Journal of Engineering and Applied Sciences 13 (20): 8511-8519, 2018
ISSN: 1816-949X

Managing Quality Performance by Legislation in Iraqi Construction Projects: A System Dynamics Approach

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Abstract: Quality performance is considered as one of the most important aspects in construction industry. This industry has a special importance in Iraq due to the adverse circumstances that took place during the last two decades. Consequently, the quality of construction projects was deeply affected what gave the motivation to legislative authorities to enact a series of enhancements to the legislations that control the construction industry. Four successive acts created four legislative periods lasted from 2003-2014. In this research, an evaluation is made to the impact of the changes in legislations on the quality performance. The data of some 30 construction projects was collected. The quality was quantitatively assessed on one hand by conducting a questionnaire which depending on the final acceptance deficiency observations and their subsequent cost redaction penalties while in the other hand, a system dynamics model was also developed in which the quantitative estimate of quality was made depending on the accumulation of defects and errors that arise during the project progress period and their subsequent reworks, modifications and change orders. The questionnaire returned the quality estimates of 69, 72, 81.5 and 84.5% for the four successive legislation periods while the system dynamics model produced the qualities 67, 76, 84 and 87.6% for the same periods. These results show that a tangible enhancement to the projects quality was noticed in each legislative change.

Key words: Quality, legislation, construction project, system dynamics, accumulation, legislative change

INTRODUCTION

The successful delivery of the project must be conducted within budget, time and quality manner. One of the most important aspects of any construction project is the quality performance which affects the projects level of success (Abas *et al*., 2015). Quality related problems usually caused by such factors as: design related factors labors, materials, equipment and quality systems (Joy, 2014). Other researchers indicated that quality defects are caused by clauses that related to contractor selection, design defects and rework (Davis *et al*., 1989), adequacy of contractor (Callistus *et al*., 2014; Raphael and Phillip, 2016), adequacy of supervision staff and ineffective health and safety program (Joy, 2014) in Iraq, quality of construction projects has special importance due to the rare circumstances that surround the local construction industry caused mainly by wars, instability of politic environment and terrorism that struck the country after 2003 (Ahmed and Yusuff, 2016). Legislations have been changed to reduce the impact of these risky circumstances on construction industry (Anonymous, 2017). Change in legislation included the modification to many terms related to the selection and classification of contractors. This study aims to investigate the impact of legislation on the quality performance in the Iraqi construction industry to this purpose, a system dynamic model is developed to assess the level of quality in each legislation period.

Literature review: Construction quality can be defined as the satisfaction to the requirements of customer conformance with plans, contracts, specifications, standards and codes (Ashford, 1989). The main challenge in assessing the quality performance is the lack of universally accepted and commonly used method of gauging quality, the construction industry lacks a common definition of quality performance (Sullivan *et al*., 2017). Juran and Gryna (1993) define quality as “fitness for purpose” whereas for Crosby (1979) it is “conformance to requirements” and according to Deming (1986) quality is “uniformity with respect to a correct target”. Using the definition of quality in the construction industry as the ability to meet the requirements contracted with clients (Kazaz *et al*., 2005) may result in the study of quality in terms of its costs (Heravi and Jafari, 2014). Many researchers studied the factor that affected quality in construction project, Jha and Iyer (2006) studied adverse factors on quality of Indian construction projects which

