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Identifying MajorProject Delay Causes in Egypt and Assessing their Impacts Using System Dynamics

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Abstract

Construction industry is one of the major industries in the economic growth of development countries especially in Egypt. It characterized by complex elements, interdependences, and inefficiency on its operations.Previous studies revealed that designs errors, omissions, poor quality material, are the causes of delay in projects and cost overrun. This paper will discuss the problem of poor project management in Egypt using literature and data from a set of interviews with expert construction managers. The main reasons for the poor quality of projects, delays in schedule, and cost overrun have been established from the outcomes of a survey undertaken and a series of interviews of experts. Also, these results used with system dynamics model to solve the rework problemdue to changes in construction phase,by application of VENSIM software. This model takes into account the impact of rework on customer satisfaction and the feedback on productivity. Also, quality and productivity are both vary along the project. In addition, the effect of moral, fatigue, overtime, and learning effect on both productivity and quality are considered. The model is validated with Rodrigues, Dharmaraj et al. model for base case. Results show good agreement with the Rodrigues model results for the base case. Also, results show that changes less than 50% of scope could be eliminated and get project to its rout. On the other hand, results revealed for changes more than 50% of scopethat project could not be finished at the planed schedule even after applying strategies to overcome these changes, and it`s better to terminate the project rather than struggle in delays and financial wastes.

Key Words—**Construction projects, system dynamics, poor project management, schedule delays, cost overrun, rework.**

1. INTRODUCTION

The construction industry is multifaceted in nature because it encompasses large numbers of parties as owners, contractors, consultants, and other stakeholders[1]. In spite of construction complexity, the industry plays a major role in the improvement of the Egyptian Economy and society. Construction industry in many countries accounts for 9% of the Gross Domestic Product[2]. In Egypt, construction industry is one of the key economic engine sectors, and it has been a major source of employment for 70% of the labor force, supporting the country's national economy [1]. The overall success of project works is determined to a large extent by the Proper management of the resources which are considered as an essential aspect of project works. So, if resources are adequately controlled, issues relate to cost overrun would not arise.

However, many construction projects report poor performance due to many causes. To ensure the construction cost is within the budget, it is important to have control on cost performance of projects. A number of studies have been conducted to examine factors impacting project performance in various countries[3-6]. For example, in Malaysia, rework factors include poor site management and supervision, lack of experience, inadequate planning and scheduling, mistakes and errors in design, mistakes during construction[3]. Also, in United Arab Emirates (UAE),rework factors include workers lack of awareness, poor design resulting in excessive offcuts; rework and variations[4]. In addition, in Turkey,rework factors include planning and scheduling, fluctuation of prices, rework due to errors, late delivery of material, owners demand, poor site management, complexity of project are all the major causes of delay[5].

And, in Gaza Strip, the major performance problem is delay because of closures leading to materials shortage, escalation of material prices, unavailability of resources as planned through project duration, unavailability of persons with a high experience and qualifications, quality of equipment and raw materials, and leadership skills for project managers [6].

Also, literature review presents that traditional techniques and procurement methods are not helpful in dealing with complexity and strategic issues in construction projects. They can`t help project managers and decision makers to view the problem from the holistic view (i.e. Strategic view) [7]. In addition, literature mentioned that system dynamics (SD) is better in dealing with complexity, closed loop feedback mechanisms, strategic issues[8]. SD is a methodology used to understand the behavior of complex systems. It captures interrelationships among variables and handles dynamic aspects of the system behavior. SD attempts to understand why things happen by identifying the structure behind the behavior[9]. It is used in modeling wide range of problems[10]. SD is helpful in predicting the impact of changes in construction projects [10]. It is helpful in representing the system holistic view, and focuses on modeling features found in actual systems. The above mentioned examples are the motivation for this work to analyze the factors affecting the performance of construction projects in Egypt. This was further broken down into the following objectives:

- To identify and evaluate factors causing performance delay in construction projects in Egypt.
- To build up a model using system dynamics methodology help in improving construction projects performance.
- To formulate recommendations to improve performance of construction Projects in Egypt.

