Managing uncertainty in fast-track construction projects: case study from South Africa

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Abstract

While academic researchers have proposed various theories for managing risk and uncertainty in construction projects, most of the propositions are conceptual in nature and based on analytical modelling approaches rarely used in practice. This research was triggered by an observation in which a R1·5 billion (~US$100 million) fast-track New Universities Project in South Africa was successfully delivered within budget despite up to 74% of the project scope not being capable of being priced by the contractor at the start of construction. The aim of this paper was to examine the client's delivery-management approach used to manage uncertainty and deliver within budget successfully. The evidence from document analyses and interviews with the client delivery-management team members shows that setting a rigorous control budget, designing to the budget, working collaboratively, disciplined management of the control budget and continuous value engineering were the key client management techniques used to manage the high degree of uncertainty and deliver the project within budget successfully. Given that these are client-led delivery-management issues, the findings fill an important gap in the knowledge and understanding of how infrastructure project outcomes can be significantly improved on when the client functions as the leader of the infrastructure delivery process.

1 Introduction

Construction is one of the most information-dependent industries. However, in practice, complete project definition is not always available at the start of construction. This creates uncertainty. Project- management teams usually have to find ways to manage uncertainty successfully in order to deliver the intended project outcomes.

The successful management of uncertainty is particularly critical in the delivery of fast-track projects that integrate the design and production processes (as explained by the Project Management Institute (PMI) (PMI, 2018), Alhomadi *et al*. (2011) and Moazzami *et al*. (2011)). One implication of integrating the design and production processes is that a significant degree of the project definition may not be available at the start of production, and the unknown project definition creates a degree of uncertainty that depends on the extent of project definition (see the recommended practice by the American Association of Cost Engineering (AACE) (AACE, 2019)).

A key project-management challenge in construction projects generally and fast-track projects specifically is the need for client teams to find appropriate and effective ways to manage the uncertainty around insufficient project information at the time that construction starts and deliver the intended project outcomes successfully.

Since the 1960s, academic researchers have proposed various theories for dealing with risk and uncertainty in construction projects (see the paper by Laryea and Hughes (2008)). However, a fundamental limitation of the formal and analytical propositions is that they are conceptual in nature and based on analytical modelling approaches that are rarely used in practice (Laryea and Hughes, 2011). Laryea and Hughes (2008) identified more than 60 such formal and analytical propositions. The modelling techniques used to develop the analytical propositions shifted from the use of classical approaches such as probability theory or Monte Carlo simulation to conceptual approaches such as neural networks and fuzzy set theory to make them more applicable. However, the research by Laryea and Hughes (2011) examined some real-life cases and explained why some underlying assumptions of formal and analytical models may not be sustainable in practice and why what actually happens in practice is important for those who seek to model the pricing of uncertainty and risk in construction bids. Laryea and Hughes (2011) also argued the need to develop a better understanding of what actually happens in practice.

This paper provides an empirical examination of the practical approach used to manage a significant degree of uncertainty successfully in the case of a fast-track R1·5 billion (~US$100 million) New Universities Project in South Africa. The project was successfully delivered within budget despite up to 74% of the project scope not being capable of being priced by the contractor at the start of construction. Furthermore, time was not negotiable, as the facilities required to be delivered were linked to the start of the 2016/2017 academic year. Therefore, time was of the essence, hence its characterisation as a fast-track project.

The research aim was to examine the client delivery-management approach and techniques used by the New Universities Project Management Team (NUPMT) to manage successfully the significant uncertainty and deliver the project within budget. As clients increasingly demand faster delivery of their projects and projects increasingly start with incomplete information, there is a need to develop a practical theory of managing infrastructure projects successfully with insufficient information and uncertainty.

2 Context of the case study

The government of South Africa took a decision in 2011 to build two new universities, the Sol Plaatje University (hereafter referred to as SPU) and the University of Mpumalanga (hereafter referred to as UMP), at Kimberly and Nelspruit, respectively.

These two universities were located on sites 800 km away from each other and 450 and 350 km, respectively, away from the University of the Witwatersrand (Wits) in Johannesburg. This necessitated putting in place the necessary capacity and professional teams to do the planning, design, construction and other functions required to turn the decision into a physical reality. The Department of Higher Education and Training (DHET) appointed Wits to perform the client 'buying' function for the project given the proven capacity of its Campus Planning and Development Unit, which had successfully delivered a R1·5 billion (US$100 million) Wits capital projects programme (see the paper by Laryea and Watermeyer (2014)). The client delivery-management team assembled by Wits and entrusted with the responsibility to deliver the new universities, which became known as the NUPMT, was led by an experienced client delivery manager with single-point accountability for the project outcomes (see Figure 1).

The client delivery manager, supported by the NUPMT, who provided strategic advice and procurement, technical and administrative support, provided chief-executive-officer-level leadership in performing the buying function. A project steering committee provided constant direction, while a technical integration committee focused on the integration of the planning activities, progress and thinking and budget and procurement approvals. A delivery team comprising a project-management team and design, support service and supply teams performed the 'supply function' at each of the two universities. Wits entered into contracts with the delivery team through its procurement system. The DHET periodically transferred monies to Wits to meet the university's contractual obligations in terms of a memorandum of agreement.

