related to defects/errors in civil /structural design, the correlation coefficient equals to 0.694 with P-value ( $\text{Sig.}$ ) = 0.000. The P-value is less than the level of significance,  $\alpha = 0.05$ , so there is a significant relationship between UNRWA Eng.'s and maintenance contractors in this group toward the opinions in this study.

### 3.2. Factors Related to Defects/Errors in Architectural Design (Group 2)

Table 5 was tabulated from 6 different factors related to defects/errors in architectural design. Using RII, the rank

order for the most important factors from the view point of the respondents is indicated. As shown in Table 5 most of the respondents graded these factors from important to very important.

**Table 5. Rank and RII of factors related to defects/errors in architectural design**

Factors	UNRWA Eng.'s		maintenance contractors		All respondents	
	RII	Rank	RII	Rank	RII	Rank
Selecting of exterior finishing and insulation material not relating to climatic condition	0.800	2	0.802	1	0.801	1
Ignore the effect of local weather conditions at the building site for the design of the external shapes	0.817	1	0.750	2	0.788	2
Unclearness of architectural detail design	0.633	3	0.625	3	0.629	3
Architectural design not integrated with the other project drawings	0.544	4	0.507	5	0.529	4
Designing inadequate expansions joint which don't lead to required purpose between finished faces, ceiling and wall	0.467	5	0.588	4	0.519	5
Designing narrow stairs, passage and doors that obstruct the transfer of equipment and maintenance work process	0.456	6	0.449	6	0.453	6
All factors	0.619		0.620		0.620	

As notice in Table 5, it is shown that, "Selecting of exterior finishing and insulation material not relating to climatic condition (paint irresistible humidity and temperature)" was ranked in the first position by all respondents with RII of 0.801. The responding UNRWA Eng.'s ranked this factor in the second position with RII of (0.800), while the maintenance contractors ranked it in the first position with RII of (0.802). This emphasizes that, this is the most important factor of defects/errors used by both UNRWA Eng.'s and maintenance contractors affecting on maintenance school in design stage in this group. Because, the selection of color and type of exterior finish of a building should be suitable to the weather and environmental conditions. The ignoring to use special materials cannot resist heat and humidity will require a lot of cleaning and maintenance, some of examples are not painting buildings with dark colors in a dusty area where they require a lot of cleaning, or using paints which cannot resist heat and humidity, most of the design for UNRWA schools ignore environmental conditions, climate, ocean, where the finishing materials itself in schools that are located close to the sea are the same to finishing materials which is located in the center of the city, where they ignore this factor that leads to damage of finishing materials and peeled so as acts outside the paint and interior, as well as there are no applying to isolate by bitumen for concrete foundation in sand or clay soil. This problem leading materials to deteriorate in shorter time and lead to defects in other parts of the building. The obtained results agreed with [3,21,35] who found that, this factor was in the first position in this group. Also, in the first line of Al-Hammad et al. [37] who found that, this factor in the second position in this group from perspective of maintenance contractors.

On the other hand, it is shown that, "Ignore the effect of local weather conditions at the building site for the design of the external shapes" was ranked in the second position by both UNRWA Eng.'s and maintenance contractors with RII of (0.788). The responding UNRWA Eng.'s ranked this factor in the first position with RII of (0.817) while it was ranked in the second position by the responding maintenance contractors with RII of (0.750). This emphasizes that, this is the most important factor of

defects/errors used by both UNRWA Eng.'s and maintenance contractors affecting on maintenance school in design stage in this group, because the most of UNRWA schools has the same architectures design way in deferent locations and environmental conditions that related to external shape, type, and color which lead to collection of moisture, water or dust. Such design will help to increase the maintenance works like cleaning and repairing damages due to water collection on building roofs. The obtained results matching to Razak and Jaafar [35] who found that, this factor was in the second position in this group.