2. RESEARCH METHODOLOGY

Based on the pilot study developed by Fayek et al. [11] that classified the construction field rework into five major areas of rework and four possible causes in each of these areas as shown in Fig .1. and depending on many other researches[3-5]for better collection the causes of wastes in construction projects, and understanding nature of rework. Using this mentioned researches; questionnaire and structured interviews are developed. In addition to that, several field visits and meetings with experts in construction projects management were done. The presented rework causes, listed in table.1,are adopted from these researches and from recommendation of several experts in the Egyptian construction field. The results of the survey are used to build up a system dynamics model.This will help improving construction projects performance; and assessing strategies used in Egyptian construction sector; help decision makers taking decisions. The introduced model is a refinement of Love model [8], Lyneis model [9], and Rodrigues model [10]. It includes five subsystems: Human resource subsystem; Productivity subsystem; Quality subsystem; Work flow subsystem; and adverse dynamics (counter actions) subsystem.

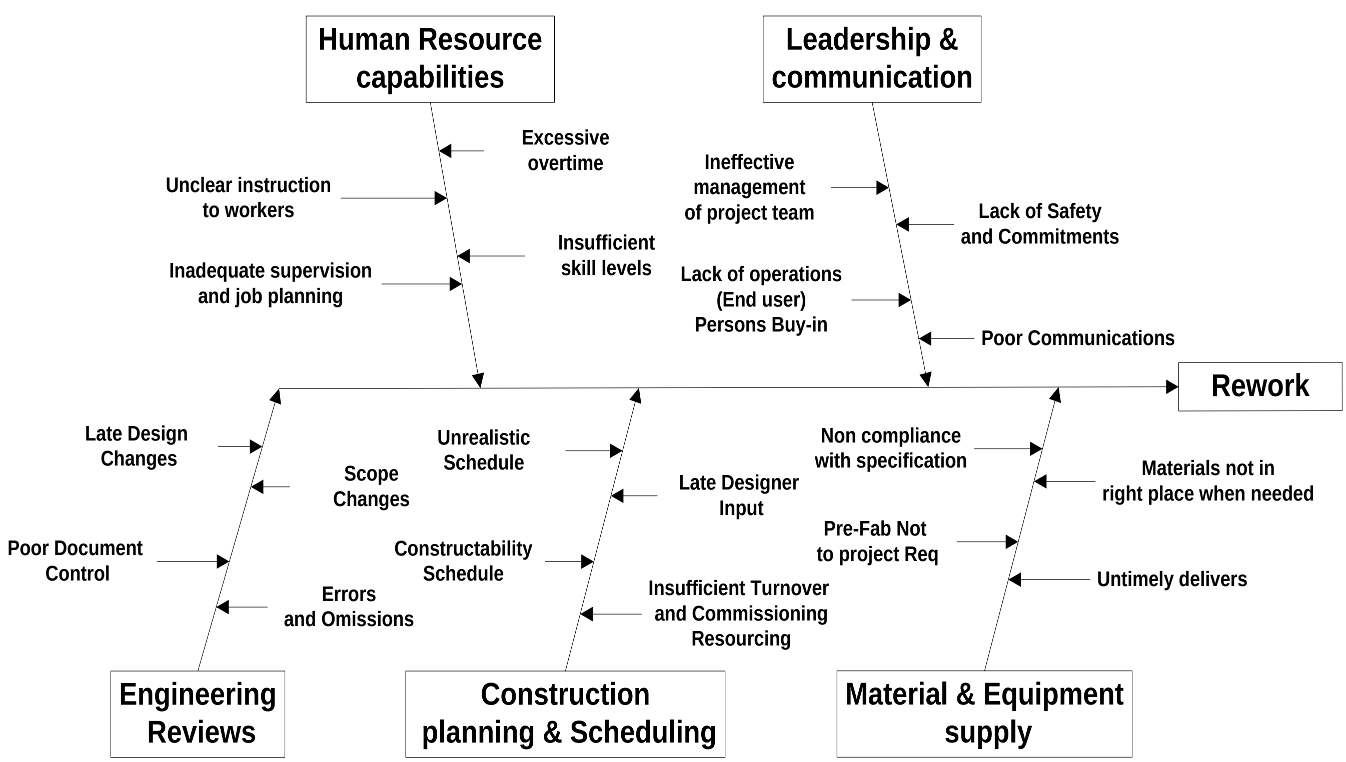

Fig.1 Classification model of rework causes [11]

3. Questionnaire

The suggested questionnaire is divided into four main sections: (1) Profile of respondent and project, (2) Organizational awareness of Quality management issues, (3) Causes of rework and its impact on project performance (cost and time), (4) respondent recommendations to reduce rework in construction projects. Questionnaire objectives are to:

- Investigate and illustrate the relation between awareness about rework and its occurrence.
- Investigate and illustrate the awareness of organizations and people about rework in construction projects.
- Investigate and illustrate actual behavior of rework occurrence and implementations to reduce rework.
- Determine the degree of occurrence of each cause in construction project.
- Determine the degree of severity (impact) of rework causes on project performance (cost & time).
- Collectrespondent recommendations to reduce rework in construction projects.

