Cost estimation and management over the life cycle of metallurgical research projects

M.M. Odendaal, F.N.S. Vermaak & E. du Toit

ABSTRACT

This study investigates whether all expected costs over the life cycle of metallurgical research projects are included in initial, normal and final cost estimates, and whether these costs are managed throughout a project's life cycle since there is not enough emphasis on the accurate estimation of costs and their management over the life cycle of metallurgical research projects. The study also determines during which phase of the life cycle of metallurgical research projects' costs are normally determined, during which phase most of the costs are incurred, and during which phase costs are managed. Project life cycles, techniques of cost estimation and cost management are examined.

A survey was used to gather information by means of face-to-face and telephonic interviews, as well as an electronic questionnaire. The total population of entities in South Africa that conduct metallurgical research projects is small, numbering only 12 in all. The ten entities that conducted the largest metallurgical research projects in terms of average size were selected for this study.

The conclusion drawn from the survey was that all costs over the life cycle of metallurgical research projects are not taken into account in the initial cost estimate of a project. Costs are mainly managed during the growth phase of a project and not during the introduction phase, when 80% of the costs are normally committed. The implication of this is that cost estimates for metallurgical research projects may not be accurate and costs are not necessarily managed properly throughout the life cycle of such projects. This may lead to cost overruns of project budgets, project budgets being depleted before the delivery stage and research sections running at a loss.

Key words: cost estimation, cost management, life cycle project management, metallurgical research projects

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This study investigates whether all the costs that are incurred over the life cycle of metallurgical research projects are included in initial, normal and final cost estimates, and whether costs are managed effectively throughout a project's life cycle. In order to evaluate how well project cost is managed, the study also determines the life cycle phases during which costs for metallurgical research projects are normally determined, most of the costs are incurred and the costs are managed. Cost estimation and cost management over the life cycle of a project are an integral part of a project and crucial to its success (Kharbanda & Stallworthy 1988). Metallurgical research projects often overrun estimated costs because the costs are not estimated accurately and are also not well managed. Project leaders of metallurgical research projects are generally engineers who are not always trained to estimate and manage costs effectively.

Metallurgy refers to a science concerned with the properties, production and purification of metals (Fowler & Fowler 2011). A metallurgical research project is thus an undertaking to research the components of metallurgy (being metallic elements and intermetallic compounds) and the exploitation of minerals in order to extract metals. Since metallurgical research projects are often technically complex and require a diversity of skills, while being subjected to constrained resources and environmental uncertainty, it can be a challenge to stay within the budget and scheduled timeframes and meet the performance requirements. Metallurgical research projects are considered to involve the transfer of knowledge and do not have a profit goal. Most organisations involved in metallurgical research make use of budgets in some form or other to manage their project costs. The question arises as to whether the estimation of budgeted cost includes all costs, and whether the budgeted costs are adequately managed over the entire life cycle of the project.

In today's competitive global markets, project budgets (therefore including metallurgical research projects) are often depleted before the delivery stage. This is unacceptable because productivity has to be increased while costs are reduced in order to stay competitive (Asiedu & Gu 1998; Ben-Arieh & Qian 2003). The ability to manage cost effectively has become a strategic objective for organisations. However, many organisations are still making use of traditional, ineffective techniques to manage costs. According to Drury (2012), many criticisms against traditional management accounting practices were widely published during the late 1980s, and new approaches that are more in tune with today's business environment were advocated. According to those against traditional management accounting practices such as Hopper and Powell (1985) and Kaplan (1992), the focus of traditional management accounting practices is mainly to compare actual results against a pre-set standard, such as a budget, in order to identify and analyse variances and to take remedial action to ensure that future outcomes conform to budgeted outcomes. This type of management is focused on preserving the status quo, and techniques to improve activities are not always considered. The emphasis of traditional management accounting practices is thus on cost containment as opposed to cost reduction. Despite its shortcomings, many organisations still use traditional management practices even though new approaches to cost management have the benefit of focusing on cost reduction instead of cost containment. The authors have no reason to believe that this would be different for metallurgical research projects. It was determined through personal interviews with the entities that they had not changed their cost estimation and cost management techniques after the initial survey had been conducted. The initial study and interviews were conducted in 2009, and it was established through follow-up interviews conducted regularly after 2014 that the entities had not changed the techniques they were using for estimating or managing their costs.