Finally, it is shown that, "Designing narrow stairs, passage and doors that obstruct the transfer of equipment and maintenance work process" was ranked in the last position by both of the UNRWA Eng.'s and maintenance contractors with RII of (0.453). Also, each of them separately ranked it in the last position with RII of (0.456) and (0.449) respectively. Which referring to the ignoring of respondents for this factor where they are take care in the design stage for the important of designing stairs and doors to be wide as possible and to transfer of maintenance tools easily. Anyway, in UNRWA school there is at least four stair case entrance to facility of students transfer and maintenance work easily. The obtained results agreed with Razak and Jaafar [35] who found that, this factor was in the last position in this group.

#### **Spearman rank correlation coefficient:**

For the group of factors related to defects/errors in architectural design, the correlation coefficient equals to 0.854 with P-value (Sig.) = 0.0005. The P-value is less than the level of significance,  $\alpha = 0.05$ , so there is a good agreement between the UNRWA Eng.'s and maintenance contractors in this group.

### 3.3. Factors Related to Defects/Errors due to Owner Administration and His Staff (Group 3)

Table 6 shows the opinion of respondents about the factors related to defects/errors due to owner administration and his staff in design according to relative importance index ranked from high to low.

**Table 6. Rank and RII of factors related to defects/errors due to owner administration and his staff**

Factors	UNRWA Eng.'s		maintenance contractors		All respondents	
	RII	Rank	RII	Rank	RII	Rank
lack of workshops to discuss construction problems between the design, supervision and implementation	0.878	1	0.867	1	0.873	1
Inadequate QA/QC programs during design stage	0.861	2	0.846	2	0.854	2
Lack of technical updating and adequate training of staff and lack of awareness of construction technology	0.778	3	0.779	3	0.779	3
Poor communication between the design team and the crew of maintenance / implementation	0.678	4	0.706	4	0.689	4
Lack of documentation and archiving of the previous maintenance	0.583	8	0.691	5	0.629	5
Lack of adequate budget for maintenance work	0.622	6	0.618	9	0.620	6
Staff pressure to accomplish works times less than the required period	0.611	7	0.625	6	0.617	7
The lack of clarity and integrity and to provide full information to the designer by the owner	0.633	5	0.581	11	0.611	8
Lack of technical background and experience of the designer	0.556	10	0.625	7	0.585	9
Misjudgment of environmental and climatic conditions	0.567	9	0.588	10	0.576	10
Not be assigned to the engineer designing the parts that belonged to	0.506	11	0.618	8	0.554	11
Ignore the designer to the properties, characteristics and behaviors of materials	0.489	12	0.567	12	0.522	12
All factors	0.647		0.676		0.659	

As notice in Table 6, it is shown that, "lack of workshops to discuss construction problems between the design, supervision and implementation" was ranked in the first position by all respondents with RII of (0.873). Also, each of them separately ranked it in the first position with RII of (0.878) and (0.867) respectively. This emphasizes that, this is the most important factor used by UNRWA Eng.'s and maintenance contractors related to defects/errors owner administration and his staff during design stage. Communication between the maintenance and design groups is important to get the views of the maintenance staff on issues related the selection of material, systems and equipment. Lack of communication would result in the repetition of faulty design, which affects the cost of maintenance. The obtained results agreed with [38], who emphasized that this factor is an important factor that in the group related to defects due owner administration and his staff.

On the other hand, it is shown that, "Inadequate QA/QC programs during the design stage" was ranked in the second position by all respondents with RII of (0.854). Also, each of them separately ranked it in the second position with RII of (0.861) and (0.846) respectively.

This emphasizes that, this is the most important factor used by UNRWA Eng.'s and maintenance contractors related to defects/errors owner administration and his staff during design stage, where that the implementation for quality assurance and quality control programs on design is very important to reduce the number of defects and mistakes in design. This procedure requests one group to do the design and another group to review and highlight the design defects. The obtained results agreed with Assaf et al. [21], Razak and Jaafar [35] who found that, this factor was in the second position in this group.

