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Assessing the Impact of Delay of Shop Drawing Process in Construction Projects

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Abstract. Delay is one of the challenges that affect the efficiency of the project. It is possible to reduce delays by assessing their real causes. Delay in the engineering shop drawings submittal/approval process is one of the common delays in construction projects. Therefore, it is important to study and analyze the causes of shop drawings delay. This paper aims to identify the causes of delays in the submittal/approval process, in addition to sorting and assessing the factors leading to such delays. A list of delay causes was retrieved from the literature review in addition to the feedback of construction experts that was obtained through interviews. Then a questionnaire survey was prepared and distributed among forty-one companies representing different types of parties (developers, consultants, and contractors). Among the twenty-four delay causes discussed, causes related to the engineering submittal/approval process were identified as the top delay causes such as: rework due to errors, delay in preparing submittals, poor qualifications of contractor technical staff, and poor communication and coordination. Delays in the submittal/approval process were split into two major groups: submittal of twenty-five delay causes and approval of eighteen delay causes. Thus, Frequency Index, Severity Index, and Importance Index were deduced and accordingly the top shop drawings delay causes of construction projects are determined. The top five causes were rework due to errors, suspension of work due to changes, delays in sub-contractors' work, coordination problems in design drawings, and unrealistic schedule. Statistical analysis was carried out on the results obtained from the survey. The test results reveal a good correlation between groups. A framework was developed as an effective solution for engineering shop drawing submittal/approval process delay. The proposed shop drawing framework is designed and developed based on the knowledge obtained from literature, observation of professionals, and the identified top factors. The framework consists of three successive phases: design/coordination review phase, shop drawing preparation /submission phase, and shop drawing reviewing/approval phase. Each phase is accomplished through sequential activities. After developing the framework, it was validated by utilizing a case study to see the effectiveness of the framework on the case study and how it helps in solving the problems of delaying submittals/approval process, and the progress after implementation of the framework was assessed.

Keywords: Framework, Shop drawings, Submittal process, and Approval process.

1. INTRODUCTION

In construction projects, little thought is given to engineering submittals. However, these documents play a key role in construction projects; and if they are effectively produced and used, problems can be resolved when they are relatively easy and cheap to fix. For example, [1]showed that owner interference, inadequate contractor experience, financing and payments, labor productivity, slow decision making, improper planning, and sub-contractors are among the ten top most important factors causing delay in Jordan. This paper answers some of the basic questions regarding submittals and the approval process.

Variation orders resulting from design mistakes increase the project time and cost[2].

Design problems and errors are causes of cost and time overruns [3];[4] According to [5], design changes cause 78% of cost escalation. Selecting the right consultant minimizes design changes, improves design documentation, and reduces cost overrun and schedule delays.

The design change has a direct impact on the project cost and time[6]. Mistakes and poor design documents presented by designers create changes during construction, which cause cost overruns and schedule delays [7];~~[5]~~. Design errors and changes are major causes of reworks [9].

Poor processes and procedures are one of the main problems causing delays and cost overruns [10]. PM processes and procedures improve the use of resources[11]. A systematic approach reduces delays in construction[12] ;[13].

Submittals provide a deeper level of detail than what is offered in design documents and act as a final quality assurance check before materials and products are delivered to the construction site. The dimensions and installation information developed for the submittal also guide contractors during construction. [14]discovered that design errors, client liability, project specification, and direct change orders by the client are the major factors that cause the time and cost overrun in Portuguese construction projects.

Shop drawings are a set of drawings produced by contractors that contain description & details based on the design drawings and then issued to the site for execution after getting approval from the consultant. They are prepared by taking into consideration the principal design drawings and specifications developed by the project design teams.

Delay in approving shop drawings is considered one of the major causes that affect construction, and preparing such professional shop drawings reduces problems in construction projects. The primary goal of the paper is to identify and assess the major delay causes of the submittal/approval process to eliminate the root causes of delay for engineering shop drawings.[15] conducted a study on delay mitigation in the Malaysian construction industry; they proved that financial problem is confirmed by the survey as the main causes of delay. The paper focuses on the following outputs: Evaluate shop drawing problems in construction as a major delay cause. Also, to identify and assess the major causes for shop drawing submittal and approval problems in construction.

2.RESEARCH METHODOLOGY

Data collection refers to gathering specific information aimed at proving specific issues. Literature review and expert interviews were used to identify the major factors of submittal/ approval process. A questionnaire survey was conducted within forty-one companies in Egypt, and the outcomes were evaluated by utilizing statistical analyses.

The procedure of the interviews was organized to have set questions that allow identifying factors of delay causes. The factors gathered from the literature review were subjected to two main questions: “Do you think, from your expert view, this reason causes a delay in construction projects?” and “Are there any further causes you might like to add?”. During the interviews, some of the causes’ descriptions were slightly changed, eliminated, and merged.

A questionnaire was designed to include four sections. The first section contains general questions about the experience, types of projects implemented by the respondents, amount of delay they experienced in their projects. The second section of the questionnaire concentrated on causes of delay in construction projects. A list of twenty-four delay causes was developed and used for assessing and ranking the top delay causes, the twenty-four causes of delay were grouped according to responsibility (owner-related, contractor-related, and consultant-related) as shown in Table (1). Each cause of delay was assessed using five options: Very low contributing (1); Low contributing (2); Medium contributing (3); High contributing (4) and Very high contributing (5).

Identification of the causes of delay used in the questionnaire was developed through literature review of similar researches in other countries like (Saudi Arabia, Kenya, Denmark, Jordan, Malaysia, Ghana, U.S. state of Wisconsin and Korea)

The causes of delay were categorized using different classification on the past researches as material related, equipment related, labor related, external factors related, etc., however the identified causes in this paper were categorized into three categories; owner related, contractor related and consultant related.