Table. 1 Causes for construction delays classified into categories[3-5]

Causes category	Causes of rework
1. Human resource capability	An insufficient manpower skill level
	Insufficient training and skill Development
	Lack of employee motivation and Rewords
	The absence of job security
	Conflict of interest
2. Construction process	Constructability problems
	Non-compliance with specification
	Unclear work specification
	Inadequate supervision
	Poor project document
	Rigidity to improvement
	Absence of clear uniform standard to accept work
3. Materials and equipment supply	Untimely deliveries
	Non-compliance with specification
	Materials not in right place when Needed
4. Client-related causes	Lack of knowledge of construction Process
	Inadequate briefing
	Lack of funding allocated for Consultation
	Changes because of change in Officials
5. Design-related causes	lack of professionalism
	Inadequate procurement methods
	Design errors and omission
	Incomplete information for design
	Incomplete design

Causes category	Causes of rework
6. Contractor - related causes	Excessive overtime
	Schedule pressures
	Poor quality system
	Misreading of drawings and Specifications
	Competitive pressure / low contract Value
	Unqualified technically
	Financial weakness (Phantom cash flow)
7. Management related causes	Inadequate coordination &integration
	Unclear line of authority and Responsibility
	Poor communication system
	Lack of Audit and control
	Inadequate pre-project planning
	Late designer input
	Ineffective management and decision-making
	Failure to implement Quality management practices
External environment related causes	Government (Regulations, taxes. Interest rates)
	Economy (Inflation, exchange rates, Market)
	Social (Changing social environment, Resistances)
	Technological (techniques, facilities, machines)
	Inadequate local education (Collectors - craftsman - technical)
	Physical conditions (Infrastructure, transportation, etc)
	Political situation (Siege- conflicts)

In order to test the appropriateness, reliability and validity of the scales before committing to the complete sample population, it`s done by two ways; first one by making face to face interviews with 12 experts, projects managers and engineers from different contract parties. Second one was undertaken by inviting 7 professionals to review the questionnaire. These professionals were selected with more than 15 years' experience in construction work. Some of them work in academic institutions and others in the practical field. Respondents were then invited to feedback on any comments in the designed questionnaires and suggestions for refining the survey instruments. Each meeting consisted of three main parts as follows:

- *Part one:* Smart view to the subject of the study and what is its significance to work in construction projects.
- *Part two:* displaying causes of rework in the construction project which were listed in Table .1. Then listening to interviewee opinions in each causes and what they can add to it from their experience.
- *Part three:* listening to their views in tools to reduce rework.

To measure the response and discover the strength of feeling or attitude towards the given statement the ranked scale is used (likert scale). The scale is five point ranges and asks respondents to indicate the rank order of agreement or disagreement by circling the appropriate number. And these are the five-level Likert[5] item: (1) Strongly disagree, (2) Disagree, (3) Neither agrees nor disagrees, (4) Agree, (5) Strongly agree.

In order to determine the ranks of all questionnaire factors the relative importance index method (RII) was used. The relative importance index was computed as[5]:

$$\mathrm{RII} = \frac{\sum W}{A*N} \qquad (1)$$

Where:
W: the weight given to each factor by the respondents (ranging from 1 to 5)
A: the highest weight (i.e. 5 in this case)
N: the total number of respondents

The RII value had a range from 0 to 1, the higher the value of RII, the more impact of the attribute[5].

3.1. Research Population

The population of this research included contractors, consultants, engineering staff (line managers, project managers, site managers and senior engineers), and owners. Thesamples selected were a small proportion of a population selected for observation and analysis. The samples were selected randomly from professional's engineers of contracting companies, consultant offices & public owner's sectors. These samples were the respondents of the questionnaire survey. Statistical equations were used in order to calculate the sample size for the study population as follows [5]:

$$SS = \frac{Z^2 * P * (1-P)}{C^2} \qquad (2)$$

Where:

SS: The sample size
Z: Z value *(e.g. 1.96 for 95% confidence level)*
P: Percentage picking a choice, expressed as decimal, (0.50 used for sample size needed)
C: Maximum error of estimation (0.08)

$$SS = \frac{1.96^2 * 0.5 * (1-0.5)}{0.08^2} = 150$$

Correction for finite population

$$SS_{new} = \frac{SS}{1+\frac{SS-1}{pop}} \qquad (3)$$

Where: pop is the population;

For contractors, consultants, engineering staff, and owners it`s assumed that every population is*:* 50 (i.e. 150/4=37.5; taken 50).