The impetus for this study came from observations by the authors, noting that costs are not always accurately estimated for metallurgical research projects before such projects start. Costs are also not always managed adequately thereafter. Project management textbooks offer little guidance on cost estimation and management, even though these two factors are crucial to a project's success. The research problem can therefore be formulated as follows: *There is not enough emphasis on the accurate estimation of costs and their management over the entire life cycle of metallurgical research projects*.

The aim of this study was to determine the extent to which appropriate cost estimation and management techniques are used in metallurgical research projects. Since 80% of all costs are committed during the introduction phase of a project, it is crucial for the initial cost estimation to be accurate. Managers of the research sections are responsible for considerable amounts of money – hence the importance of accurate estimates and careful cost management. This study confirmed that all costs are not always included in the initial cost estimates of metallurgical research projects and that project costs are not always managed during the correct phases of the project life cycles. In a period of economic recession, where the research sections of the entities are under pressure, these factors could be fatal for the successful completion of metallurgical research projects.

The layout of the article is as follows: In section 2, previous studies on the different cost estimation and cost management techniques are described. In section 3, the research method is explained. The results of the analyses are described in section 4, followed by a discussion, and recommendations in sections 5 and 6, respectively.

Life cycle of a project and the importance of cost estimation and cost management

A typical project has four life cycle phases, namely introduction, growth, maturity and decline (Emblemsvåg 2003; Drury 2012). Up to 80% of a product's costs are committed during the planning and design stage, that is, during the introduction phase (Asiedu & Gu 1998; Drury 2012). The vast majority of costs, however, are incurred in the growth phase of a project. Costs that have been committed in the introduction phase are difficult to alter in later phases. Cost management tends to be most effectively exercised during the introduction phase and not during the growth and maturity phases, when the product design and process have been determined and costs have been committed (Emblemsvåg 2003).

Cost estimation is the process of estimating the relationship between costs and the cost drivers that cause those costs. Organisations estimate cost for three purposes, namely planning, decision making and control (Hilton, Maher, & Selto 2006). Drury (2012) defines cost management as those actions that managers take to reduce costs, some of which are prioritised on the basis of information extracted from the accounting system, while other actions occur without the use of accounting information. Cost and its estimation are an integral part of a project and crucial to its success (Kharbanda & Stallworthy 1988). Therefore, where an opportunity is identified to perform a process more effectively and efficiently, and has obvious cost reduction outcomes, process improvements should be made. The ideal situation is to take action that both reduces costs and enhances customer satisfaction.

It is thus essential to include all costs in the initial cost estimate of a project. This includes initial costs (such as research and development costs, planning and design), normal costs (such as manufacturing costs and sales costs), and final costs (such as repair costs, and discontinuation or disposal costs). Once costs have been committed, they need to be managed effectively and efficiently to ensure that no cost overruns occur. The next section describes the different costing systems that can be implemented in metallurgical research projects. Owing to a lack of material relating directly to the use of costing systems in metallurgical research projects, the discussion is of a general nature to provide a basis for the empirical part of the study.

Cost estimation techniques

According to Kharbanda and Stallworthy (1988), accurate cost estimation is essential for the success of a project. In an ideal world, no estimation would be necessary and costs would occur as a project develops. However, it was confirmed during the interviews that clients requesting metallurgical research project work expect quotations for such projects, and it is only in rare circumstances that they react favourably to adjustments being made to a quotation after it has been accepted. Unfortunately, accurate cost information is not readily available in the introduction phase, and tends to be estimated using any one of a number of techniques (Tornberg, Jämsen & Paranko 2002). The techniques that are generally used in the field of engineering to estimate costs are described briefly in this section. The use of these techniques is later tested in terms of usage in a sample of metallurgic research organisations.