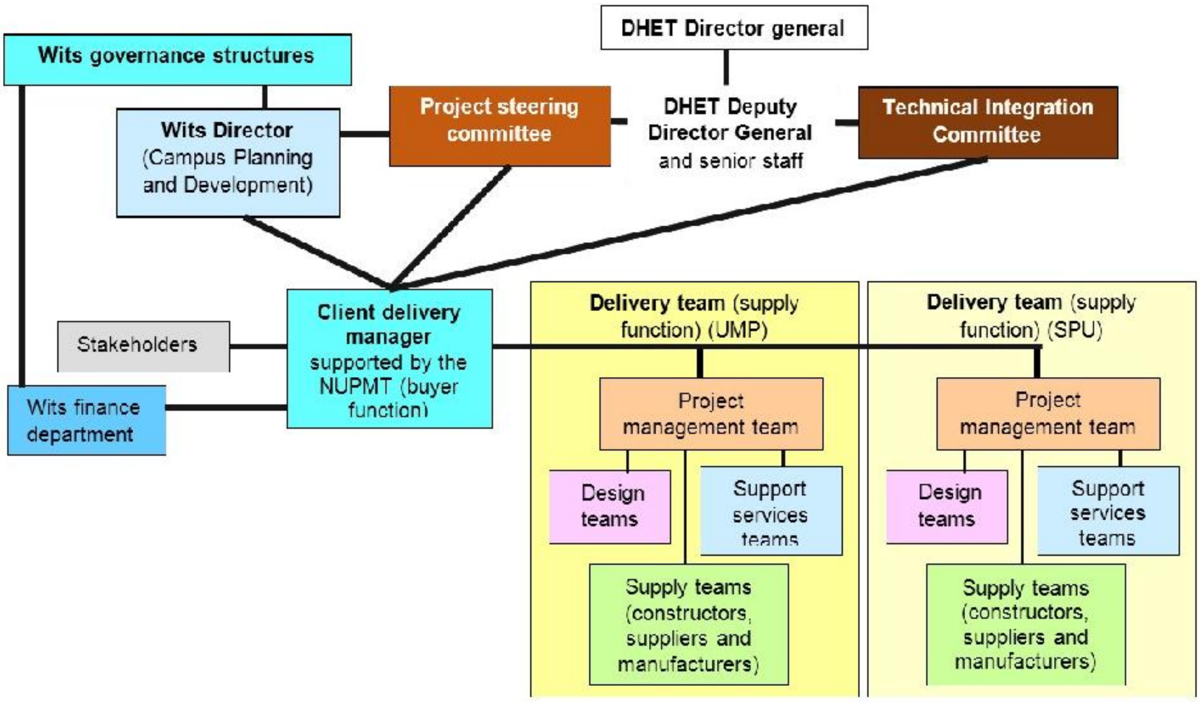

Figure 1. Line function, reporting and governance structures

A decision was taken early on in the project for the client to retain rather than transfer design and interface management responsibilities to the contractor as described by Watermeyer (2018a). This was driven by a number of considerations mainly surrounding the client's brief. First, the content of the academic programme, and hence, the detailed requirements for academic spaces was a moving target. The DHET made some initial assumptions, which were modified by interim university councils and finalised by the appointed university councils (see Figure 2). Second, it was the NUPMT's view that such an approach would provide more flexibility given the uncertainties in requirements and enable the use of expertise within universities to ensure that the designs of the teaching spaces are aligned with current and future best practice. The team was also of the view that such a strategy would better serve the design competition approach adopted to create a superior design that would not only be responsive to spatial requirements but also result in architectural landmarks symbolic of intellectual aspiration (Watermeyer *et al*., 2018).

An architectural design competition and tender process for the architectural services for the SPU and the UMP was conducted for 6 months and completed in September and October 2013, respectively. Nine architects were appointed for both SPU and UMP using professional service framework contracts (NEC3 Professional Services Contract (Option G: term contract)). The tender processes for the remaining professional services (design, cost planning and control, specialist investigations and project management) were completed for both campuses between March 2014 and September 2014. Thirty-nine contracts for engineering design, cost planning and control, project management and specialist support services (NEC3 Professional Services Contract (Option G: term contract)) were concluded. This was followed by the appointment of contractors. Tenders were invited for the construction of buildings within the university precincts of both universities in 2014 in terms of a restricted competitive negotiations procedure (see ISO 10845-1:2010 (ISO, 2010)). This process was completed in August 2014, and construction started in October 2014 (Watermeyer *et al*., 2018).

The appointment of professional service teams and contractors was done relatively quickly due to the tight timelines. One implication of the fast-tracking was that the various teams had relatively little mobilisation time. The consequence of not having facilities available at the start of an academic year was that the intake would have to be cancelled. Accordingly, time became the dominant projective objective, possibly at the expense of quality and cost (see Figure 2).

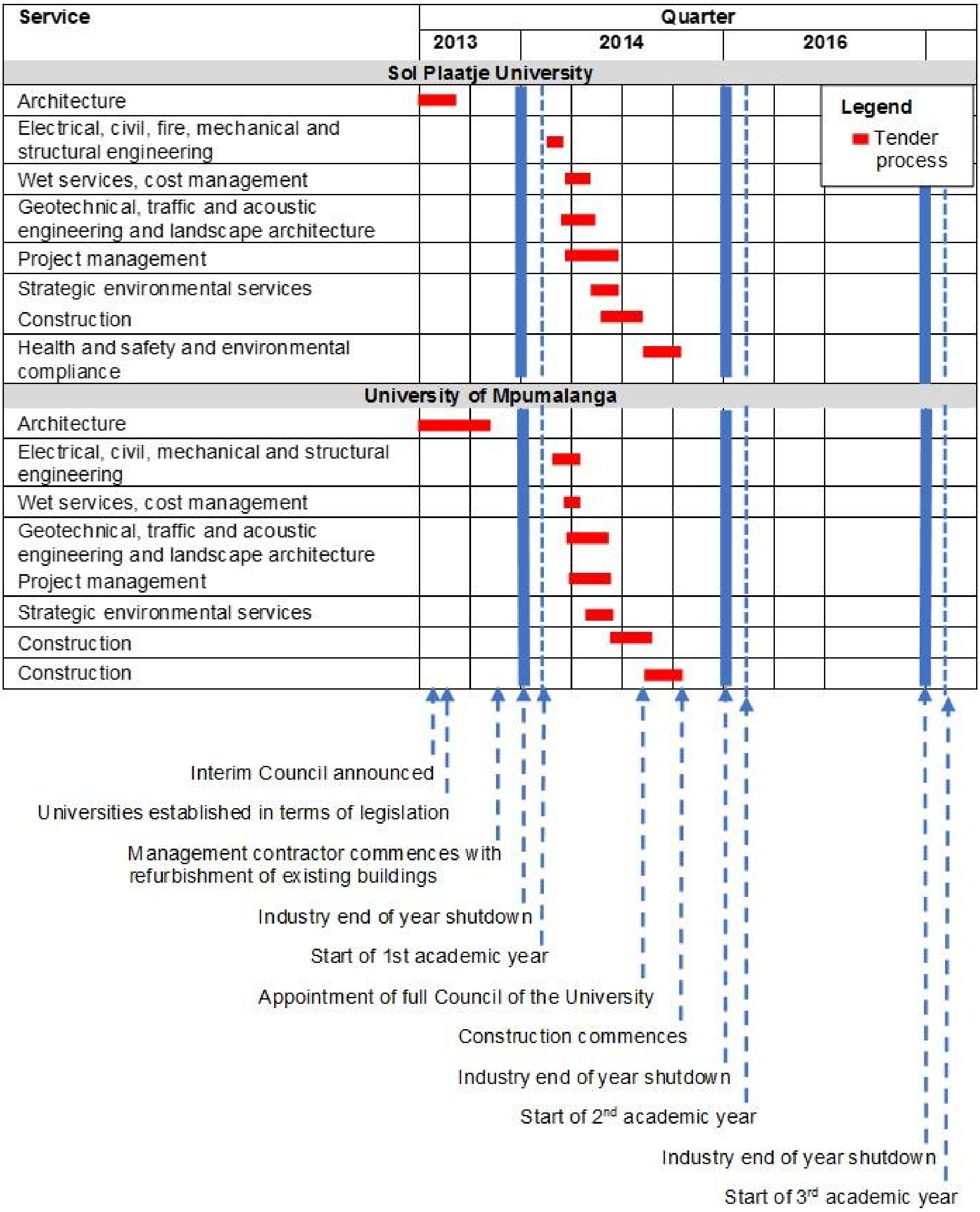

Figure 2. Timelines for the delivery of new facilities for the 3rd intake of students

The buildings required to be constructed for the 2016/2017 intake of students are summarised in Table 1. The DHET cost and space norms were used to develop a control budget for the buildings summarised in Table 1. A target price was developed for each building based on the design information available and capable of being priced and elemental cost estimates of work not yet defined and hence not capable of being priced accurately. Therefore, the target price for each building comprised certain and uncertain amounts.