So that: $SS_{new} = \frac{150}{1+\frac{150-1}{50}}$ = 37.68 = taken 38.

Initially, 80 questionnaires were sent out to contractors, 80 to consultants, 80 to engineering staff (line managers, project managers, site managers and senior engineers), and 80 to owners. And there are 75 interviews took place during which the questionnaire was filled up. Finally, 43 answers by contractors, 53 by consultants, 47 by engineering staff, and 39 by owners were collected. These answers include 16 interviews to contractors, 23 to consultant, 17 to management staff, and 19 by owners. Table 2 presents a summary of requests and responses obtained, distributed across the four groups of stakeholders surveyed.

Table. 2 Summary of survey results

Group	Quest. sent	Answers	Interviews	Percentage of answers
Contractors	80	43	16	53.75%
Consultants	80	53	23	66.25%
Engineering staff	80	47	17	58.75%
owners	80	39	19	48.75%
Total	320	182	75	56.875%

3.2. Survey Results

Results revealed that the responsibility of delay can be attributed to all parties involved.And the largest share was to management department. The highly ranked causes (RII > 0.5) from the 47 causes by 4 groups involved in the construction sector (consultants, engineering staff, owners, contractors) are presented in Table 3.

Table. 3 Raking of highly relevant causes

Causes for delays in construction projects	RII	Related causes
1. Ineffective management and decision-making	0.903	Management
2. Incomplete design and Design errors	0.877	Design
3. Lack of funding allocated and Financial weakness (Phantom cash flow)	0.862	Client- Contractor
4. Inadequate pre-project planning and Late designer input	0.835	Management
5. Inadequate coordination & integration	0.802	Management
6. Schedule pressures and Excessive overtime	0.810	Contractor
7. Materials not in right place when needed	0.758	Materials and equipment supply
8. Inadequate procurement methods	0.730	Design
9. Inadequate supervision	0.700	Construction process
10. Economy (Inflation, exchange rates, Market)	0.655	External environment
11. Failure to implement Quality management practices	0.632	Management
12. Poor project document	0.627	Construction process
13. Poor communication system	0.614	Management
14. An insufficient manpower skill level	0.565	Human resource
15. Insufficient training and skill Development	0.502	Human resource

Also, Based on the opinions provided by the survey respondents in Egypt, there is a need to implement a national database with the quantity works list for different construction projects. Plus implementing more appropriate and efficient management approach. In addition, they mentioned that owners should give greater care when they prepare their schedules, preliminary programmers and viability studies. And should clearly define and segregate responsibility and liability in the bid. It`s obvious that mismanagement go hand in hand with unrealistic bids that do much to worsen the quality of the work, wasting a lot of time and money. Which in the public sector these three parameters are very important specially in developing countries as Egypt. In struggled developed countries each pound and second is very important in go forward progress. In the next section the presented model will simulate the owner changes and the strategies used by contractor to resolve these changes. Also, presenting the effect of these changes on cost and schedule of the project, hence assessing the strategy used by contractor.

4. MODEL BUILDING

Using the data collected from the survey and by refinement of Love model [8], Lyneis model [9], and Rodrigues model [10],a system dynamics model is built to help in improving construction projects performance; and in assessing strategies used in Egyptian construction sector.Also, help decision makers in taking decisions. It includes five subsystems: Human resource subsystem; Productivity subsystem; Quality subsystem; Work flow subsystem; adverse dynamics (counter actions) subsystem.

These subsystems are discussed in the following sections. And all equations mentioned in the following subsections are taken from [8-10]models.

4.1. Human resource subsystem:

Human resources are main power of projects. By means of work force, the processes and tasks are executed. It controls the productivity of project and the quality of work done too. This subsystem is shown in Fig .2.

