Planning and organizing the post-conflict reconstruction of damaged housing stock in Syria

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Abstract. Planning and organizing the post-conflict reconstruction of damaged areas is a fundamental challenge that the concerned authorities will face when deciding to begin reconstruction. This challenge lies in the need to determine how to properly plan and organize the process, and to determine the basis on which the process should be designed in order to ensure rapid reconstruction and rapid resettlement of refugees by reconstructing damaged housing stock. In this paper, we found that by adopting the concept of reconstruction priority and reconstruction sequence, we obtained a group of alternatives for planning and organizing the reconstruction process. After this, irrational alternatives were excluded, and the remaining ones were compared to choose the one that gives the shortest duration and, at the same time, less spread in the commissioning of the housing stock. The correlation between the main parameters of these alternatives was then examined and it was concluded that, by determining the approximate output per worker during reconstruction, it is possible to determine the values of other parameters that should be taken into account when designing reconstruction schedules for damaged areas in Syria.

Keywords: post-conflict reconstruction, complexity in construction, scheduling in construction, duration of post-war reconstruction, technical condition of damaged buildings.

1. Introduction

Studies show that, unlike conventional construction, reconstruction projects are complex, chaotic, dynamic, inflexible and inadaptability when dealing with large-scale projects [1].

In comprehensive reconstruction projects, many construction management issues arise [2, 3]. Executor's failure to adequately manage these issues results in the ineffective delivery of reconstruction projects [4]. These issues as identified in other studies relate to the following headings [5], which include human resource issues, quality management issues, monitoring and control issues, coordination and communication issues, logistics and supplies issues, financial management issues and planning issues with starting the project timely [6, 7].

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This study aims to investigate the issue of planning and organizing reconstruction projects in damaged countries to develop reconstruction schedules that ensure shortening the reconstruction duration and speed up the commissioning of damaged housing stock to ensure rapid refugee resettlement.

The design stage of reconstruction projects post-conflict reconstruction plays an important role in the success of these projects, since at this stage it is necessary to select the best alternative for planning and organizing the reconstruction of the damaged housing stock. These reconstruction schedules must ensure that two key concepts, namely the priority of reconstruction and the sequence of reconstruction, are applied in a manner that achieves the best reconstruction schedule parameters.

Priority of reconstruction is determined by the technical condition of damaged objects, which gives a clear idea of which objects should be reconstructed first and which can be postponed [8, 9], and the sequence of reconstruction is determined by the comprehensiveness of reconstruction, which allows us to plan the reconstruction not by individual buildings, but by residential blocks [10, 11].

2. Methods

The development of reconstruction schedules requires the adoption of a specific work breakdown structure that defines the dependencies between all levels in the damaged area, as presented in fig. (1), where C-I refers to objects with minor degree of damage, C-II refers to objects with low degree of damage, C-III refers to objects with moderate degree of damage and C-IV refers to objects with high degree of damage.

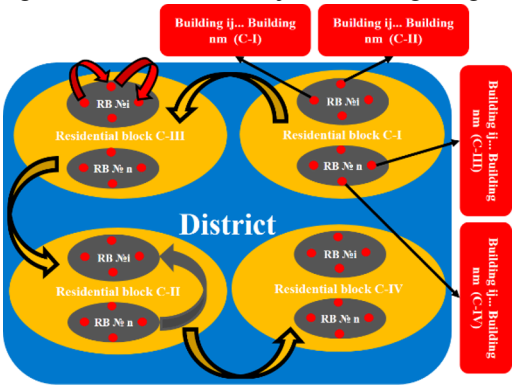

Fig. 1. Proposed levels in post-conflict damaged areas and dependencies between them.

The levels in damaged areas are as follows:

- work inside residential blocks, where relationships are formed between buildings of varying degrees of damage;
- work at the blocks level, where relationships are formed between blocks of the same degree of damage;
- work at the district level, where relationships are formed between blocks of varying degrees of damage.

