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A linear regression modelling of the relationship between initial estimated and final achieved construction time in South Africa

Peer reviewed

Abstract

The estimation of contract completion time has always been inaccurate despite there being a need for certainty regarding the completion of projects. This article reports on an investigation of the relationship between initial and final contract time with the aim of developing an equation for reasonably estimating project period. Data for the study was secured from a total of eighty-eight questionnaires and sixty-five projects. The sample population consisted of architects, contractors, quantity surveyors, structural engineers and clients. Five metropolitan cities in the provinces of the Eastern Cape, Free State, Gauteng, KwaZulu-Natal, and the Western Cape, namely Bloemfontein, Cape Town, Durban, Johannesburg and Port Elizabeth, constitute the geographical area in which the study was conducted. Inferential statistical analysis, including regression analysis, was used to evolve, *inter alia*, a model and linear equations for estimating building construction time. The equations involved in the respective phases of the study are Y = 9.9 + 1.0586x for phase one, and Y = 13.1159 + 1.1341x for phase two. During phase two of the study, it was determined that 35.3% additional time needs to be added to the amount of the initial contract period in order to estimate final contract time. It is recommended that either the equation Y = 13.1159 + 1.1341x be used, or that 35.3% additional time be added to the amount of initial contract time to estimate the final contract time.

Keywords: Relationship, initial & final construction time, project delivery

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Abstrak

Die skatting van die konktrakvoltooiingstydperke was altyd inkorrek ten spyte daarvan dat daar ‘n behoefte is vir sekerheid betreffende die voltooiing van projekte. Hierdie artikel doen verslag oor ‘n ondersoek na die verhouding tussen aanvanklike en finale kontraktydperke met die doel om ‘n berekening vir redelike geskatte projekperiodes te ontwikkel. Data vir die studie is verkry uit ‘n totaal van agt en tagtig vraelyste en ses en vyftig projekte. Die steekproefpopulasie het bestaan uit argitekte, kontrakteurs, bourekenaars, strukturele ingenieurs en kliënte. Vyf metropoolstede, in die provinsies van die Oos-Kaap, Vrystaat, Gauteng, KwaZulu-Natal en Wes-Kaap, naamlik Bloemfontein, Kaapstad, Durban, Johannesburg en Port Elizabeth, het die geografiese gebied gevorm waarin die studie gedoen is. Inferensiële statistiese analise, insluitende regressive analise is gebruik om, onder andere, ‘n model en lineêre vergelykings om bou-konstruksie tydperke te skat, te ontwikkel. Die vergelykings wat ontwikkel is in die onderskeie fases van die studie is Y = 9.9 + 1.0586x vir fase een, en Y = 13.1159 + 1.1341x vir fase twee. Gedurende fase twee van die studie, is dit vasgestel dat 35.3% addisionele tyd tot die aanvanklike kontrakperiode bygevoeg behoort te word om die finale kontraktydperk te kan skat.

Daar word aanbeveel dat die vergelyking Y = 13.1159 + 1.1341x eerder gebruik word, of dat 35.3% addisionele tyd tot die getal van die aanvanklike kontraktydperk bygevoeg word om sodoende die finale kontraktydperk te kan skat.

Sleutelwoorde: Verhouding, aanvanklike en finale kontraktydperke, projek lewering

1. Introduction

Success with respect to delivery of a building project could be referred to as the completion of a building within specified time, budget limits, quality standards, and void of accidents. This indicates the level of management control on the project and a measure of competence. Observation has revealed that peculiar problems concerning project management still exist (Jha & Iyer, 2005: 314). There are many means of control in the delivery of projects: activity planning, labour, materials, and plant and equipment planning, as well as supervision of work in the form of allocation of daily tasks, specification of work direction and guidance, the designing of temporary works, and the sequencing of activities. These require firm control in order to deliver the project as designed. Various stakeholders on a project, namely clients, contractor, and designers, as well as external influences contribute to the process of delivery of a project. The objective of this article is to determine the relationship between these factors and the delivery dates achieved on projects.

2. Project delivery time

Based on the aforementioned, the influences on project delivery time were identified from previous studies conducted by Sambasivan & Soon (2007: 522), Assaf & Al-Hejji (2006: 352-353), and Faridi & El-Sayegh (2006: 1171-1172). Seventy-six factors were identified (sub-problems), which were then grouped into twelve categories (problem category). Table 1 indicates these groups and the number of factors associated with each group. These form the theoretical framework of the study.