"Lack of technical updating and adequate training of staff and lack of awareness of construction technology" was ranked in the third position by all respondents with RII of (0.779). Also, each of them separately ranked it in the third position with RII of (0.778) and (0.779)

respectively. This referring to the important of owners in update and expose their staff to the latest construction material and methods in the market. In addition, they should maintain and keep track of the new materials redundant or construction methods and make sure that they perform adequately in the existing building environment. All UNRWA schools till now not used the technology and modern finishing materials in schools as examples, in new covering materials like acoustic texture exterior paint (popcorn Gargamish paint), that are resistant to dampness and bad weather. The obtained results agreed with Razak and Jaafar [35] who found that, this factor was in the second position in this group.

Finally, it is shown that, "Not be assigned to the engineer designing the parts that belonged to" was ranked in the last position by both of the UNRWA Eng.'s and maintenance contractors with RII of (0.522). Also, each of them separately ranked it in the last position with RII of (0.861) and (0.846) respectively because, there are many numbers of specialist engineers in design unit, where every engineer responsible for his specialization.

#### **Spearman rank correlation coefficient:**

For the group of factors related to defects/errors due to owner administration and his staff in design stage, the correlation coefficient equals to 0.929 with P-value (Sig.) = 0.0007. The P-value is less than the level of significance,  $\alpha = 0.05$ , so there is a total agreement between UNRWA Eng.'s and maintenance contractors in this group.

### **3.4. Factors Related to Defects/Errors due to Drawing (Group 4)**

Table 7 was tabulated from 5 different factors related to defects/errors due to drawing in design stage. Using RII, the rank order for the most important factors from the view point of the respondents is indicated. As shown in Table 7 most of the respondents graded these factors from important to very important.

**Table 7. Rank and RII of factors related to defects/errors due to drawing**

Factors	UNRWA Eng.'s		maintenance contractors		All respondents	
	RII	Rank	RII	Rank	RII	Rank
Lack of auditing and archiving of approved as-built drawing documents electronically	0.811	2	0.860	1	0.832	1
Dependence on repetition and lack of updating	0.839	1	0.816	2	0.829	2
Poor and inaccurate details (detailed sections)	0.656	3	0.699	3	0.674	3
Conflicts of architectural and civil drawings	0.639	4	0.691	4	0.661	4
Lack of references (cross sections and detailed)	0.567	5	0.478	5	0.529	5
All factors	0.702		0.709		0.705	

As notice in Table 7, it is shown that, "Lack of auditing and archiving of approved as-built drawing documents electronically " was ranked in the first position by all respondents with RII of (0.832). Also, in the first position by maintenance contractors with RII of (0.860). While, in the second position by UNRWA Eng.'s with RII of (0.811). Which means the importance of as built drawing where, the construction contractors sometime do not provide accurate as-built drawings to the owner after completed the works. Such drawings are used by the maintenance contractor discrepancies between actual conditions and conditions reflected in the as-built drawings would draw the maintenance contractor to wrong assumptions.

On the other hand, it is shown that, Dependence on repetition and lack of updating " was ranked in the second position by both UNRWA Eng.'s and maintenance contractors with RII of (0.829). Also, in the second position by maintenance contractors with RII of (0.816), while, in the first position by UNRWA Eng.'s with RII of (0.839). This emphasizes that, this is the most important factor used by UNRWA Eng.'s and maintenance contractors related to defects/errors due to drawing in design stage. The wrong sections and not update lead to repeat the same mistake and repeat the same works that you need to remove and increase the cost and time to repeat.

Finally, it is shown that, "Lack of references such as cross sections and detailed " was ranked in the last position by all respondents with RII of (0.529). Each of them separately ranked it in the last position with RII of (0.567) and (0.478) respectively. Which means most of UNRWA school buildings design drawings were show the cross section and detailed references clearly on the drawing. Also, the designer not allow to the contractors to construct the building according to his understanding and experience to avoid defects and errors which lead to increasing of maintenance work.

#### **Spearman rank correlation coefficient:**

For the group of factors related to defects/errors due to drawing in design stage, the correlation coefficient equals to 0.920 with P-value (Sig.) = 0.0012. The P-value is less than the level of significance,  $\alpha = 0.05$ , so there is a total agreement between the UNRWA Eng.'s and maintenance contractors in this group.

