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A systems thinking approach to eliminate delays on building construction projects in South Africa

Peer reviewed

Abstract

It is obvious that the performance of firms and their market competitiveness hinge on project delivery time. Many approaches have been used to reduce the effect of the potential factors of delay on project delivery time. In this study, the system approach has been employed and validated. Inferential statistical analysis was conducted to analyse eighty-eight questionnaires returned during the primary study and twenty-four during the validation phase. The holistic role of professionals in the construction industry was illustrated with the aid of causal loop analysis, showing cause and effect relationships.

Based on the findings that eight out of the twelve categories of problems of delays are construction-related, the study identified seven stages of construction project delivery and various activities in these stages that could reduce the negative influence of delay factors on project delivery time. The interventions category, which has the most influence on the elimination of delays in project delivery, occurs during the construction stage, followed by interventions during the briefing/design stage. The interventions category with the least influence is pre-qualification of suppliers.

The study recommends that adequate planning, pre-qualification of suppliers, provision of work schedule, and prompt payment of interim certificates be focused on to mitigate delays in project delivery time. Furthermore, the following courses should be included in all built-environment education programmes: operational planning; quality; design, and generic management.

Keywords: System thinking, building construction projects, South Africa

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Abstrak

Dit is duidelik dat die prestasie van firmas en hul markmededingbaarheid om projek- voltooiingstyd draai. Baie benaderings is al gevolg om die effek van die potensiële faktore van vertraging op projekvoltooiingstyd te verminder. In hierdie studie is die sisteembenadering gebruik en gevalideer. Inferensiële statistiese analise is gebruik om die agt-en-tagtig vraelyste teruggestuur gedurende die primêre studie en vier-en-twintig gedurende die validasiestadium te bestudeer. Die holistiese rol van professionele persone in die konstruksie-industrie is geïllustreer met die hulp van oorsaaklike lusanalise wat gevolg en effek-verhoudings aandui.

Gebaseer op die bevinding dat agt van die twaalf kategorieë van probleme van vertragings met konstruksie verband hou, het die studie sewe fases van konstruksie projekvoltooiingstyd asook verskeie aktiwiteite in hierdie fases geïdentifiseer wat die negatiewe invloede van vertragingsfaktore op projekvoltooiingstyd verminder.

Die intervensieskategorieë wat die meeste invloed op die eliminasie van vertragings van projekvoltooiings gehad het, is dié gedurende die konstruksiestadium, gevolg deur intervensies gedurende die opdrag-/ontwerpstadium. Die intervensieskategorie met die minste invloed is pre-kwalifikasie van verskaffers.

Die studie beveel aan dat daar genoeg gefokus moet word op beplanning, pre-kwalifikasie van verskaffers, voorsienning van werkskedule, en vinnige betaling van tussentydse sertifikate om vertragings in projekvoltooiingstyd te verminder. Verder, behoort die volgende kursusse in alle bou-omgewingsonderrigprogramme ingesluit te word: operasionele beplanning, kwaliteit, ontwerp en generiese bestuur.

Sleutelwoorde: Sisteembenadering, bou-konstruksie projekte, Suid-Afrika

1. Introduction

The principle of Right-First-Time holds great value. Right-First-Time requires accuracy and precision. Accuracy means reflecting the realities (specifications), whereas precision implies meeting the specific dates. The processes of construction demand accuracy and very high precision. The capacity of prediction of estimated period of a building construction project indicates level of accuracy. The prediction of project completion time is a means of realising client satisfaction and will result in competitive advantage, all other things being constant. However, both external and internal forces influence the delivery time of projects. The ability to comprehend these influences on project delivery from inception to completion is dependent on experience and the level of training obtained by the planner, best summarised as competence. Furthermore, Sambasivan & Soon (2007: 527) state that the inability of the client and his representatives in the project team to have a comprehensive overview of the construction process from inception to completion of the project, and environmental effects on the process, are very likely reasons for the non-realisation of projected delivery dates. Lack of project management competence could adversely affect delivery time of a project (Dainty, Cheng & Moore, 2003: 189). According to Cooke-Davies (2001: 185), project management is a tool for project success. The site-based nature of projects characterised by complexity, uncertainty, poor communication in the form of timing, extent, and content, inadequate coordination of organisations and activities, and inadequate integration of tasks, organisations, and personnel, provide an ideal climate for the empowerment of individuals and teams (Tuuli, Rowlinson & Koh, 2010: 205). Therefore, the project management competence level is directly proportional to the level of success a project may attain.

