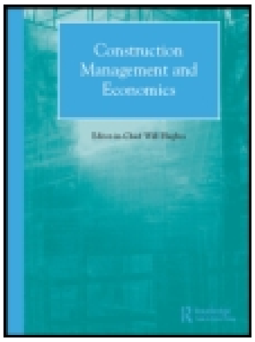

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The cost of non-conformance during a highway project: a case study

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Poor quality resulting from non-conformance during construction leads to extra cost and time to all members of the project team. The costs of rectifying non-conformance can be high and they can affect a firm's profit margin and its competitiveness. Construction-related firms can identify non-conformance information by employing a quality cost matrix as illustrated in a case study as a basis for improvement. Findings indicate the applicability of the matrix, the usefulness of the information for quality improvement and the positive change in attitude of personnel involved in the case study. Areas and frequency of non-conformance and the viability and importance of preventive measures are also highlighted.

Keywords: Quality cost, non-conformance, matrix, quality management.

Introduction

The management of quality in construction is related to time and cost management and vice-versa (Abdul-Rahman, 1993a). A poorly managed project may lead to extra cost and time extensions and a poor time and cost controlled project can effect the conformance of a client's requirements, i.e. a crucial aspect of project quality management. It is vital for project managers to understand the client's requirements in terms of cost, quality and time (Barnes, 1990). Management has to be aware of customer requirements and be responsible for creating the right environment for a stewarded and progressive improvement (Pimblott, 1990).

The proper implementation of a quality management system can lead to the fulfilment of quality requirements and simultaneously provide for cost savings, increased productivity and better product reliability (Round, 1985). Feigenbaum (1951) pointed out that one of the mistaken notions in early years was that quality demands much higher cost. Juran and Gryna (1988) advocated that the cost of achieving a desired level of quality can be divided into prevention oriented and those factors arising out of defects and failures. Traditional accounting does not include the quality function except for testing and inspection activities. This led to quality-related costs being 'lost' or absorbed in various business accounts, especially overhead accounts. Dale and Plunkett (1991) believe that these hidden costs are substantial, can have serious implications to inventory levels and be obstacles to production if not minimized.

In this paper the author describes the use of a matrix which he has developed to capture the cost of quality, especially the cost of failure or non-conformance during road construction using the matrix. The case study is used to illustrate the practicality of the matrix in capturing relevant information from a main contractor.

A background on the cost of quality

Despite much literature discussing quality cost there is no uniform view to what quality cost means (Dale and Plunkett, 1991). In this paper, 'cost of quality' is synonymous to 'quality cost' and so is the 'cost of non-conformance' to 'cost of quality failure'. The cost of quality concept has been developed and used mainly in the manufacturing industry (Feigenbaum, 1983). Quality cost was used in Western Europe in the 1960s and may have been attributed to a paper by Feigenbaum in the mid 1950s (Dale and Plunkett, 1991). The American Society for Quality Control (ASQC) produced several publications on this subject (ASQC Quality Costs Committee, 1974, 1987a,b; ASQC, 1984).

For the purpose of this paper the author adopts the following definition of quality cost, i.e. 'all costs

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Table 1 Glossary of terms

Appraisal cost	The cost of evaluating the achievement of quality requirements including, e.g. cost of verification and control performed at any stage of the quality loop[a]
Failure cost	The cost incurred to rectify a departure, which may be in the form of an imperfection, non-conformance or defect, to meet established requirements
Prevention cost	The cost of any action taken to investigate, prevent or reduce the risk of non-conformity or defect[a]
Quality	The totality of features and characteristics of a product or service that bear upon its ability to satisfy stated or implied needs[b]
Quality assurance	All those planned and systematic actions necessary to provide adequate confidence that a product service will satisfy given requirements for quality[a]
Quality control	The operational techniques and activities that are used to fulfil requirements for quality[b]
Quality management	That aspect of the overall management function that determines and implements the quality policy[b]
Quality cost matrix	A matrix developed and used by the author to capture the cost of poor quality on construction site

[a] BS 4778 'Quality vocabulary'.
[b] BS 6143: Part 1 (192) *Guide to the Economics of Quality: Process Cost Model.*

incurred by the business because the product was not designed, produced, or serviced in a perfect manner during the initial cycle' (Simmons, 1970). Table 1 provides a glossary of terms used.

The British Standards Institution produced BS6143 (1981) the *Guide to the Determination and Use of Quality Related Costs* and later revised it to *Guide to the Economics of Quality* (BS6143: Part 2, 1990; BS6143: Part 1, 1992) in two parts. BS6143: Part 1 (1992), 'a process model' concerns the application of quality costing to any process or service and Part 2 (1990), 'the prevention, appraisal and failure model' is a revised version of the traditional method of capturing product quality cost. Dale and Oakley (1991) described the identification, determination and modelling of both models. Despite the existence of the above classifications there is no standard method available to collect the costs.