Table 1: Problem categories which influences project delivery time

S/No	*Problem category*	*Sub-problem*
1	Client understanding of the design, procurement and construction processes	5
2	Quality of management during design	7
3	Quality of management during construction	7
4	Motivation of staff	8
5	Site ground conditions	8
6	Site access	3
7	Constructability of design	7
8	Management style	8
9	Management techniques used for planning and control	2
10	Physical environmental conditions	5
11	Economic policy	6
12	Socio-political conditions	3

Each of these problem categories will now be discussed:

- Clients' understanding of the design and construction processes means the level of their contributions to the design and construction teams, and the ability to quickly make authoritative decisions regarding the progress of the project;
- Quality of management during design – this refers to the extent of competence of engineers and architects regarding building design. The ease of construction depends on the level of freeness from ambiguity relative to design. Factors for consideration include dimensional accuracy; revision of drawings; conflicting design information; missing information, and expediting shop drawings;

- Quality of management during construction implies the various efforts put into the construction stage of the project, such as analysis of construction methods and resource; work sequencing to adhere to and maintain workflow, and monitoring and updating of plans to appropriately reflect work status;
- Motivation of staff – the degree of labour performance depends largely on motivation. Motivation is defined as inducement given to enhance productivity. These are: job security; a sense of belonging; recognition of contribution made; opportunity to improve skills, and career advancement;
- Site ground conditions – an indication of the nature of the site soil, and related factors. Frimpong, Oluwoye & Crawford (2003: 325) state that ground problems such as extent of ground contamination and archaeological finds; the height of the water table, and underground services impact on the speed of delivery of a project;
- Site access reflects the ease of traffic ingress and egress, both vehicular and people. Factors for consideration include congestion at ingress and egress points, and road conditions;
- Constructability of design – this is the ease at which a design can be constructed. Constructability requirements are major factors necessitating the integration of construction experience into building designs. Oyedele & Tham (2006: 2093) schedule factors that could be used to assess constructability, *inter alia*: flexibility of design to changes; dimensional coordination of elements; scope and complexity of off-site fabrication; appropriateness of design tolerance, and working space;
- Management style – machines and systems are operated by people, but generally the nature of people tends towards not wanting to work, except being coerced. Griffith & Watson (2004: 57) identify three main types of management style, namely autocratic, democratic, and *laissez-faire;*
- Management techniques used for planning and control. These are the various scheduling tools available and employed in activity sequencing and executing them. These include critical path method; bar chart; line of balance; horse blanket, and s-curves;
- Physical environmental conditions – this refers to the influence of weather and natural occurrences, which negatively impact on the speed of construction. They are: natural hazard/fire;

flood; adverse local weather – rainfall and temperature differences; adverse light, and noise;

- Economic policy – this refers to government policies such as restriction on importation of building materials; interest rates, and inflation which may negatively affect construction period (Koushki & Kartam, 2004: 127-128), and
- Socio-political conditions. These are government policies and its effects on projects and individuals. Factors include civil strife or riots; influence of civil action groups, and disruption due to environmental concerns.

3. Previous predictive studies on construction duration

Table 2 presents the results of previous predictive studies undertaken by several researchers in different parts of the world.

Table 2: Predictive model equations

Ogunsemi & Jagboro (2006: 257)	
Country of study:	Nigeria
Predictive Equation:	T = 118.563 – 0.401c (c > 408) or T = 603.427 * 0.610c (c >408) R^2 = 0.765 (high predictive power)
Where:	c is in millions of naira.
Love, Tse & Edwards (2005: 192)	
Country of study:	Australia
Predictive model:	log (t) = 3017.8 + 0.274 log (GFA) + o.142 log (floor)
Where:	t = completion time; GFA = gross floor area, and floor = number of floors.
Moselhi, Assam & El-Rayes (2005: 356)	
Country of study:	Canada and USA
Model equation:	TPi = HCOi/PHi
Where:	TPi = time impact of change or a period, HCOi = actual change order hours during period i, Phi = planned hours during period i, and i = period when change order occurs, i = 1-5.
Al-Moumani (2000: 55)	
Country of study:	Jordan
Model equation:	Y = 82.87 + 1.0016x
Where:	Y = number of days of actual construction, and X = number of days specified in the contract.