Table 1: Facilities for the 2016 / 2017 intakes (Watermeyer, 2018a)

Work package	**Required facilities**	**Approximate gross building area** (m2)
	Sol Plaatje University	
C001	The building comprises 342 beds located on floors 1 to 4 with large residential common rooms, lounges and games rooms located on the ground floor facing onto a semi-private square shared with Building C002.	12 747
C002	The building is a multiuse building comprising a dining hall and kitchen, ground floor retail space and a residence comprising 122 single rooms, 48 double rooms, TV rooms, games rooms and meeting rooms. There is also a large flat floor teaching venue, lecture rooms, seminar rooms and meeting rooms	13 532
C003	Building comprises ground floor and three floors above, laid around a central open to sky courtyard. Ground floor - retail area, raked lecture halls, class rooms, health and wellness and open amphitheatre, First floor – lecture halls and flexible classrooms. Second floor – academic meeting rooms, offices and gymnasium. Third floor – sports centre, student SRC, Union and clubs	9 624
CX01	The works comprise the construction of bulk on site infrastructure for the new buildings (C001, C002, C003 and C004) for all the services outside of the footprint of the buildings being constructed including services and associated works to connect all infrastructure to existing municipal infrastructure.	-
	University of Mpumalanga	
L001	Building L001 is predominantly a student residence comprising 6 distinct buildings integrated into the existing residential precinct. Residence seminar rooms, student centre, games rooms and laundries also form part of the complex.	6 153
L004	L004 is a distinct new building comprising a range of various size lecture venues, auditorium and study spaces as well as seminar rooms and offices	2 123
L006	Building L006 comprises: • 3 distinct new building portions (a dean's office comprising office and office facilities with a lift, a student resource centre, study centre and study service with a lift and a 250 seat auditorium comprising classroom and classroom services); • a combination of refurbishment and new construction which includes a range of various size lecture venues, auditorium, laboratories, student life centre and study spaces The facilities associated with building 6 include seminar rooms, staff offices, facilities for postgraduates and tutors, recreational spaces, IT resources, facility and library. They also include a Student Life Centre which contains retail facilities for the students such as specialist bookshop, coffee shop and food outlet.	7 536

The degree of project definition or design completion for each building at the start of construction work on-site is summarised in Table 2. This was calculated using the value of provisional sums included in the activity schedule that formed the basis of the target price – that is, allowances for work that is foreseen but cannot be accurately specified and which would be adjusted through the compensation event procedures embedded in the NEC3 forms of contract.

Table 2: Assumptions relating to work not priced in the Package Orders (Watermeyer, 2018a)

Work package	Assumptions excluding VAT included in the target price	Value of assumptions as a percentage of the Target Price
Sol Plaatje University		
C001	- all the work excluding the concrete structure and embedded services is R 109 388 176 including the Fee - allowance or earthworks subcontractor's P & Gs of R0,26 m - soft and hard rock and earthworks quantities, quantities for mass concrete under bases, concrete reinforcement quantities and uncertainties in structure of building - allowances for items embedded in and associated with the structure for R 2.9m	**69%**
C002	- all the work excluding the concrete structure and embedded services is R 116 559 784.50 including the Fee - uncertainties in structure of building, soft and hard rock and earthworks quantities and concrete reinforcement quantities	69%
C003	- all the work excluding the concrete structure and embedded services is R 90 549 866 including the Fee - allowances for printing, soft and hard rock of R0,7 m. permanent formwork for the auditorium seating of R1,7m and concrete reinforcement quantities - diesel rate for generator	74%
CX01	- allowance for breaking up concrete and provision of additional pipes for R0,45 m - uncertainties in information - allowance for thermally activated building systems (TABS) for R5,95m, wet services for R5,4m, fibre optic installation of R 2.1 m, fire services of R1,6m, emergency generator of R1,65 m and miscellaneous items of R2.74m	25%
University of Mpumalanga		
L001	- civil works, foundations, structural frame, roof, external works, internal plumbing etc – R37.4 m	44%
L004	- electrical, HVAC and lift - R4.70 m, piling – R1,63 m and other – R2.43 m - hard and soft rock and reinforcement quantities.	23%
L006	- civil works, foundations, structural frame, roof, internal plumbing etc – R34,2m - provisional sums - R20,7 m - hard and soft rock and reinforcement / steel quantities.	36%

Note: R1 = US$0.0666

Due to the nature of the DHET funding regime, which requires higher-education institutions to pursue their own fundraising in the event that an institution exceeds the approved budget, it was imperative for the NUPMT to deliver the project within budget. Successful delivery within the control budget was, therefore, clearly outlined in the procurement strategy as one of the primary objectives of the project (NUPMT, 2018). The need was then for the NUPMT to provide client leadership for the project and adopt a set of effective delivery-management techniques to achieve successful delivery within budget.

3 Research problem and aim

Clients need to define the priorities for the trade-offs between cost, time and quality at the outset of a project. Fixing the time variable frequently impacts negatively on cost and quality. Time was fixed on the New Universities Projects, as academic facilities were required at the start of the 2016 academic year. This necessitated that the works start before the designs were complete and assumptions be made on the value of the work (25–74%) not capable of being accurately priced when work was instructed (see Table 2 and Figure 1).

Despite up to 74% of project definition not being capable of being priced due to insufficient information at the start of construction, the NUPMT adopted a combination of practical and effective delivery-management approaches to manage the significant degree of uncertainty successfully and delivered the project within the approved budget, which had been rigorously developed using elemental estimates and DHET cost and space norms.

The research aim was to examine and analyse the delivery- management approach and techniques adopted by the NUPMT to manage the uncertainty and control costs throughout the design development and construction phases in order to deliver the project within the approved budget.

4 Specific objectives

The specific objectives were to:

- ascertain the way that a control budget was established for the project, taking into account the high degree of unknown project definition;
- examine the way that the control budget and uncertainty were managed by the client from start to finish to achieve successful delivery within the approved budget; and
- examine the project outcomes to ascertain the effectiveness of the delivery-management techniques adopted.

5 Literature review

Formal and analytical models for assessing risk and uncertainty in construction are briefly discussed in Section 1. This section covers the literature on fast-track projects and delivery-management techniques for developing control budgets and controlling costs. Using ‘fast track project’ and ‘fast track construction’ as search terms in Scopus, 73 publications were identified and reviewed. The ones adjudged the most relevant to the objectives of the current study are critically reviewed in this literature review.

5.1 Fast-track construction projects

The PMI (2018) Guide to the Project Management Body of Knowledge and 73 studies identified through a search in Scopus in September 2019 provided a reference point for understanding the definition of fast-track construction projects. Fast-tracking is the process of overlapping sequential activities or phases in parallel to compress the project schedule (see the publications by Faris and Schlechter (2013) and PMI (2018)).

Fast-tracking involves the performance of project activities in parallel, often design development and construction. Girmscheid (1996) describes one advantage of fast-track projects as the ability to begin construction on each phase of a project, without waiting for overall project design completion. The objective is to shorten the construction time for the overall project by starting portions of work as soon as they have been designed even though other portions of the project have not yet been designed.

Moazzami *et al*. (2011: p. 2553) explain that as ‘earlier project completion is the main purpose of fast-tracking strategy in construction projects’, the structuring of an appropriate contracting strategy should take this into account.

Alhomadi *et a*l. (2011) conducted a questionnaire-based research in Canada to examine the impact of fast-tracking, overlapping and compressing schedules on project predictability in terms of achieving the planned objectives (time, cost and quality). The authors sought to identify the relationship between fast-tracking and the predictability of the project objectives with regard to success in meeting the project’s planned objectives. Sixty-two responses were received from professionals with 15 different specialities, and the key outcome was that fast-tracking led to less predictability for the project’s outcomes. The 12 most effective variables or project-management practices required for improving the predictability of fast-track projects were identified as follows: (a) experienced and knowledgeable project team members, (b) well-defined scope of work, (c) availability of resources, (d) effective pre-project planning, (e) design effectiveness to minimise errors and rework, (f) effective project controls, (g) applying lessons learned from similar projects, (h) effective and rapid coordination/communication, (i) leadership effectiveness, (j) senior management support, (k) effective stakeholder involvement and (l) project team alignment.

