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# Factors Affecting Upstream Production Rate and Causing Reworks in Downstream Activities due to Activities Overlapping

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**Abstract** Overlapping (or fast tracking) is a schedule compression technique in which phases or activities normally performed in sequence are performed in parallel, PMI, [1]. Rework has both direct and indirect effects on the performance of construction projects. The direct effect of the impact of rework are: additional time for rework, additional costs of rework, additional materials spent on rework and control next waste, additional labor for rework, difficulty of managing resources. To reduce the impact of reworks there is a need to understand their basic reason for their existence or set of conditions that stimulate their occurrence in a building process. This paper aims to identify the top important changes that affecting upstream production rate and causing reworks in downstream activities. These changes were identified through three stages. The first stage twenty three changes which causing reworks in downstream activities were collected from past literature review and were divided into three major categories: designer, contractor and owner changes. One hundred effective interviews were conducted and their results are employed. The second stage, the twenty three changes were then ranked from the most significant to the less significant. The third stage, the 80/20 rule applied to the changes identified to get the eight most important changes that represented about 25% of the causes. The result shows the top important eight factors which were considered as the factors affecting upstream production rate and causing reworks in downstream activities as follows: 1) Lack of coordination and poor communication, 2) The contractor instruction to modify a design, 3) Non-compliance with specification, 4) The owner instruction to modify a design, 5) Incomplete design at the time of tender, 6) Poor planning and coordination of resources, 7) Errors made in the contract documentation and 8) Lack of experience and knowledge of the design and construction process.

***Keywords:*** *fast tracking, activities' overlapping, rework time, construction schedule*

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## 1. Introduction

Rework in construction projects is defined as Activities in the field that have to be done more than once in the field, or activities which remove work previously installed as part of the project regardless of source, where no change order has been issued and no change of scope has been identified by the owner, Jason and James, [2].

Construction project time overrun is defined as an addition of time further than the agreed contractual time at the tender stage. Rework can lead to a considerable addition of a project's time and cost overrun, especially during the construction stage. The effect of delays or time overruns for the contractor included increased costs, reduced profit margin and battered reputation, Eze and Idiake [3]. Resource-constrained project scheduling is the process of constructing a project schedule within the limited amount of resources available. It requires the examination of the possible unbalanced use of resources over time to resolve over-allocations (the so-called resource conflicts) when more resources are required than available. When more resources such as machines or people are needed than there are available, these activities will have to be rescheduled concurrently or even sequentially to resolve the resource constraints. Hence the resource constrained project scheduling is the process of resolving these resource conflicts under different scheduling objectives, Vanhoucke, [4]. Abeku et al., [5] mentioned that the factors that causing rework during construction are poor management and employee training, low skill level of sub-contractors, lack of supervision and on-site inspection damage due to carelessness, poor planning and co-ordination of site resources and poor workmanship and use of materials. The accuracy of the drawings, the number of design errors, omissions and ambiguities within the plans and specifications that affect

the quality of the facility are identified according to Musa and Obaju [6]. Dosumu et al. [7] concluded that errors in contract documents are frequently caused by clients' change of design and specifications, lack of adequate time to prepare contract documents use of inexperienced designers to prepare contract documents, oversight, negligence and laziness. Fast tracking can result in rework and increased risk. This approach can require work to be performed without completed detailed information, such as engineering drawings. It results in trading cost for time, and increases the risk of achieving the shortened project schedule, PMBOK [1]. Sen et al., [8] concluded that the lack of experience and knowledge of design and construction process, poor quality of construction technique and poor used of advanced engineering are more responsible for rework in construction process. Enshassi et al., [9] indicated that the most important rework causes that have a significant impact on project performance are: attempt to fraud, competitive pressure, ineffective management, schedule pressure, and the absence of job security.

A summary of a huge number of different scheduling objectives and the studies of modeling construction schedule was developed and reproduced in Table 1. These factors which gathered are forty one which affecting the construction schedule. The effects of rework include: Lost of profit by the contractor, extra project cost to the client, schedule delay, reduced project performance and changed project outlook Love et al., [10].