TABLE 1. Causes of delay in construction projects

Category	No.	Causes of delay	References
Owner-related	1	Change orders by owner during construction	[16]
	2	Poor communication and coordination	[17]
	3	Delay in progress payments	[18]
	4	Slowness in decision making process	[16]
	5	Suspension of work by owner	Author suggestion
	6	Delay to furnish and deliver the site	[19]
	7	Conflicts between joint-ownership of the project	[20]
	8	Sudden stop of work	Author suggestion
Contractor-related	1	Poor qualifications of the contractor's technical staff	[21]
	2	Ineffective planning and scheduling of project	[22]
	3	Poor communication and coordination	[17]
	4	Delays in sub-contractors work	[23]
	5	Frequent change of sub-contractors	[24]
	6	Conflicts in sub-contractor's schedule in execution of project	[20]
	7	Conflicts between contractor and other parties	[20]
	8	Delay in preparing submittals	Author suggestion
	9	Rework due to errors	Author suggestion
Consultant-related	1	Delay in approving major changes in the scope of work	[18]
	2	Poor communication and coordination	[17]
	3	Delays in producing design documents	Author suggestion
	4	Unclear and inadequate details in drawing	[18]
	5	Mistakes and discrepancies in design documents	[17]
	6	Late in revising and approving submittals	Author suggestion
	7	Inadequate experience of consultant	Author suggestion

The following formulas have been used to determine the importance index, probability index, impact index, and severity index. [25].

The mean value of responses for importance "the importance index I" was calculated by the following formula:

$$I = \sum \frac{i}{N} \quad (1)$$

where:

i = Response importance weight (1,2,3,4,5).

N= Total number of delays.

The third section of the questionnaire concentrated on shop drawing factors of delay in construction projects. Forty-three shop drawing factors were grouped according to submitting and approving process; twenty-five related to factors delay of submittal shop drawings and eighteen factors related to delay of approval shop drawings as shown in Table (2), each factor was categorized as a responsibility of the owner, consultant, or the contractor in addition to that the probability assessed by respondents using three options: low (1); Medium (2) and High (3), while the impact was assessed by respondents using three options: low contributing (1); Medium contributing (2) and High contributing (3).

The mean value of responses for probability "the probability index P". And, the mean value of responses for impact "the impact index I" was calculated by the following formulas.

$$P = \sum \frac{p}{N} \qquad (2)$$

$$I = \sum \frac{i}{N} \qquad (3)$$

where

P = Response probability weight (1,2,3).

i = Response impact weight (1,2,3).

N= Number of Delays.

These indices were then used to rank the levels of probability and impact of occurrence for the delay factors stated in the document. Finally, the product of respective probability and impact responses was named "the severity index SI" and it was calculated using the following formula.

$$SI = \sum P \text{ x } \frac{i}{N} \qquad (4)$$

Severity indices were used to rank the overall severity of the shop drawings delay factors on construction projects, The greater the index, the more severe the delay factor. The index ranges from zero (lowest) when the problem is not applicable in the project (I =zero); to twelve (highest) when the factor is a high probability (p = 3) and with high impact (I = 3).

TABLE 2. Delay factors of submittal and approval process.

	No	Causes of delay	Responsibility			Probability			Impact		
			Owner	Cons.	Cont.	1	2	3	1	2	3
Submittal	1	Delays in producing design documents									
	2	Unclear or inadequate details in design drawings									
	3	Rework due to errors									
	4	Slowness in decision making process									
	5	Poor communication and coordination									
	6	Mistakes and discrepancies in design documents									
	7	Delays in sub-contractors work									
	8	Late in revising and approving design documents									
	9	Poor qualifications of technical staff									
	10	Suspension of work due to changes									
	11	Impact due to informal meetings with parties									
	12	Late in approving material samples									
	1 3	Staff changing									
	14	Ignorance of technology and updated programs									
	15	Unclear directions for submittal process									
	16	Outsourcing shop drawing works									

	No	Causes of delay	Responsibility			Probability			Impact		
			Owner	Cons.	Cont.	1	2	3	1	2	3
	17	Inadequate technical staff size									
	18	Ignorance of models to gather all the departments									
	19	Using documentation systems									
	20	Unclear specifications									
	21	Complexity of work									
	22	Coordination problems in design drawings									
	23	Lack of commitment by the time schedule									
	24	Unrealistic time schedule									
	25	Late in receive full design package									
Approval	1	Rework due to errors									
	2	Slowness in decision making process									
	3	Poor communication and coordination									
	4	Long reviewing time									
	5	Poor qualifications of technical staff									
	6	Suspension of work due to changes									
	7	Impact due to informal meetings with parties									
	8	Staff changing									
	9	Ignorance of technology and updated programs									
	10	Unclear directions for approval process									
	11	Out sourcing shop drawing works									
	12	Ignorance of models to gather all the departments									
	13	Using documentation systems									
	14	Unclear specifications									
	15	Complexity of work									
	16	Time schedule commitment									
	17	Unrealistic time schedule									
	18	Inadequate technical staff size									

The fourth section of the questionnaire concentrated on methods for minimizing submittals/approval delays. Twenty-four solutions for minimizing submittal and approval delays were identified as shown in Table (3). Each solution was assessed by respondents using five options: Very low contributing (1); Low contributing (2); Medium contributing (3); High contributing (4) and Very high contributing (5).

The same factors number (1, 2, 3, 4, 6, 20 and 23) were mentioned in previous researches[16], [19] and [20] as a solution for minimizing the delay of submittal and approval process.

TABLE 3. Factors for minimizing submittal and approval delays.

No.	Factors
1	Ensure receiving full design approved package at the right time
2	Develop clear details in design drawings
3	Develop clear specifications in design drawings
4	Coordinate specifications and details in design drawings
5	Avoid outsourcing shop drawing
6	Review all design package before preparing submittals
7	Avoid suspension of work from changes caused by owner
8	Avoid informal meetings with parties
9	Perform frequent progress meeting
10	Avoid staff changing
11	Use up-to-date technology utilization
12	Clear directions for submittal process
13	Use models to gather all departments
14	Using documentation systems
15	Time schedule commitment
16	Effective strategic planning
17	Clear information and communication skills
18	Frequent coordination between the parties involved
19	Proper emphasis on past experience
20	Collaborative working
21	Use structure steel program for shop drawing steel bars
22	Select the qualifications of the technical staff
23	Long reviewing and approving submittal process
24	Using of framework

The sample size has been determined using the following formula [26]

$$no = Z^2 * P\frac{(1-P)}{d2} \quad (5)$$

$$n = no \bigg/ \frac{1+(no-1)}{N} \quad (6)$$

where:

no = sample size for unlimited population

Z = statistic for a level of confidence (Z= 1.64 for 90% confidence level)

P = expected prevalence or proportion, or degree of variance between element population (20% P =0.2)

d = precision (90% confidence; 10% error d=0.1)

n = sample size of limited population

N = population (1000)

Sample size of limited population calculated from equation (5,6) was equal to 43 respondents. The sample size was calculated to represent all types of project participants related (owner, consultant and contractor) to be equal 129 respondents.