2. Literature review

There is a plethora of literature pertaining to the subject of delay in the delivery of projects: Aibinu & Jagboro (2002: 593-599) in Nigeria; Belout & Gauvreau (2004: 1-11) in Canada; Koushki & Kartam (2004: 126-132), Assaf & Al-Hejji (2006: 349-352), and Faridi & El-Sayegh (2006: 1167-1176) in Saudi Arabia; Frimpong, Oluwoye & Crawford (2003: 321-326) in Ghana; Bryde & Robinson (2005: 622) in the UK, and Toor & Ogunlana (2008: 395-406) in Thailand. Based on the survey of the literature, seventy-six potential factors that could influence project delivery time were identified and classified into twelve categories. These classifications and the factors that constitute each classification are:

- Client understanding of the design, procurement and construction process. Lim & Ling (2002: 303-394) identify the following as factors that lead to this problem: clients' understanding of the project constraints; the ability to effectively brief the design team; the ability to contribute ideas to the design and construction processes; the ability to make authoritative decisions quickly, and the stability of these decisions.
- Quality of management during design. Project success is dependent on, *inter alia*, the performance of the design team. Defective designs adversely impact on project performance, and the participants are responsible for many construction failures (Andi & Minato, 2003: 297). Failure at the conceptual planning and design stages may lead to significant problems in successive stages of the project. Oyedele & Tham (2007: 2097) provide a listing of clients' ranking of designers' performance criteria among which were those that relate to

quality of design coordination, smooth flow of work, *vis-à-vis* conflicting design information, timeliness of issuing of revised drawings, missing information, dimensional inaccuracies as well as delay of release of shop drawings.

- Quality of management during construction. Dainty *et al.* (2002: 217) cited Cooke-Davis (2001) who declares that project management competence represents only one of many criteria upon which project performance is contingent. According to Ponpeng & Liston (2003: 281), problems such as schedule delays, budget overruns, non-achievement of quality standards, as well as a large number of claims and litigation result to a large extent from not selecting the best contractor to construct the facility. Quality of management during construction concerns the steps taken to ensure that products are in accordance with the quality standards and measure the effectiveness/competency of consultants and contractors. The factors that contribute to quality of management during construction are forecasted planning data such as analysis of construction methods; analysis of resource movement to and within site; analysis of work sequencing to achieve and maintain workflow; monitoring and updating of plans to appropriately reflect work status; responding to, and recovering from problems or taking advantage of opportunities present; effective coordination of resources, and the development of appropriate organisational structure to maintain workflow.
- Motivation of staff. Productivity in the construction industry has been steadily declining. Labour efficiency has been cited as poor, resulting in delays. Several techniques can be used to positively influence workers' behaviour. Two of these techniques are the behavioural and economic approaches. The former views motivation from the workers' psychological requirements, and the second views it from the economic approach, placing emphasis on monetary rewards (Andawei, 2002: 2). Motivation variables that could impact on construction time are: pay and allowances; job security; a sense of belonging and identification with the project team; recognition of contribution made; opportunity to extend skills and experience through learning; equitable rewards relative to others' input into the project, and the exercise of power and opportunity for career advancement for future benefit.
- Site ground conditions. The inherent site conditions of a project affect the speed of delivery (Frimpong *et al.*, 2003:

325). This is often due to a lack, or poor investigation of site ground conditions to obtain data regarding site soil conditions. The research of Frimpong *et al.* (2003: 325) found that ground problems and unexpected geological conditions contribute to delays. Other ground factors that impact on the speed of construction include the nature of demolition of work; the nature of restoration work; the structural stability of ground; the extent of ground contamination; the extent of archaeological finds; the impact of the water table; the impact of underground services, and the impact of underpinning existing structures.