**Table 1. A summary of factors affecting construction schedule according to different authors**

| Authors | year | Factors Affecting Construction Schedule | No. of Factors |
|---|---|---|---|
| **Jing Liu and Ming Lu, [11]** | **2018** | **1)** Crew Limits, **2)**Technical Precedence Relationships, **3)**Predefined Deadline, **4)** Multiple Activity Modes, **5)** Material Logistics,**6)** Material Inventory and Material Supply **7)** Crew Availability, **8)** Material Demand of Each Activity and **9)** Crew Resource Demand of Each Activity. | **9** |
| **Razavi Alavi and Abou Rizk, [12]** | **2017** | **Site layout planning has an effect on construction schedules: 1)** Costs for Mobilization and Demobilization of Facilities, **2)**Transportation Cost of material, workers and Equipment and **3)** Rent Cost of off-Site Storage | **3** |
| **Arashpour et al., [13]** | **2015** | **Cash Constraints: 1)** Direct Capacity Balancing, **2)** Partial Skill Chaining, **3)** Closed Skill Chains, **4)** Hybrid Cross-Training, and **5)** Full Cross-Training. | **5** |
| **El-Abbasy, [14]** | **2015** | **Finance-based scheduling: 1)** Interest Rate, **2)** Credit Limits, **3)** Establishing Bank Overdrafts. **Cash Flow**: **1)** Project Direct Cost Disbursement, **2)** Expenses of Overheads, **3)** Taxes, **4)** Mobilization, and **5)** Bond at Period. **Ressource: 1)** The Total Amount of Resources, **2)**Total Daily Resource Fluctuations, **3)** Maximum Resource Demand Dring The Entire Project Duration and **4)** The Total Number of Idle and Nonproductive Resource Days. | **12** |
| **Pakgohar, [15]** | **2014** | **Single Project Scheduling: 1)** Single Mode or Multi-Mode, **2)** Multiple Renewable Resource and (Multiple) Non-Renewable Resource, **3)** Precedence Relations, **4)** Precedence Constraints | **4** |
| **Chen and Weng, [16]** | **2009** | A project Consists of a set of interrelated activities. **Each activity**: **1)** Execution Modes, **2)** Activity Duration, **3)** Activity Cost, 4) Precedence Relationship, 5) Resource Requirements, **6)** Overlap, **7)** Interruption, **8)** State of The Activity. | **8** |
| **Total Factors Affecting Construction Schedule** | | | **41** |

## 2. Problem Statement

Starting a downstream activity based on unfinished information introduces the risk of rework in the downstream work should there be a change in upstream information. The information exchanged is also associated with a level of uncertainty depending on the type of the upstream activity in question. Future upstream information modifications require rework in the downstream activity to address the changes of the initial information based on which the downstream has started. The resulting rework usually consumes resources (e.g. time and money) and is disruptive to the flow of the downstream work.

## 3. Objectives

The objectives of this research are outlined as follows:

1. Identifying the different factors affecting Upstream Production Rate and Causing Reworks in Downstream Activities
2. Ranking these factors according to their relative importance to find out the most important factors.
3. Develop practical recommendations and guidelines to time reworks effect in downstream activities.

## 4. Research Methodology

The following sections present the research steps to achieve the objectives. An exploratory survey was carried out to identify factors affecting upstream production rate and causing reworks in downstream activities.

1. The different causes of changes affecting upstream production rate and causing reworks in downstream activities were gathered through a comprehensive literature review.
2. A questionnaire survey was conducted to identify the most important factors of those causing reworks in downstream activities depending on overlapping degree.

## 5. Questionnaire Survey

In this survey, thirty nine (39) factors affecting upstream production rate and causing reworks in downstream activities as shown in Table 2. Then, a brainstorming session was conducted to reduce the number of these factors and get the most important factors and remove the repeted factors. Three main categories (designer, owner and contractor factors) as shown in Table 3, the selected twenty three (23) factors were ranked according to their relative importance to find out the most important factors

of causing factors affecting upstream production rate and causing reworks in downstream activities.

**Table 2. Summary of Changes Arising in Upstream Activities and Causing Reworks in Downstream Activities According to Different authors, Soliman [17]**