Drury (2012) defines *life cycle costing* as a method that estimates and accumulates costs over a product's entire life cycle to determine whether profits earned during the manufacturing stage will cover the costs incurred before, during and after the project. Costs incurred during the different phases of a project should be identified in order to provide insight into the management of total costs over the life of a project. Life cycle costing, by definition, therefore takes into account all the costs that will be incurred throughout the life cycle of the project from the design stage (Wübbenhorst 1986; Gransberg & Ellicott 1997; Asiedu & Gu 1998). This holistic and dynamic approach to determining the cost of a project looks at the entire project and considers the consequences of all possible elements. Asiedu and Gu (1998) add to this by indicating that life cycle costing also facilitates decision making. According to Frangopol (2011), the presence of uncertainties in decision making necessitates the use of probability and statistical analysis in some cases of life cycle planning. This will not eliminate all risk, but can significantly reduce the inherent risk of a project (Jaafari 2001). Within the concept of life cycle costing, there are many cost estimation techniques that can be applied to determine the values of costs that will be incurred over the lifetime of a project. Fisher and Krumwiede (2012) developed a model of cost allocations that supports the above thoughts by indicating that life cycle costing is most appropriate for environments where all costs need to be considered and included in estimations. This makes life cycle costing suitable for metallurgic research projects since a variety of costs, from direct materials to customer service, need to be included.

Analogy cost estimation is used when a similar project to the one at hand has been completed successfully in the past and the cost estimation of the old project can be used for the proposed project, with only a few changes (Angelis & Stamelos 2000; Ben-Arieh & Qian 2003; Cuadrado-Gallego, Luis & Miguel-Ángel 2006). It is essential, however, to establish key parameters to ensure that no key elements are left out of analogy estimation. Angelis and Stamelos (2000) suggest the use of statistical software to ensure the accuracy of estimates by reviewing the differences and similarities between projects. Parametric cost estimation, like analogy cost estimation, makes use of previous projects as a basis, but is more sophisticated in that it makes use of mathematical models that are developed from cost driver information determined by designers, experts and from historical projects (Melin 1994; Cuadrado-Gallego *et al*. 2006). According to Asiedu and Gu (1998), parametric models based on specifically defined parameters generate and apply equations that describe even potential relationships that may exist between the variables that form part of a project. This factor makes analogy and parametric cost estimations useful for life cycle costing where uncertain costs have to be included in estimations.

Engineering cost techniques are generally regarded as being in the same category as analogy and parametric cost estimation. However, this is deemed to be a time-consuming method because it makes use of direct observations of particular cost elements in order to make cost estimations. According to Emblemsvåg (2003), this method is mainly used where statistical techniques rely on past data to plan for the future. One advantage of engineering cost techniques is that they provide significant detail for every step needed to perform an activity, which is required for estimating future life cycle cost accurately.

Standard costing is a costing method that was created for the manufacturing industry and operates on the principle of standards that are set on a per unit basis for different expected cost items in a product (Drury 2012; Sani & Allahverdizadeh 2012). Even though many practitioners believe that standard costing is obsolete in the modern business environment, there are many organisations that still make use of it (Sulaiman, Nik Nazli Nik & Norhayati Mohd 2005). According to De Zoysa and Herath (2007), this observation cannot be generalised because it differs from country to country, with standard costing being used far less in Japan than in the United States. The principles of standard costing go against what modern cost management techniques propose. For example, cost savings by means of bulk buying are promoted in standard costing, but cannot work in a just-in-time system (discussed in section 2.2) where the goal is to reduce excess inventory, as it is considered to waste resources. Standard costing is thus a method that is still widely used even though it may not be the most appropriate method in a modern business environment, especially in the services industry.