The studies reviewed showed little empirical research on the practical approaches used in practice to manage uncertainty in fast-track projects despite the significant uncertainty inherent in many fast-track projects.

5.2 Techniques for developing control budgets and controlling costs

The construction industry is often characterised by projects that significantly exceed the estimated cost and time (see the publication by Flyvbjerg *et al*. (2018)). Several reasons have been ascribed to this phenomenon, particularly the risky nature of construction and inefficient implementation practices, including poor cost-control practices as well as the poor setting of the budget, including setting it too early (see e.g. the paper by Laryea (2019)).

The fact that many projects experience cost overruns indicates that budget setting and cost control is a difficult area of practice when it comes to the management of construction. However, a number of techniques for undertaking cost control are presented in the academic and professional practice literature. These include earned value method theory and control system (see the publication by Li (2017)). The techniques highlighted include proper planning of a control system, providing timely information, managing by exception and analysing cost overruns.

Recommended Practice No. 56R-08 by the AACE (2019) is Cost Estimate Classification System – as Applied in Engineering, Procurement, and Construction for the Building and General Construction Industries. This system maps the phases and stages of project cost estimation together with a generic project scope definition maturity and quality matrix, which can be applied across a wide variety of industries and scope content. The purpose is to align the estimating process with project stage-gate scope development and decision-making processes.

Table 3, extracted from Recommended Practice No. 56R-08 by the AACE (2019), shows a relationship between the degree of project definition, purpose of the estimate, estimating methodology and expected accuracy range of the estimate. Different cost-estimating methods are also shown in Table 3 and explained in the recommended practice by AACE (2019). Table 3 provides primary and secondary characteristics and expected estimate uncertainty ranges as a function of the estimate class. These characteristics and ranges provide expected estimate accuracy ranges based on scope definition data from historical projects.

Table 3: Cost estimate classification and primary characteristics for building and general construction industries (AACE, 2019)

	Primary characteristic	**Secondary characteristic**		
Estimate class	**Maturity level of project definition deliverables** Expressed as % of complete definition	**End usage** Typical purpose of estimate	**Methodology** Typical estimating method	**Expected accuracy range** Typical variation in law and high ranges at an 80% confidence interval
Class 5	0% to 2%	Functional area, or concept screening	Square foot or square metre factoring; parametric models, judgement or analogy	L: -20% to -30% H: +30% to +50%
Class 4	1% to 15%	Schematic design or concept study	Parametric models, assembly driven models	L: -10% to -20% H: +20% to +30%
Class 3	10% to 40%	Design development, Budget authorization, feasibility	Semi-detailed unit costs with assembly level line items	L: -5% to -15% H: +10% to +20%
Class 2	30% to 75%	Control or bid/tender, semi-detailed	Detailed unit cost with forced detailed take-off	L: -5% to -10% H: +5% to +15%
Class 1	65% to 100%	Check estimate or pre bid/tender, change order	Detailed unit cost with detailed take-off	L: -3% to -5% H: +3% to +10%

The US Department of Energy's Cost Estimating Guide (DOE, 2018: p. 15) developed by its Project Management Office explains that 'typically, as a project evolves, it becomes more definitive. Cost estimates depicting evolving projects or work also become more definitive over time'.

Recommended Practice No. 56R-08 by the AACE (2019) enables the quality of cost estimates to be appropriately considered throughout the evolution of a project. Class 3, 2 and 1 estimates typically occur towards the end of concept/viability, design development and design documentation stages, respectively. As a result, the decision to proceed with a project may be based on a class 3 estimate with a −5 to +20% accuracy where the degree of project definition is between 10 and 40%.

Estimates at an early stage of a project may be tainted by 'optimism bias' and 'strategic misrepresentation' (National Treasury, 2016). Strategic misrepresentation explains behaviour that deliberately underestimates costs and overestimates benefits for strategic advantage, usually in response to incentives during the budget process (National Treasury, 2016). Her Majesty's Treasury's Green Book: Appraisal and Evaluation in Central Government (HM Treasury, 2018: p.6) defines optimism bias as the demonstrated systematic tendency for appraisers to be over- optimistic about key project parameters including capital costs, operation costs, works duration and benefits delivery'. The Green Book suggests that optimism bias is caused by two main factors – namely, (a) poor definition of the scope and objectives of projects in the business case, due to poor identification of stakeholder requirements, resulting in the omission of costs during project costing, and (b) poor management of projects during implementation, so the schedules are not adhered to and risks are not mitigated. Explicit adjustments for bias need to be made in the form of increasing estimates of the cost and decreasing (and delaying the receipts of) estimated benefits. In its supplementary Green Book guidance, HM Treasury (2013) provides adjustment percentages for generic use in project categories where more robust evidence is not available.

6 Research questions

There is little empirical research on the practical approach and client delivery-management techniques used to manage uncertainty in fast-track projects particularly in relation to cost control. This study addresses that gap by investigating the following questions:

- What degree of project definition was known at the start of execution?
- How was a control budget developed using the information available and controlled throughout the project?
- How was an allowance made in the control budget for the unknown project definition?
- How did the project definition and design development progress in the execution phase?
- How was the up to 74% unknown project scope managed throughout the execution phase to achieve the intended outcome?

7 Research design and methods

The purpose of this study was to examine the specific techniques adopted by the NUPMT to manage a significant amount of uncertainty arising from incomplete detailed design (project definition) and control costs in the design and construction phases to achieve successful delivery within budget. Most of the design was at the stage between preliminary/concept design and detailed design development at the time that the contractors providing the construction service were appointed. Table 2 provides the data on the extent of design completion in the seven projects examined and analysed in this study.

A comprehensive research design was needed to capture the full context of the New Universities Project, the infrastructure procurement and delivery-management approaches, the interactions between the professional team members and the delivery-management techniques adopted during the construction phase to control costs.

A case study research strategy was deemed appropriate, as such a study provides a comprehensive, intensive and inductive means to probe deeply into the specific approaches used by the NUPMT to manage successfully the uncertainty arising from incomplete designs and the management techniques used to control costs in order to deliver within a control budget (Saunders *et al*., 2019). As explained by Mintzberg (1973), the research methodology adopted for such a study needs to be comprehensive to help capture the whole context of the project. It needs to be intensive to help probe deeply into the means used to manage uncertainty and control costs. Furthermore, it needs to be inductive to help develop a general statement on the overall approach employed to deliver successfully within budget.

The primary method adopted for data collection was document analysis. The close-out report for the project provided the necessary details for a documentary analysis. This was then followed by unstructured interviews with a selection of the NUPMT and professional team members. The interviews provided anecdotal insights into issues around the research aim.

8 Data collection and results

The NUPMT outlined the primary procurement objectives for the project as follows.

- Deliver the universities within a control budget.
- Ensure that expenditure is within the amounts allocated in each financial year of the government's medium-term expenditure framework period and is capable of being accelerated should additional funding become available.
- Ensure that teaching spaces are capable of being occupied at the start of the required academic year.
- Provide works that are capable of being readily maintained.
- Make use of expertise within universities to ensure that the designs of the teaching spaces are aligned with current and future best practice.
- The quality of facilities is such that maintenance costs are minimised.