Quality costs in the construction industry are relatively high in terms of total project cost (Davis *et al.*, 1989). These consist of the cost for the provision of quality assurance and control programme and the cost of rework and failure. For industrial construction in the USA more than 12% of the total project cost is believed to be spent on rework alone (Burati and Farrington, 1987) and more than 15% of the total cost of any industrial project is spent in terms of producing the required quality (Davis *et al.*, 1989). Davis and Ledbetter (1987) proposed a model of the quality cost relationship. They stressed that the model illustrates the importance of determining the actual relationship between quality management cost and non-conformance costs, i.e. huge savings can be achieved at little prevention and/or appraisal cost.

No data on the cost of poor quality is available for the UK construction industry but it is expected to be high as the following research findings suggest. The Building Research Establishment (BRE) (1981) found that 50% of errors in buildings had their origin in the design stage and 40% in the construction stage. The National Economic Development Office (NEDO) (1987), in its survey aimed at improving methods of quality control for building works, noted 501 quality-related events. These events were classified into three main areas: 'design', 'poor workmanship' and 'other'. Design and poor workmanship combined to form more than 90% of the total. The aforementioned references may not be applicable to civil engineering works but are indicators of major sources of poor quality in construction.

Investigations on the cost of quality in construction

Patterson and Ledbetter (1989) developed a quality cost collecting procedure, i.e. the quality performance management system (QPMS) to track the cost of quality management by activity. It was tried on four widely differing industrial projects and the cost of quality, when cost of rework was assumed to be 12.5% of the project cost, was found to almost one-quarter of the project cost. Later, an updated version of QPMS called the 'quality performance tracking system' (QPTS) was developed to characterize quality cost for the purposes of quantitative analysis and tracking (Davis *et al.*, 1989). QPTS categorizes quality costs into two parts, namely the cost of quality management and the cost of correcting deviations (otherwise known as failures). This system uses 15 categories under quality management and 24 categories under rework (deviation) to classify quality costs.

QPMS and QPTS do not consider the effect of failure on time-related and knock-on costs, i.e. the cost to speed up work to make up for the time lost and the cost of delays to the following trades. They do not consider the specific source of the problem, rather the major causes of origin are stressed. In coding cost information, the QPTS is most compatible with the work breakdown structure system (WBS). Other types of cost-coding systems require some modification before the QPTS can be implemented. The QPTS is suitable for reporting the overall quality cost status but is not suitable when the specific nature and the cause(s) of quality-related problems are required. It also does not prioritize the problems in relation to cost.

In another study (Haamarlund *et al.*, 1990a), an observer was used to record quality failures throughout the construction of a community service building which took 2 years to complete. A total of 1460 quality failures were recorded on-site out of which 80% were remedied satisfactorily and 8% were not remedied at all. Another 21 sites were investigated in a 3 week period to validate results of the full investigation. The result showed that 79% of the failure cost arose from 20% of the quality failures registered. The rectification cost (part of failure cost) was 5.9% of the production cost and approximately 10% of the production time was spent on remedying failures. It was found that the presence of a quality observer itself has had a considerable effect in improving quality. However, Haamarlund *et al.* (1990a,b) did not propose a procedure to collect these costs.

The author feels there is potential for cost of quality information to be used in the analysis of performance failure during construction (not to be limited to analysis of a physical failure such as that of a structural failure). Such information can help management identify, analyse and measure each non-conformance during construction and take precautionary actions to prevent the recurrence of similar problems. Quality cannot be improved if nobody is interested in knowing what is happening in the field.

Development of the quality cost matrix

Due to the limitations on existing methods of collecting cost of quality failures an alternative approach was sought to acquire the relevant information. The method of acquiring data has to be simple, systematic, flexible, has to be understood by junior staff, practical and able to record relevant information. A matrix was developed to capture the cost of non-conformance during construction and can include other classifications of quality cost. The collection non-conformance cost was stressed at the initial development of the matrix because such information is not available in a contract and it can draw management's attention to performance improvement if its value is significant. The initial stage of the matrix development sought to answer the following questions.

1. What category of non-conformance should be used and which activity is affected.
2. What the specific problem is.
3. What is the cause of the non-conformance?
4. How long to rectify problem?
5. What is the direct cost to remedy the situation?
6. Whether there is any indirect cost involved.

Existing forms used to record information in the construction industry include defect notice, daily report, site instructions and variation orders. The information contained in such records is useful for the matrix and can simplify the information collection process.

Ten professionals, involved in quality and project management, interviewed during the early development stage of the matrix indicated that the concept of quality cost is applicable in construction but were doubtful of its implementation and whether it is economically significant. One of the obstacles in implementing a quality cost collecting system in a construction firm is justifying its adaptability to the firm's operation. For a quantity surveyor, gathering quality cost information is an added burden, for a site agent and engineer the system reveals any lack of planning and management skills and for a contract manager to be exposed to failures in projects under his control can be a bitter memory.

Despite the arguments against the implementation of a quality costing system in construction, most professionals met, including senior managers, directors and those who prefer improvement, showed a keen interest in this subject. It is not clear whether this interest was prompted by the need to prove whether or not there is a problem.