In contrast to standard costing, activity-based costing (ABC) assigns costs based on those activities that drive the cost, instead of on volume. This method relates to those indirect costs that are best associated with the project (Sani & Allahverdizadeh 2012). Some claim that ABC is one of the most accurate techniques to estimate costs (Asiedu & Gu 1998; Ben-Arieh & Qian 2003; Pazarceviren & Celayir 2013). The benefit of ABC is that it breaks a project into separate elements for which the behaviour is known, making the management of cost easier as well. Feature costing is a spin-off from ABC, based on the principle that each project will have particular features that will result in costs being incurred (Ou-Yang & Lin 1997). Features are defined by predetermined parameters, and cost estimates are therefore based on the expected features of the project being considered. Another development from ABC is attribute-based costing, which is not widely used. This costing method depends on a set of attributes that is presented in a general design framework to which the activities of a project are compared in order to determine which cost items are relevant (Yao 1977; Walker 1999). This costing method can be quite complex to develop and it may not contain all the attributes necessary to estimate the life cycle cost of a project.

Cost management techniques

It was evident from the interviews conducted that, once a research project's cost has been established and the client has accepted the quotation, in most organisations it is the engineer's responsibility to manage the expenditure on the project in order not to overrun the estimation. Only in very few cases do engineering organisations such as those performing metallurgical research projects have the capacity to employ separate management accountants to manage the costs of the organisation's projects. A number of modern cost management techniques were investigated for the purposes of this study. The use of these techniques is later tested in terms of usage in a sample of metallurgic research organisations.

Life cycle project management refers to a management approach where the initial life cycle objective functions are used as criteria for decision making throughout a project's life. Jaafari (2001) also refers to it as strategy-based project management. The success of life cycle costing and life cycle project management lies in the fact that most of the hard work of planning, coordination and system integration is done before the work actually starts (Gransberg & Ellicott 1997). According to Cole and Sterner (2000), life cycle project management directs the focus to those areas in which the bulk of the costs are incurred, namely at the start of the project. It reduces instances where cost reduction only starts with end-of-project expenses as cost overruns become visible. Any alternative cost management technique can be used in conjunction with life cycle project management, as discussed in the section that follows.

Total quality management (TQM) is a cost management method consisting of a set of disciplines that is coordinated to ensure that the organisation consistently meets and exceeds customer requirements (Richards 2012). In some circles, TQM is also referred to as continuous improvement. In order to implement TQM successfully it needs to be a strategic decision and permeate every part of an organisation and individual projects (Dereli, Durmuşoğlu, Delibaş & Avlanmaz 2011). According to Sani and Allahverdizadeh (2012), TQM focuses on rendering a service that complies in all life cycles with predetermined specifications, without the need for any alterations or corrections.

Related to the concept of TQM is the Kaizen costing method. Kaizen is a term that originated in Japan, and Kaizen costing refers to a process of continuous improvement of all aspects of an organisation or project (Sani & Allahverdizadeh 2012; Okoye, Egbunike & Meduoye 2013). This includes a continuous process of reducing costs without reducing the quality of service in order to retain a competitive advantage. Kaizen costing is a management rather than an estimation technique, because it is applied throughout the life cycle of a project in order to improve processes and reduce costs. This method fits in well with life cycle project management, ensuring that initial cost estimates are maintained. Another method, also of Japanese origin, is the just-in-time (JIT) costing method. JIT refers to a system where materials are purchased and units are produced only as needed in order to meet real (not budgeted or estimated) customer demand (Svensson 2001; Wang & Sarker 2004). This method of cost control sets out to eliminate all forms of waste, for example, the use of storage for inventory, the time it takes to transfer goods from storage and so forth. According to De Zoysa and Herath (2007), JIT is one of the reasons standard costing has become obsolete in many organisations. By eliminating waste, quality and efficiency are improved, but it can also have disastrous consequences if there is some breakdown or delay in a project.