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include bad weather, problem of communication, shortage of project management skills and low bids due to high competition. Raphael and Phillip (2016) indicate that the most factors that influence the quality performance of government financed construction projects are: methods of project financing, contractor's adequacy in construction industry, technology of construction project, ability of getting the equipment and plant, procurement methods and systems and the project manager expertise and knowledge. Ahmed and Yusuff (2016) divided the factors affecting quality of project in construction into eight categories: design, labors, materials, equipment, quality systems, site staff, owner and contractor. The ideal indicator of construction quality is the rework in construction project. Rework is consider a measure of activities that repair their defects in the products and obtained the required specifications Construction Users Roundtable (Anonymous, 2005a, b). Thus, the percentage of rework cost and defects is considered as the major indicators of construction quality. The quality of construction project can be evaluated by the defect observations of the acceptance committee as well as the amount of cost deduction penalty due to non-conformity of the completed work with the contract requirements (Thikra, 2007). Quality issues is rather pronounced in the local construction industry due to the special circumstances and tragic working environment in the wake of the last war in 2003 and its consequences in the following years. Many governmental projects stumbled and failed to complete due to many reasons such as politic environment, economic and security situation (Al-Ageeli and Alzobaee, 2016).

In order to reduce the impact of these risky events on construction industry, legislations have been changed many times during the period from 2003-2014 (Anonymous, 2017). The change covered many acts including; The General Term of the Civil Engineering Contracts (Anonymous, 2005) Governmental contracts implementation Instructions No.1 (Anonymous, 2008) and the Registry Instructions of Iraqi Contractors (RIC) (Anonymous, 2009). The ministry of planning also made changes in their regulation that is Related to the Certification of Materials Source (Anonymous, 2011) and the regulation of insertion of delayed bidder in implementation their contractual obligation in the delayed company list (Anonymous, 2013). The effects of these changes on the construction quality performance could best be observed and quantified through the dynamic modelling which is commonly used in construction projects (Rodrigues and Williams, 1998). The system dynamics approach which was originated by Forrester (1961) has been widely utilized in modelling construction projects management (Lyneis and Ford, 2007). In this approach, the system is modeled by a combination of independent variables that interact with each other in a stable way where two major characteristics are presented, the first is the change of variables over time and the second is the feedback effect (Martin, 1997).

Important researches in system dynamics that deal with issues related to changes and errors in projects, asserting the rework cycle impact on project performance (Cooper, 1980; Richardson and Pugh, 1981; Abdel-Hamid, 1984; Ford and Sterman, 1997; Lyneis *et al*., 2001, Park and Pena-Mora 2003). Love and Li (2000) used a case study and system dynamics methodology to describe the impact of changes and rework on the project management system. They observed the major factors that influenced the performance of project. They found that there is a need to understand how particular dynamics could delay the performance of a project management system. Lee *et al*. (2005) proposed a framework to determine the impact of iterative cycle on the performance of concurrent design and construction projects and then this framework is integrated into SDM to evaluate negative impacts of changes and errors on construction performance. Lee and Pena-Mora (2005) discussed the system dynamics use in recognizing multiple feedback processes and flexibility aspects of managing changes and errors.

MATERIALS AND METHODS

This research aims to investigate the effect of the changes in the Iraqi legislations that govern the solicitation, contractor selection, project delivery method and contract award procedures on the quality performance in construction projects. The data concerning quality performance of some 30 projects was collected these projects were scattered over 11 consecutive years period in which some four changes to the pertinent legislation were made by the government in its quest to enhance construction projects in terms of quality, time and cost efficiency. The data was classified according to the legislation validity period.

In order to quantify the quality performance in each project, a questionnaire was made to give each project a quality index depending on the defects observations in the final acceptance and the cost deduction penalties due to poor quality of some accepted items. This quantitative figure may reflect the overall impact of the legislation on quality performance as a whole without pointing out to the mechanism by which this effect takes place. To this purpose a system dynamics model was developed to simulate the behavior of quality performance under different changes of legislation. In this model, the accumulated costs of the initial defects, rejected works, undiscovered errors and change orders are taken into consideration to assess the quality of the project. Since, the cost accumulations are deeply influenced by the effective legislation, the produced quality is therefore, dependent of these legislations and should correspond to the quality assessed by the questionnaire.