| Authors | year | Changes arising in upstream activities and causing rework in downstream activity | No. of Factors |
|---|---|---|---|
| **Aman Sen,et al., [18]** | **2019** | 1) Lack of experience and knowledge of design and construction process, 2)Poor quality of construction technique, 3)Poor use of advanced engineering, 4) Adverse natural condition, 5) Lack of use of advanced mechanical equipment's. | **5** |
| **Enshassi et al., [9]** | **2017** | 1) Competitive pressure / low contract value, 2)Ineffective management and decision-making, 3) Schedule pressures, 4)The absence of job security, 5) Competitive pressure / low contract value, 6) An insufficient skill level, 7) Emergency conditions, 8) Poor quality system, 9)Disturbances in personnel planning and 10) Adulterated Materials | **10** |
| **Wakefield et al., [19]** | **2014** | 1) Contractor Field Management, 2) external environment, 3) contract management, 4) subcontractor management, 5) design management, 6) project communication management, 7) project plan changes, 8) changes for quality improvement 9) project scope management, 10) client management and 11) project process management | **11** |
| **Love and Li, [10]** | **2000** | 1) Errors, 2) Omissions, 3) Failures, 4) Damage and 5) Change Orders. | **5** |
| **Mohammad and Majid, [20]** | **2019** | 1) Improper handling of material and delivery, 2) Unclear project management process, 3) Poor sub-contractor management, 4) Poor design constructability or misunderstanding of the design, 5) Precedence Constraints, 6) The need to categorize the complicated operations , 7) Lack of standard method statements, 8) Poor clear contracting with sub-contractors and executive staff. | **8** |
| **Total Factors Affecting Construction Schedule** | | | **39** |

**Table 3. The (23) Changes Arising in Upstream Activities and Causing Reworks in Downstream Activities and its Category, Soliman [17]**

| Change No. | Changes of Predecessor Activities that Causing Reworks in Downstream Activities Due to Period Overlapping | Changes Category |
|---|---|---|
| **F1** | Incomplete Design at the time of tender. | Designer Related Changes |
| **F2** | Poor Coordination of design. | |
| **F3** | Design change is initiated due to financial and economic changes. | |
| **F4** | Omissions of activity or task from the contract documentation. | |
| **F5** | Errors made in the contract documentation. | |
| **F6** | Insufficient time to prepare contract documentation. | |
| **F7** | Inadequate client brief to prepare detailed contract documentation. | |
| **F8** | Ineffective use of information technologies. | |
| **F9** | The contractor instruction to modify a design | Contractor Related Changes |
| **F10** | The contractor instruction to modify a construction methods | |
| **F11** | Non-compliance with specification. | |
| **F12** | Machine breakdown and defects | |
| **F13** | Poor planning and coordination of resources. | |
| **F14** | Omission errors some activity or task by construction personnel. | |
| **F15** | Unqualified work force in the project | |
| **F16** | Lack of training and experience. | |
| **F17** | Lack of coordination and poor communication. | Owner Related Changes |
| **F18** | The owner instruction to modify a design | |
| **F19** | Lack of experience and knowledge of the design and construction process. | |
| **F20** | Lack of funding allocated for site investigations. | |
| **F21** | Lack of client involvement in the project. | |
| **F22** | Insufficient time and money spent on the briefing process. | |
| **F23** | Lack of Expenditure for preparing contract documentation | |

## 5.1. Sample Size

According to Easterby-Smith et al. [21] which uses **Eq.1** to compute the required sample size for unlimited population:

$$n = \frac{2500}{E^2} \quad (1)$$

Where:
*n*: is the required sample size for infinite population,
*E:* is acceptable standard error is less than5% which used as percent

## 5.2. Data Analysis

One hundred and thirty questionnaires (see appendix) were administered to professionals and experts in different construction projects. A total of one hundred questionnaires representing 76.92% of the total questionnaires administered were returned. Table 4 shows details of questionnaires administered and the rate of return.

The respondents' job titles were classified into three categories in construction projects. The first category form designer point of view owner represented 73.23 %, the second category form contractor point of view (cost estimators, civil engineers and project managers) represented 87.33.% and the third category from owner point of view represented 77.5 %. Figure 1 illustrates the number of each category.

The respondents to the questionnaire were classified according to their experience in Table 5 and Figure 2. A closer inspection to Figure 2 clearly shows that about 14% of the respondents have experience Less than 10

years, around 48 % have experience greater than or equals to 10 years and less than 20, around 30 % have experience greater than or equal 20 years and less than 30 and finally, 8 % of respondents have experience greater than or equals to 30 years.