Target costing is a cost management technique where a cost target is first set for a project, based on the target price that will be charged (Everaert, Loosveld, Tom Van, Schollier, & Sarens 2006). One of the main benefits of target costing is that, from the outset, it focuses on cost prevention (Zaki 2013), while realising a target profit and not making any concession on quality (Pazarceviren & Celayir 2013). This means that costs are reduced during initiation instead of during the project or after its finalisation. Target costing is also customer oriented (Sani & Allahverdizadeh 2012), focusing on the elements of added features, quality and time in order to determine an ideal end product that a customer is willing to pay for.

Activity-based management (ABM) is a system engineered to evaluate costs and the value of process activities to identify opportunities to improve efficiency. It is based on the principles of ABC, but includes activity analysis (AA) and activity cost analysis (ACA) in order to create a complete managerial style (Tardivo & Di Montezemolo 2009; Alabbadi & Areiqat 2010; Phan, Baird & Blair 2014). According to Phan *et al.* (2014), in the life cycle phases of an organisation, the maturity phases more often make use of ABM than the introduction, growth and decline phases. If implemented correctly, ABM can be a form of continuous improvement because it provides timeous and sufficient information to drive improvement.

Business process re-engineering (BPR) is a management approach aimed at radical once-off, rather than continuous, improvements by means of elevating the efficiency and effectiveness of the processes that exist within and across organisations (Ozcelik 2010). Altinkemer, Ozcelik and Ozdemir (2011) conducted a detailed study on the use of BPR and found that productivity and performance improve remarkably as a result of implementing BPR. BPR therefore has the potential to provide a competitive advantage, which is essential in the modern competitive market.

Research method

This study was descriptive and employed structured and quantitative methods. A survey was used to gather information by way of face-to-face and telephonic interviews, as well as an electronic questionnaire. Face-to-face or telephonic interviews were conducted in cases where it was not possible for the respondent to complete an electronic questionnaire.

The total population of entities in South Africa that conduct metallurgical research projects is small, numbering only 12 in total. A judgemental nonprobability sampling approach was used and the ten entities that conducted the largest metallurgical research projects in terms of average size were selected for this study. The project sizes undertaken by the remaining two entities were too small to be eligible for meaningful comparison. Ethical clearance was obtained for the study to be conducted.

The data derived from the electronic questionnaires were analysed manually by means of spreadsheets in order to generate information, and to facilitate conclusions to be drawn from the processed data. Analysis of the information was conducted to determine what cost estimation techniques and cost management techniques were used and in which phase of the life cycle of a metallurgical research project these costs were estimated and managed.

Detailed analysis of the questionnaire results

For the purposes of confidentiality, the entities used in the study remained anonymous and were referred to as A, B, C, D, E, F, G, H, I and J. Their survey results were not analysed and described in alphabetical order, but in the order in which they had submitted their questionnaires. An interview was also conducted with one person per entity, either the head of the respective research section or a person assigned by him/her. For the purposes of this study, only selected questions in the questionnaire were discussed. The selection was made on the basis of the significance of the outcome.

Comparability of respondents

The purpose of a first set of three questions in the questionnaire was to obtain background information on the number of metallurgical research projects, their duration and the technical sophistication required from the entities involved in such projects.

Responses to these questions showed that the respondents were predominantly involved in more than ten metallurgical research projects (67% of respondents) with an average duration of more than 12 months, and which required high technical sophistication. The entities were therefore engaged in similar projects in terms of numbers, duration and technical sophistication, the information of which could be used for meaningful comparisons.

Project budgets

A question was included in the questionnaire to determine the magnitude of budgets in metallurgical research projects. It is evident that all entities in the metallurgical research field use budgets in some form or other in order to manage their costs. The results indicated that 36% of metallurgical research projects had a budget of more than R1 000 000, followed by 24% of budgets being between R500 001 and R1 000 000.

Cost estimation

As stated earlier, the aim of this study was to determine the extent to which appropriate cost estimation and management techniques are used in metallurgical research projects and how well these costs are managed over the life time of a project. The study also determined during which phase of the life cycle of metallurgical research projects costs are normally determined, during which phase most of the costs are incurred and during which phase costs are managed. The different cost estimation techniques used in metallurgical research projects, as determined by the questionnaire, are indicated in table 1.