Quality performance: In order to establish a quality relative value for the group of projects encompassed in the survey, it was found reasonable to utilize the number of defects observed in the final acceptance and the contractor was notified to rectify them in a specified period. If any of these observations was not corrected up to the standards, the item could be accepted with cost deduction penalty. Both, the number of observations and the amount of cost deduction penalties can reflect the quality deficiency in a project. The relative value of quality is established according to expert opinions that were collected in the questionnaire. This questionnaire included three parts, part one provide data regarding to the personal profile of the surveyed respondents, this contain general information about the professions, educational attainment, engineering specialization and working experience the second was dedicated to the assessment of quality level depending on the final findings of the project after completion regardless of any defects noticed during the progress of the project while the third part of the questionnaire investigates the defects that occur as the project is underway and the assessment of the weight of each type of defects of the overall quality level.

In the second part of questionnaire, the quality related inquiries were collected in three orientations. The first was dealing with the highest quality level that seems to be requested by the governmental authorities in each legislation. This unusual inquiry could be justified by the very exceptional circumstances the country went through, since, the last war in 2003 and all the consequences that followed and lead to create the unhealthy environment for the construction industry. The first period from 2003-2006 was the hardest one in many aspects while the following periods which respectively are 2007-2008, 2009-2011, 2012-2014 kept improving in all aspects and consequently the expected or planned quality. Table 1 shows the final suggestions for the planned quality in each legislation period.

The second inquiry was dealing with the assessment of the impact of the number of these items that have been observed as poorly implemented and need some sort of rectifying before the final acceptance. The experts were asked about the impact of the number of these observations on the overall quality of the project.

Table 1: Suggested values of planned quality and reduction percentages

Legislation	Period	Planned quality (%)	Av. reduction due to observations (%)	Average reduction due to cost penalty (%)	Quality index (%)
1	2003-2006	80	8.5	3.0	69.0
2	2007-2008	85	7.3	5.3	72.0
3	2009-2011	90	6.7	1.7	81.5
4	2012-2014	95	7.0	2.9	84.5

Table 2: Suggested weights of the defect/contract ratio on quality level

Defect ratio	Symbol	Impact (%)
Initial defects/contract value	IDC	0-1
Undiscovered errors/contract value	UCC	10-20
Change orders/contract value	COC	10-20
Rejected works/contract value	RWC	60

Certainly; the higher number of observations, the less level of quality. Two figures were to be determined; the initial reduction in quality if there is such observations, no matter how little they were while the other figure was how much is the increment in this reduction per each 10 additional observations. The final outcome would lead to derive an equation that estimates the reduction in quality level due to the number of observations in which the first figure represents the intercept and the second represents the slope. The assessed reductions in quality level values are shown in Appendix 1.

The third inquiry was dealing with the percentage of reduction in quality due to the amount of cost deduction out of the low quality accepted items. The same procedure in the second inquiry was adopted and lead to derive another equation by which the percentage of quality reduction due to cost deduction penalties could be assessed. This reduction value is also, shown in Appendix 1.

The final value of the quality relative value is calculated by the subtraction of the two estimates out of the planned quality value in each period. Table 1 shows the averages of the reduction due to the acceptance observations estimates and the averages of the reduction due to the cost deduction penalty estimates as well as the quality index for each legislation period. These outcomes of the questionnaire reveals the gradual improvement in the overall level of quality represented by the quality index, apparently due to the recovery of the healthy environment with the diminution of the acts of terror and military related actions.

The third part of the questionnaire investigates the impact of the defects and errors that take place during the construction period on the quality level of the project. These defects are classified into four types; initial defects, undiscovered errors, change orders and rejected works. The main inquiry was the extent to which the ratio of the value of each defect to the total value of the contract may reduce the quality level. Accordingly, the questionnaire form included a premeditated ranges for each type of defects and the highest votes were as in Table 2.