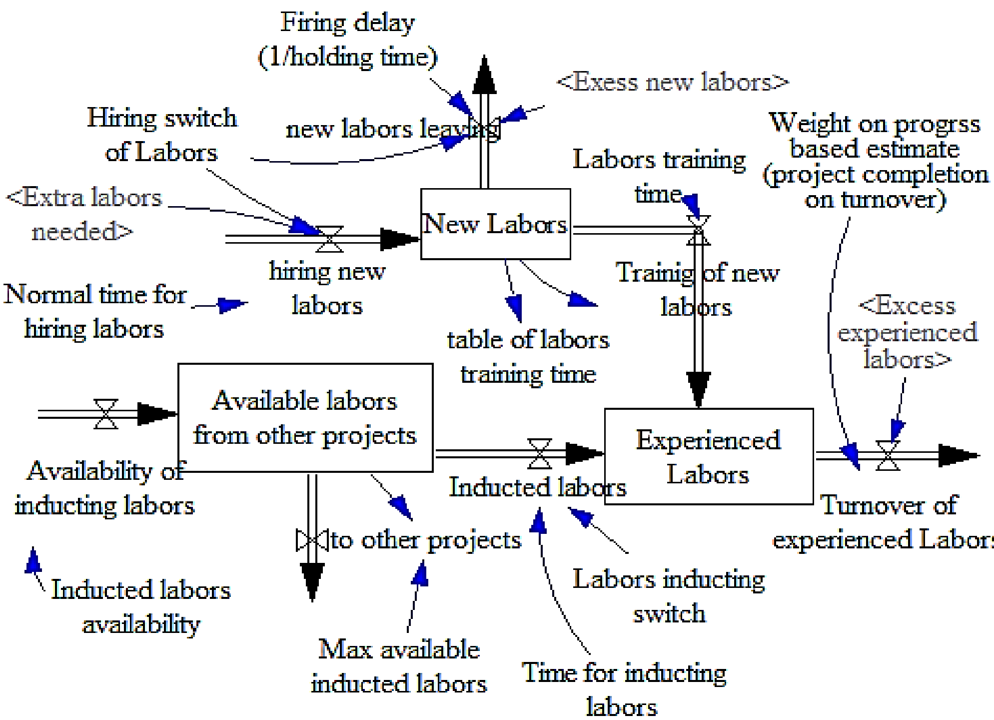

Fig.2 Human resource subsystem

Fig.2 show that labors of project may be hired as “New labors”, and then trainedand/or labors may be inducted from other projects within the organization as “Inducted labors”. These inducted labors are not requiring training; because they already trained at first time they hired to the organization. Both inducted and trained labors are accumulated in “Experienced labors” pool. Labors from this pool are executing the required tasks.

The level of experienced labors not necessarily equal the labors level required, but it can be the maximum allowable labors on site. Maximum labors on site depend on many variables like site conditions, available space, cash availability, etc… while the higher it is, the more effort required in communication and coordination.

4.2. Productivity subsystem:

Productivity within this model refers to the rate at which tasks are produced. Productivity of labors depends on various controllable and uncontrollable factors. For example, staff skills, staff availability, overtime, supervision, management system, material availability, and so many others.

Productivity in this model depends on outsourcing, hired labors, inducted labors, overtime, fatigue, moral, training, and management system. It is calculated as:

$$P_{nl} = P_{il}(1 - O_f) + P_o * O_f \quad (4)$$

$$P = Mean(F_{pl}, M_{pl}, L_{pl}) * Min(\frac{W_l}{T_{nw}}, P_{nl} * L_{ex}) \quad (5)$$

Where;

P_{nl}: Normal productivity.

P_{il}: Normal productivity of in-house labors.

O_f: Outsourcing fraction.

P_o: Normal productivity of outsourced organization.

P: Productivity of doing tasks.

F_{pl}: Effect of fatigue on productivity of labors.

M_{pl}: Effect of managerial gap on productivity of labors.

L_{pl}: Learning effect on productivity of labors.

W_l: Work load.

T_{nw}: Normal time for doing work required.

L_{ex}: Experienced Labors.

Productivity of project is calculated as mentioned in Eq. (5) by taking the mean of effect of fatigue, managerial gap, learning effect on productivity of labors. And then multiplied by normal productivity from Eq. (4) i.e. the minimum of work required divided by the time available to do this work, or the experienced labors multiplied by the normal productivity of labors. The minimum here is taken because it`s not reasonable to work with productivity more than the experienced labors or to work with max productivity of labors and there are enough time to do the required work. Productivity is not fixed number entire the project. So, Normal productivity of in-house labors and Normal productivity of outsourced organization from Eq. (1) are represented in the model by a random variable within acceptable limits. These limits are the minimum and maximum productivity could be achieved.