Table 1: Cost estimation techniques

	Analogy	Parametric estimation	Engineering cost techniques	Standard costing	ABC	Life cycle costing
Use in project planning	4	2	6	4	3	1
Have used earlier	2	1	4	3	2	1
Heard of, do not use	2	2	0	1	1	5
Never heard of	1	4	0	1	0	0
Use in project cost estimation	3	2	8	4	4	1
Use in project selection	1	0	1	1	1	1
Use for cost management	1	1	7	3	4	1

Attribute-based costing and feature costing were included as an option in the questionnaire, but are not included in Table 1 because these cost estimation techniques were not selected for any of the options in the survey question.

It is evident from table 1 that engineering cost techniques were mainly used for project planning while life cycle costing was the least used. For most of the companies, engineering cost techniques had been used earlier and for project cost estimation. Life cycle costing was the method that most of the respondents had heard of, but had never used. Except for attribute and feature costing, parametric cost estimation was the least known to the respondents. All but two of the respondents had used engineering cost techniques for cost estimation, while seven had utilised these techniques for cost management. Four of the respondents had used standard costing and ABC. Cost estimation techniques were not significantly used for project selection.

All the cost estimation techniques as identified in the literature study, except for attribute-based and feature costing, had been used by the respondents for cost estimation of metallurgical research projects. Most of the respondents had combined techniques to estimate costs. No respondent mentioned any other method of cost estimation in the open-ended section of the question. Respondent A explained that in his organisation, the major problem was that almost all their metallurgical research projects were new, and that there was thus no basis from a previous project to use as an example. The entire calculation of cost for respondent A was therefore based on estimates.

To further elucidate the problem, respondent A indicated that his organisation's cost consisted of two components, namely internal labour costs and procurements from outside. Internal labour costs were estimated using estimated hours per person multiplied by a predetermined rate for that rank. This was first determined by how many people would be required for a project, together with their competency level, for example, technician, scientist, engineer or principal engineer. The charge-out rate per person was then determined by taking into account his/her cost-to-company salary, as well as the recovery of the total operational budget. The hours to be spent per person on the project were then estimated. This estimation was often the reason for overspending, because the estimation of man-hours is generally incorrect to some extent. This is also influenced by the calculation of the charge-out rate. Quotations are gathered for procurement costs, and actual costs are used. If estimations for procurements are incorrect, this may influence the estimation of cost. This method is a combination of engineering cost techniques and actual costs.

The question remains as to how accurately the costs are estimated, how well such costs are managed over the life time of a project and when in a project most costs are incurred. The purpose of metallurgical research projects, as confirmed by respondents A and E, is to transfer knowledge and not to make a profit. To break even, the price the customer is willing to pay obviously has a huge influence on the cost estimation. Because procurement costs are based on actual quotations, man-hours are the easiest figures to manipulate in order to break even.

Responsibility for cost estimation

With regard to who in the organisation estimates the cost of metallurgical research projects, the respondents could choose more than one option on the questionnaire. From the respondents' answers, it was clear that the project leaders were mainly responsible for the estimation of costs. Respondent A indicated that the project leader, together with the project team, was responsible for estimating project costs and that this was signed off by the financial manager. Respondent G indicated that estimators were responsible for cost estimation.

Project life cycle

A set of three questions was included in the questionnaire to resolve part of the research problem, namely to determine during which phase of the life cycle of metallurgical research projects costs are normally determined, during which phase most of the costs are incurred, and during which phase costs are managed.

As mentioned in the literature study, it is clear that a typical project consists of four life cycle phases, namely introduction, growth, maturity and decline. During the introduction phase, only 20% of the costs of a project are incurred, but 80% are committed. It is therefore imperative that the initial cost estimates should be accurate. Most of the costs are incurred during the growth phase. Cost management, however, may be most effectively practised during the introduction phase of a project and not during the growth phase when the costs have been committed and the product design and processes have been determined. During the growth phase, the focus should be more on cost containment as opposed to management.