- Site access. The condition of site access to a project will determine the rate of flow of materials, machines and people to the project site (Griffith & Watson, 2004). Where there is difficulty in getting to the site, in the form of bad road surfacing, narrowness of the road or a long distance between storage space and entry point, these factors will negatively affect construction speed. According to Toor & Ogunlana (2008: 406), these cause delays in construction.
- Constructability of design. Mbamali, Aiyetan & Kehinde (2005: 1268) define the extent to which a building design facilitates the ease of construction as buildability, the British term, or constructability, the American term, which is defined as the grouping of similar work components and the use of modular dimensions in design to reduce construction cost and time. Oyedele & Tham (2007: 2091) provide a list of factors that could be used to assess constructability, *inter alia*, flexibility of design to changes; dimensional coordination of elements; knowledge of performance of materials and components; effective constructability review of design; effective participation in site inspection and control; the scope of off-site fabrication; complexity of off-site fabrication components; appropriateness of design tolerances; appropriateness of working space; implication upon trade coordination; impact of materials storage and movement, and impact on smooth activity workflow and activity sequencing.
- Management style. People undertake work, which is complex, and they have varying personality traits and characteristics. Supervision is required to enable workers to meet scheduled targets. The following factors could be used in assessing the management style of those in positions of authority: setting specific goals employees are to accomplish; organising the work environment for people; setting timelines; providing

specific direction; conducting regular updates on progress; providing support and encouragement; involving team members through discussion of work, and seeking people's opinions and concerns.

- Management techniques used for planning and control. Project-controlling techniques indicate the direction of the project at each time and reveal progress. According to Burke (2006: 130), there are various types of planning tools, namely the Gantt (Bar) chart, network diagrams, and the CPM, as well as the Programme Evaluation Review Technique (PERT). Others include line of balance, horse blanket, and S-curves.
- Physical environmental conditions. These are factors over which no party to a contract has control (Faridi & El-Sayegh, 2006: 1108). Mbachu & Nkado (2006: 43) contend that sociocultural issues and unforeseen circumstances constitute these factors and constrain successful construction project delivery in South Africa. They include the impact of natural hazards such as fire, and floods; adverse local weather conditions such as rainfall and high temperatures; ambient noise beyond tolerance level, and either the lack or intenseness of lighting conditions.
- Economic policy. This refers to the level of general economic activity and resources available to carry out construction work. Koushki & Kartam (2004: 127) identify twenty-five such factors that could impact on construction time. Those applicable to this study include the availability of materials; the availability of equipment; the availability of trades/ operatives; the availability of supervision/management staff; the indirect impact of interest rates/inflation and insolvency, and bankruptcy.
- Socio-political conditions. The socio-political environment concerns projects or individuals while the political environment is concerned with government policy and the effect of political decisions on projects. Political sociology is defined as the study of power and the intersection of personality, social structure, and politics. Factors which constitute this are civil strife or riots, the influence of civil action-groups, and disruptions due to environmental concerns.

3. Methodology

Both the quantitative and qualitative research approaches were used. The sample consisted of architects, clients, contractors, quantity surveyors, and structural engineers in the South African construction industry. Eighty-eight practitioners were surveyed during phase one of the study and twenty-four during the validation of the model. These were used as proxy, and were randomly selected from samples in phase one. The samples for the phase-two investigation are adequate, relative to the statistical tool used for the analysis. Inferential statistical analysis was conducted, which included reliability tests and factor analysis. Relative to phase one, respondents that were over the age of thirty years predominated (76.5%). The highest academic qualifications of respondents were Bachelors (25%), Honours (23%), and BTech (17%), collectively totalling 65%. Managing directors/Managing members/Principal (35%), senior staff (20%), and managers (17%) represent the distribution of respondents' status. The mean number of years of experience of respondents is 17. The types of facility with which respondents are involved include residential, commercial offices, and institutional facilities such as education, and health. The mean value of projects with which respondents have been involved is R866.63 million.

4. Presentation of results and discussion

Table 1 presents the ranking of mean scores (MSs) on the factor categories investigated.

Table 1: Ranking of the influences of factor categories on project delivery time

Factor category	*MS*	*Rank*
Construction planning and control techniques	3.98	1
Management style	3.92	2
Economic policy	3.76	3
The quality of management during construction	3.73	4
Site access conditions	3.54	5
Site ground conditions	3.49	6
Motivation of workers	3.40	7
Constructability of designs	3.37	8
Socio-political conditions	3.16	9
Client understanding of the design, procurement and construction processes	3.12	10
The quality of management during design	3.06	11
Physical environmental conditions	2.87	12

Table 1 reveals that construction planning and control techniques (MS = 3.98) used for activity scheduling is the most influential factor category regarding the delivery of projects with reference to time, followed closely by management style (MS = 3.92), and then distantly by economic policy (MS = 3.76), and quality of management during construction (MS = 3.73). The least influential factor category is physical environmental conditions (MS = 2.87). Table 1 also indicates that, with the exception of economic policy, the categories of factors ranked from 1 to 7 are construction-related. This means that the primary cause of delays in the delivery of projects is construction-related. Based on this, a system model was developed to address this problem.