8.1 Control budgets and cost norms

The NUPMT went through a process of setting the control budget for each of the buildings (see Table 2) using the DHET cost norms. The Space and Cost Norms for Buildings and Other Land Improvements at Higher Education Institutions by the DHET (2009a) establish the need norm, the area norm and the cost norm that are necessary for the DHET to establish a budget allocation for higher-education facilities.

The assignable square metres (ASM) of a building (area that is available for assignment to an occupant or for specific use) is determined in accordance with the provisions of the Building and Space Inventory and Classification Manual by the DHET (2009b). A building cost unit (BCU) per ASM (space use factor) is then obtained from the Space and Cost Norms for Buildings and Other Land Improvements at Higher Education Institutions by the DHET (2009a). The cost for a building in the year of its completion is then derived from the product of the ASM, the BCU per ASM and a published BCU that is representative of the all-inclusive estimate of building costs to provide one ASM within a particular space use category.

The linking of the BCUs to ASM rather than to the gross building area encourages efficient design. An efficiency of 70% is considered achievable. Efficiencies of 70–75% are targeted in design.

The BCU is defined annually as the current rand equivalent of R3065 in June 1995 (R1 = US$0·0666), the latter amount being escalated by the Building Cost Index Report on Building Costs published quarterly by the Bureau for Economic Research (BER), University of Stellenbosch. A 13% allowance for the total cost units for new buildings is provided for the associated land improvement other than buildings. The BCU was revalidated using a bottom-up approach in 2017.

The shifts in control budget at various stages in the delivery process are indicated in Table 4. All the buildings at SPU fell within the DHET cost norms, while the construction of bulk on-site infrastructure for the new buildings fell within 13% of the sum of the costs based on the DHET ASMs for the buildings that were serviced. One of the buildings at the UMP that had an awkward footprint exceeded the cost norm.

Table 4: Changes in control budgets as the work packages were developed (Watermeyer, 2018a)

Work package (see Table 2)	Control budget (including VAT)		Final account (including VAT and professional fees)[3]	Cost based on DHET ASM of completed building including professional fees and VAT[4]
	Based on elemental cost analysis prior to contractor pricing the order[1]	**Based on agreed target price at the time that the order was issued[2]**		
Sol Plaatje University (SPU)				
C001	235 409 325	217 870 833	209 650 271	227 542 314
C002	248 472 064	243 958 078	232 145 660	245 227 872
C003	187 391 695	174 421 800	172 072 166	177 137 214
CX01	83 480 485	89 773 571	81 895 017	84 487 962[6]
Total			695 763 114	734 395 362
University of Mpumalanga (UMP)[7]				
L001	121 079 793	100 117 037	91 605 442	114 361 048
L004[5]	47 224 073	47 621 235	47 070 781	31 797 058
L006	202 436 746	184 023 243	180 106 624	185 734 436
Total			320 468 897	331 892 542

Notes

1 Includes estimate of construction based on limited information, a provision for price adjustment for inflation, a contingency of 5% and professional fees at 17% (UMP) and 19% (SPU).

2 Includes construction cost, a provision for price adjustment for inflation, a contingency amount of 5%, and a professional fee estimate based on the tendered fees.

3 Based on actual costs.

4 Based on a BCU of R 21 975.00 including VAT (2016) and ASM calculated from record drawings.

5 Estimated costs exceeded the ASM value due to the awkward nature of the site, expensive foundations and the small footprint of the building with high wall to floor ratio.

6 Value derived from 13 percent of the sum of the DHET ASM values for buildings C001, C002 and C003.

7 The electrical, civil and bulk infrastructure control budget amounted to R 87 482 995. The final account amounted to R 76 692 025. This equates to 24% percent of the ASM costs for L001, L004 and L006. However, this infrastructure is able to service the next phase of buildings and will reduce as a percentage when all the buildings which are serviced are taken into account.

The DHET Project Management Team in April 2015 derived a June 2016 BCU. The published 2015 BCU value of R20 328 was used as the base value. This was escalated, using the medium-term forecasting associates (MTFA) and first quarter 2015 BER indices, to a value of R21 975 (average index of 8·1% forecasted escalation for 2016). What was not realised at the time was that the 2015 published value of R20 328 overestimated the BCU. The correct procedure should have been to calculate the actual increase from the 15 June 1995 rand equivalent value of R3494 including the value- added tax using actual indices and applying a forecasted index only for 1 year in advance. During an exercise conducted in 2017 to revalidate the BCU, based on an elemental cost analysis it was discovered that from 2009 the forecasted indices had not been replaced with actual indices so that the increase was overestimated. The actual 2016 value calculated in 2017 should have been R17 239. The recalibration exercise indicated that the June 2016 BCU based on Gauteng rates should have been R19 256, the difference being attributed to changing requirements in security (access control and closed-circuit television), information technology provision and green building design, including adequate sun shading and low-E glass. If, however, the adjustment factors (location rate factor × coastal factor × climatic factor) are taken into account, the 2016 BCU will be R21 953 and 21 664 for the SPU and UMP, respectively (Watermeyer, 2018b).

8.2 Degree of project definition at start of construction

The South African National Treasury (2016) defines 'degree of project definition' as a percentage measure of design completed at the end of the concept and viability stage. The data in Table 2 provide an indication of the state of the design development when the target price for each package order was agreed on. The designs were mostly at the stage between preliminary/concept design and detailed design development at the start of construction in 2014. Table 2 provides data on the pricing assumptions made, including the amount of work not priced at the time that the package orders were issued in order to allow contractors to start with the works before the design had advanced to a stage where all the works could be accurately priced. The SPU buildings had uncertainty in the pricing of the three buildings of between 69 and 74% of the target price included in the package orders issued to contractors. The uncertainty in the pricing of the UMP buildings was between 23 and 44% (see Table 2).

8.3 Cost and time performance

Table 5 indicates the number of days between the starting date for a package order and planned and actual completion dates. The schedule for completion was always optimistic given that there were in several instances two December/January industry shutdowns and a late start to construction following the procurement processes (see Figure 1). Acceleration was paid for on building C002 to advance the completion date on the academic facilities. All academic teaching spaces were capable of being used at the start of the term despite the package orders not achieving the original completion dates. The office spaces on building C002 were completed late due to a design error arising from the failure to connect a beam in a stairwell to a column. This resulted in excessive deflection of a floor slab and damage to the staircases in the stairwell. Remedial works were required to jack up the floor slab, connect the beam to the column, demolish and rebuild a portion of the stairs and install hangers to tie the floor slab that sagged to the floor above to reduce deflections – a delay of 2·5 months. No delay damages for late completion wereapplied, as the completion dates that were revised in accordance with the contracts were achieved.

Table 5: Planned and actual Completion (Watermeyer, 2018a)

Work package (see Table 2)	**Starting date for order**	**Completion Date**		**Planned calendar days**	**Actual calendar days**	**Percent variance**
		When order issued	**When order completed**			
Sol Plaatje University						
C001	13 October 2014	15 January 2016	2 March 2016	460	508	+10,4%
C002	13 October 2014	15 January 2016	5 July 2016	460	602	+30,9%
C003	13 October 2014	15 January 2016	8 April 2016	460	544	+18.3%
CX01	27 April 2015	15 January 2016	20 May 2016	264	390	+47,8%
University of Mpumalanga						
L001	1 November 2014	15 December 2015	5 February 2016	410	462	+13%
L004	27 June 2014	18 February 2016	24 March 2016	237	272	+15%
L006	27 October 2014	17 November 2015	2 February 2016	387	464	+20%

Table 6 indicates the shifts in the costs from the initial agreed target price to the final cost to client. The contract made provision for price adjustment for inflation. The contract price adjustment is calculated in accordance with the provisions of the contract on the progress payments that are based on ‘today’s cost’ plus the fee (price for work done to date) and is added to the target price. Accordingly, the today’s cost plus the fee needs to be de-escalated to the starting date before calculating the adjustment to the target price. An allowance for price adjustment for inflation needs to be made in the initial target price so that the growth in target price arising from compensation events (events for which the contractor is not at risk) can be compared with the final cost plus the fee and the target price at completion.