The first question in the set was focused on establishing the phase of a project in which life cycle costs are determined. Some of the respondents selected more than one option and most of them indicated that they determined their costs during the introduction phase. It is of some concern that costs are still being determined during the maturity and decline phases.

The second question in the set asked about the phase of a project during which costs are most often incurred. Some of the respondents chose more than one option. Most of them indicated that they incurred their costs during the growth phase. According to respondent E, costs were incurred uniformly during all four phases of life cycle.

The last question in the set was to determine during which phase of the life cycle the majority of the costs were managed. Again, some of the respondents chose more than one option. Most of them indicated that they managed their costs during the growth phase. According to respondent E, costs were not only incurred but also managed uniformly during all four phases of the life cycle. Since costs are committed and product design and processes determined during the introduction phase, cost should also be managed mainly during this phase. During the growth phase, the focus should be on cost containment and not on cost management.

Accuracy of the cost estimate

The level of accuracy of the cost estimate during the potential estimate, prefeasibility estimate and the feasibility estimate was indicated by the respondents in terms of percentages. During the pretesting of the e-mail questionnaires, it was determined that the norm for accuracy of cost estimates in metallurgical research projects was 70% during the potential estimate, 80% during the prefeasibility estimate and 90% during the feasibility estimate.

Seven of the respondents believed they were generally 70% accurate in terms of the potential estimate, while one respondent indicated that they were up to 80% accurate. One of the respondents indicated that his entity's potential estimate was normally less than 70% accurate. Four of the respondents estimated that they were 70% accurate in terms of the prefeasibility estimate, while five were generally 80% accurate. Five of the respondents were about 90% accurate with the feasibility estimate, three about 80% accurate and one about 70% accurate. The vast majority of the respondents were therefore in line with the norm as indicated in the pretesting of the questionnaires. Of concern was the finding that three of the respondents were only 80% accurate in the feasibility estimate, and one only 70% accurate.

Costs included in the total estimated project cost

A question was posed in the questionnaire to determine whether all costs were included in the cost estimate of metallurgical research projects. All costs, including initial costs, normal costs and final costs are supposed to be included in the life cycle of a project.

The conclusion drawn was that the respondents did not include all their costs over the entire life cycle in the estimation of their costs. All the responents, however, did include the initial cost, which would typically include research and development, planning and design costs. Normal costs include all manufacturing costs. It is concerning that the respondents did not all select this option, because it is highly unlikely that they do not incur these costs. Final costs include dicontinuation and disposal costs. Only five of the respondents indicated that they included these costs in their estimates.

Cost management

Table 2 provides information supplied by the respondents about the extent to which the cost management techniques identified in the literature study were being used in metallurgical research projects in their respective organisations.

Table 2: Techniques of cost management

	TQM	Kaizen costing	Target costing	JIT	ABM	Life cycle project management	BPR
Used in project planning	1	1	2	1	6	5	2
Used earlier	0	0	1	1	2	1	1
Heard of, do not use	4	4	1	3	1	1	2
Never heard of	1	2	2	1	0	1	2
Use in project cost estimation	1	0	2	0	4	1	0
Use in project selection	0	0	1	0	2	1	1
Use for cost management	1	0	3	0	4	2	0

The following conclusions were drawn from the data in table 2: ABM and life cycle project management were mainly used for project planning purposes. The respondents had heard of TQM, Kaizen costing and JIT, but did not use them. ABM was also generally used by the respondents to estimate costs. Target costing and ABM were mainly used for cost management purposes. None of the respondents indicated that they used other techniques of cost management. However, it was established that they all used budgets in some or other form. Respondent A indicated that his entity used a software program written to the company's specification, which was interlinked with SAP and MS projects. The program is budget based and compares budgeted and actual information as a project progresses. Any variations from the budgeted figures are followed up. Respondent C found it difficult to answer the question because it did not fit in with the type of research and development his organisation conducted. His entity's approach was largely driven by customer preferences. Respondent E commented during a telephonic interview that budgeting occurred once a year. Once approved, the budget was also used for forecasting. The project leader was responsible for managing the budget.