**Table 4. Details of Questionnaires Administered and the Rate of Return Soliman [17]**

| Professionals and Experts | No. of Questionnaires | No. of Questionnaires Returned | % Returned Rate |
|---|---|---|---|
| Designer | 30 | 22 | 73.23 % |
| Contractor | 60 | 47 | 87.33 % |
| Owner | 40 | 31 | 77.5 % |
| Total | 130 | 100 | 76.92 % |

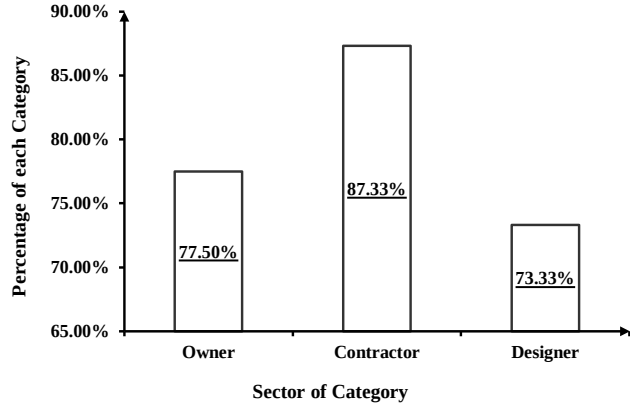


**Figure 1.** Classification of Respondents Based on Their Job Title Category, Soliman [17]

**Table 5. Classification of the Surveyed Experts Based on Their Experience, Soliman [17]**

| Experience Practicing | Owner | Contractor | Designer | Total | % |
|---|---|---|---|---|---|
| Less than 10 years | 6 | 6 | 2 | 14 | 14 |
| Greater than or Equals to 10 years and Less than 20 | 10 | 21 | 17 | 48 | 48 |
| Greater than or Equal 20 years and Less than 30 | 4 | 15 | 11 | 30 | 30 |
| Greater than or Equals to 30 years | 2 | 5 | 1 | 8 | 8 |
| Total | 22 | 47 | 31 | 100 | 100 |

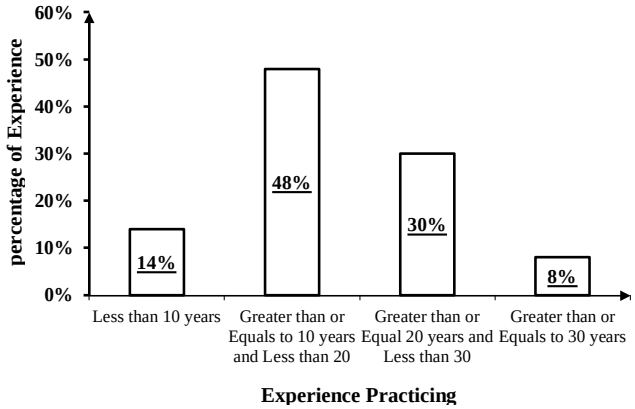


**Figure 2.** Classification of the Surveyed Experts Based on Their Experience**,** Soliman [17]

## 5.3. Top Effective Upstream Changes

The respondents have inserted two scores in front of each factor in each percentage degree of overlapping between activities. First, the degree of impact of each factor causing reworks in downstream activities. Second, the probability of occurrence of Rework for each factor on downstream activities, then calculate importance index for the previously identified twenty three changes, finally all changes are ranked in a descending order according to their importance index according to **Eq.2**, **Eq.3 Eq.4** and **Eq.5.**

$$\text{Total Score of Rework Frequency} = \text{Rework Frequency of each problem} = \sum_{i=1}^{n}(Fr) \quad (2)$$

$$\text{Total Score of Severity} = \text{Severity of each factor} = \sum_{i=1}^{n}(SI) \quad (3)$$

$$\text{Rework Frequency Index } (F_I) = \frac{\text{Total Score Rework Frequency}}{\text{No. of Respondents } (N)\times 10} \quad (4)$$

$$\text{Severity Index } (S_R) = \frac{\text{Total Score of Severity}}{\text{No. of Respondents } (N)\times 10} \quad (5)$$

$$\text{Importance Index} = (FI)*(SI)*100 \quad (6)$$

Where:
**N:** is total number of respondents to each factor, (N=100).
**10**: represented the upper scale of the measurement.

The analysis also shows that the weight of all categories. Where (Owner changes) represented 25.80% followed by (Contractor changes) represented 41.93% and finally (Designer changes) represented 32.25% as shown in Figure 3.