The questionnaire was distributed to 143 engineers, which was approximately 10% more than the sample size calculated; 30 owners, 40 consultants and, 73 contractors. Not all the engineers replied to the questionnaire as there is only 16 owners replied, 25 consultants, and 41 contractors ~~at~~ during the period from October 2020 to September 2021.

3. Results and Discussion.

The overall response to the survey comprised a total of 82 completed questionnaire representing circa 60% response rate.

The first section includes some general information about the respondents as the percentage of respondents' years of experience as shown in Figure (1).

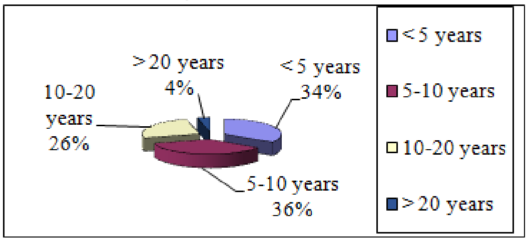

FIG 1: Years of Experience

Also, the percentage of respondents in each project type ~~as~~ is shown in Figure (2).

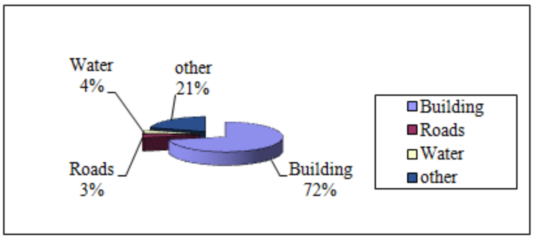

FIG 2: Respondents in each project type.

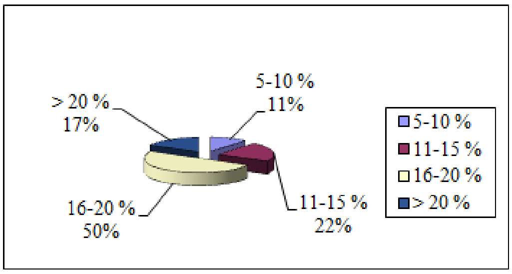

FIG 3. Respondents faced percentage delays.

Average percentage of respondents faced delay percentage from estimated project duration, it represents the percentage of overall delays with respect to the original project durations as shown in Figure (3).

The figure shows that 11% of the respondents faced from 5 to 10 % delay in their projects' completion, 22 % of the respondents faced from 11 to 15 % delay in their projects' completion, 17 % of the respondents faced more than 17 % delay in their projects' completion and 50 % of the respondents faced from 16 to 20 % delay in their projects' completion.

The second section discusses the data collected from the questionnaire responses regarding the importance of the delay causes based on the responses. Moreover, two ways of ranking are used; all causes rank, and main groups rank. The analysis and discussion of ranking focuses directly on the importance of causes. The delay causes were grouped into three main categories, and were analyzed based on the average importance index of each cause. The importance index was calculated based on respondent answers for each cause as shown in Table (4). After obtaining these indices, the problems were ranked individually and as groups according to their relative importance as shown in Table (4).

TABLE 4. Ranking of construction problems according to their relative importance.

Related to	Delay Causes	Importance Index	Rank	Average Importance Index	Group Ranking
Owner	Change orders by the owner during construction	2.785	3	2.080	3
	Poor communication and coordination	2.285	15		
	Delay in progress payments	2.535	7		
	slowness in decision making process	2.285	15		
	suspension of work by the owner	1.464	24		
	Delay to furnish and deliver the site	1.892	21		
	conflicts between joint-ownership of the project	1.535	23		
	Sudden stop of work	1.857	22		
Contractor	Poor qualifications of the contractor's technical staff	2.571	6	2.623	1
	Delay in preparing submittals	2.535	7		
	Rework due to errors	2.535	7		
	Poor communication and coordination	2.607	5		
	Conflicts between contractor and other parties	2.285	15		
	Delay in sub-contractor works	2.642	4		
	Frequent change of sub-contractors	2.428	10		
	Conflicts in sub-contractors' schedule in execution of project	2.928	2		
	Ineffective planning and scheduling of project	3.071	1		

Related to	Delay Causes	Importance Index	Rank	Average Importance Index	Group Ranking
Consultant	Delay in approving major changes in the scope of work	2.392	12	2.250	2
	late in revising and approving submittals	2.357	14		
	Poor communication and coordination	2.071	19		
	inadequate experience of consultant	1.964	20		
	Delays in producing design documents	2.142	18		
	unclear and inadequate details in drawing	2.392	12		
	Mistakes and discrepancies in design documents	2.428	10		

The results of the second section indicated that the top ten causes leading to construction project delays as shown in Table (4) were: Ineffective planning and scheduling of project with importance index 3.071 from a scale 0 to 4, followed by Conflicts in sub-contractors schedule in execution of project which was ranked second delay cause with importance index 2.928, Change orders by owner during construction was ranked third with importance index 2.785, followed by Delay in sub-contractor works with importance index 2.642, Poor communication and coordination was ranked fifth with importance index 2.607, followed by Poor qualifications of contractor technical staff with importance index 2.571, Delay in preparing submittals, Rework due to errors and Delay in progress payments also ranked from the top ten problems, as all were ranked seventh with importance index 2.535, also Mistakes and discrepancies in design documents, and Frequent change of sub-contractors both were ranked with importance index 2.428.

The third section discusses the data collected from the questionnaire responses regarding the probability and impact of the submittals and approval delay factors based on the responses. Based on the respondents' answers, the probability indexes P and the impact index I were calculated for each factor. After calculating these indices, the delay factors were ranked according to their relative probability and impact.

The results indicate that the top ten delay factors affecting submittal shop drawing in construction projects as shown in Figure (4) were: Rework due to errors, Suspension of work due to changes, Delays in sub-contractors' work, Delays in producing design documents, Coordination problems in design drawings, Late in receiving full design package, Lack of commitment by the schedule, Unclear or inadequate details in design drawings, Late in approving material samples, Slowness in decision-making process, Poor communication and coordination and Unclear specifications. Rework due to errors probability index 1.384, followed by Suspension of work due to changes which were ranked second important problem with probability index 1.346. Delays in sub-contractors' work were ranked third with a probability index of 1.3076.