Development of system dynamics model: The key role of the system dynamics model is to simulate the dynamic relations between the various defects and errors that arises during projects progress and their consequential reworks, modifications and change orders on one hand and the quality performance of the project on the other hand. The simulation process considers a quantitative assessment to the impact of all the aforesaid factors which are represented as exogenous variables.

The model is simply developed depending on the available, quality related, data of the group of projects included in this study. The model utilizes the initial defects, undiscovered errors, rejected works, undiscovered changes and organizing change orders as exogenous variables while their values are presented as they were collected for each project.

The "initial defects" refer to the defects that occur at the beginning of the project and after a short period of the awarding to the contractor. These defects mainly related to the original errors either in the bill of quantities due to miscalculation or estimation or due to discrepancies in designs. These defects should be discovered at the beginning of the project and mostly corrected without the need for any rework, hence, they have small impact on the quality of the project as compared to other factors.

The undiscovered errors have the same nature as in initial defects, only they have not been discovered early and consequently their correction requires some sort of rework or modification which may affect the quality of the project more than the initial defects.

The rejected works represents those items that were poorly implemented and need to be removed and reworked once again. This type of correction necessitates such acts like demolition and removal of debris which may very well affect the nearby structures and sometimes cause serious damages. Accordingly this factor represents the highest impact on the quality of the project as compared to all other factors.

The modifications that require change orders, either due to some sort of shortage in the design or bill of quantities or due to an arising need to the owner which was not included in the original design and it is necessary to be added as the project is in progress. Both types of modifications, "undiscovered changes" and "organizing change orders" has an identical effect on quality that is most of the change orders lead to add new items similar to those already implemented but with different timing. This may affect the quality in many aspects especially when the new additions include certain structural parts such as strip foundations which in nature, endure time dependent settlement which in turn leaves noticeable marks between the old and the new additional parts as well as the adjacent areas.

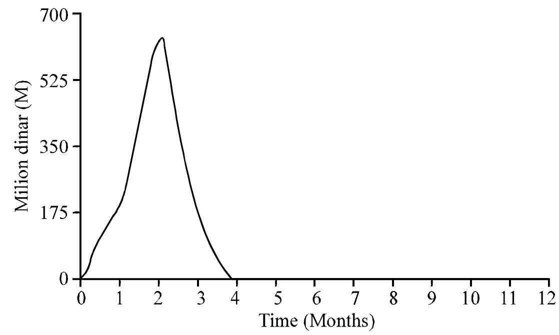

Fig. 1: Look up table graph for the rejected works

The values of these variables are tabulated as a look up tables which could also be presented as graphs as well in order to resemble its exact magnitude and timing manner. Figure 1 shows a sample graphical representation of a look up table for the rejected work variable. Each one of these look up variables influences its correspondent flow rate which is in turn, accumulated in a stock.

Four stocks are encompassed by this model; "initial defect accumulations", "undiscovered errors accumulations", "rejected work accumulations" and "change order accumulations". These stokes accumulate defects, errors, reworks and change orders along the duration period of the project (Fig. 2).

Each stock influences the quality to a certain extent depending on its nature and its intensity. It is deemed reasonable to consider the influence in terms of the ratio of the value of the stock to the total value of the contract multiplied by the weight suggested by the questionnaire panel as they listed in Table 2. The total reduction in projects quality is the sum of all influences that is computed in the auxiliary "quality multiplier". This auxiliary is influenced by the four stocks and their corresponding impact weights as well as the total value of the contract. The mathematical formula for this auxiliary is as in Eq. 1.

$$\text{Qualitymultiplier} = \frac{\sum_{i=1}^{4} C_i V_i}{\text{Contact value}} \quad (1)$$

Where:
V = The value of the stock
C = The Corresponding impact of the stock

The actual quality is then determined by subtracting the value of the multiplier from the ultimate quality of 100% which is mathematically calculated in the auxiliary "actual quality". This value should represent the quality of the work completed by the contractor and accepted by