Table 6: Shifts in the total of the prices in the construction works contract (Watermeyer, 2018a)

Work package (see Table 2)	**Target price at the start**	**Target price at the start with allowance for inflation**[1]	**Final target price**[2]	**Price for Work Done to Date at Completion**[4]	**Client gain (+) / pain (-)**	**Cost to client**
Sol Plaatje University (SPU)						
C001	178 336 429	184 703 040	184 543 260	181 652 357	+ 1 445 452	183 097 809
C002	191 776 818	198 623 250	208 263 636[3]	198 036 334	+ 5 208 489	203 055 148
C003	140 366 859	145 377 956	149 129 474	154 303 411	-2 586 969	151 716 443
CX01	76 109 401	77 920 805	78 443 843	73 980 895	+ 2 297 733	75 405 110[5]
Totals		606 625 051	620 380 213	607 972 998	+ 6 364 705	613 274 510
University of Mpumalanga (UMP)						
L001	79 392 515	82 171 599	79 802 745	78 685 387	+ 558 679	79 244 067
L004	38 749 003	40 234 912	38 945 512	42 768 205	-1 529 076	40 474 589
L006	152 222 456	158 570 132	156 082 984	155 720 087	+ 181 448	155 901 536
Totals		280 976 643	274 831 241	277 173 679	-788 949	275 620 192

Notes

[1] The escalation allowances (estimates) were calculated using the MFA/BER indices.

[2] Includes compensation events and price adjustment for inflation calculated in accordance with the provisions of the contract.

[3] Includes R 5,1 m for compensation event associated with the failure by a structural engineer to connect a beam to a column in a stairwell and an acceleration cost of R 2,1 m.

[4] Audited value for Defined Cost plus the Fee less Disallowed Costs

[5] Includes a low performance damage deduction of R 741 000 for failure to attain development targets

9. Discussion of results

Three main points are discussed in relation to the specific objectives.

- Ascertain the way that a control budget was established for the project.
- Examine the way that the control budget was managed from start to finish to achieve successful delivery within the approved budget.
- Examine the project outcomes to ascertain the effectiveness of the project-management techniques adopted.

9.1 Establishment and adjustments of control budgets

According to NUPMT (2018), a control budget can be defined as the amount of money that is allocated to deliver a work package, including site costs, professional fees, applicable taxes, risk allowances (contingencies) and provision for price adjustment for inflation. Separate control budgets were set for each work package with the objective that the delivery of the portfolio of facilities (see Table 1) would be within a budget derived from cost norms. Accordingly, whenever a control budget was set, such a budget was benchmarked against the budget derived from the cost norms in order to test design efficiency.

The control budget was developed using the DHET cost and space norms. Costs were benchmarked against DHET cost norms – this set the project cost. Control budgets were then set to ensure that the project was delivered within the DHET cost norm or as close as possible to it. The idea was that the programme of building would be within these norms. Some would be above and some would be below. Ultimately, at the programme level, the project would be delivered within the budget.

The degree of design information available for pricing is described in Table 2. The unknowns were related to what was known but was not yet capable of being priced. The percentages were calculated from the assumptions made in the activity schedules in the package orders that were issued. The project definition or information that was available at the start of construction was the DHET cost norms and information somewhere between a concept and a design development report. Finishes were not resolved. There was sufficient information to price the reinforced-concrete frames, while the rest of the project definition remained uncertain at the start of construction.

Appropriate allowances were made in the control budget for the unknown project definition taking into account the authorised amounts (project value set, based on the cost norms), contingencies and price adjustment for inflation. A 5% contingency was included in the budget. The goal was then to ensure that the starting price for a construction contract was within the control budget. The contractor engaged on an early contractor involvement (ECI) basis worked withthe design team to ensure that the target price (priced items and allowances for work not yet priced) at the start was within the control budget (see the paper by Laryea and Watermeyer (2016)). The quantity surveyor (QS) (cost manager) developed an elemental cost model. This was updated with contractor inputs, including their proposed construction programme. The target price was then the sum of the work priced by the contractor and agreed with the employer and the work to go identified from the cost model. The contractors then programmed and priced their preliminary and general (P&G) costs for the full scope of work (priced and assumed). The P&G costs were fixed and not time related as is the case with local forms of contracts in South Africa, such as the Principal Building Agreement by the Joint Building Contracts Committee (JBCC, 2005) (see 'Adjustments in respect of preliminaries' in the book by Segal (2018)). Fixing the P&G costs against a programme for construction provided a key means of controlling uncertainty in the cost of preliminary items.

The project definition shifted from concept to detailed design, taking into account the control budget. This required client leadership and changing the role of the QS from measuring and costing what others have designed to designing a project within a budget.

9.1.1 Designing to a budget

The design team was tasked to complete the outstanding work as far as possible within the target prices for a package order. Where design solutions during the detailed design stage and production information stage resulted in cost increases, savings or trade-offs were sought elsewhere to bring the total of the prices back to within the agreed target price. This was achieved through rigorous discussions between the client, contractors and designers. Further details of the approach used here, its application in the ECI phase and the production information/construction phases and some specific examples of its application can be found in the paper by Laryea and Watermeyer (2016), which examines specific cases of ECI in framework contracts pertaining to this context. Any changes supported by the client were always referred to the cost manager prior to implementation with the proviso that such changes had to be accommodated within the control budget. It should be clarified that the employer's design consultants are still doing the detailed design/producing the production information in this phase, albeit with contractor input.

No provision for contingencies (budget covering construction work that can be required but cannot be foreseen or predicted with certainty) or price adjustment for inflation was included in the target price at the start of construction so that contingencies could be managed above a package level. A stepwise approach to accessing of contingencies was provided (Watermeyer, 2018a). The project managers for the construction contracts were only authorised to increase the total of the prices at the start of construction by not more than 2%. The client delivery manager was empowered to increase the prices up to 10%. Thereafter permission to increase prices came, depending on the value of the increase, from the vice chancellor or the university council. This approach encouraged both the NUPMT and the supply team to seek alternative ways to deal with issues that lead to increases in the total of the prices for a package.

The proactive approach here is in contrast to the traditional approach, which characterises conventional industry practice. The NUPMT's previous experience in the delivery of the Wits capital project programme (see the paper by Laryea and Watermeyer (2014)) showed two contrasting approaches to cost management in construction, which are sometimes influenced by the form of contract adopted. The first one can be described as a pay-as-you- go delivery culture, where the client basically pays for the evolving designs of the architect and the actual cost is known only after the project is complete (see the article by the National Treasury (2016)). The second approach is to design to a budget (discipline of continuous budget control). Interestingly, design and project costs in the construction industry have often been characterised by the former approach, which places the value for money for a project at risk.