4.3. Quality subsystem:

Quality in general is conformance to establish requirement. Quality in this model is the percentage of conformance of work done by labors (i.e. the percentage of work done correctly). The more the quality, the less errors generated (i.e. less rework), and the more customer satisfaction. Quality here depends on many factors such as standard used (required quality), market conditions (i.e. normal quality of labors), management system used, and labors moral, and quality of outsourced organization. Quality here is calculated as:

$$Q_n = Q_i(1 - O_f) + Q_o * O_f \tag{6}$$

$$Q = Q_n * Mean(F_q, C_q, M_f, S, F_{es}) \tag{7}$$

Where;

Q_n: Normal quality.

Q_i: Normal in-house labors quality.

Q_o: Quality of third party.

O_f: Outsourcing fraction.

Q: Quality of produced work.

F_q: Effect of fatigue on quality.

C_f: Effect of communication on quality.

M_f: Effect of managerial gap on quality.

S: Effect of Stress on quality.

F_{es}: Effect of fees ratio on quality.

Quality of work done is not fixed number all the project. So, Normal in-house labors quality and quality of third party from Eq. (6) are represented in the model by a random variable within acceptable limits. These limits are the minimum and maximum quality could be achieved. In the following section it will be shown how quality splits the work into correct and defective categories.

4.4. Work flow subsystem

The work flow is based on the rework cycle which is the core of the model (Fig.3). Starting from the “Initial work load required”, this is the initial value of the “Work required”. It performed by the “Construction productivity” and “Quality” (calculated by Eq. (5) and Eq. (7)). “Quality” splits work into two categories “Work done” and “Work with Errors”.

“Work done” is the amount of work done correctly either from the first time or after reworked. As shown in Fig.3 “Work accomplished rate” is the responsible for the “Work done”. It is calculated as multiplication of productivity and quality. But, “Work with Errors” is the portion of work does not do correctly from first time. Here, errors generated by “Error generation rate” depend on many factors and it is calculated as multiplication of productivity and one minus quality.

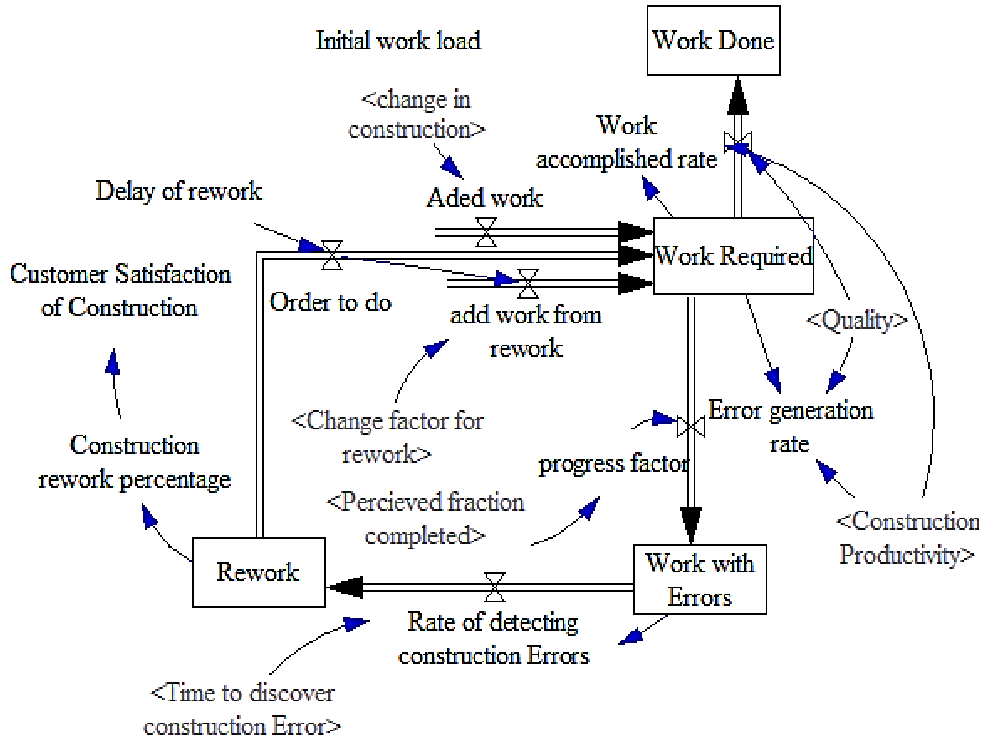

Fig.3 Construction reworks cycle

These errors are not detected at once it is generated but it takes time to be detected “Time to discover construction Errors”. Time of detecting these errors depends on the management system used i.e. if the management system is powerful then the time required to discover the errors is small. After detecting these errors it`s called “Rework” and are waiting for the order to be redone again. The time taken for reordering this rework is assumed to be the same as detecting time. It also assumed that every reworked task in construction requires first doing a task of removing the old defective task “add work from rework” which extend project duration and work load far beyond what is originally conceived. Then the rework is redone again by the construction productivity and may have errors again then take the same cycle to redoing it.