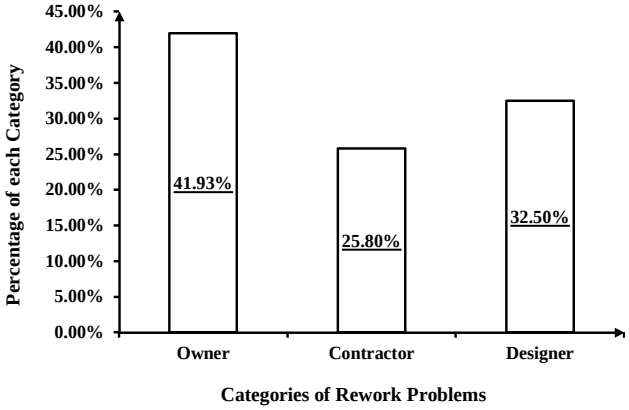


**Figure 3.** Categories of the Changes that Causing Reworks in Downstream Activities, Soliman [17]

The calculated important index for all changes causing Reworks in Downstream Activities Table 6.

## 5.4. Top Effective Changes

Based on the analysis and review of the construction industry surveyed experts' opinion and according to Pareto Principle, which states that 80 percent of the

changes come from 20 percent of the causes, to select a certain number of changes which represent all changes and also these changes are the changes with the highest importance indexes. The minimum number of changes considerable according to Pareto = 20% * 24 ≈ 5 changes. The top eight changes and their importance indices are as follows: Lack of Coordination and Poor Communication were ranked in the first position with a (R.II) 33.8 7% as the most important cause downstream reworks. The contractor instruction to modify a design was ranked in the second position with a (R.II) 25.65 %. Non-compliance with specification was ranked in the third position with a (R.II) 23.84 %. The owner instruction to modify a design is in the fourth position with a (R.II) 21.66 %. Incomplete Design at The time of Tender was ranked in the fifth position with a (R.II) 21.58 %.Poor planning and coordination of Resources in the sixth position with a (R.II) 21.20 %. Errors made in the contract documentation in the seventh position with a (R.II) 20.94 %. Lack of experience and knowledge of the design and construction process in the eighth position with a (R.II) 20.72 % as shown in Figure 4.

**Table 6. Changes Causing Reworks in Downstream Activities, Soliman [17]**

| Factor No. | Changes Causing Rework in Downstream Activities | Category | R1 | | R2 | | →R100 | | Total Responses (N) | Total Score of Severity | Severity Index | Total Score of Frequency | Frequency Index | Important Index % | Rank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | S | F | S | F | S | F | | | | | | | |
| **F1** | Incomplete Design at The time of Tender | **Designer** | 4 | 6 | 3 | 3 | 8 | 4 | 100 | 486 | 0.486 | 444 | 0.444 | 21.58 | **5** |
| **F2** | Poor Coordination of Design | | 3 | 1 | 3 | 3 | 4 | 6 | 100 | 429 | 0.429 | 363 | 0.363 | 15.57 | **20** |
| **F3** | Design change is initiated due to financial and economic changes | | 5 | 2 | 3 | 4 | 3 | 9 | 100 | 442 | 0.442 | 345 | 0.345 | 15.25 | **21** |
| **F4** | Omissions of activity or task from the contract documentation. | | 2 | 4 | 4 | 4 | 9 | 1 | 100 | 396 | 0.396 | 448 | 0.448 | 17.74 | **11** |