Chan (2001: 226)	
Country of study:	Malaysia
Model equation:	$Y = 269C^{0.32}$
Where:	T = time of completion, and C = project estimated cost.
Stoy, Dreier & Schacher (2007: 79)	
Country of study:	Germany
Model equation:	$Ln(y) = 4.753 + 0.0002x_1 – 0.001x_2$
Where:	y = construction speed (m^2 gross external floor area/ month); x_1 = absolute size (m^2 gross external floor area), and x_2 = project standard (building construction cost/m^2 gross external floor area)
Ling, Chan, Chong & Ee (2004: 180)	
Country of study:	Singapore
Predictive model:	Y = 145 + 0.017 Gross floor area + 133 Contractors design capability (1) R^2 = 0.93 (very high predictive power) Y = 3.462 + 0.024 gross floor area – 464 Project scope definition completion when bids are invited – 443 Extent to which the contract period is allowed to vary during bid evaluation – 180 Design completion when budget is fixed.(2) R^2 = 0.90 (very high predictive power).
Xiao & Proverb (2003: 326)	
Country of study:	Japan; UK, and USA
Model equation:	Y = 5.458 + (-6.403E – 02)DELAYEDT + 0.489LIFEEMP2 + 0.172CSTIME + 0.415PSUBCON2 + (-2003E – 03)DCARATI R^2 = 0.52 (good predictive power)
Where:	DELAYEDT represents the typical delay on similar projects as percentage of the original contract time; LIFEEMP2 is a dummy variable for a commitment towards lifetime employment (one for “yes” and zero for “no”); CSTIME represents the importance contractors allocate to construction time to satisfy clients (on a scale of one to ten, where one represents totally unimportant and ten very important); PSUBCOW2 is a dummy variable for the partnering with subcontractors (one for “yes” and zero for ”no”), and DVARIATI represents the typical number of design variations during construction.
Proverbs & Holt (2000: 663)	
Country of study:	UK
Model equation:	Y = 14.439 = 13.377 (“concrete pump” transportation method) + -4.125 (“property” types of formwork) + -3.609 (productivity of erecting formwork to floor slabs) + 1.690 (number of supervisions). R^2 = 0.473 (average predictive power).

It is observed from Table 2 that researchers in each country have a distinctive predictive model for the estimation of final completion time of projects. This cannot be separated from the following: the construction business environment for each country differs; socio-political conditions and policy of each country differ; the prevailing weather and geo-physical conditions of regions differ, and the technological developments of countries are different. These key construction performance factors have associated subfactors that influence each main factor, with a consequential result on project delivery time. As a result, a particular model developed in a country cannot be used for the estimation of project completion time in other countries based on the foregoing argument. Therefore, this study was embarked on to establish a model for the estimation of final project delivery time in South Africa.

4. Methodology

Both the quantitative and qualitative research approaches were used in this study. Probability sampling techniques were employed in the selection of the sample for the study – proportional stratified, simple random, and systemic sampling.

The concept of these sampling techniques is to allow each sample equal opportunity of occurrence. Relative to the proportional stratified samples, details of respondents were documented alphabetically from A to Z. These constitute layers from which sample sizes of each layer were calculated before drawing from each layer, in a box, the required number of samples. Systemic sampling is that process that allows samples to be picked at regular interval.

The geographical areas included in the study are the three most active areas of South Africa in terms of construction, namely Gauteng, KwaZulu-Natal, and the Western Cape. The Eastern Cape was used as a proxy. Respondents to the study included architects, contractors, clients, structural engineers, and quantity surveyors. These were drawn from the South African Institute of Architects (SAIA), the Association of South African Quantity Surveyors (ASAQS), the South African Property Owners Association (SAPOA), Civil Engineers of South Africa (CESA), and Master Builders Associations (MBAs).

The questionnaire was based on the twelve problems categorised, which formed the framework for the study, and the associated sub-problems evolved from the survey of the literature which initially identified seventy-six factors. These were crystallised and developed into questions that addressed the issue of delays in the delivery of projects.

The statistical tools used for the analysis of data include descriptive and inferential statistical tools. Cronbach's *alpha*; Cohen's d, and factor analysis loading were used to test for reliability and consistency of data.

The data for the study was collected in three phases using questionnaires. Relative to Phase 1, the primary survey of the study, eighty-eight questionnaires were analysed, representing a response rate of 6.1%. Relative to Phase 2, the historical survey (in this phase, data relative to causes of delay on projects were obtained and the extent of delay in weeks), twenty-four questionnaires were analysed (the number of projects handled previously were considered, in this case, and data from a total of fifty-six (56) were obtained and analysed), representing a response rate of 33.5%. The Phase 3 survey is not applicable to this article.