Delays in producing design documents, coordination problems in design drawings, late in receiving the full design package and lack of commitment to the time schedule also ranked among the top ten problems, as all were ranked the fourth important problem with a probability index of 1.269, followed by unclear or inadequate details in design drawings and Late in approving material samples both ranked eighth with importance index 1.230. Three problems with an equal probability index of 1.115 were ranked tenth; these problems are slowness in decision-making process, Poor communication and coordination, and unclear specifications.

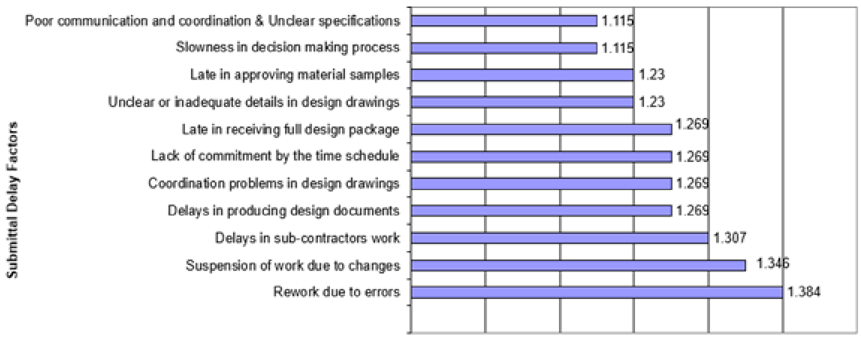

FIG 4. Top ten submittal delay factors according to the probability of occurrence

It is obvious that the top-ranked factors according to relative probability have a minor difference in their probability index as shown in Figure (4), which submit the need to calculate the impact index to assess the severity of the factors correctly. Figure (5) shows the top ten ranking factors which range from 1.592 to 1.370.

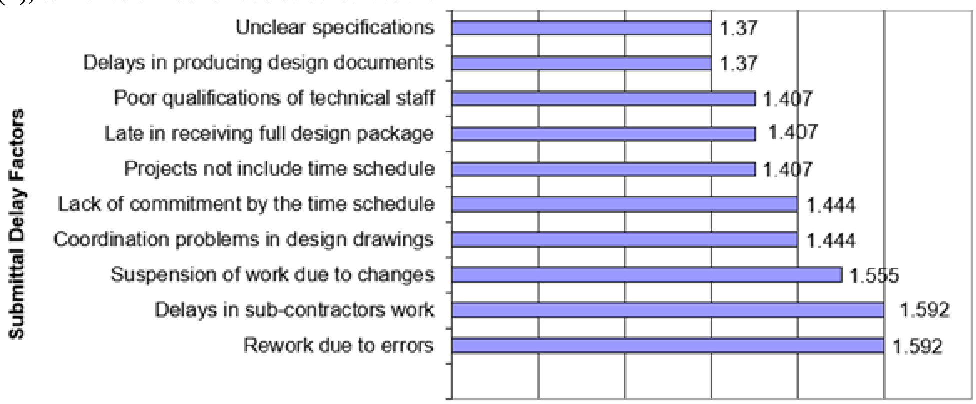

FIG 5: Top ten submittal delay factors according to impact.

TABLE 5. Severity index of submittal shop drawing delay factors.

Submittal Delay Factors	Severity Index	Rank
Delays in producing design documents	5.192	7
Unclear or inadequate details in design drawings	4.846	11
Rework due to errors	6.115	1
Slowness in decision making process	5.038	10
Poor communication and coordination	4.846	11
Mistakes and discrepancies in design documents	4.500	14
Delays in sub-contractors work	5.884	3
Late in revising and approving design documents	4.461	15
Poor qualifications of technical staff	5.192	7
Suspension of work due to changes	6.038	2
Impact due to informal meetings with parties	3.538	22
Late in approving material samples	5.115	9
Staff changing	4.307	17
Useless of technology and updated programs	3.692	21
Unclear directions for submittal process	3.269	23
Out sourcing Shop drawing works	4.384	16
Inadequate technical staff size	4.500	14

Submittal Delay Factors	Severity Index	Rank
Useless of models to gather all the departments	3.923	20
Using documentation systems	4.038	19
Unclear specifications	5.038	10
Complexity of work	4.269	18
Coordination problems in design drawings	5.615	4
Lack of commitment by the time schedule	5.461	6
Projects not include time schedule	4.730	13
Late in receiving full design package	5.538	5

After calculating the probability index P and impact index I of each factor, the severity index SI was calculated and factors were ranked according to their severity index as shown in Table (5).

The results indicate that the top ten delay factors affecting the approval process in construction projects were: Suspension of work due to changes, Staff changing, Schedule commitment, Projects not including time schedule, Long reviewing time, Useless of models to gather all the departments, Complexity of work, Inadequate technical staff size, Rework due to errors, Unclear specification. four problems with highest the probability index equals 1.185, these problems are Suspension of work due to changes, Staff turnover, Schedule commitment, and Projects not including time schedule. followed by another four problems also ranked among the top ten problems with a probability index of 1.148, these problems are: Long review time, Useless models to gather all the departments, Complexity of work, and Inadequate technical staff size. Rework due to errors and Unclear specifications with a probability of index 1.111 also ranked among the top ten problems as shown in Figure (6).

It is obvious that the top-ranked factors according to relative approval probability have minor difference in their probability index as shown in Figure (6), which submit the need to calculate the impact index to assess the severity of the problems correctly as shown in Figure (7) that shows the top ten ranking factors which range from 1.444 to 1.259.

After calculating the probability index P and impact index I of each problem, the severity index SI was calculated and factors were ranked according to their severity index as shown in Table (6).