| **F5** | Errors made in the contract documentation | | 7 | 3 | 7 | 4 | 4 | 7 | 100 | 517 | 0.517 | 405 | 0.405 | 20.94 | **7** |
| **F6** | Insufficient Time to Prepare Contract Documentation | | 4 | 4 | 3 | 4 | 4 | 1 | 100 | 377 | 0.377 | 425 | 0.425 | 16.02 | **17** |
| **F7** | Inadequate Client Brief to Prepare Detailed Contract Documentation | | 4 | 3 | 2 | 2 | 3 | 6 | 100 | 381 | 0.381 | 341 | 0.341 | 12.99 | **24** |
| **F8** | Ineffective Use of Information Technologies | | 3 | 3 | 9 | 6 | 4 | 9 | 100 | 447 | 0.447 | 420 | 0.42 | 18.77 | **9** |
| **F9** | Design Change is Initiated by The Contractor | **Contractor** | 2 | 3 | 7 | 5 | 6 | 9 | 100 | 579 | 0.579 | 443 | 0.443 | 25.65 | **2** |
| **F10** | Change in construction methods in order to improve construct-ability or due to site conditions | | 3 | 4 | 9 | 9 | 4 | 4 | 100 | 454 | 0.454 | 380 | 0.38 | 17.25 | **14** |
| **F11** | Non-compliance with Specification | | 6 | 1 | 6 | 9 | 4 | 5 | 100 | 515 | 0.515 | 463 | 0.463 | 23.84 | **3** |
| **F12** | Machine not working satisfactorily or breakdown or defects | | 2 | 5 | | 4 | 6 | 4 | 100 | 452 | 0.452 | 370 | 0.37 | 16.72 | **15** |
| **F13** | Omission errors some activity or task by construction personnel | | 3 | 6 | 5 | 4 | 7 | 4 | 100 | 491 | 0.491 | 352 | 0.352 | 17.28 | **13** |
| **F14** | Poor planning and coordination of Resources | | 2 | 1 | 6 | 4 | 1 | 1 | 100 | 576 | 0.576 | 368 | 0.368 | 21.1968 | **6** |
| **F15** | Shortage or low skilled of labour | | 3 | 4 | 7 | 5 | 9 | 7 | 100 | 462 | 0.462 | 396 | 0.396 | 18.30 | **10** |
| **F16** | Lack of training and experience | | 4 | 5 | 6 | 6 | 2 | 9 | 100 | 428 | 0.428 | 386 | 0.386 | 16.52 | **16** |
| **F17** | Lack of Coordination and Poor Communication | **Owner** | 2 | 4 | 2 | 4 | 8 | 3 | 100 | 659 | 0.659 | 514 | 0.514 | 33.87 | **1** |
| **F18** | Design change is initiated by the owner | | 6 | 7 | 3 | 4 | 4 | 2 | 100 | 517 | 0.517 | 419 | 0.419 | 21.66 | **4** |
| **F19** | Lack of experience and knowledge of the design and construction process | | 6 | 3 | 7 | 10 | 3 | 4 | 100 | 497 | 0.497 | 417 | 0.417 | 20.72 | **8** |
| **F20** | Lack of funding allocated for site investigations | | 4 | 2 | 8 | 7 | 7 | 6 | 100 | 441 | 0.441 | 401 | 0.401 | 17.68 | **12** |
| **F21** | Lack of client involvement in the project | | 6 | 3 | 5 | 0 | 1 | 3 | 100 | 432 | 0.432 | 366 | 0.366 | 15.81 | **18** |
| **F22** | Insufficient time and money spent on the briefing process | | 2 | 3 | 4 | 4 | 2 | 3 | 100 | 355 | 0.355 | 367 | 0.367 | 13.03 | **23** |
| **F23** | Expenditure on low fees for preparing contract documentation | | 2 | 3 | 7 | 4 | 3 | 4 | 100 | 411 | 0.411 | 357 | 0.357 | 14.67 | **22** |