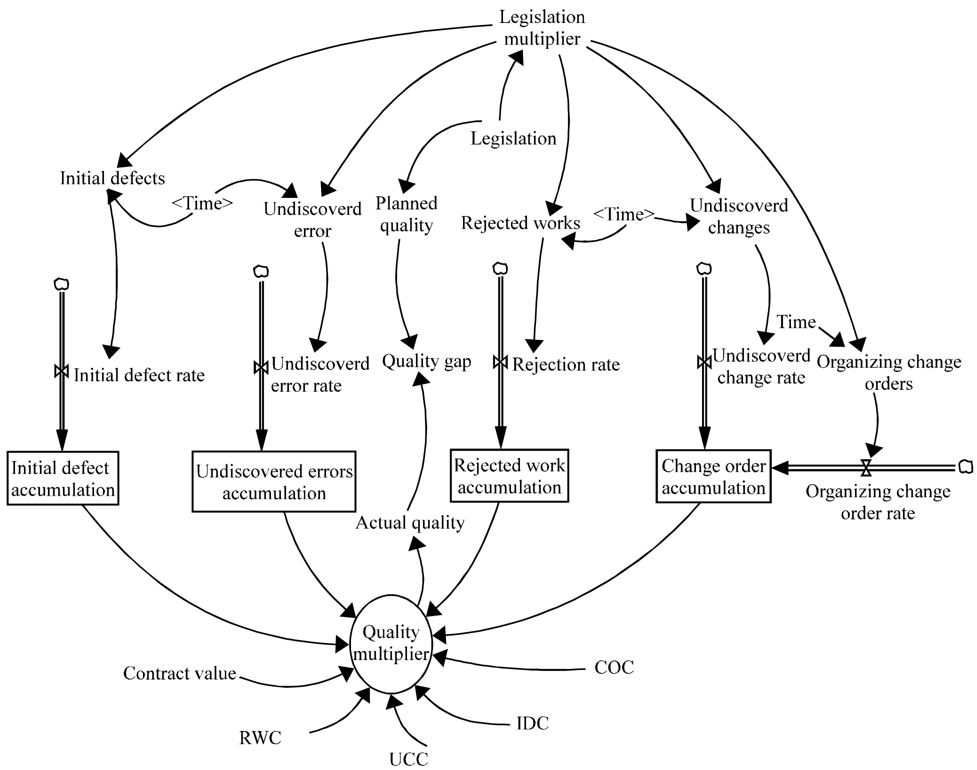

Fig. 2: System dynamic model

the owner, yet this value is mostly far from the ultimate quality and often below the planned quality targeted by the governmental authorities in each legislation period. The difference between the planned and actual qualities may shed some light on the performance of all parties in the local construction industry at that period and under its specific legislation. This figure is calculated in this model by the "quality gap". The mathematical equations of the model are shown in Appendix 2.

Model calibration and validation: By simulating the system dynamics model, a quite variety of inputs were used to test the applicability of the model. The outcomes that obtain from the questionnaire are entered to the system dynamics model to evaluate the quality performance in construction projects. The results of the model are then compared with the results of the second part of questionnaire to test the validity of the model. The comparison between these results are shown in the Table 3.

Sensitivity analysis was used to understand the behavior of the system dynamics model. To conduct sensitivity analysis, different patterns of legislations that changed during the study period were used. The analysis evealed that the model is sensitive to the legislation changings and external factors. The model reflected the real system as understood and expected.

Table 3: Comparison between quality index and actual quality

Legislation	Period	Quality index (%)	Actual quality	Difference (%)
1	2003-2006	69.0	67.0	3.00
2	2007-2008	72.0	76.0	5.50
3	2009-2011	81.5	84.0	3.00
4	2012-2014	84.5	87.6	3.60
Average				3.77

RESULTS AND DISCUSSION

The results of second part of the questionnaire which dealt with the final acceptance disadvantages, represented by the deficiency observations and the cost redaction penalties, revealed a relatively positive change in construction projects quality as legislation were changed progressively. During the first period from 2003-2006, the quality estimated as 69% while in the second period from 2007-2008, the quality estimate was increased by 4% to become 72%. The level of quality estimates in the third and fourth periods that lasted from 2009-2011 and 2012-2014 were 81.5 and 84.5% respectively. This pattern of quality change with respect to the legislations periods is shown in Fig. 3.