In order to test the reliability of the data, a Cronbach's coefficient test was conducted and found that values for all the categories of factors were > .70, which is regarded as adequate proof of internal consistency of the factors. Factor analysis loading for sample sizes of 88-99 is 0.60. Most factors have a loading greater than 0.60. This is an indication that factors adequately describe the constructs.

Respondents over the age of thirty years and above predominate (76.5%) in the sample investigated. The most common academic qualifications of respondents are Bachelors (25%), Honours (23%), and B.Tech (17%), totalling 65%. Managing directors/Managing members/Principal (35%), senior staff (20%) and managers (17%) predominate in terms of respondents' status. The mean number of years of experience of respondents is 17. The type of facility with which respondents were involved include residential; commercial offices, and institutional facilities in the form of education, health, and others. The mean value of projects with which respondents have been involved is R866.63 million.

4.1 Linear regression

A linear regression test was conducted to determine the relationship between the start and the finish times of contracts. The conditions relative to the data and the tests are discussed as follows. It should be noted that, in terms of the study, working days and not weekdays represent a week. The start date was when a contractor started work on site, and the end date was the date of handing over of a site to the client or his/her representative. The specified duration and actual duration are not inclusive of the retention period. Actual duration provided by respondents was accurate, because data was obtained from archives of past projects. Relative to the reasons for delay in project delivery, a closed ended questionnaire was used to access the amount of delay experienced on each project. A space was provided in the questionnaire for respondents to specify, in their own opinion and relative to the projects handled, the causes of delay in project delivery, which is not included in this article, because the focus of this article is the relationship between initial and final contract duration. Changes to the contract in the form of design, additional work, and so on have being taken care of among the seventy-six factors identified and categorised into the twelve problem categories for this study. The results are presented in Figures 1 to 4.

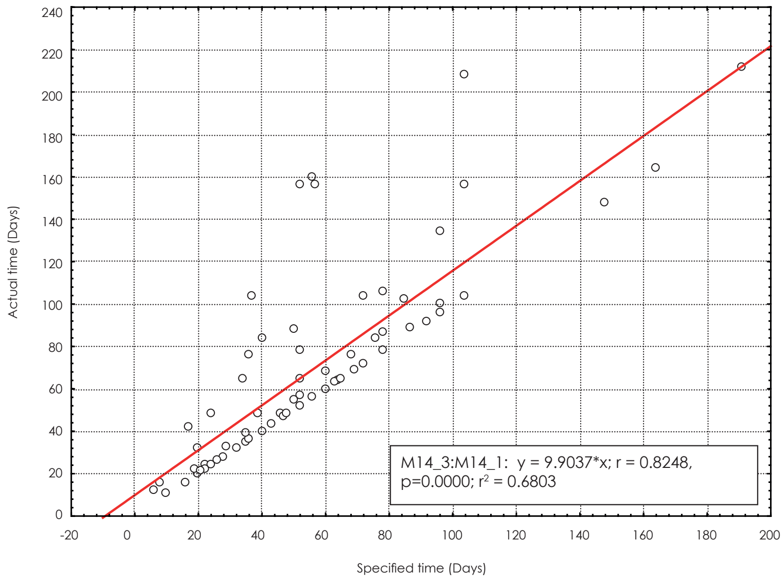

Figure 1: Regression of initial contract duration and final contract duration

Regression analysis was conducted to determine the kind of relationship between the initial and actual or final contract duration. The scatter plot (Figure 1) indicates a good fit, the correlation coefficient r = 0.82 suggests a strong linear relationship between the factors, and $r^2 = 0.68$ indicates that the predictive ability of the equation found is high. A relationship in the form of Y = 9.9 + 1.0586x was obtained, where Y = actual completion duration and X = initial contract duration.

4.1.1 Phase 2 questionnaire: Regression analysis

Linear regression analysis was conducted to determine the relationships between:

- Initial contract duration and final contract duration for the public and private sectors;
- Initial contract duration and final contract duration for the public sector, and
- Initial contract duration and final contract duration for the private sector.

Figure 2 shows the initial contract duration and final contract duration for the public and private sectors.

It should be noted that in all the tests that were conducted a is set at 5%.