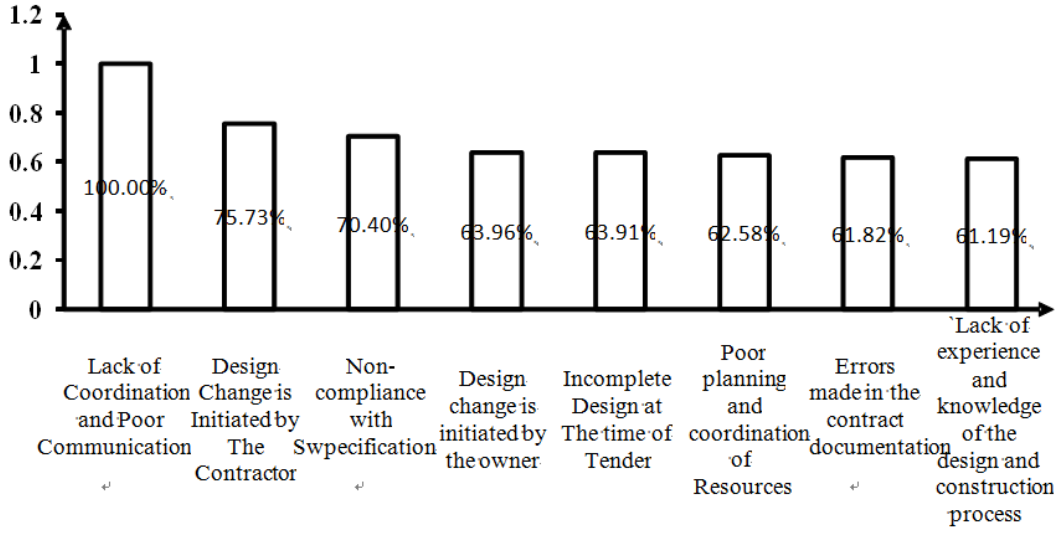


**Figure 4.** The Top Important Eight Changes That Causing Reworks in Downstream Activities, Soliman [17]

**Table 7. Rank of All changes and Highlights the Most Important Eight Changes, Soliman [17]**

| Rank | Change No. | Changes Causing Reworks of Construction Downstream Activities | Problemes Category | Total Score of Severity | Severity Index | Total Score of Frequency | Frequency Index | Important Index % | Weight |
|---|---|---|---|---|---|---|---|---|---|
| 1 | F18 | Lack of Coordination and Poor Communication | Owner | 659 | 0.659 | 514 | 0.514 | 33.87 | 100.00 |
| 2 | F9 | Design Change is Initiated by The Contractor | Contractor | 579 | 0.579 | 443 | 0.443 | 25.65 | 75.73 |
| 3 | F11 | Non-compliance with Swpecification | Contractor | 515 | 0.515 | 463 | 0.463 | 23.84 | 70.40 |
| 4 | F19 | Design change is initiated by the owner | Owner | 517 | 0.517 | 419 | 0.419 | 21.66 | 63.96 |
| 5 | F1 | Incomplete Design at The time of Tender | Designer | 486 | 0.486 | 444 | 0.444 | 21.58 | 63.71 |
| 6 | F14 | Poor planning and coordination of Resources | Contractor | 576 | 0.576 | 368 | 0.368 | 21.20 | 62.58 |
| 7 | F5 | Errors made in the contract documentation | Designer | 517 | 0.517 | 405 | 0.405 | 20.94 | 61.82 |
| 8 | F20 | Lack of experience and knowledge of the design and construction process | Owner | 497 | 0.497 | 417 | 0.417 | 20.72 | 61.19 |
| 9 | F8 | Ineffective Use of Information Technologies | Designer | 447 | 0.447 | 420 | 0.42 | 18.77 | 55.43 |
| 10 | F15 | Shortage or low skilled of labour | Contractor | 462 | 0.462 | 396 | 0.396 | 18.30 | 54.02 |
| 11 | F4 | Omissions of activity or task from the contract documentation | Designer | 396 | 0.396 | 448 | 0.448 | 17.74 | 52.38 |
| 12 | F13 | Omission errors some activity or task by construction personnel | Contractor | 491 | 0.491 | 352 | 0.352 | 17.28 | 51.03 |
| 13 | F10 | Change in construction methods in order to improve construct-ability or due to site conditions | Contractor | 454 | 0.454 | 380 | 0.38 | 17.25 | 50.94 |
| 14 | F12 | Machine not working satisfactorily or breakdown or defects | Contractor | 452 | 0.452 | 370 | 0.37 | 16.72 | 49.38 |
| 15 | F16 | Lack of training and experience | Contractor | 428 | 0.428 | 386 | 0.386 | 16.52 | 48.78 |
| 16 | F6 | Insufficient Time to Prepare Contract Documentation | Contractor | 377 | 0.377 | 425 | 0.425 | 16.02 | 47.31 |
| 17 | F22 | Lack of client involvement in the project | Owner | 432 | 0.432 | 366 | 0.366 | 15.81 | 46.68 |
| 18 | F17 | Problems associated with multilayered subcontracting | Contractor | 383 | 0.383 | 408 | 0.408 | 15.63 | 46.14 |
| 19 | F2 | Poor Coordination of Design | Designer Related Problemes | 429 | 0.429 | 363 | 0.363 | 15.57 | 45.98 |
| 20 | F3 | Design change is initiated due to financial and economic changes | Designer | 442 | 0.442 | 345 | 0.345 | 15.25 | 45.02 |
| 21 | F24 | Expenditure on low fees for preparing contract documentation | Owner | 411 | 0.411 | 357 | 0.357 | 14.67 | 43.32 |
| 22 | F23 | Insufficient time and money spent on the briefing process | Owner | 355 | 0.355 | 367 | 0.367 | 13.03 | 38.47 |
| 23 | F7 | Inadequate Client Brief to Prepare Detailed Contract Documentation | Designer | 381 | 0.381 | 341 | 0.341 | 12.99 | 38.36 |

All changes have been ranked according to their important index as shown in Table 7. Also the result showed that instead of eight changes, two changes were only considered under designer changes. Also instead of nine changes, three changes were only considered under contractor changes. Finally, it demonstrates that the weight of designer changes, contractor changes and changes related to owner changes are 25 %, 37.5 %and 37.5 % respectively as shown in Table 8.