5. Introduction to systems thinking

The evolution of a systems model for this study is an approach to develop a holistic understanding of the delivery process of building construction projects, the complexity of the interrelationships of tasks, the actions of professionals, and the influence the environment has on the process and delivery time of projects. Given that the study investigated the relationship between actions initiated by professionals in the process of construction of a facility and its delivery time, and that Illustration 1 presents a graphic review of the salient conclusions using a primary causal loop analysis and modelling, it is necessary to address systems thinking.

Senge (2006: 1-6) states that the art of systems thinking lies in being able to recognise increasingly dynamic and/or complex and subtle structure amid the wealth of details, pressures and crosscurrents that attend all real management settings. In fact, the essence of mastering systems thinking as a management discipline lies in seeking patterns where others see only events and forces to react to.

Figure 1 presents the holistic role of influences on construction project delivery time in industry performance.

The right-hand ellipse in Figure 1 indicates the holistic role of the pre-qualification of contractors, commitment of designers to improve design, tendering documents and TQM contractors in overall performance, directly and indirectly, and ultimately the image of the construction industry. Clients are the initiators of a project. Whatever affects the client has a direct or indirect effect on other stakeholders in the industry. A lack of client commitment leads to a lack of designer and contractor commitment to the processes of construction. A client lack of commitment as a result of poor performance will cause, *inter alia*, clients' non-release of funds and slowness in decision-making, ultimately resulting in the contract falling behind schedule.

A lack of client commitment results in client prioritisation of cost which, in turn, results in budget pressure on the contractor in an endeavour to be price competitive, marginalises H&S and engenders accidents, injuries and fatalities which result in absenteeism and reduced productivity. Further, it engenders the use of inadequate/ poor materials and unskilled labour, which ultimately results in rework and the project being behind schedule.

Inadequate/poor skills, inadequate materials, as well as inadequate plant and equipment, engender poor practices, which result in accidents, poor labour productivity, rework, and poor schedule performance. However, the aforementioned result in poor performance as a result of both their individual impact and the negative synergy between the other manifestation of poor practices, fuelled by the catalysts of accidents and rework.

A lack of client commitment manifests in, *inter alia*, a lack of pre-qualification of contractors and subcontractors constituting poor practice. A lack of designer commitment manifested in, *inter alia*, the lack of design QA also constitutes poor practice.

Although poor performance results in client, designer, contractor and workers' dissatisfaction due to, *inter alia*, late completion, increased supervision and reduced profit directly as a result of rework and accidents, a further aspect is that of poor image. Poor image marginalises the ability of the industry to attract 'suitable' human resources at both management and worker level.

A problem associated with poor image is the perception that 'anyone can contract', which results in unqualified people entering the industry at both management and worker level. These, in turn, force skilled human resources, at management and worker level, to leave the construction industry for other industries owing to the working and other conditions. The aforementioned merely worsens the situation relative to the level of skills.

The left-hand ellipse indicates that the only way to break the cycle represented by the right-hand ellipse, represented by the break in the arrow between poor performance and client/designer/ contractor/owner dissatisfaction, lack of designers' commitment and lack of contractors' commitment is for the industry and the primary construction industry stakeholders to acknowledge that poor performance can be remedied. The acknowledgement of a problem and the fact that the problem can be remedied is a prerequisite for commitment.

Industry commitment is essential. Registration of contractors based on criteria engenders a core of suitable contractors. Practitioners and industry associations should embrace; promote and engender 'best practice', so too tertiary education and other training bodies, which contribute to the production of 'optimum' human resources. Professional and industry associations can develop 'best practice' guidelines and benchmarks, and enforce construction activities to be practised according to the benchmarks of industry stakeholders. Industry commitment reinforces client, designer and contractor commitment, which is engendered by benchmarking, optimum human resources and 'suitable' contractors.