The priority of reconstruction, as mentioned earlier, is achieved by taking into account the technical condition of buildings and residential blocks. For example, firstly, priority is given to residential blocks with a minor degree of damage, in which the amount of work is less and, accordingly, the duration of reconstruction is shorter. After this, priority is given to the reconstruction of residential blocks with moderate degree of damage, which are in critical condition compared to residential blocks with minor damage, after which priority is

given to the reconstruction of residential blocks with a high degree of damage, the reconstruction of which takes longer.

The comprehensiveness of the reconstruction of districts is measured by the complexity coefficient, which takes different values depending on the selected sequence of work between objects, which can be the following: simultaneous commissioning, simultaneous start of reconstruction, sequential reconstruction and sequential reconstruction with lead-time.

Based on the foregoing, it can be said that there are various alternatives for reconstruction schedules, the best of which will be selected by taking into account the priority of reconstruction and commissioning of buildings.

A well-known criterion for comparing schedules is the duration of construction. However, with the same duration, a various complexity coefficient is obtained. In order to eliminate this discrepancy, the shortest total waiting time from the moment of commissioning of individual buildings to the completion of construction can be used as an optimality criterion [12, 13]. In order to take into account the need to reduce the duration and increase the complexity in the design of reconstruction schedules, equation (1) was chosen [13].

$$F = \frac{1}{n}\sum_{i=1}^{n}\tilde{T}_i^{\,2} = \sigma(\tilde{T}_i) \qquad (1)$$

Where $\tilde{T}_i$ is the time interval between the beginning of the reconstruction of the district and the commissioning of the i residential block.

$\sigma(\tilde{T}_i)$ is the distribution of $\tilde{T}_i$.

Taking into account the value of the arithmetic mean $\overline{T}$ and the deviation from it τ_i:

$$\overline{T} = \frac{1}{n}\sum_{i=1}^{n}\tilde{T}_i;\ \tilde{T}_i = \overline{T} + \tau_i;\ \tau_i = \tilde{T}_i - \overline{T};\ \sum_{i=1}^{n}\tau_i = 0 \qquad (2)$$

Where $\overline{T}$ is the reconstruction duration of the district.

n is the number of residential blocks in the district.

Equation (1) provides a reduction in the duration of reconstruction and a reduction in the spread of $\tilde{T}_i$ values, that is, an increase in complexity, which is confirmed by equations (3,4):

$$\frac{1}{n}\sum_{i=1}^{n}\left(\overline{T} + \tau_i\right)^2 = \frac{1}{n}\left(\sum_{i=1}^{n}\overline{T}^2 + 2\overline{T}\sum_{i=1}^{n}\tau_i + \sum_{i=1}^{n}\tau_i^{\,2}\right) = \overline{T}^2 + \frac{1}{n}\sum_{i=1}^{n}(\overline{T} - \tilde{T}_i)^2 \qquad (3)$$

$$F = \overline{T}^2 + \frac{1}{n}\sum_{i=1}^{n}(\overline{T} - \tilde{T}_i)^2 \rightarrow min \qquad (4)$$

Where $\frac{1}{n}\sum_{i=1}^{n}(\overline{T} - \tilde{T}_i)^2$ is the spread of commissioning of residential blocks.

The development of reconstruction schedules should mainly depend on the assessment of the technical condition of buildings in the damaged areas and, depending on the degree of damage, a decision will be made to either reconstruct the damaged buildings or replace them with new buildings. Fig. 2. shows a flowchart diagram of the design methodology for

the reconstruction of damaged housing stock, which consists of several actions during which the best alternative for planning the process is achieved.

After presenting the most common cases of damage to designers and experts in Syria, they indicated that all buildings classified as highly damaged should be demolished, while buildings with moderate damage could be reused after strengthening their structural elements and eliminating all defects recorded in them.