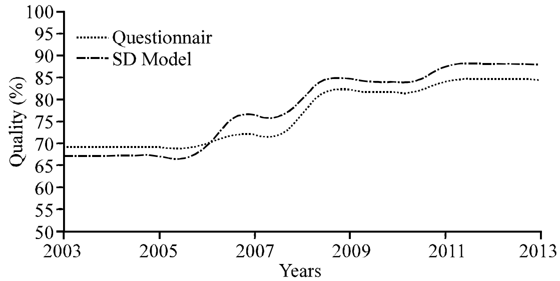

Fig. 3: Change in quality performance with legislative periods

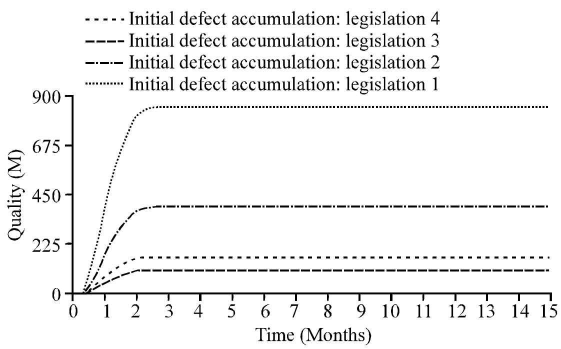

Fig. 4: Initial defect accumulation value in all legislations

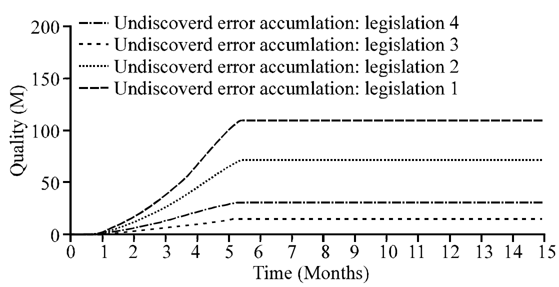

Fig. 5: Undiscovered errors accumulation value in all legislations

On the other hand, the results that were obtained from the system dynamics model revealed the enhancing behavior of quality in a similar pattern. By running the model, the behavior of each factor is considered as illustrated in Fig. 4 and 5 the main outcomes represented in quality estimate were very close to the findings of the questionnaire. The quality estimates for the first period through the fourth one were 67, 76, 84 and 87.6%, respectively. The obvious proximity between the questionnaire quality estimates and those of the system dynamics model throughout the study period could be reflected by the average difference which is found to be 3.77% as listed in Table 3.