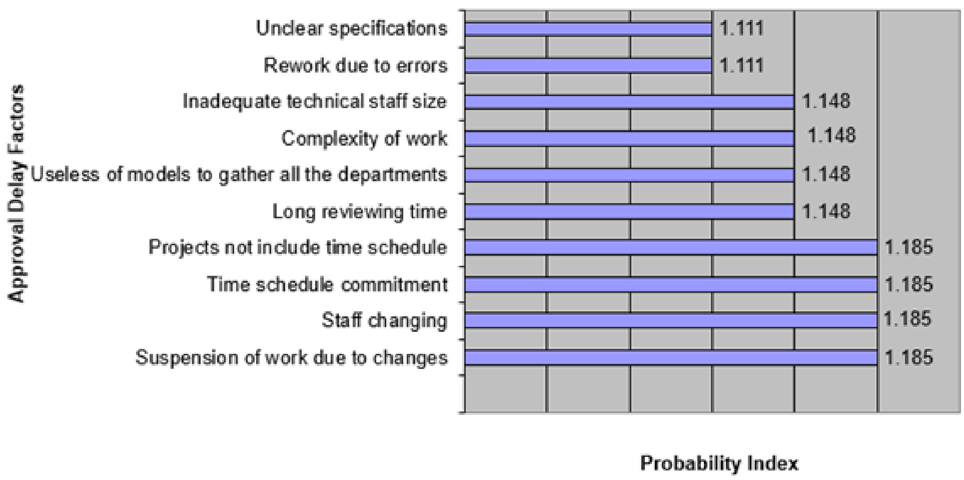

FIG 6. Top ten approval delay factors according to the probability of occurrence.

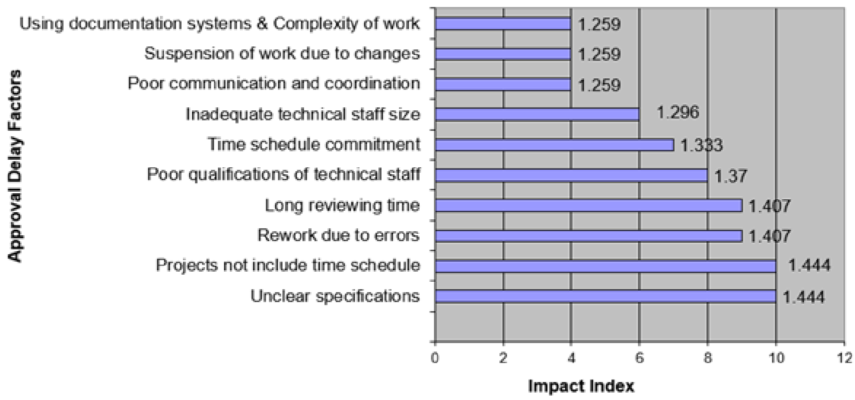

FIG 7. Top ten approval delay factors according to impact.

TABLE 6. Severity index of approval shop drawing delay Factors.

Approval Delay Factors	Severity Index	Rank
Rework due to errors	5.192308	5
Slowness in decision making process	4.307692	14
Poor communication and coordination	4.807692	11
Long reviewing time	5.461538	2
Poor qualifications of technical staff	5.115385	7
Suspension of work due to changes	5	8
Impact due to informal meetings with parties	3.923077	15
Staff changing	4.807692	11
Useless of technology and updated programs	3.576923	17
Unclear directions for approval process	3.923077	15
Out sourcing Shop drawing works	4.653846	13
Useless of models to gather all the departments	4.730769	12
Using documentation systems	4.884615	9
Unclear specifications	5.230769	4
Complexity of work	4.846154	10
Time schedule commitment	5.461538	2
Projects not include time schedule	5.576923	1
Inadequate technical staff size	5.153846	6

TABLE 7. Factors for minimizing submittals/approval delays.

Factors	Importance Index	Rank
Ensure receiving full design approved package at the right time	3.07407403	4
Developing clear details in design drawings	2.888888836	9
Developing clear specifications in design drawings	2.962962866	8
Coordination between specifications and details in design drawings	3.111111164	3
Avoid outsourcing shop drawing	2.777777672	14
Review all design package before preparing submittals	2.85185194	12

Factors	Importance Index	Rank
Avoid suspension of work from changes caused by owner	2.888888836	9
Avoid informal meetings with parties	2.518518448	22
Perform frequent progress meeting	2.777777672	14
Avoid staff changing	2.740740776	16
Use up-to-date technology utilization	2.555555582	20
Clear directions for submittal process	2.555555582	20
Use models to gather all departments	2.444444418	23
Using documentation systems	2.888888836	9
Time schedule commitment	3.185185194	1
Effective strategic planning	3.07407403	4
Clear information and communication skills	2.740740776	16
Frequent coordination between the parties involved	3.07407403	4
Proper emphasis on past experience	2.629629612	19
Collaborative working	3	7
Use structure steel program for shop drawing steel bars	2.444444418	23
good qualifications of the technical staff	3.14814806	2
Long reviewing and approving submittal process	2.740740776	16
Using of framework	2.814814806	13

The fourth section represents and discusses the data collected from the questionnaire responses regarding the importance of the solutions based on the responses. Table (7) shows the factors ranked based on importance are provided. The respondents were asked to assess the importance of each solution from the 24-solution included in the questionnaire minimizing submittals/approval delays in their sites. Based on respondents' answers, the importance index I was calculated for each solution. After calculating these indices, the solutions were ranked according to their relative importance.

The results indicate that the top ten important methods for minimizing submittals/approval delays in construction projects as shown in Table 7 were: Schedule commitment with the importance index of 3.185 on a scale of 0 to 4, followed by good qualifications of the technical staff which was ranked the second factor with importance index 3.148, Coordination between specifications and details in design drawings was ranked third with importance index 3.111. Three factors also ranked among the top ten factors with an importance index of 3.074, these factors are: Ensuring receiving full design approved package at the right time, Effective strategic planning, and Frequent coordination between the parties involved, followed by Collaborative working ranked seventh with an importance index of 3. Developing clear specifications in design drawings was ranked eighth with an importance of index 2.962, followed by Developing clear details in design drawings, avoid suspension of work from changes caused by the owner, and Using documentation systems all with an importance index of 2.888.

In order to evaluate the correlation between the items, the correlation between the factors and the delays was calculated by the Pearson product moment correlation coefficient using the following formula [27]
and Positive values indicate associations between items, in view that a strong correlation (>0.7) shows strong association.

$$r = \frac{N\sum XY - (\Sigma X)(\Sigma Y)}{\sqrt{\{N\sum X^2 - (\Sigma X)^2\}\{N\sum Y^2 - (\Sigma Y)^2\}}} \quad (7)$$

where:

r = Pearson’s Product Moment Correlation Coefficient.

N = Number of pairs of values.

$\sum XY$ = Sum of the products of X and Y.

$\sum X$ = Sum of the X values.

$\sum Y$ = Sum of the Y values.
$\sum X^2$ = Sum of squares ofX values.
$\sum Y^2$ = Sum of squares of Y values.
$(\sum X)^2$ = Square of the sum of X values.
$(\sum Y)^2$ = Square of the sum of Y values.