### **3.5. Factors related to defects/errors due to specification (Group 5)**

Table 8 shows the opinion of respondents about the factors related to defects/errors due to specification in design stage according to relative importance index ranked from high to low.

**Table 8. Rank and RII of factors related to defects/errors due to specification**

Factors	UNRWA Eng.'s		maintenance contractors		All respondents	
	RII	Rank	RII	Rank	RII	Rank
Not specifying quality assurance & control procedures (QA/QC)	0.789	2	0.816	1	0.801	1
Lack of local specifications and standards related of requirements of materials and workmanship	0.794	1	0.779	2	0.788	2
The specification is unclear and unrealistic	0.628	3	0.691	4	0.655	3
Absence of laws to building maintenance items and specifications (manual or code)	0.500	5	0.706	3	0.589	4
Not specifying to appropriate materials and specifications	0.517	4	0.581	5	0.544	5
Not specifying to the allowable load limits	0.417	6	0.419	6	0.418	6
Inadequate experience and expertise to design concrete admixtures	0.367	7	0.309	7	0.342	7
All factors	0.573		0.615		0.591	

Table 8 shows that the all respondents ranked " Not specifying quality assurance & control procedures " in the first position with RII of (0.801). The responding UNRWA Eng.'s ranked this factor in the second position with RII of (0.789), while the maintenance contractors ranked it in the first position with RII of (0.816).

This emphasizes that, this is the most important factor used by UNRWA Eng.'s and maintenance contractors related to defects/errors due specification in design stage. This means the old specification in UNRWA schools building do not specify the relation between owner, the inspector and contractor, and how to communicate properly to avoid any defect or solve any problem. Also,

not specify the responsibility of each party, but I think in the updated specifications, there are referring to this issues and identify the responsibilities for the entire party. The obtained results agreed with Razak and Jaafar [35] who found that, this factor was in the second position in this group.

On the other hand, it is shown that, "Lack of local specifications and standards related of requirements of materials and workmanship " was ranked in the second position by all respondents with RII of (0.788). The responding UNRWA Eng.'s ranked this factor in the first position with RII of (0.794), while the maintenance contractors ranked it in the second position with RII of

(0.779). This means the important of standard and specification documents to building maintenance, as it constitutes a schedule of instructions to contractor and workmanship requirement .

Finally, it is shown that, "Inadequate experience and expertise to design concrete admixtures" was ranked in the last position by all respondents with RII of (0.342). Each of them separately ranked it in the last position with RII of (0.367) and (0.309) respectively. Which means ignoring this factors by all respondents, where the UNRWA design section have a designers, which design the concrete mix to meet the strength requirements and the equality and durability side.

**Spearman rank correlation coefficient:**

For the group of factors related to defects/errors due to drawing in design stage, the correlation coefficient equals to 0.777 with P-value (Sig.) = 0.0001. The P-value is less than the level of significance,  $\alpha = 0.05$ , so there is a good agreement between the UNRWA Eng.'s and maintenance contractors in this group.

**3.6. Comparison between All Groups of Factors Leading to Errors/Defects in Design Stage**

Table 9 shows the opinions of the respondents about the groups of factors leading to errors/defects in design stage according to relative index from high to low.

**Table 9. Rank and RII group of factors related to defects/errors in design stage**

Factors	UNRWA Eng.'s		maintenance contractors		All respondents	
	RII	Rank	RII	Rank	RII	Rank
factors related to defects/errors due to drawing	0.702	1	0.709	1	0.705	1
factors related to defects/errors due to owner administration and his staff	0.647	2	0.676	2	0.659	2
factors related to defects/errors in architecture design	0.619	3	0.620	3	0.620	3
factors related to defects/errors due to specification	0.573	4	0.615	4	0.591	4
factors related to defects/errors in civil/ structural design	0.519	5	0.527	5	0.523	5
All factors	0.603		0.621		0.605	

From Table 9, it is shown that, "factors related to defects/errors due to drawing "was ranked in the first position by all respondent's with RII of (0.705). Each of them separately ranked it in the first position with RII of (0.702) and (0.709) respectively. This emphasizes that, this is the most important group used by both the UNRWA Eng.'s and maintenance contractors which affecting maintenance of UNRWA schools building in design stage. Because, lack of references, cross sections and details of structural elements will lead the contractor to construct the building according to his understanding and experiences, which cause many maintenance defects which can only be discovered during building operation.