Support systems used for the management of project costs

The purpose of the last question in the questionnaire was to establish which support systems were being used for the management of project cost. From the results, one can infer that the project leader, using a personal computer to monitor costs, in conjunction with the finance department, was mainly responsible for the management of the cost of metallurgical research projects.

Discussion

The results of the study can be summarised as follows:

- Managers of the research sections are responsible for managing considerable amounts of money – hence the importance of estimating the cost of their metallurgical research projects accurately and managing them with care.
- Most of the companies use engineering costing techniques for estimating costs in metallurgical research projects, and use them in combination with other techniques.
- The respondents understood the basic principles of life cycle costing in terms of the phases in which costs were committed and incurred. The costs, however, were managed mainly during the growth phase, instead of the introduction phase, which could be a reason for cost overruns, since the vast majority of costs were already committed and could not be changed.
- There may not be enough emphasis on the accurate estimation of the costs of metallurgical research projects, as three of the respondents admitted that they were only 80% accurate in the feasibility estimate and one admitted to 70% accuracy.
- All costs were not included in the initial cost estimate, which means that cost estimation was not done accurately throughout the entire life cycle of metallurgical research projects.
- ABM, target costing, life cycle project management and TQM were used for the cost management of metallurgical research projects while Kaizen costing, JIT and business process re-engineering (BPR) were not used. The authors are of the opinion that the cost management techniques currently in use are employed in a limited way for cost management, because all the respondents mainly used budgets for their cost management.
- The project leader, using a personal computer to monitor costs, in conjunction with the finance department, was mainly responsible for the management of the cost of metallurgical research projects.

The results of the study show that, too often, the initial cost estimate of a research project does not take into account all the costs over the life cycle of metallurgical research projects. Final costs, including discontinuation costs, are often not included. If, for example, the closure of a project involves getting rid of harmful chemicals, and this cost was not budgeted for, it cannot be recovered from clients. Costs are mainly managed during the growth phase of a project and not during the introduction phase when 80% of the costs are normally committed. The dangers are that, if all costs are not included in the initial cost estimates, cost overruns above initial quotations will occur and project budgets will be depleted before the delivery stage, and the metallurgical research projects will make a loss for the organisation, and research sections will not reach their targets. If project costs are managed mainly during the growth phase of a project, it is too late. Costs are already committed by that time and cannot be altered. At such a late stage, the purpose of cost management to reduce costs will not have been reached, but costs will only have been contained.

Relevance to industry

The findings in this study are of significant concern to industry, since it was found that the costing techniques applied to metallurgical (and possibly also other engineering) projects are not always to the benefit of the organisation. Those in industry are trained to do specific tasks relating to the industry involved. However, only in rare cases are these individuals trained in business skills. A business can only survive if its financial position is healthy and it is therefore imperative for industry leaders to heed the importance of the cost estimation and management techniques employed for engineering projects. The last section in this study makes a number of recommendations for those in industry, especially project managers in metallurgical research projects.

Recommendations

Project leaders should not only have sufficient training, but also an interest in estimating costs. Alternatively, project managers or management accountants should be appointed to do the cost estimation and management of metallurgical research projects. It is vital to include all costs in the initial cost estimates, and to manage these costs before they are committed; if this is not done, the research sections will not break even, but operate at a loss. It would also be of great assistance if project management textbooks could include more information on cost estimation and management.

The following are possible topics for future research:

- It is necessary to determine the reasons why modern techniques of cost management are not widely used in metallurgical research projects in South Africa.

- It would be useful to investigate the possible influence of the South African culture on the lack of innovation in costing techniques in metallurgical research projects.
- Some of the respondents indicated that they use these cost management techniques. It would be useful to determine which management accounting information is in fact used for these techniques.
- It would be interesting to ascertain how organisations can combine their current systems with these cost management techniques in an effort to manage cost more effectively.

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