Table (8) shows the importance index of the factors and the importance index of the delays that used to calculate the Pearson product moment correlation coefficient.

TABLE 8. Correlation between the factors and the delays.

Number of values	Importance Index of factors (X)	Importance Index of delay causes (Y)
1	3.07407403	2.785
2	2.888888836	2.285
3	2.962962866	2.535
4	3.111111164	2.285
5	2.777777672	1.464
6	2.85185194	1.892
7	2.888888836	1.535
8	2.518518448	1.857
9	2.777777672	2.571
10	2.740740776	2.535
11	2.555555582	2.535
12	2.555555582	2.607
13	2.444444418	2.285
14	2.888888836	2.642
15	3.185185194	2.428
16	3.07407403	2.928
17	2.740740776	3.071
18	3.07407403	2.392
19	2.629629612	2.357
20	3	2.071
21	2.444444418	1.964
22	3.14814806	2.142
23	2.740740776	2.392
24	2.814814806	2.428

After calculating the correlation between the factors and the delays, the Pearson product moment correlation coefficient (r = 0.76) which shows strong association.

4. Framework

A framework is a set of rules, ideas, or beliefs which is used to deal with problems or to decide what to do. In general, a framework represents a set of ideas or facts that provide support for a process. In the case of construction problems, a framework creates the basic structure that gives focus and support to solve the problem. A good framework makes the process much easier and must also assist in significantly minimizing the time it takes to be completed.

This paper aims to develop a framework for solving the problems that results in delaying the submittal/approval process.

The framework developed consists of three sequential phases. Design / Coordination Review, Shop Drawing Preparation/Submission Process, and Shop Drawing Reviewing/Approval Process.

According to the questionnaire done to assess the causes of delay for shop drawing submittal/approval process in construction projects, the results showed that the design/coordination review process is the phase that affects the most the submittal /approval process followed by the preparation/submission Process and the reviewing/approval Process comes latest.

The efficiency and the accuracy of design drawings affect the submittals process. as there are conflicts or unclear information, while submittals preparation will take more time to repeat all these steps which results in delaying the construction project. In addition to the review and approval which will results in not approving if there are conflicts or missing in the submissions.

The overall aim of the framework will be achieved in each phase through a series of sequential activities:

4.1Design/coordination review phase:

The design/coordination phase is a simple visual structure that helps organize the information and ideas of a problem so you can work on it more effectively, the framework for the design/coordination phase can be summarized as: review the selected design proposal, coordinate design information among disciplines, prepare drawings and specifications, re-coordinate design information among disciplines, develop the detailed design drawings, develop the detailed specifications and re- coordinate for the last time the design information among disciplines as shown in Figure (8).

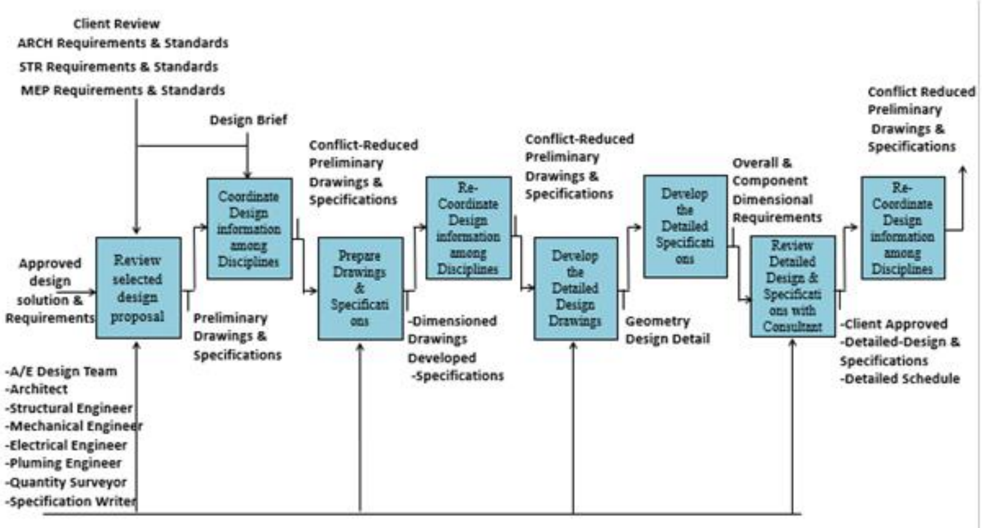

FIG 8. Design/Coordination Review Phase Framework

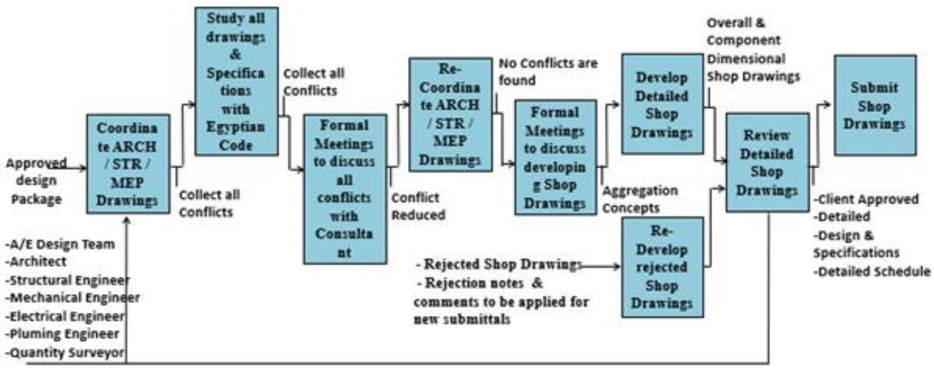

FIG 9. Shop Drawing Preparation/Submission Phase Framework.