Client commitment engenders designer and contractor commitment and is essential to realise the selection of an appropriate procurement system for the practice of pre-qualifying contractors, for effective project delivery as well as for constructability reviews.

Contractor commitment is important for the implementation of an H&S programme, the proper planning of resources, plant and equipment, materials, adequate sequencing of activities, and the engagement of skilled workers, which collectively realise total quality management (TQM) contractor and facilitate TQM.

Designer commitment engenders contractor commitment and is essential to realise the selection of an appropriate procurement system, for the implementation and practice of design QA as well as for effective constructability reviews.

An appropriate procurement system facilitates constructability reviews and engenders the pre-qualification of contractors. Design QA complements constructability reviews and the practice of TQM.

TQM results in enhanced H&S, improved labour productivity, and enhanced quality and schedule, which individually and as a result of the synergy between them, result in enhanced performance.

Enhanced performance results in enhanced client, designer, contractor and worker satisfaction which, in turn, results in the project being delivered on schedule, as well as enhanced image, which reinforces the acknowledgement and awareness that poor performance can be remedied. However, a critical aspect is that enhanced image increases the ability of the industry to attract 'suitable' human resources, culminating in improved productivity and projects delivered on schedule.

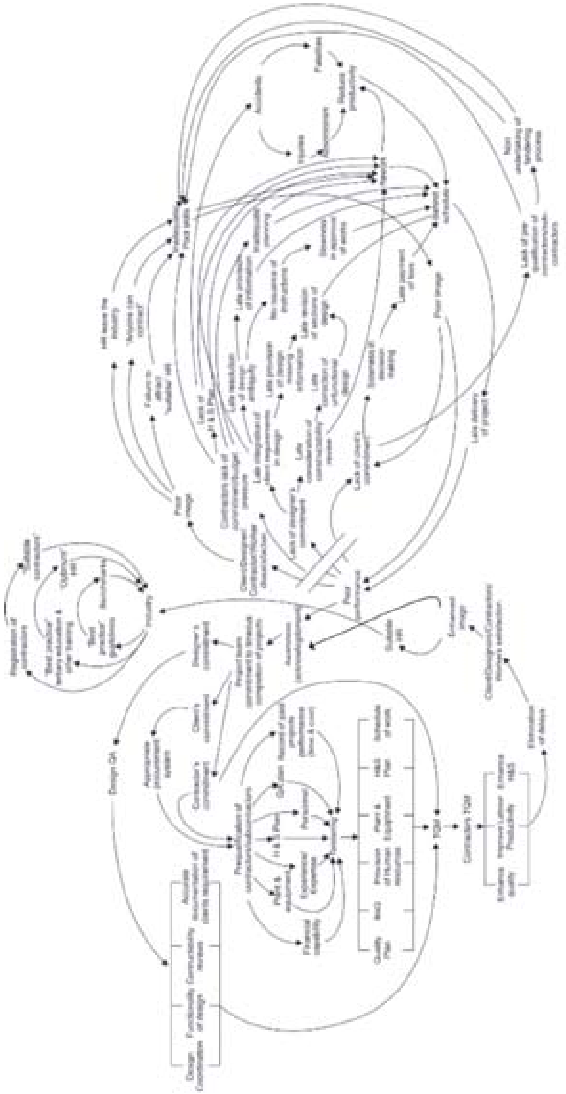


Figure 1: The holistic role of influences on construction project delivery time in industry performance
Source: Compiled by Aiyetan (author)

6. Proposed model for the delivery of projects on time

The research findings enabled the identification of the factors that are problematic and require attention. These can be summed up as poor performance practices in the building construction industry in South Africa, which lead to the late delivery of projects.

The identification of the problem resulted in the identification of the related aspects linked to each problem. The problem of delay from the findings is mainly construction-related. A construction stage-related problem has associated links to all other stages of project delivery. These stages begin with the briefing up to the handing over of the project. Therefore, the model proposes an intervention at the various stages in order to ensure project delivery on time.

The model is discussed in this section and unfolds in the following sequence:

- Basis for the model;
- The model flowchart;
- Elements constituting the model;
- Validation of the model, and
- Summary of the validation of the model.