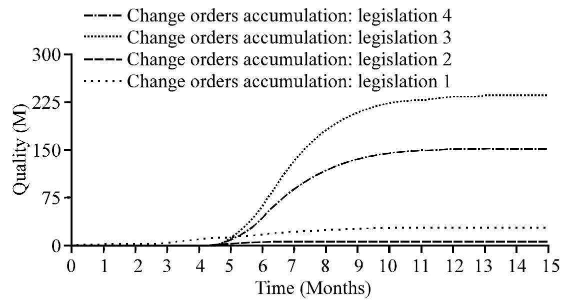

Fig. 6: Change orders accumulation value in all legislations

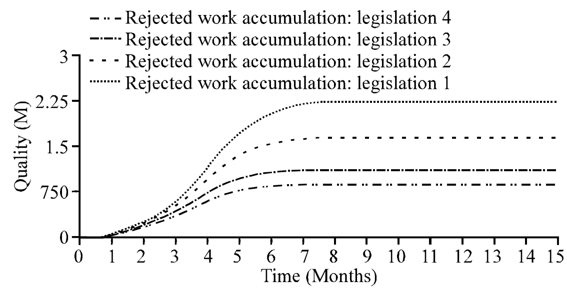

Fig. 7: Rejected work accumulations in all legislation

This closeness in results give credit to the system dynamics model and the whole quality estimating process due to the fact that the questionnaire depended on the final acceptance shortcomings which are obvious and noticeable to everyone while the system dynamics model estimated the quality of the project depending on several shortcomings that take place during the construction progress such shortcomings are internally solved in nature yet, they have their impact on quality or in other words are the hidden reasons behind the final and obvious shortcomings.

Figure 4 through 7 show the defects accumulation behavior for each legislation. The initial defects and undiscovered errors accumulations showed tangible reductions in each successive act except in the fourth one in which the value of these accumulations indicated an increase over that of the third legislative act as shown in Fig. 4 and 5.

The change order accumulation, Fig. 6 showed a decrease in the second legislation but the third and fourth ones caused a successive increase in its value mainly due to the additional powers authorizing the owner higher change order limits and the increase is mostly driven by the change orders issued on the request of the owner. This manner in negatively affecting the overall quality performance.

The rework accumulation which represents the most detrimental influence on quality performance, showed noticeable decrease in value gradually descending from the firs legislation through the fourth Fig. 7 to this pattern

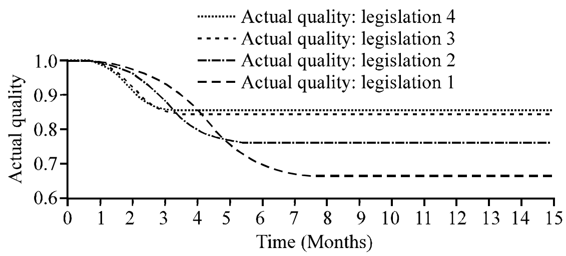

Fig. 8: The actual quality change in all legislations

of rework decrease all the actual quality improvements and consequently the convergence with the planned quality could be related. The progressive increase in actual quality with the change of legislation is shown in Fig. 8.

CONCLUSION

In this study the impact of legislation change on the quality performance that affected by adverse conditions in Iraqi construction sector was investigated. Questionnaire and system dynamics model were developed for this purpose. The data was collected from 30 construction projects implemented during the period from 2003-2014 in which four legislative acts were enacted. The questionnaire depended in quantitative quality assessment on the final acceptance deficiency observations and their subsequent cost redaction penalties. The quality estimates were 69, 72, 81.5 and 84.5% for the four successive legislative periods. These estimates showed progressive enhancement of 15.5% throughout the 11 years period.

The system dynamics model on the other hand was developed to estimate the projects quality depending on the shortcomings that accumulate during the project progress period and their consequent reworks, modifications and change orders. Such shortcomings are the hidden reasons that are internally solved in nature yet they have their impact on the overall projects quality. The highest impact is generated by the rejected work accumulation and less influence is initiated by the undiscovered errors and change order accumulations while the least effect is created by the initial defects that usually corrected before commencing the work. The model yielded the values of 67, 76, 84 and 87.6% for the same successive periods showing that some 20.6% improvement in quality through the same period. The tight proximity between these results and those of the questionnaire with an average difference of 3.77% may give credit to the system dynamics model and the whole quality estimating process.

The developed model represent an easy manner that can be used in estimating quality performance in any construction project once the internal deficiencies are known. The deficiency accumulations are represented by the reworks, errors and change orders. By this way an estimate to the overall quality performance of the project could be established even before the final acceptance is granted or even before the project is fully completed.

The improvement in the actual quality is still below the quality level planned by the legislation authorities, thus, further detailed studies would be needed to deal with similar projects completed in the time interval following the study period in order to find out whether the actual and planned qualities are converging to close the gap or further legislation enhancement is in required.