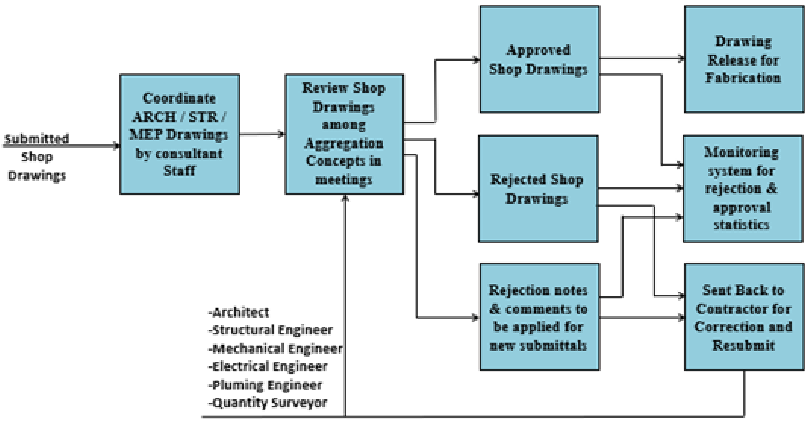

FIG 10. Shop Drawing Reviewing/Approval Phase

4.2 Shop Drawings preparation/submission process:

While the overall process related to the preparation and submission of shop drawings by contractors should be dealt with contractually prior to the start of a project.

There are a lot of problems that faces the contractor according to the preparation process of shop drawing, for example, structural components are not located in a plan or an elevation, details are not complete or specific to the project, and design drawings and specifications are in conflict and structural drawings are not thoroughly coordinated with architectural or mechanical drawings.

Prior to shop drawings submission to the consultant, it is recommended that the contractor review and approve all shop drawings. The intent is that by this review and approval, the contractor represents that it has determined and verified all field measurements, field construction criteria, materials, catalogue numbers and similar data, and that it has was checked and coordinated each shop drawing with the requirements of the work and the contract documents. It is recommended that the contractor indicate its review and approval by including the date and the signature of a responsible person on each shop drawing.

The framework for the preparation/submission phase can be summarized as: coordinate architectural with structural and MEP drawings, study all drawings and specifications with the codes, formal meetings to discuss all conflicts with the consultant, re-coordinate architectural with structural and MEP drawings, review the detailed shop drawings, formal meetings to discuss developing of the shop drawings, develop detailed shop drawings, and finally submit the shop drawings as shown in Figure (9).

4.3 Shop drawing reviewing/approval process:

It is the consultant's responsibility to review the Shop Detail Drawings to ensure that the contractor has correctly interpreted the intent of the Contract documents and that details properly reflect material and connection requirements.

The consultant will forward the shop drawings to the appropriate members of the technical consultant team for review. In performing the review, the consultant will only review for conformity to the design concept and for general arrangement. Unless a deviation on the shop drawings has been previously approved in writing by the consultant, such a review by the consultant does not relieve the contractor from its responsibility for any errors or omissions in the shop drawings or from its responsibility for meeting all the requirements contained in the contract documents.

The consultant must confirm the reviewed shop drawings e.g., using a stamp that confirms the shop drawings have been reviewed. The shop drawing review stamp should include appropriate wording to indicate the nature of the review, and that the shop drawings were reviewed for general conformance only to the design concept and general arrangement.

Where variations from the design intent are identified during the review of shop drawings they must be documented and followed up.

The framework for the shop Drawing reviewing/approval process phase can be summarized as: coordinate architectural with structural and MEP drawings, review shop drawings among aggregation concepts in meetings, for approved shop drawings and the drawings released for fabrication, for rejected shop drawings the rejection notes and comments, a monitoring system for rejection and approval statistics and finally send back to the contractor for correction and re-submit as shown in Figure (10).

5. Verification Case Study

The case study presented in the paper is a phase of 300 acres in a residential compound located in 6th October city. It is divided into several development parcels, (V1, V2 & V3) villa parcels consisting of 1065 units. (A1, A2, A3 & A4) Apartment parcels consist of 39 blocks each block containing 3 buildings, 41 parks each park containing 1 building and 12 complexes where the complex consists of 3 parks having the same basement.

The case study was limited to shop drawings of structural elements only where the set of data was provided by the consultant and the contractors during the Case Study. After a first contact was established with the consultant, its managers showed interest in participating in research in which the submittal process could be studied.

The start of implementation in the project coincided with the time the project was being built (after starting execution by 6 months). It took three months to collect all the required data and find out solutions for the problems and another three months for verifying the framework of the case study and find out the results.

Shop drawing traditional process in the project started after the design drawings are completed, the technical team of the contractor starts to review and coordinate all the design drawings before preparing the Shop drawings to solve any clashes or conflicts, at this stage the review sessions take a long time. Also, the client change orders consumes time. Too many meetings were held to solve all these problems where some issues cannot be resolved on spot then preparing the shop drawings submittals takes place where the paper-based submission takes a long time to be printed. Then the technical team of the consultant starts to the review and approval stage which takes long time in addition to the design changes that occur after approval. As shown in Figure (11):

The following table represents the summary sheet for the status of the submittal and approval process of apartment parcels (A1, A2):

The number of approved drawings is 3052 drawings, 355 only of them approved from the first submission, 1553 drawings approved from the first revision, 764 drawings approved from the second revision, and 380 drawings approved from the third revision. As shown in Figure 12 and Figure 13.

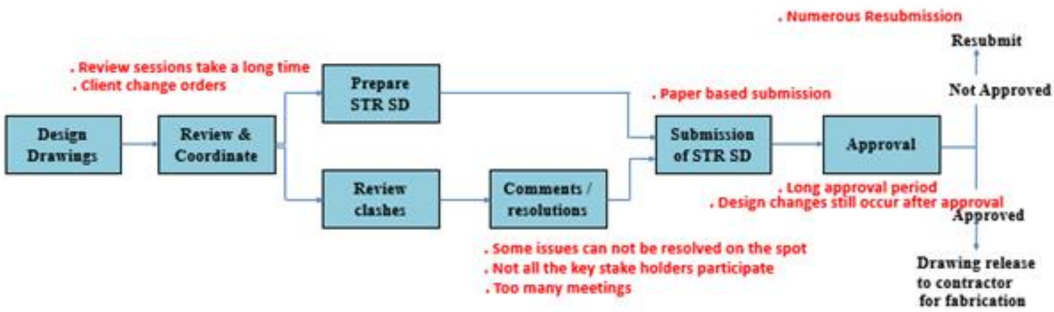

FIG 11. Shop drawing traditional process.