The difference between the two delivery cultures became more evident in a 2017 judgement in which one of the UK's leading architectural design practices, Foster + Partners, was ordered by a High Court to pay compensation of £3·6 million to a property development firm, Riva Properties, for designing a hotel that significantly exceeded the client's budget and proved too expensive to build (see Riva Properties Ltd & Ors v. Foster + Partners Ltd [2017]). This landmark case demonstrates how the architects were found wanting in specific relation to the Royal Institute of British Architects stages of delivery 0 and 1.

- Stage 0 – strategic definition. This is the stage in which a project is strategically appraised and defined before a detailed brief is created. Certain activities in Stage 0 are derived from the former (RIBA Outline Plan of Work 2007 (Riba, 2007)) Stage A – Appraisal.

- Stage 1 – preparation and brief. This is the stage in which the detailed tasks relating to the appraisal and design brief are carried out in tandem in preparation for the project.

The claimants' lawyer, Stephen Homer, said, 'This case serves as a warning to designers that they cannot design in a vacuum. Cost and budget is a key constraint and should always be identified and considered when designing any project, even when the provision of cost advice is expressly excluded from the designer's obligations' (Homer and Edwards, 2017).

A key implication of the Riva Properties Ltd & Ors v. Foster + Partners Ltd [2017] judgement is the need for design professionals to design to a budget. The traditional pay-as-you-go culture of the construction industry impacts negatively on clients and puts value for money for a project at risk.

9.2 Working collaboratively

Collaborative working provided a means to integrate the design and production teams to achieve the project outcomes successfully. A specific set of collaborative working practices was strategically adopted to shift away from the traditional contracting culture and actively promote a culture of collaboration/ collaborative working and integration between design and construction teams (see the publications by the National Treasury (2016: p.21) and Watermeyer (2018a) for details on cultural changes that enhance project outcomes). These included framework contracts, NEC3 contracts, target cost contracts based on activity schedules and ECI (see the guide by Watermeyer (2018a)).

The works contracts (see Tables 5 and 6) and professional service contracts (see details in Section 2) were based on NEC3 contracts that require the parties to work in a spirit of mutual trust and collaboration. The architects were appointed in September 2013, and other members of the professional team were appointed between March and September 2014. Contractors were appointed in September 2014 (see Figure 1). Once the contractors were appointed, the design teams and contractors were required to work collaboratively and complete the designs within the set target cost. If this was achieved, there would be no reasons for the client not to instruct further work packages over the term of the framework agreement – a win–win situation for all. Thus, there was cultural shift from the traditional approach of 'constructability and cost model determined by the design team and quantity surveyor/cost consultant only' to one of 'constructability and cost model developed with contractor's insights' (see the guide by Watermeyer (2018a: p. 81)). The significant cultural shifts from traditional collaborative working practices provided one of the keys for successful delivery.

9.2.1 Target cost contracting arrangements for the construction contract

A target price in a target contract, based on activity schedules, is agreed between the employer and the contractor to control productivity. The initial target price is adjusted for compensation events (e.g. scope changes and events that are at the employer's risk) throughout the contract to arrive at a final 'cost' to keep the target equitable, based on cost as defined uplifted by tendered fee percentages. The contractor is paid their costs (people, materials, plant, equipment, site overheads, subcontractors etc.) at open-market or competitively tendered rates plus their tendered fee percentage to cover items such as profit, company overheads, finance changes, insurances and performance bonds on a monthly basis as the work proceeds. The difference between the 'final cost' and the amount paid to the contractor when the work is completed is shared between the employer and contractor in agreed proportions (see Figure 3) (Watermeyer, 2009, 2015). Accordingly, every decision on the project impacts on the 'pockets' of both the client and the contractor.

9.2.2 Fast-tracking construction

The scope of work (works information) for a package needs, in a perfect world, to be complete in order to develop and price an activity schedule. However, this is not always possible due to time constraints, particularly where the project is driven by schedule considerations. As a result, certain pricing assumptions needed to be made regarding allowances for items or budgetary items. When the production information for such items is complete, the works information can be changed in accordance with the provisions of the contract. A change in works information triggers a compensation event, which then allows the total of the prices, the time forcompletion and key dates to be changed in accordance with the provisions of the contract (see Figure 4).

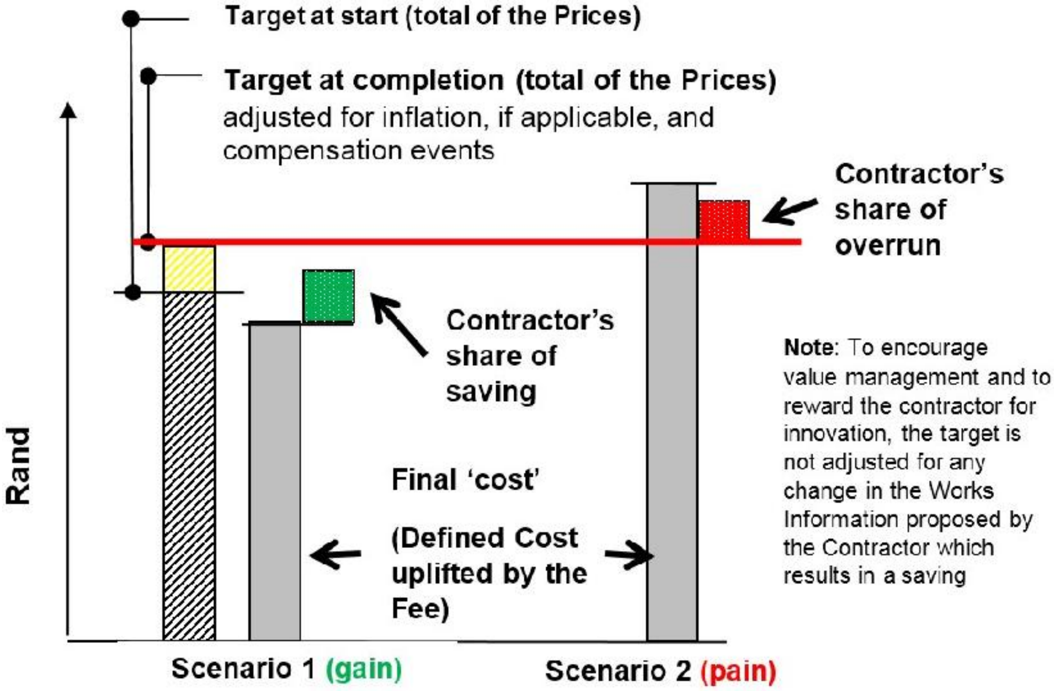

Figure 3. Target contract concept as provided for in the NEC3 ECC (Watermeyer, 2015)

Figure 4. Setting and adjusting incremental targets to "fast track" construction (Watermeyer, 2015)