4.5. Counter actions subsystem

Since project managers seek to deliver on time, on budget, and with accepted quality; the counter actions are modeled (the controlling feedback loops) through which management attempts to close gaps between project performance and targets. There are four alternatives for counter actions represented here: Overtime, Hiring new employees, Extending completion date, reducing requirements.

5. SIMULATION PARAMETERS

A summary of the parameters assumptions for the simulation are taken as follows[10]:

- Work to be done: 100 Task.
- Scheduled completion time: 32 months, dt=0.25.
- Initial available labors: 5 labors.
- Base case – simulation for project with no change.
- Case 1, 2, 3, 4 are for projects with 20, 40, 60, and 80 per cent change in scope.
- Training time value one month.
- All rework identified is assumed to be reworked within one month.
- If-then-else logic is employed in many equations to prevent negative draining of stocks as well as to prevent recurring fractional computations.

5.1. Base case:

The results of the two models are the same for the base case wherever 100% of work completed at 32 Months from Rodrigues, Dharmaraj et al. model [10], and 32 Months for this introduced model as shown in Fig.4 (0% change).

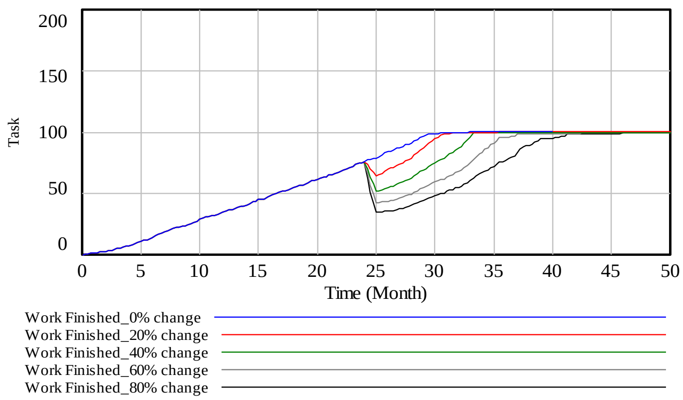

Fig.4 Work Finished Behavior

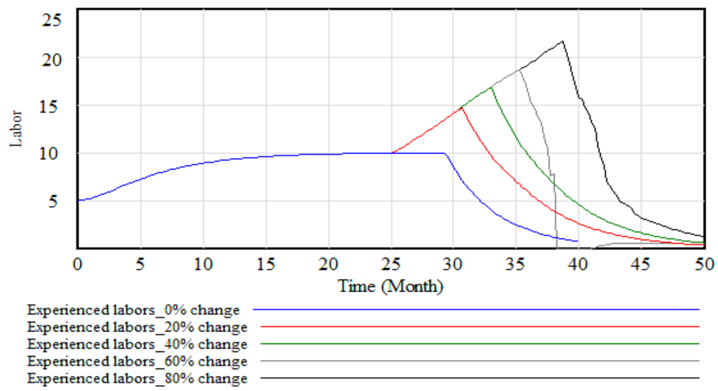

Fig.5 Experienced Labors

5.2. Case (1, 2):

When applying changes, the behavior of work finished exhibits instantaneous drop and then gradually arise again (as shown in Fig.4). For the 20% change of work the strategy of applying extra workers or add more one shift is working to get the project to its rout again (the extra workers added is equivalent to the number of workers in one shift). Also, the strategy of applying over time to workers could do it either. At 40% change of work the project is still could be finished at the same time, where 99% of work finished at 33.25 months for this model. This is done by means of hiring extra labors as shown in Fig.5 and applying one shift overtime for the whole labors working. The productivity and quality of work, in this model, are taking into account the effect of fatigue, and communication between these labors. This illustrates why the duplication of working labors does not reduce the time to the half. Also, by taking into consideration, the more rework (triple the initial rework value) due to these conflicts as shown in Fig.6, which will require more time to be redone correctly. In addition, the cost of these changes doubled the cost of the project which is a very bad side effect to these changes as shown in Fig.7.