On the other hand, it is shown that, "factors related to defects/errors due to owner administration and his staff " was ranked in the second position by all respondents with RII of (0.659). Each of them separately ranked it in the second position with RII of (0.647) and (0.676) respectively. This emphasizes that, this is the most important group used by both the UNRWA Eng.'s and maintenance contractors which affecting maintenance of UNRWA schools building in design stage. Because the experiences of owners and his staff which play big role in maintenance works to avoid a lot of maintenance defects. This referring to the importance of owner role in minimizing of defects through identifying type of errors,

causes, and proposed prevention methods to minimize it appearance in future projects.

Finally, it is shown that, "factors related to defects/errors in civil/ structural design" was ranked in the last position by both of the UNRWA Eng.'s and maintenance contractors with RII of (0.523). Each of them separately ranked it in the last position with RII of (0.519) and (0.527) respectively. This means the ignoring of responding to this factor, where there is a big design unit in ICIP at UNRWA, which have a number of experts and trained staff in all specialties of construction.

**Spearman rank correlation coefficient:**

For the group of factors related to groups factors leading to defects / errors in design stage, the correlation coefficient equals to 0.953 with P-value (Sig.) = 0.0001. The P-value is less than the level of significance,  $\alpha = 0.05$ , so there is a total agreement between the UNRWA Eng.'s and maintenance contractors in this group.

**3.7. Top Ten Factors Leading to the Errors/Defects in Design Stage**

Table 10 was tabulated from ten (10) factors leading to the errors/defects which affecting maintenance of UNRWA schools buildings in design stage ranked from high to low.

**Table 10. Top ten factors leading to errors/defects in design stage**

The factors	All respondents		Group
	RII	Rank	
lack of workshops to discuss construction problems between the design, supervision and implementation	0.873	1	Owner administration
Inadequate (QA/QC) programs during design stage	0.854	2	Owner administration
Lack of auditing and archiving of approved as-built drawing documents electronically	0.832	3	drawing
Dependence on repetition and lack of updating	0.829	4	drawing
Selecting of exterior finishing and isolation material not relating to climatic condition	0.801	5	Architecture design
Not specifying quality assurance & control (QA/QC) procedures	0.801	6	Specification
Ignore the effect of local weather conditions at the building site for the design of the external shapes	0.788	7	Architecture design
Lack of local specifications and standards related of requirements of materials and workmanship	0.788	8	Specification
Lack of technical updating and adequate training of staff and lack of awareness of construction technology	0.779	9	Owner administration
Lack of attention to the design details and the concrete block walls and the intersection with the structural elements	0.763	10	Civil/ Structural design

From Table 10, it is shown that "lack of workshops to discuss construction problems between the design, supervision and implementation" related to factors leading to defects/errors due to owner administration and his staff group in design stage was ranked in the first position by all respondents with RII of (0.873). This emphasizes that, this is the most important factor used by all respondents related to defects/errors owner administration and his staff during design stage. Communication between the maintenance and design groups is important to get the views of the maintenance staff on issues related the selection of material, systems and equipment. Lack of communication would result in the repetition of faulty design, which affects the cost of maintenance. The obtained results agreed with Hassanain et al. [38], who emphasized that this factor is an important factor that in the group related to defects due owner administration and his staff.

"Inadequate (QA/QC) programs during design stage " which related to factors leading to defects/errors due to owner administration and his staff group in design stage was ranked in the second position by both the UNRWA Eng.'s and maintenance contractors with RII of (0.854). This emphasizes that, this is the most important factor used by UNRWA Eng.'s and maintenance contractors related to defects/errors owner administration and his staff during design stage, where that the implementation for quality assurance and quality control programs on design is very important to reduce the number of defects and mistakes in design. This procedure requests one group to do the design and another group to review and highlight the design defects. The obtained results agreed with Assaf et al. [21], Razak and Jaafar [35] who found that, this factor was in the second position in this group.