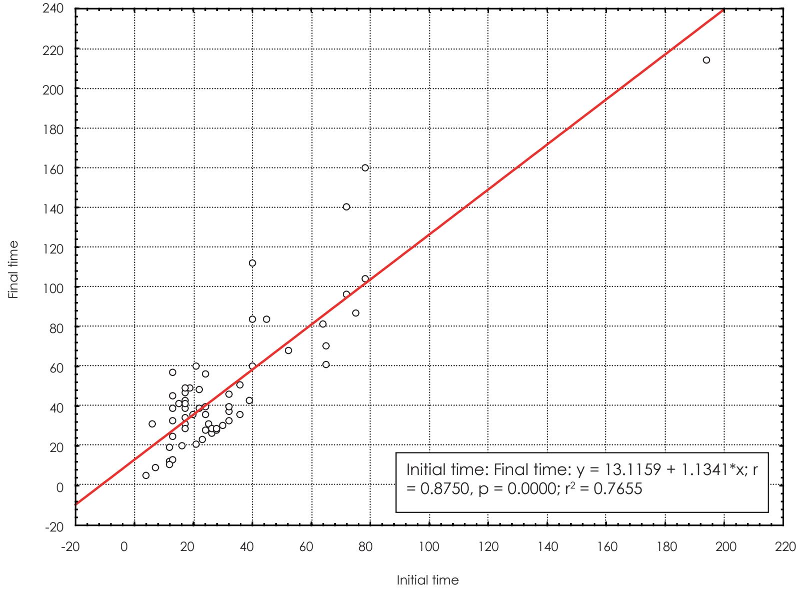

Figure 2: Scatter plot for initial and final contract duration (public and private)

Based upon the correlation coefficient r = 0.86, the relationship between initial and final contract duration can be deemed to be strong and statistically significant, because the p value is < 0.05 (Figure 2). The predictive ability $r^2 = 0.77$ is high. Therefore, the equation Y = 13.1159 + 1.1341x can be used to predict final contract duration of projects, where Y is final project duration and X is initial project duration.

Figure 3 shows the initial contract duration and final contract duration for the public sector.

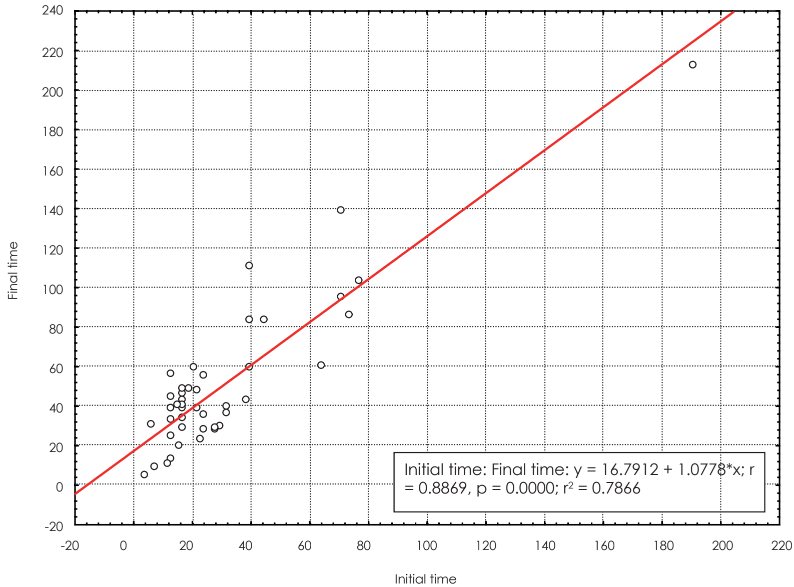

Figure 3: Scatter plot for initial and final contract duration (public)

The correlation coefficient r = 0.89, presented in the scatter plot in Figure 3, indicates that a strong linear relationship exists between the initial and the final contract duration and is statistically significant as a result of the p value being < 0.05. The predictive ability $r^2 = 0.79$ is high. Therefore, the equation Y = 16.7912 + 1.0778x can be used to predict final contract duration, where Y is final contract duration and X is initial contract duration.

Figure 4 shows the initial contract duration and final contract duration for the private sector.