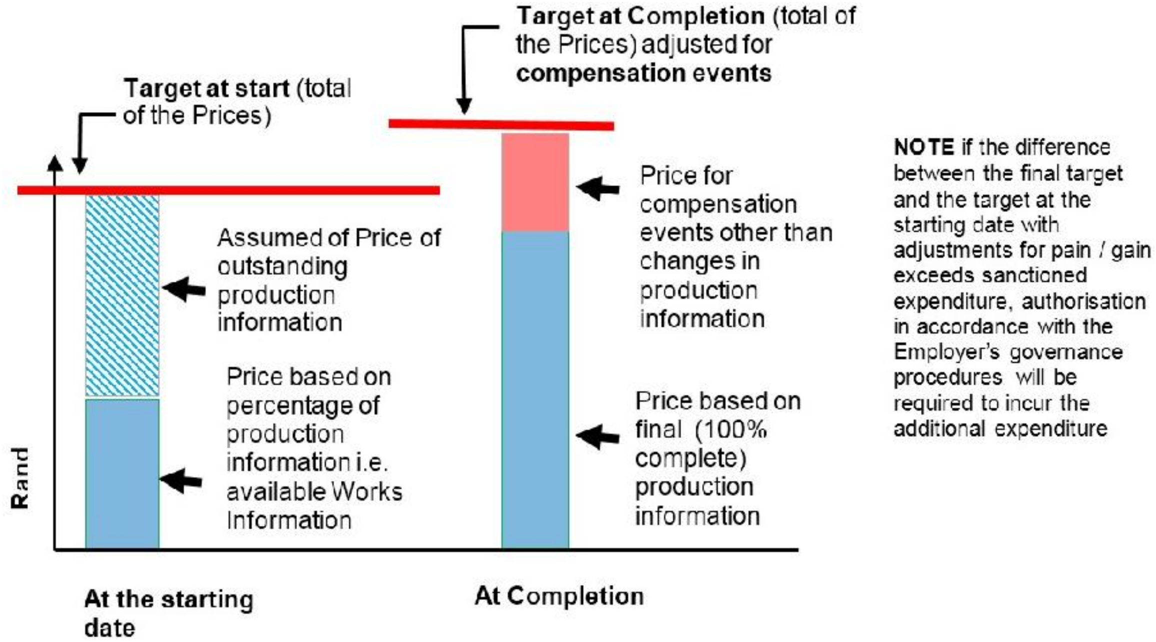

Figure 4. Setting and adjusting incremental targets to "fast track" construction (Watermeyer, 2015)

Accordingly, a contractor can be provided with a description for the whole of the works that they are ultimately to provide and base their P&G items and programme on the available information.

They can, prior to starting the works, be required to programme the whole of the works and to price only a portion of the works where the production information is complete. An assumption can then be made as to what allowance should be made for the balance of the works for which production information is not yet available. These assumptions can be revisited as compensation events as and when new production information is available and adjustments to the target, the date for completion and key dates can be made. The accuracy of the assumptions made can be improved on should they be developed with contractor insights (Watermeyer, 2015). This is the approach that was used on both campuses.

The breaking down of the work into activities linked to a construction programme as required by the NEC3 Engineering and Construction Contract facilitated the agreeing of compensation events relating to the assumptions associated with an activity. Once the work associated with an activity became known, the price associated with the assumptions could be adjusted in terms of the compensation event procedure.

9.3 Project outcomes

The project outcomes are summarised in Tables 4 and 5. The project outcomes in terms of time and cost can be summarised as follows.

- Time. Although the package orders were not completed within the optimistic initial time frames agreed to at the start of such orders, which straddled in some instances two industry shutdown periods, and the actual time for completion exceeded the planned time for completion between 10 and 48%, all academic facilities were opened at the start of the 2016 academic year.

- Cost. The buildings were delivered slightly below the DHET cost norms for university facilities while the work packages were delivered within 1% of the target price (with an allowance for price adjustment for inflation) agreed to when the orders were issued, despite extensions of time being granted and the designs being incomplete when the works started.

- Quality. Quality and fit-for-purpose buildings were delivered in accordance with the specifications. Building C001, for example, received a commendation in the Education and Research category at the World Architectural Festival (2017).

It can be seen from Table 5 that, despite the assumptions regarding the work not being capable of being priced and significant changes in the completion dates being made (between 10 and 48% in the case of the SMU and between 13 and 20% in the case of the UMP), the average difference between what was planned (initial target price with an allowance for price adjustment for inflation) and the final amount paid to contractors was on average plus 1% in the case of the SPU where the uncertainty at the start was greatest and −1% in the case of the UMP.

A ‘gain’ was achieved on five of the seven package orders that were issued. The average gain made by the employer at the SPU was approximately 1% of the total of the prices for work done to date at completion, whereas the ‘pain’ incurred at the UMP was approximately 0·3%.

Relating the project outcomes in Table 6 to the degree of project definition and expected accuracy ranges in the AACE (March 2019) cost estimate classification and primary characteristics for building and general construction industries (see Table 3) demonstrates the effectiveness of the client delivery-management techniques adopted by the NUPMT for managing uncertainty and costs relating to the aspects of the project that had not yet been defined at the start of construction. Given the degree of project definition summarised in Table

2, which ranged between 23 and 74%, the expected accuracy range of the target prices (based on Table 3) could be predicted to be in the range of −5 and +20% (see Table 3). However, the successful delivery of the portfolio of projects within −1% of the control budget demonstrates greater efficiency in delivery of the intended outcomes and value for money.

10. Conclusions

A review on current knowledge on and approaches to managing uncertainty in construction projects generally and fast-track projects specifically provided the theoretical context for this study. The findings contribute knowledge that clients and their delivery managers can utilise to manage successfully a significant amount of uncertainty in projects where project information is not sufficiently available and hence incapable of being priced meaningfully by the contractor at the start of construction and the client prefers a collaborative delivery-management approach.

The findings demonstrate that the practical approach used in practice for managing risk and uncertainty is different from the analytical propositions developed by academic researchers. This paper reports on the practical approach used to manage successfully a significant degree of uncertainty in the case of a New Universities Project in South Africa.

The degree of project definition across a portfolio of seven building projects ranged between 23 and 74%. Design development took place as construction of the works progressed. The practical approach adopted comprised five steps. A rigorous control budget was developed for each building, which was set during the project briefing stage and confirmed during the concept stage. Contractors were appointed to work with the client's professional team soon after the completion of the concept stage to develop a target price. The design teams were required to work collaboratively with the contractors, within a framework contract and target cost contracting arrangement, to ensure that the design was within the control budget. The design team was tasked to complete the outstanding work as far as possible within the target prices for a package order. Where design solutions during the construction phase resulted in cost increases, savings or trade-offs were sought elsewhere to bring the total of the prices back to within the agreed target price, thus reflecting a culture of continuous value engineering and disciplined management of the control budget during the design development and construction stages.

The key drivers of the successful management of uncertainty and delivery of the New Universities Project are client-led delivery- management practices – namely, a combination of

- strong governance arrangements being in place to enable sound decision-making;
- project delivery being managed as an enterprise rather than an ad hoc collection of contracts;
- a client delivery manager being appointed who had single- point accountability for delivering the client's value proposition and who provided strong leadership in the delivery process;
- a competent client delivery-management team being assembled who had complementary expert skills;
- procurement being led by the client delivery manager as a strategic function;
- the adoption and implementation of innovative procurement strategy and tactics aligned to the client's procurement and delivery-management objectives, which enabled competent and capable contractors and consultants to be appointed;

- the high quality of procurement documents;
- the setting of control budgets for projects and the accessing of contingencies to fund risk events on a stepped-access basis;
- ECI, which enabled fragmentation in design to be addressed;
- clearly defined roles and responsibilities between the client delivery-management team and the delivery team;
- framework agreements that incentivised performance in order to secure future orders and enabled long-term relationships focused on maximising efficiency and shared value; and
- the adoption of a collaborative culture to mitigate risks.

Hence, the findings demonstrate how the management of uncertainty and infrastructure project outcomes can be significantly improved on should the client function as the leader of the delivery process.

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