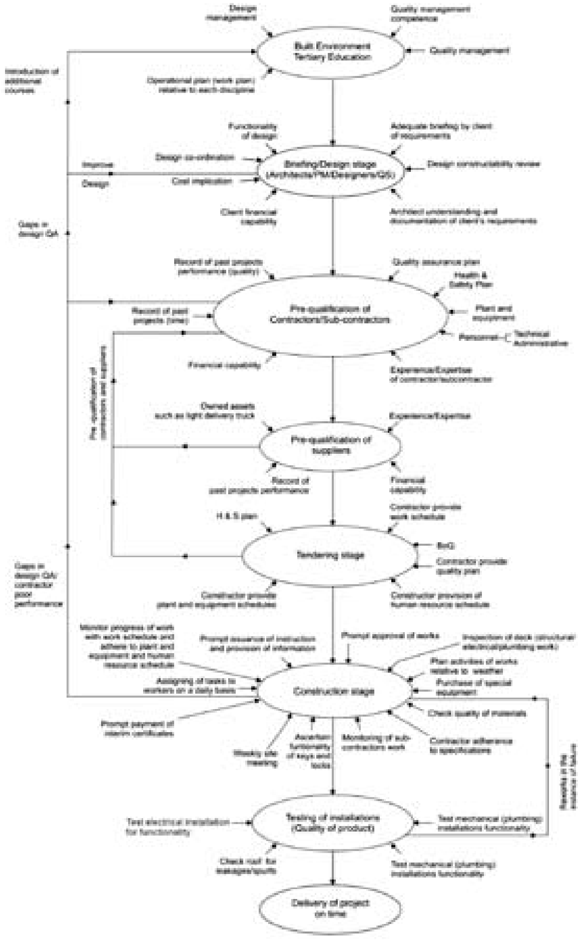
6.1 Basis for the model

In developing the model, the aim was to provide a structured systemic process which practitioners in the building industry can adopt in realising building facilities without delays, stemming from the most significantly influencing factor category, which is management style and construction-related. This implies that the construction stage is crucial to the delivery of projects and that whatever transpires in the construction stage affects the project delivery time. Therefore, the construction stage is the focus. But the construction stage cannot on its own be the only determining stage to projects being delivered on time of all the stages of facility procurement. It is important to note that client briefing and quality of design have an impact on the speed of construction, and that client commitment to the project success has an impact on the construction stage of a project. The contributions of the client towards the project success are in terms of commitment to an appropriate procurement system, such as the pre-qualification of contractors/subcontractor/supplier, i.e., sourcing for TQM contractors.

Based on the foregoing, six stages of construction were identified, namely briefing/design, pre-qualification of contractors/subcontractors, pre-qualification of suppliers, tendering, construction and testing of installation stages. There might be gaps in the performance of professionals at various stages of construction. Therefore, built environment tertiary education has been proposed as the seventh stage.

6.2 The model flowchart

The model proposed for the delivery of projects on time is presented below:



Fiigure 2: Model for the delivery of projects on time
Source: Compiled by Aiyetan (author)

6.3 Elements constituting the model

In order to achieve the purpose of the development of the model, which is the improvement of the delivery of construction projects, the model processes commence with a description of the stages involved in the realisation of a project. It is based on the fact that the initiator of a project does not need to acquire a built environment qualification before s/he can build.

The model consists of seven stages, hereafter referred to as interventions category. The stages, commencing with the briefing/ design stage are:

- The briefing/design;
- Pre-qualification of contractors/subcontractors;
- Pre-qualification of suppliers;
- Tendering;
- Construction;
- Testing of installation before handing over, and
- Built environment tertiary education.

6.4 Validation of the model

A survey was conducted among twenty-four practitioners in the building construction industry in order to validate the model presented (Illustration 2). They included architects, quantity surveyors, contractors, and clients. The MS, percentage frequency and test of means difference were employed in the analysis of the data. To enable interpretation of the MS, the MS range used during the interpretation of means of data from the first phase questionnaire analysis was used.

7. Data presentation and analysis

The Cronbach's α value for interventions category are all ≥ 0.70. Based on these, the internal consistency of the data can be deemed reliable. Table 2 presents the MSs of the interventions per category.