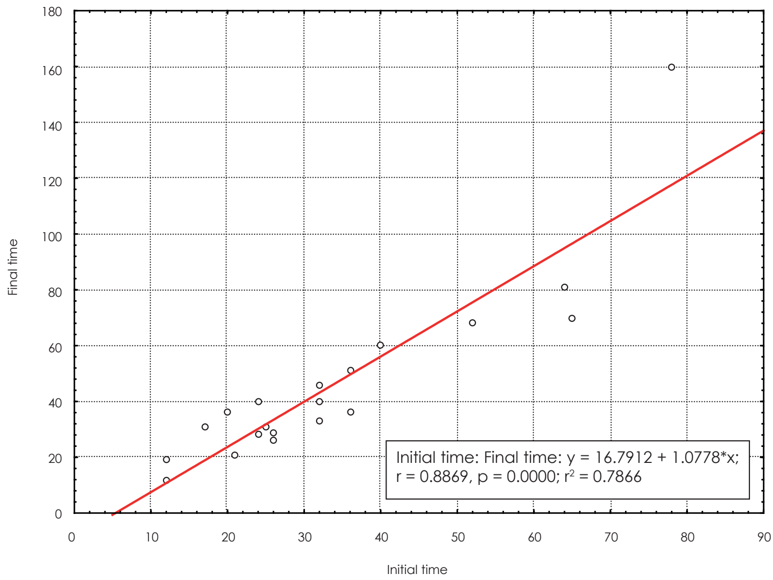

Figure 4: Scatter plot for initial and final contract duration (private sector)

Figure 4 presents the result of the linear regression analysis for the private sector. The value for $r = 0.90$, which indicates that a strong linear relationship exists between the initial and final contract duration. Given that the p value is < 0.05, a statistically significant relationship exists between both times. The predictive ability $r^2 = 0.82$ is high. Therefore, the equation $Y = 16.7912 + 1.0778X$ can be used to predict the final completion time of a project, where Y is project final contract duration and X is initial contract duration.

When comparing the results of the linear regressions analysis for the private and public sector it will be observed that the results obtained from the private sector have greater predictive ability. Therefore, the combined result is recommended for use.

Respondents were asked to indicate the number of weeks from one to eight and over relative to the twelve problem categories identified as contributors to delay, that were experienced in the delivery of contract or projects during the first phase of the study. Note that this is the opinion of the respondents. Table 3 presents the result.

Table 3: Percentage delay on project delivery time

Problem category	*Frequency of respondents*	*Standard deviation*	*Percentage mean (%)*
Quality of management during construction	12	10.63	4.9
Physical environmental considerations	12	10.02	4.8
Client understanding of design, procurement and construction processes	9	6.39	3.4
Economic policy	8	7.91	3.2
Site ground conditions	8	5.54	3.0
Constructability of design	7	6.42	2.9
Quality of management during design	7	5.30	2.9
Management techniques used for planning and control	6	4.04	2.4
Management style	5	4.23	2.2
Socio-political conditions	5	4.91	2.2
Motivation of staff	5	3.46	1.8
Site access	4	3.28	1.6
Total	88		35.3

The percentage mean was computed for the delays caused by factors in various categories. Respondents were asked to indicate the actual delay experienced on the project in terms of days or weeks with reference to the problem category. The percentage delays were calculated relative to the specified project durations. These were then added up to obtain the percentage contribution of the problem categories to delay. The standard deviation was included to enable the ranking of the problem categories. It was found that the factors identified in the research could cause 35.3% addition of time, which is the delay with respect to the initial contract duration.

5. Conclusions

Based on the regression analysis conducted in Phases 1 and 2, the equation for predicting the actual contract duration based on the initial contract duration is given as:

- For the Phase 1 study:
  - $Y = 9.9 + 1.0586x$
- For the Phase 2 study:
  - $Y = 13.1159 + 1.1341x$

The difference between the two equations is not statistically significant. Therefore, the equation from the Phase 2 survey is suggested for use. The quality of management during construction such as the level of supervision, activity sequencing and ineffective coordination of resources negatively affects the completion time of projects. Physical environmental conditions such as rainfall and high and low temperatures negatively affect delivery time of projects.

6. Recommendations

It is recommended that the regression equation $Y = 13.1159 + 1.1341x$ be used for the estimation of final contract duration of projects in the South African construction industry.

Based on the minimum percentage of delay, the twelve problem categories of the study could contribute 35.3%, i.e. additional time to the contract duration. The difference in these two results is insignificant, that will be obtained, when using the regression equation, and adding a percentage to initial contract duration for computing final contract duration. Therefore, both are recommended for use, depending on the initiative of the user.