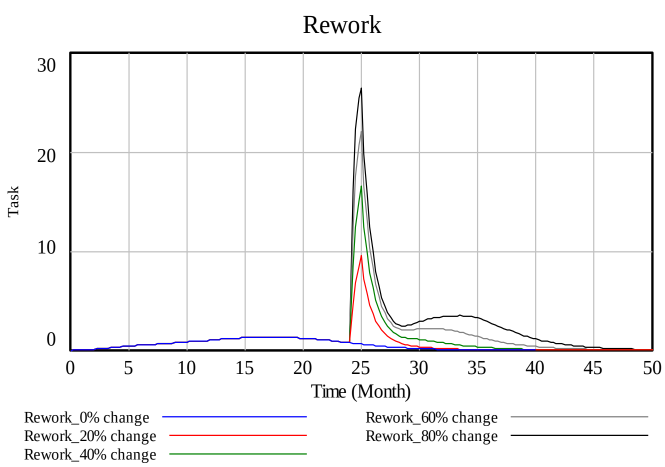

Fig.6 Rework behavior

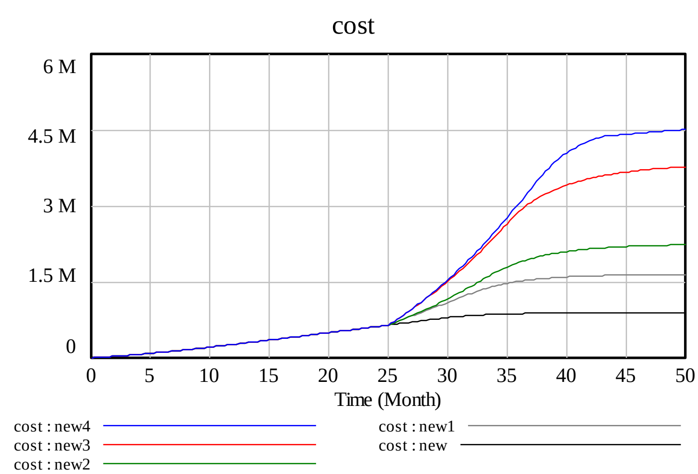

Fig.7 Project cost

5.3. Case (3, 4):

It is quite different in case of 60% and 80% change of scope. In 60% change workers 1st doubled and then added more shifts of working. The work finished behavior (Fig.5) exhibits some troubles in overcome these changes. In 80% change of work the workers are raised to four times and the workers are working in three shifts,but the project is exhibiting delays in schedule by 33% of its original schedule. In addition the rework is 30% of the original work or in other words it`s 7 times the base case (Fig.6 shows the sudden increase of rework due to changes). As a result of these changes labors productivity decreased and the quality is also decreased. So, project schedule will exhibit sever slippage at finished date. In addition, cost of these changes, as shown in Fig.7, is five times the base case i.e the costof project has become even worse. And cost of doing work does not reward the actual value of what has been done due to the large number of rework that led to pay for work implementation and forchanged work removal and redoingthe required work. Thisimpact delay of work dependson changed work. This makes it very expensive to make changes more than 60% or 80% of work done after 25 months of project.

6. CONCLUSIONS AND RECOMMENDATIONS

The increase of competition among construction industry, lack of management in construction sector led to deficient projects. As a consequence, there are cost and time overruns. Results of this paper revealed that:

- Ineffective decision-making ranked the first cause of project delays, while incomplete design and design errors ranked the second reason projects delays, and shortage of management department in managing projects, ranked the third reason projects delays.
- Client changes by 20% and 40% after the middle of project (at 75% of schedule) increase rework by 10% to 20% according to the percent of change as shown previously in Fig.6.
- As presented by the model changes of scope less than 50% of the scope could be overcome by increasing schedule by10%;and increasing working labors equivalent to one shift or increasing working shifts.
- In addition the cost of project is doubled as shown in Fig.7.
- On the other hand, in case of changes 60% and 80%increase rework it's 4 to 7 times according to the percent of change as shown previously in Fig.6.
- Added work doubles the working labors and rose to four times the base case. Also, doubling and tripling working shifts, but the project is still struggle by sever delays up to 30% of its original duration.
- Cost of these changes will be seven times its original value which is not equivalent to the done work and make terminating project is better than struggling in sever delays and financial wastes.

Furthermore, this model has limitations could be eliminated in the future work:

- It does not consider the two phases of design and construction.
- It does not consider the effect of multiple defects per task.
- And it does not consider the probability of missing rework in testing.

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