Table 2: Ranking of interventions categories

Intervention category	*Unsure*	*Responses (%)*					*MS*	*Rank*
		Minor...............................Major						
		1	*2*	*3*	*4*	*5*		
Construction stage:								
Weekly/monthly meeting with key staff/subcontractors	0.0	0.0	4.2	8.3	29.2	58.3	4.42	
Determining to what extent planning work two weeks before it takes place will contribute to eliminating delay in project delivery	0.0	0.0	0.0	20.8	25.0	54.2	4.33	
Planning ahead activities of work that weather could affect	0.0	0.0	0.0	20.8	29.2	50.0	4.29	
Prompt inspection and approval of work by consultants	0.0	0.0	0.0	16.7	37.5	45.8	4.29	
Contractor monitoring of subcontractors' work	0.0	0.0	4.2	20.8	29.2	45.8	4.17	1
Prompt issuance of instructions	4.2	4.2	0.0	4.2	41.7	45.8	4.13	
Prompt payment of interim certificates and payments	0.0	4.2	9.3	8.3	37.5	41.7	4.04	
Testing of concrete strength regarding ascertaining of its strength against rework	0.0	0.0	4.2	20.8	41.7	33.3	4.04	
Contractor and consultant checking quality of materials supplied as they arrive on site, and carry out steel strength test	0.0	0.0	8.3	16.7	45.8	29.2	3.96	
Briefing/Design stage								
Adequate briefing by the client	0.0	0.0	8.3	12.5	25.0	54.2	4.50	
Accurate coordination of design	0.0	4.2	0.0	12.5	33.3	50.0	4.25	
Reviewing constructability of design at design stage	0.0	0.0	4.2	16.7	45.8	33.3	4.08	
Well-defined functionality of design	0.0	0.0	12.5	20,8	33.3	33.3	3.88	2
Adequate estimation of project cost	0.0	0.0	8.3	29.2	33.3	29.2	3.83	
Ascertaining client financial capability	0.0	4.2	4.2	29.2	33.3	29.2	3.79	
Lack of dimension ambiguity	0.0	0.0	20.8	20.8	33.3	25.0	3.63	

Intervention category	*Unsure*	*Responses (%)*					*MS*	*Rank*
		Minor..............................Major						
		1	*2*	*3*	*4*	*5*		
Built environment tertiary education								
Operational planning (work planning) relative to each discipline	0.0	0.0	12.5	8.3	45.8	33.3	4.00	3
Quality management competencies	0.0	0.0	8.3	25.0	29.2	37.5	3.96	
Design management	0.0	0.0	12.5	8.3	45.8	33.3	3.88	
Generic management	0.0	4.2	8.3	25.0	41.7	20.8	3.67	
Testing of installation before handing over:								
Testing mechanical (plumbing) installation	4.2	0.0	0.0	20.8	37.5	37.5	4.00	4
Testing electrical installation	4.2	0.0	4.2	16.7	37.5	37.5	3.96	
Ascertaining the functionality of windows fixed	4.2	4.2	12.5	25.0	37.5	16.7	3.38	
Checking roof for leakages	4.2	4.2	4.2	33.5	37.5	16.7	3.46	
Checking drains/spouts against blockage	4.2	0.0	25.0	12.5	37.5	20.8	3.42	
Tendering stage:								
Inclusion of work schedule in tender document by contractor	0.0	4.2	8.3	25.0	41.7	20.8	3.67	5
Inclusion of plant and equipment schedule in tender documents	4.2	0.0	8.3	33.3	41.7	12.5	3.46	
Inclusion of human resource schedule in tender document by contractor	4.2	0.0	12.5	33.3	33.3	16.7	3.42	
Inclusion of quality assurance plan in tender document by contractor	4.2	0.0	12.5	41.7	25.0	16.7	3.33	
Pre-qualification of contractors/ subcontractors:								
Ascertaining the financial capability of contractors	0.0	0.0	4.2	16.7	33.3	45.8	4.21	6
Ascertaining past record of contractor	4.2	0.0	8.3	8.3	45.8	33.3	3.92	
Ascertaining contractor's health and safety plan	4.2	0.0	15.5	25.0	37.5	20.8	3.50	
Verification of quality assurance plan of the contractor	0.0	8.3	16.7	29.2	29.2	16.7	3.29	
Verification of equipment, plant and tools	4.2	4.2	29.2	41.7	12.5	8.3	2.79	