Clients should evaluate the quality performance of contractors before awarding contracts. This will reduce the incidence of delay on projects. Yasamis, Arditi & Mohammadi (2002: 221) propose a model for evaluating contractors' quality performance (Figure 5). This model is recommended for evaluating contractors' quality performance in South Africa. Note that the actions to be taken at each stage are specified in the various boxes. The benefit of this is a motivation for contractors to improve and document their quality management approach in order to be competitive and maintain a continuous flow of business.

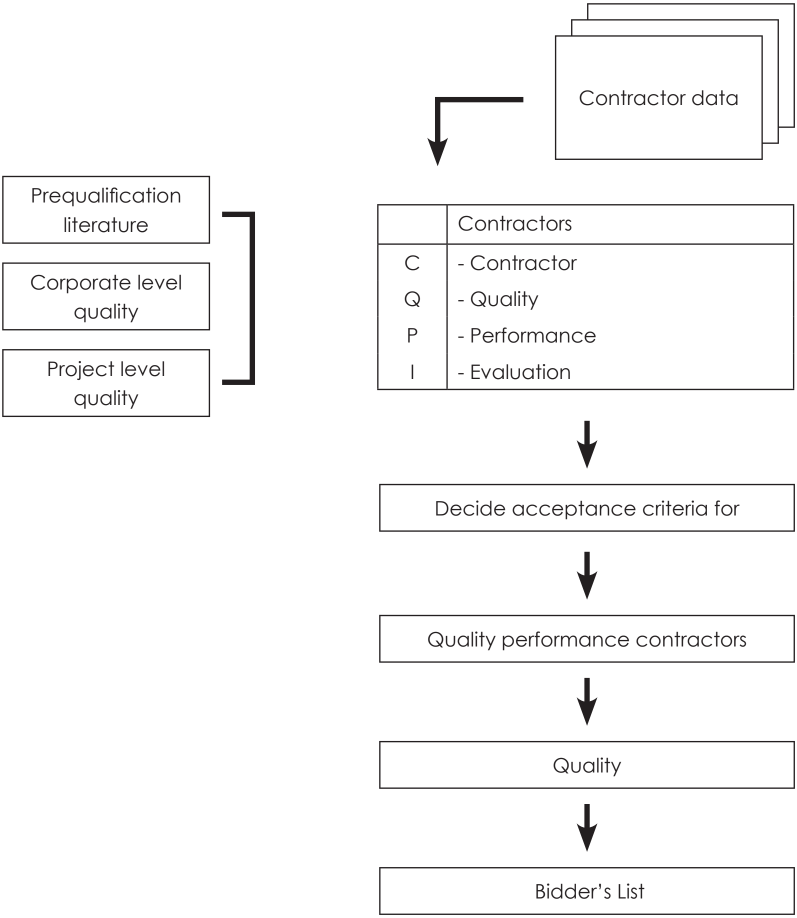

Figure 5: Contractor quality performance (CQP) evaluation model
Source: Yasamis *et al.*, 2002: 221

Figure 5 documents processes to follow in the selection of quality-conscious contractors. First, obtain the data of the contractor. Secondly, set out the criteria for evaluating contractors, including prequalification, corporate level quality standards, and project level quality standards. Thirdly, decide on acceptable standards relative to the foregoing, and select quality-conscious contractors, which will constitute the schedule of bidders.

One major advantage of the CQP evaluation model is that it moves existing contractor evaluation methods to a new baseline that includes the evaluation of contractor quality performance. This is expected to allow the owner to select a quality-oriented contractor and consequently avoid some of the problems related to construction quality (rework resulting in delay) and client satisfaction. Based on these, a reasonable delivery date of projects could be calculated with no delay experienced, and the result of the model for the calculation of completion duration will be accurate when used.

Contractors' technical and financial performance should be evaluated. This will result in a better understanding of the contractors' overall capabilities.

The hiring of a materials manager to independently supervise and monitor the progress of the construction work will contribute significantly to on-time delivery of materials to sites**.**

The construction industry should provide quality management guidelines to be enforced by consultants on projects. Stakeholders should be committed to quality management, designers included. Designers' quality management should focus on the following:

- Commitment to providing a quality service;
- Production of correct and complete drawings and specifications;
- Coordinating and checking of design documentation;
- Conducting design verification through design analysis reviews;
- Conducting constructability reviews, and
- Off-site prefabrication should be encouraged in areas susceptible to heavy rainfall.

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