Columns in buildings with a moderate degree of damage can be strengthened with steel plates in an amount of 15-20 kg per square meter of their surface area. As for damaged concrete beams and shear walls, they can be strengthened by jacketing them with reinforced concrete using the shotcrete method. In these buildings, the holes in the slabs formed as a result of explosions should be filled with reinforced concrete, then these slabs should be strengthened with carbon fiber Sheets in an amount of at least 10-20% of the slab area. After developing the design solutions, the scope of work is determined, and based on that, the labor intensity of reconstruction works will be determined using the regulatory documents in force in the country.

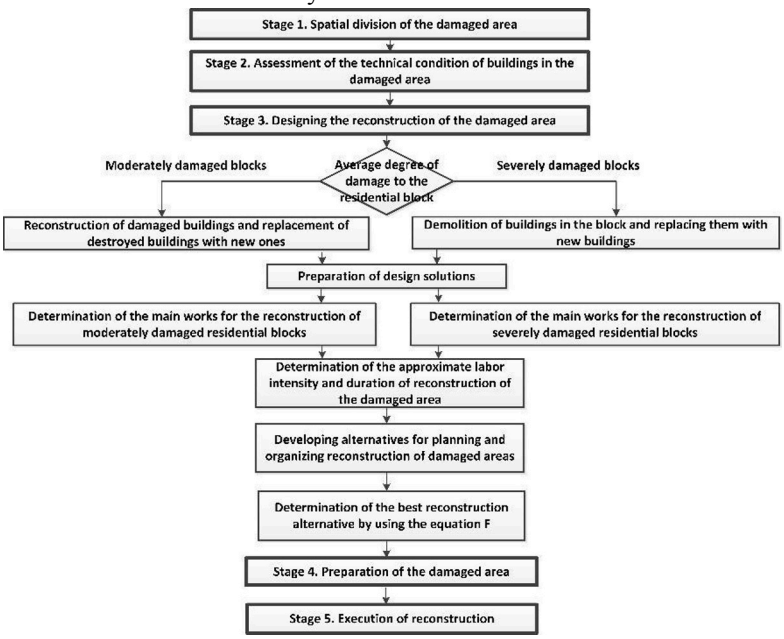

Fig. 2. Flowchart diagram of the design methodology for the reconstruction of damaged housing stock.

Taking into account the priority of reconstruction and the sequence of reconstruction, we will have 64 alternative for reconstructing the housing stock in any damaged area, as demonstrated in fig. (3).

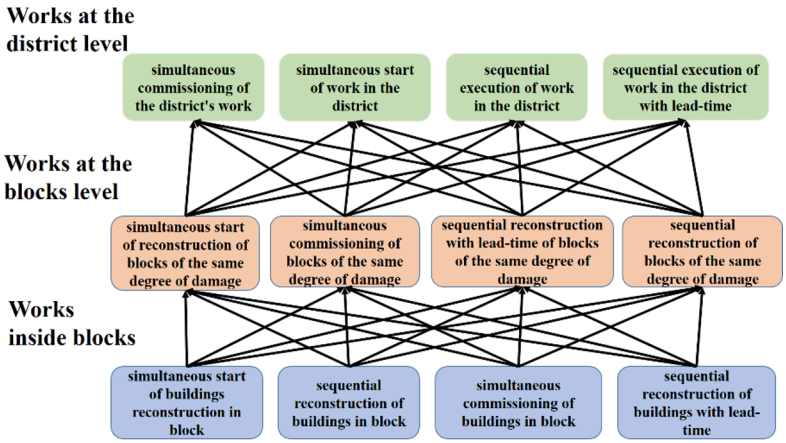

Fig. 3. Formation of alternative for planning and organizing the reconstruction of the damaged areas.

After calculating the F value using equation (4) for all alternatives, we excluded the ones that gave a duration of more than 5 years, as it is not desirable for reconstruction projects to last longer than that. Thus, 29 alternatives remain, among which there are alternatives of simultaneous start of work in block and alternatives of simultaneous commissioning of buildings in the block. It should be noted that the alternative of simultaneous start of work in the block is considered irrational because the amount of resources that will be needed at the starting point is greater than the alternative of simultaneous commissioning, so they were excluded and 21 alternatives remained.