Appendix 1:

Attachment 1: Quality performance of construction project

Project	Years	Number of observation	Deduction penalty ratio	Observations reduction (%)	Penalty reduction (%)	Planned quality (%)	Quality index (%)
1	2005	30	0.00233872	8	8.0806	80	63
2	2005	50	0	9	0	80	71
3	2005	50	0.000725965	8	3.88750	80	68
4	2005	50	0	9	0	80	71
5	2008	50	0	9		85	76
6	2008	30	0	7		85	78
7	2008	33	0	7.5		85	77.5
8	2008	2	0.00744121	6	21.3471	85	58
9	2009	17	0	6	0	90	84
10	2010	24	0	7	0	90	83
11	2010	25	0	6	0	90	84
12	2010	25	0.00227707	6	7.92039	90	76
13	2010	25	0	6	0	90	84
14	2010	61	0.00082719	10	4.15069	90	76
15	2010	15	0	6	0	90	84
16	2010	25	0	7	0	90	83
17	2010	20	0	6	0	90	84
18	2010	15	0	6	0	90	84
19	2010	15	0.00005380	6	2.13989	90	82
20	2011	50	0.0036	9	11.36	90	69
21	2011	11	0	6	0	90	84
2	2011	11	0	7	0	90	83

Attachment 1: Continue

Project	Years	Number of observation	Deduction penalty ratio	Observations reduction (%)	Penalty reduction (%)	Planned quality (%)	Quality index (%)
23	2011	25	0	6	0	90	84
24	2011	25	0.00053112	7	3.38093	90	79
25	2011	25	0	7	0	90	83
26	2012	20	0.00267022	6	8.94259	95	79
27	2012	21	0.00267022	7	0	95	88
28	2013	30	0	7	8.5	95	79
29	2013	25	0.0025	7	0	95	88
30	2013	27	0	7	0	95	88

Attachment 2: Equations of the model

Variables	Equations
COC	0.16
Actual quality	1-quality multiplier
Change orders accumulation	INTEG (organizing change orders rate+undiscovered changes rate, 0)
Contract value	3.75E+09
FINAL TIME	40
IDC	0.003
Initial defect accumulation	INTEG (initial defect rate, 0)
Initial defect rate	Initial defects
Initial defects	WITH LOOKUP (Time*legislation multiplier)
INITIAL TIME	0
Legislation	1, 2, 3, 4
Legislation multiplier	IF THEN ELSE (legislation = 1, 1, IF THEN ELSE (legislation = 2, 1.4, IF THEN ELSE (legislation = 3, 2.1, 2.3)))
Organizing change orders	WITH LOOKUP (Time*legislation multiplier)
Organizing change orders rate	organizing change orders
Planned quality	IF THEN ELSE (legislation = 1, 0.8, IF THEN ELSE (legislation = 2, 0.85, IF THEN ELSE (legislation = 3, 0.9, 0.95
Quality gap	MAX (Planned Quality-actual quality, 0)
Quality multiplier	("C. O. C."*Change orders accumulation "I. D. C."*initial defect accumulation+"R.W. C."*Rejected work accumulation+"U. C. C."*undiscovered Errors Accumulation)/contract value
RWC	0.6
Rejected work accumulation	INTEG (rejection rate, 0)
Rejected works	WITH LOOKUP (Time*legislation multiplier)
Rejection rate	Rejected works
SAVEPER	TIME STEP
TIME STEP	0.0625
UCC	0.14
Undiscovered changes	WITH LOOKUP (Time*legislation multiplier)
Undiscovered errors	WITH LOOKUP (Time*legislation multiplier)
Undiscovered errors accumulation	INTEG (undiscovered Errors rate, 0)
Undiscovered errors rate	Undiscovered errors
Undiscovered changes rate	Undiscovered changes

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