Intervention category	*Unsure*	*Responses (%)*					*MS*	*Rank*
		Minor..............................Major						
		1	*2*	*3*	*4*	*5*		
Pre-qualification of suppliers:								
Ascertaining the financial capability of suppliers	16.7	8.3	20.8	12.5	25.0	16.7	2.71	7
Accessing the past record of supplier	16.7	8.3	20.8	16.7	29.2	8.3	2.58	
Ascertaining the educational qualification of supplier regarding materials performance knowledge	20.8	12.5	12.5	29.2	16.7	8.3	2.33	
Owned assets of supplier such as light delivery vehicles	16.7	12.5	16.7	37.5	8.3	8.3	2.33	

The most important interventions to minimise or eliminate delays in the delivery of projects are those interventions at the construction stage. This stage has the highest mean MS of the seven categories of interventions. Furthermore, it is notable that, although the intervention contractor and consultants inspection of quality of materials on site as they arrive, and conducting of steel strength test has the lowest MS in the category (3.96), it is nonetheless higher than the MSs of most factors in other intervention categories. Briefing/Design stage category of interventions is second in ranking, followed by built environment tertiary education, testing of installations before handing over, tendering stage interventions, pre-qualification of contractor and subcontractor, and pre-qualification of suppliers. Arguably, if pre-qualification of contractors and subcontractors, which is the only screening done to select the best constructor, could be rated the second to the last option in the chain of intervention categories, the judgement of the respondents may be deemed inappropriate. The same contention applies to the intervention category 'pre-qualification of suppliers'.

8. Conclusions relative to validation of the model

The most important category of interventions is that of the construction stage. The interventions at the construction stage have an average MS of 4.19. The MS of 4.19 falls within the range > 3.40 ≤ 4.20, and therefore respondents can be deemed to be of the opinion that the interventions relative to this intervention category have between a moderate influence to near major/near major influence on the delivery of projects on time. However, the MS falls just outside the upper category, namely > 4.20 ≤ 5.00, which indicates the interventions relative to this intervention category have between a near major to major/major influence. Furthermore, given that all the MSs are > 3.00, it can be concluded that all the interventions at the construction stage could eliminate delays in project delivery. The interventions that have a major influence in this category are weekly/monthly meetings with key staff/subcontractor (MS = 4.42); planning work two weeks before it takes place (MS = 4.22); planning activities that weather could affect (MS = 4.29); prompt inspection and approval of work by a consultant (MS = 4.29); contractor monitoring of subcontractors' work (MS = 4.17); prompt issuance of instructions (MS = 4.13), as well as concrete cube and steel tests (MS = 4.04).

Based on the average MSs of intervention categories, it can be concluded that respondents deemed all interventions proposed at each stage of construction to have between a moderate influence to a near major/near major influence on the delivery of projects in South Africa.

The only category of interventions that falls outside the above-mentioned range is the pre-qualification of suppliers (MS = 2.49), which has between a minor to near minor influence/near minor influence on eliminating delays on projects.

However, it could be argued that interventions at the construction stage are deemed as most effective by the respondents for the elimination of delays on project delivery time. The requirements suggested for contract documentation as interventions at both the pre-qualification of contractors/subcontractors and suppliers stage are in place, required for facilitating the smooth flow of activities during construction are ranked sixth and seventh. This amplifies the importance of the interventions at both the pre-qualification of contractors/subcontractors and suppliers categories.

From the foregoing, it can be concluded that interventions at all stages of construction proposed in the model are important for the completion of projects on time.

9. Recommendations from the validation of the model

The following courses/modules are recommended for inclusion in built environment tertiary education programmes for all disciplines: quality management; operational planning; design management, and generic management.

The pre-qualification of suppliers is suggested. A brief description of requirements for consideration during the pre-qualification are assessing the past records of the suppliers; ascertaining the financial capability of supplies; ascertaining the educational qualification of suppliers regarding their materials performance knowledge, and owned assets, such as light delivery trucks.

At the brief/design stage, attention should be paid to adequate briefing, confirmation of client financial capability, and design quality assurance/constructability reviews.

At the construction stage, focus on adequate planning/resource management, work schedules, and monitoring of subcontractors' work, and prompt payment of interim certificates will contribute to eliminating delays in projects.

At the tendering stage the following should be made part of the tender documents, including pre-tender programme; primary materials; method statement; site layout; subcontractor schedule; human resources schedule; plant and equipment schedule; quality plan, and work schedule.

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