"Lack of auditing and archiving of approved as-built drawing documents electronically" which related to factors leading to defects/errors due to drawing group in design stage was ranked in the third position by both the UNRWA Eng.'s and maintenance contractors with RII of (0.832). The Construction contractors sometime do not provide accurate as-built drawings to the owner. Such drawings are used by the maintenance contractor discrepancies between actual conditions and conditions reflected in the as-built drawings would draw the maintenance contractor to wrong assumptions.

"Dependence on repetition and lack of updating "which related to factors leading to defects/errors due to drawing group in design stage was ranked in the fourth position by both the UNRWA Eng.'s and maintenance contractors with RII of (0.829). This emphasizes that, this is the most important factor used by UNRWA Eng.'s and maintenance contractors related to defects/errors due to drawing in design stage. The wrong sections and not update lead to repeat the same mistake and repeat the same works that you need to remove and increase the cost and time to repeat.

"Selecting of exterior finishing and isolation material not relating to climatic condition" which related to factors leading to defects/errors due to architecture design group in design stage was ranked in the fifth position by both the UNRWA Eng.'s and maintenance contractors with RII of (0.801).

This emphasizes that, this is the most important factor of defects/errors used by both UNRWA Eng.'s and maintenance contractors affecting on maintenance schools

in design stage in this group, because the selection of color and type of exterior finish of a building should be suitable to the weather and environmental conditions. The ignoring to use special materials cannot resist heat and humidity will require a lot of cleaning and maintenance, some of examples are not painting buildings with dark colors in a dusty area where they require a lot of cleaning, or using paints which cannot resist heat and humidity, most of the design for UNRWA schools ignore environmental conditions, climate, ocean, where the finishing materials itself in schools that are located close to the sea are the same to finishing materials which is located in the center of the city, where they ignore this factor that leads to damage of finishing materials and peeled so as acts outside the paint and interior, as well as there are no applying to isolate by bitumen for concrete foundation in sand or clay soil. This problem leading materials to deteriorate in shorter time and lead to defects in other parts of the building. The obtained results agreed with Assaf et al. [21], Hoe [3], and Razak and Jaafar [35] who found that, this factor was in the first position in this group. Also, in the first line of Al-Hammad et al. [37] who found that, this factor in the second position in this group from perspective of maintenance contractors.

"Not specifying quality assurance & control procedures)" which related to factors leading to defects/errors due to specification group in design stage was ranked also in the sixth position by both the UNRWA Eng.'s and maintenance contractors with RII of (0.801). This emphasizes that, this is the most important factor used by UNRWA Eng.'s and maintenance contractors related to defects/errors due specification in design stage. This means the old specification in UNRWA schools building do not specify the relation between owner, the inspector and contractor, and how to communicate properly to avoid any defect or solve any problem. Also, not specify the responsibility of each party, but I think in the updated specifications there are referring to this issues and identify the responsibilities for the entire party. The obtained results agreed with Razak and Jaafar [35] who found that, this factor was in the second position in this group.

"Ignore the effect of local weather conditions at the building site for the design of the external shapes " which related to factors leading to defects/errors due to architecture design group in design stage was ranked in the seventh position by both the UNRWA Eng.'s and maintenance contractors with RII of (0.788). This emphasizes that, this is the most important factor of defects/errors used by both UNRWA Eng.'s and maintenance contractors affecting on maintenance school in design stage in this, because the most of UNRWA schools has the same architectures design way in deferent locations and environmental conditions that related to external shape, type, and color which lead to collection of moisture, water or dust. Such design will help to increase the maintenance works like cleaning and repairing damages due to water collection on building roofs. The obtained results matching to Razak and Jaafar [35] who found that, this factor was in the second position in this group.