These 21 alternatives include simultaneous commissioning of district blocks, which is unacceptable in the case of post-conflict reconstruction projects due to the presence of low damaged blocks with a small amount of work, and it is irrational to postpone their commissioning until all the blocks in the district are reconstructed, so they were excluded and 15 alternatives remained.

Among these 15 alternatives, there are those that suggest simultaneous start of reconstruction of blocks of the same degree of damage, and because the amount of resources needed at the starting point is greater than the alternative of simultaneous commissioning of blocks, the simultaneous start of reconstruction of blocks is excluded.

Therefore, after excluding all irrational alternatives, 7 alternatives remained, which are presented in table (1) with calculations of the main parameters for the reconstruction of the housing stock in part of Joubar district in Damascus, Syria, which was damaged to varying degrees, as we explained in our previous studies.

Table 1. Calculations of rational alternatives for planning and organizing the reconstruction of damaged housing stock.

Alternative	Duration (days)	workers per day	Work in man-hour	F	Spread of commissioning blocks	Complexity coefficient relative to the district	Average complexity coefficient relative to the blocks
8B: simultaneous commissioning of buildings in blocks with simultaneous commissioning of blocks of the same degree of damage with	404	1157	7473602	1868	23663	0.720	0.897

the simultaneous start of work in the district.				79			
8C: sequential reconstruction of buildings with lead-time with simultaneous commissioning of blocks of the same degree of damage with the simultaneous start of work in the district.	528	885		30653	27739	0.824	0.517
9B: simultaneous commissioning of buildings in blocks with simultaneous commissioning of blocks of the same degree of damage with sequential execution of work with lead-time in the district.	586	798		40276	59330	0.612	0.893
3B: simultaneous commissioning of buildings in blocks with simultaneous commissioning of blocks of the same degree of damage with sequential execution of work in the district	738	633		64739	102595	0.544	0.894
9C: sequential reconstruction of buildings with lead-time with simultaneous commissioning of blocks of the same degree of damage with sequential execution of work with lead-time in the district.	850	550		81346	90546	0.663	0.515
3C: sequential reconstruction of buildings with lead-time with simultaneous commissioning of blocks of the same degree of damage with sequential execution of work in the district	1171	399		15780 16	206775	0.555	0.515
8P :sequential reconstruction of buildings in blocks with simultaneous commissioning of blocks of the same degree of damage with the simultaneous start of work in the district	1321	354		19881 16	243075	0.691	0.335

3. Results

From table (1) it was found that the most rational alternative for planning and organizing the post-conflict reconstruction of damaged areas is 8B, which gave the smallest value of F, which, in turn, gives the smallest spread in the commissioning of housing stock and the shortest duration of reconstruction.

Also in table (1) it can be noted that each alternative has different values of complexity coefficients, and the best case is when both coefficients are closer to 1. This condition can be achieved by having a duration of more than 404 days and less than 528 days, and this is what we will get if we accept the alternative 8C, the duration of which can be shortened by increasing the lead-time in it.

By examining the correlation between the value of F and output per worker during the reconstruction period, it was found that there is a strong correlation as shown in fig. (4).

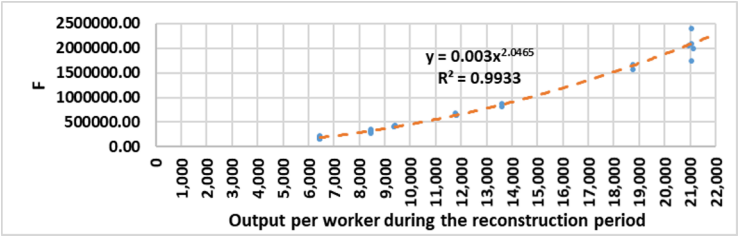

Fig. 4. The correlation between the F value and the output per worker.

In addition, fig. (5) shows the correlation between the value of F and the duration of housing stock reconstruction in the damaged area.