Action code	**A**	**B**	**C**	**D**	**Under review**	**Not submitted yet**	**Total**
Number of drawings	525	2527	4002	189	255	4333	11831

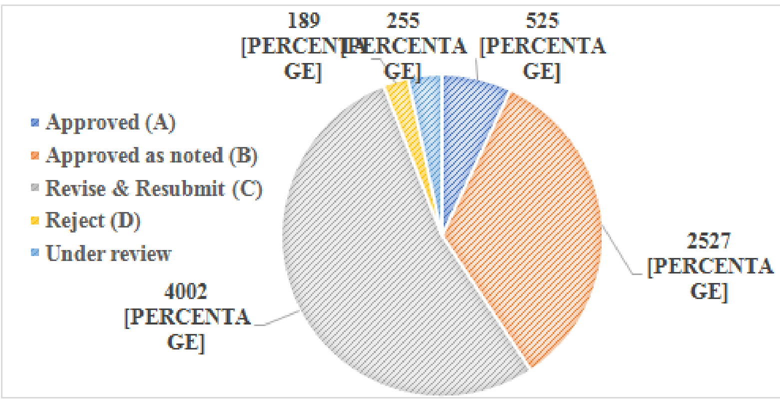

Fig 12: Shop drawings progress status.

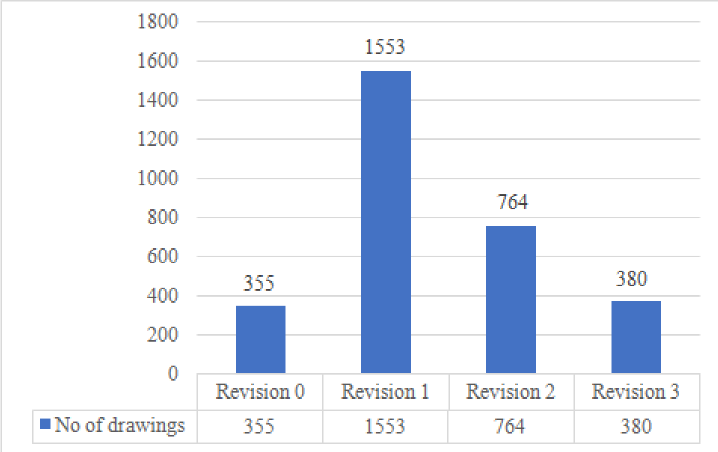

FIG 13. Shop drawings revision status.

After the kickoff of meetings with technical department engineers of the contractors & the consultant and studying the project, it was found that most of the structure shop drawings took code C for revising and resubmit because of technical reasons, engineering reasons and, management reasons.

The following table shows the results after the implementation of the framework, the status of the Submittal and approval process of apartment parcels (A1, A2):

The number of approved drawings is 5408 drawings, 3350 of them approved from the first time, 1850 drawings approved from the first revision, and 208 drawings approved from the second revision. As shown in Figure 14 and Figure 15.

It is obvious that the percentage of the delayed drawings compared to the total number of the project drawings was reduced from 74% to 54% after the implementation of the framework.

The percentage of the drawings took code C was reduced from 34% to 25%, the percentage of the drawings took code D was the same, the percentage of the under-review drawings reduced from 2% to 1% and the finally the percentage of the not submitting drawings reduced from 37% to 27%.

Action code	**A**	**B**	**C**	**D**	**Under review**	**Not submitted yet**	**Total**
Number of drawings	525	4883	3002	189	99	3133	11831

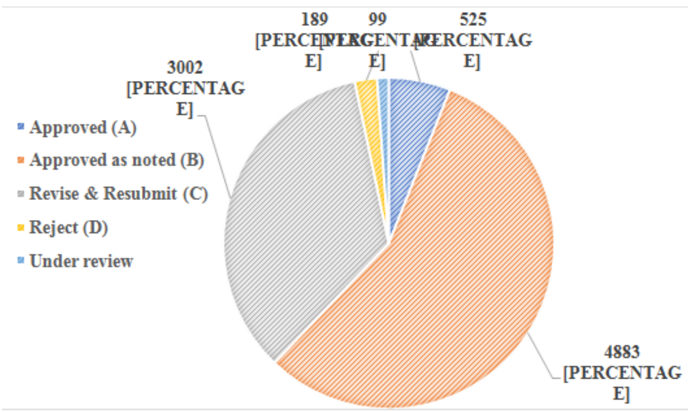

FIG 14. Shop drawings progress status.

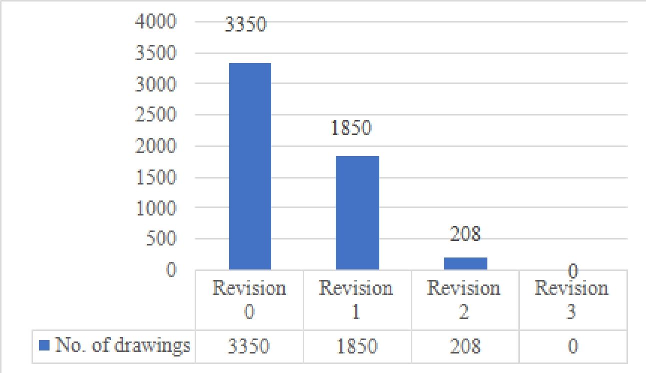

FIG 15. Shop drawings revision status.

6. Conclusions

Since this paper aimed to identify the causes of delays in the submittal/approval process, in addition to sorting and assessing the factors leading to such delays then survey the shop submittal/approval drawings problems in construction projects from different stakeholders' points of view, searching for solutions for the problems, developing a framework and implementation of the framework on a case study. It is clear that the construction projects suffer from an excessive delay due to the delay of engineering shop drawings prosses. As discussed previously the most common factor related to the engineering shop drawings prosses leading to project delay were: rework due to errors, delay in preparing submittals, poor qualifications of contractor technical staff, and poor communication and coordination.

The research showed that the common factors related to the submittal/approval process were: reworked due to errors, suspension of work due to changes, delays in sub-contractor's work, coordination problems in design drawings, and Unrealistic schedule.

Proposed solutions and procedures were conducted in a framework for solving and avoiding these main problems. Such framework was presented, summarizing all conducted and proposed solutions for the shop drawings prosses. The framework was presented in three phases; design/coordination review, shop drawing preparation/submission and reviewing/approval phase.

Implementation of the proposed framework showed as discussed previously with the results of the case study that the number of rejected shop drawings decreased which effectively impact the time and the cost of the project.

Developing a new framework through different stages leads to enhancement in time and decreases in the percentage of the rejected submissions, and decreases number of submittal revisions, that justifies the need for applying such procedures in order to minimize the problem.

Future researches can focus on the problems related to other engineering phases from the start of the project such as: design, maintenance, and closeout.

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