"Lack of local specifications and standards related of requirements of materials and workmanship" which related to factors leading to defects/errors due to

specification group in design stage was ranked also in the eighth position by both the UNRWA Eng.'s and maintenance contractors with RII of (0.788). This emphasizes that, this is the most important factor of defects/errors used by both UNRWA Eng.'s and maintenance contractors affecting on maintenance. This means the important of standard and specification documents to building maintenance, as it constitutes a schedule of instructions to contractor and workmanship requirement.

"Lack of technical updating and adequate training of staff and lack of awareness of construction technology subcontractors)" which related to factors leading to defects/errors due to owner administration and his staff group in design stage was ranked in the ninth position by both the UNRWA Eng.'s and maintenance contractors with RII of (0.779). This emphasizes that, this is the most important factor of defects/errors used by both UNRWA Eng.'s and maintenance contractors affecting on maintenance. This referring to the important of owners in update and expose their staff to the latest construction material and methods in the market. In addition, they should maintain and keep track of the new materials redundant or construction methods and make sure that they perform adequately in the existing building environment. All UNRWA schools till now not used the technology in schools as examples in new covering materials like acoustic texture exterior paint (popcorn Gargamish paint). The obtained results agreed with Razak and Jaafar [35] who found that, this factor was in the second position in the group of factors leading to errors/defects in design.

"Lack of attention to the design details and the concrete block walls and the intersection with the structural elements" which related to factors leading to defects/errors due to civil/ structural design group in design stage was ranked in the tenth position by both the UNRWA Eng.'s and maintenance contractors with RII of (0.763). This emphasizes that, this is an important factor used by both UNRWA Eng.'s and maintenance contractors affecting on maintenance school in design stage in this group, There is no clear referring in the design details for most UNRWA schools to leave a distance not less than 15 cm between walls and columns (Infill between columns and block), installation steel bars  $\Phi 8\text{mm}$  each 40cm horizontally and one steel bar  $\Phi 8\text{mm}$  vertically, which should be cast later with a reinforcement concrete (B200), or as the opinion of the supervising engineer. Also, the design in detail drawing ignored identifying the locations of stop beads, angel beads, movement beads and metal latching in plaster works that are required to minimize shrinkage cracks between block and concrete elements. Lack of attention to the design details between concrete block walls and the intersection with the structural elements leading to causes different type of cracks which increase maintenance work. The obtained results agreed with Al-Farra [25], who emphasized that this factor is an important factor that in the group related to defects due to civil design.

#### 4. Conclusions and Recommendations

The design stage is very important phase of the project. Special care should be taken since it has a vital effect on

the amount of maintenance work that will be needed after the building completed. In this study, forty one factors (41), which leading to defects/errors in design stage were identified. Lack of workshops to discuss construction problems between the design, supervision and implementation staff is the most important factor that leading to defects/errors in design stage, the second important factor is inadequate QA/QC programs during design stage, the third factor is Lack of auditing and archiving of approved as-built drawing documents electronically, then the fourth factor is dependence on repetition and lack of updating. Selecting of exterior finishing and isolation material not relating to climatic condition was in the fifth important factors. Finally, the lowest five factors leading to defects/errors in design stage are, not specifying to the allowable load limits, inadequate concrete cover on structural elements, exceeding the allowable deflection limits, and inadequate experience and expertise to design concrete admixtures.

The designers are recommended to take into account maintenance considerations during the design and supervision stages by choosing of durable materials which suitable for sever environmental conditions. The designers should consider the feedback by the maintenance teams to reduce the repetition of maintenance work. UNRWA is recommended to coordination between design, construction, and maintenance branches/divisions in all aspects of project implementation cycle as much as we can, especially in approval of the material samples. UNRWA is recommended to develop a maintenance standard of checklist and drawing library of good practical details. The maintenance standard checklist considers the lessons-learned that arising from construction and maintenance filed, where it is considered as an important factors that causes maintenance problem. UNRWA is recommended to provide data library and report of defects/errors for different types of UNRWA building projects in Gaza to be used as benchmarking references.

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