**Table 8. Changes Causing Rework in Downstream Activities Before and After Ranking, Soliman [17]**

| Change Category | All Changes Before Ranking | | Changes After Ranking | |
|---|---|---|---|---|
| | Sum | Weight | Sum | Weight |
| **Designer** | 8 | 33.23 % | 2 | 25 % |
| **Contractor** | 9 | 37.5 % | 3 | 37.5 % |
| **Owner** | 7 | 29.17 % | 3 | 37.5% |
| **Total** | **24** | **100 %** | **8** | **100 %** |

# 6. Conclusion and Recommendations

Based on a survey among the different construction experts in Egypt, the most important factors affecting cost contingency were: Importance Index (Relative significance index scores) were developed for the factors identified to be affecting the time rework contingency estimation. According to these Importance Index, the most eight effective factors affecting the estimation of cost contingencies are 1) Lack of coordination and poor communication, 2) The contractor instruction to modify a design, 3) Non-compliance with specification, 4) The owner instruction to modify a design, 5) Incomplete design at the time of tender, 6) Poor planning and coordination of resources, 7) Errors made in the contract documentation and 8) Lack of experience and knowledge of the design and construction processIt is recommended to avoid the disputable claims the following:

1. Owners need to effectively manifest their needs and requirements before designs are conducted.

2. The need for training of construction Stkeholders on construction rework and other Variables That cause Projects To over shoot The Budget, time and other resource. consultants need to give special care to the review and approval of shop drawing.
3. Make sure that everyone understands the contractual notice provision.
4. Owners, contractors, designers, etc must be aware of the notice provision in contract document.
5. Recognize that a "risk-sharing" philosophy will probably produce the lowest overall project cost for the owner and maximum profit to the Contractor.

## Declaration

This paper is based on PhD. prepared by the third author (corresponding author) and under supervision of the first two authors.

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# Appendix (A)

## Questionnaire Survey

In this survey, the factors that arising in the upstream Activities and Causing Reworks in the downstream Activities are categorized into three main categories as follow:

1. The Owner Related Changes.
2. The Designer Related Changes.
3. The Contractor Related Changes.

The rework time values are allocated to each factor depending on the degree of overlapping between each pair of activities. Degree of overlapping (duration of overlapping) will be a percentage of the smallest duration of the upstream and downstream activities.

Note:

- Please give a rank number for each factor to reflect its significance, Time as ***Frequency***, where 0 indicates lack of factor's ***Frequency*** and from 1to10 indicates no. of ***Frequency*** for each factor, Time as factor ***Severity***, where 0 indicates lack of factor and from 1 to 10 indicates to value of factor ***Severity***

## Questionnaire Survey Design

| Factor No. | Changes of Predecessor Activities that Causing Reworks in Downstream Activities Due to Period Overlapping | Problem Category | Severity on Causing Rework in Downstream Activities (0 T0 10) | The Probability of Occurrence of Rework (0 T0 10) |
|---|---|---|---|---|
| F1 | Incomplete Design at the time of tender. | Designer Related Changes | | |
| F2 | Poor Coordination of design. | | | |
| F3 | Design change is initiated due to financial and economic changes. | | | |
| F4 | Omissions of activity or task from the contract documentation. | | | |
| F5 | Errors made in the contract documentation. | | | |
| F6 | Insufficient time to prepare contract documentation. | | | |
| F7 | Inadequate client brief to prepare detailed contract documentation. | | | |
| F8 | Ineffective use of information technologies. | | | |
| F9 | The contractor instruction to modify a design | Contractor Related Changes | | |
| F10 | The contractor instruction to modify a construction methods | | | |
| F11 | Non-compliance with specification. | | | |
| F12 | The contractor instruction to modify a construction methods | | | |
| F13 | Machine breakdown and defects | | | |
| F14 | Poor planning and coordination of resources. | | | |
| F15 | Omission errors some activity or task by construction personnel. | | | |
| F16 | Unqualified work force in the project | | | |
| F17 | Lack of training and experience. | | | |
| F18 | Lack of coordination and poor communication. | Owner Related Changes | | |
| F19 | The owner instruction to modify a design | | | |
| F20 | Lack of experience and knowledge of the design and construction process. | | | |
| F21 | Lack of funding allocated for site investigations. | | | |
| F22 | Lack of client involvement in the project. | | | |
| F23 | Insufficient time and money spent on the briefing process. | | | |