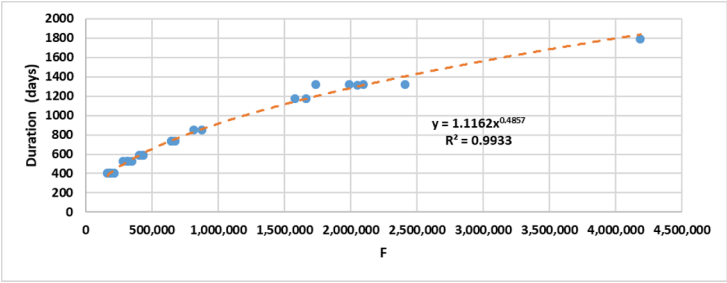

Fig. 5. The correlation between the F value and the duration of reconstruction.

Furthermore, by studying the correlation between the duration of reconstruction and the spread of commissioning blocks, it was concluded that there is a strong correlation between them, as shown in fig (6).

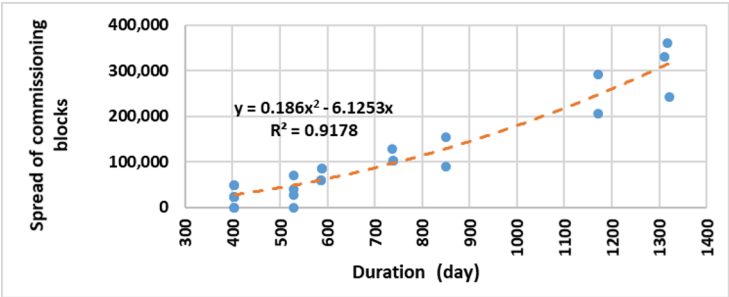

Fig. 6. The correlation between the duration of reconstruction and the spread of commissioning blocks.

Also fig. (7) shows the correlation between the spread of commissioning blocks and the complexity coefficient relative to the district.

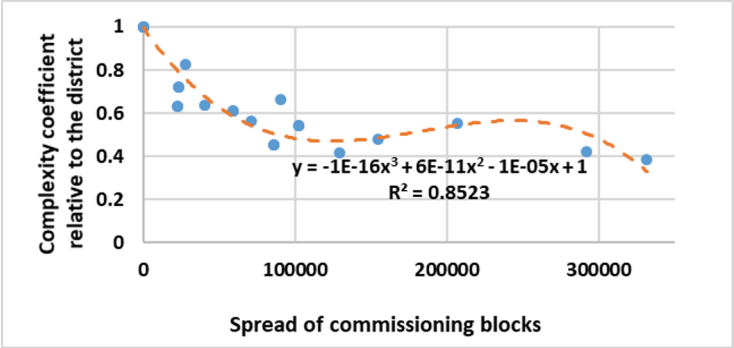

Fig. 7. The correlation between the spread of commissioning blocks and the coefficient of complexity relative to the district.

4. Discussion

In this paper, we concluded that by adopting the reconstruction priority and the sequence of reconstruction in damaged areas, we will have many alternatives for planning and organizing the reconstruction of housing stock, which must be compared not only in terms of duration, but also regarding the commissioning of residential blocks.

By studying the case of housing stock reconstruction of a part of Joubar district in Damascus, we identified the best alternatives for planning and organizing the reconstruction process. These alternatives will help reconstruction stakeholders in devastated countries know how the process should be planned and organized and in what sequence to ensure that refugees are resettled as quickly as possible.

The presented diagrams will benefit parties interested in developing reconstruction schedules for the reconstruction process in Syria. This is because, knowing the expected output per worker, the value of F can be determined, which, in turn, will allow us to determine the approximate duration of the reconstruction project, then determine the spread of commissioning of blocks and, finally, determine the complexity coefficient relative to the district. All these parameters to be determined will give an idea of how reconstruction schedules should be built and what they should provide.

It should be noted that the buildings in the study area were mainly built using monolithic reinforced concrete, therefore, we recommend in future studies the necessity of researching the reconstruction of damaged areas where the building mainly are of precast concrete.

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