After consulation with the professionals it was felt that the matrix was suitable for collecting quality-related information on a construction site. An improvement to the original matrix, i.e. the inclusion of a separate column for time-related and knock-on costs, was made after further discussions with the professionals. The final matrix with some extracted information representing different categories of failure is shown in Table 2. To examine its practicality on real projects the author used the matrix on a hypothetical

Table 2 Matrix used to capture no-conformance events during construction of a motorway

Problem category (A)	Specific problem (B)	Activity affected and when discovered? (C)	Causes of problem (D)	Extra duration needed to correct problem (E)	Additional cost of activity (F)		Amount of additional time-related on-cost (G)	Any other additional cost (H)		Prevention/ appraisal costs for this activity (I)	Quality cost (J)
Personnel	Failure to work to set procedures	14 February 1993	Reluctance to work to set procedures	Nil	Chasing up Administration	 £40	Nil	Nil		Training to set procedures	£40
Subcontractor	Gap too large between wingwall and edge beam	18 March 1993	Setting out error	3 days	Labour Plant Material	£160 £45 £31	2 days	Reinspection	£120	Nil	£356
Material	Unsuitable fill material	2 June 1993	Incorrect placing of fill. Poor supervision	2 days	Excavation and redeposition of material	£1260	Nil	Reinspection	£15	Correct procedure to be adhered to by subcontractor	£1275
Planning	Poor planning sequence	16 June 1993	Varying pile steel prevented perfect positioning of cage. Best fit achieved and a minimum of 35 mm cover dictated the line of concrete	Nil	Labour Plant Material Engineering Time	£40 £88 £60 £94	Nil	Time to achieve best fit and survey – 2 days	£200	Better information in planning	£482
Design/ information of temporary works	Cast concrete not complying with specification	26 June 1993	Shutter design unsuitable	2 weeks	Labour Plant Material	£1480 £324 £1215	1 week £1000 to subcontractors	Reinspection Design	£120 £30	Properly design shutter and review £30	£4084

Note: the above information is a representation of problems from the full list. The examples illustrate that most of the problems could have been avoided without additional cost except for the final one which is estimated to cost £30.

case which is described elsewhere (Abdul-Rahman, 1993b). Items in columns A–D in Table 2 are self-explanatory. The following are explanatory notes for items E to J.

1. Item E: the extra time needed to remedy the problem i.e. actual duration minus estimated duration.
2. Item F: the additional costs (costs of labour, material and plant) incurred by the activity to rectify the problem using normal rates of production.
3. Item G: the additional time-related cost incurred because of extra time needed to complete the activity or additional costs required to speed up work as a result of the problem.
4. Item H: any other additional remedial costs not associated with items F and G but adding to the activity cost indirectly.
5. Item I: the expected cost or cost incurred to prevent the problem (failure event) and/or inspection costs during the course of the activity.
6. Item J: the total quality cost for the activity in question.

Information on each problematic activity is recorded on-site. The cost of each activity can be calculated on-site or at the head office on a weekly basis or at the end of the project depending on the objective of the exercise. If the objective is to start using quality-related information for the remaining construction period cost information has to be obtained as soon as possible. The use of this matrix in capturing the cost of non-conformance on a case study is described in the following section.

Capturing the cost of non-conformance of a highway project

The information obtained for this case study was not easy to obtain and tended to be sensitive. It took more than 1 year to gather the information. Due to the sensitive nature of information and to safeguard the participating company's interest much detail of the project is deliberately excluded and the firm's identity kept anonymous.

The main contractor in this case study was responsible for the preparation, design and construction of a motorway for a national transportation organization. The lump sum design and construct contract was carried out as a joint venture with a design firm. This means the burden of contract risk for all information is assumed by the joint venture. A client's representative monitored the progress of work and certified milestone payment as the work progressed. Part of the work was sublet to subcontractors. The criteria used in the selection of subcontractors were knowledge, past experience and competitiveness; implementation of quality assurance is not a requirement. Other information on the project is as follows.

Project profile

Type	Road contract
Pricing	Fixed price
Estimated duration	55 weeks
Actual duration	43 weeks
Length of carriageway:	
Dual	XX^* km
Single	$0.35XX$ km
Project organization	Joint-venture (design and construct type of contract)

*Note: XX represents the length of the carriageway.

Principal quantities

Earthworks	584 000 m^3 cut
	540 000 m^3 fill
Structures – *in situ*	One underbridge
Reinforced concrete	One overbridge (additional works)
	Three badger tunnels – total length 246 m
Main carriageway	Dense bituminous Macadam
Planting	More than 10 000 trees and shrubs

Objectives of case study

This case study was initiated by the managing director (MD) of a contracting and design company. The first meeting was held at the firm's headquarters between the MD, the firm's quality manager and the author in mid-October 1991. It was aimed to set objectives for the investigation. These were

outline strategy for quality performance/cost evaluation to be defined;
examination of historical data on selected contracts;
identification of key problem areas and failures examined to see how cost information could have been used to initiate appropriate preventive actions.

The firm recognized that in order to maintain its competitive position it needed to identify and prevent non-conformances and intended to pursue these purposes by putting the matrix to trial. For the matrix approach to work all non-conformance needed to be well documented. It was decided that the exercise should be conducted on a project that implements a quality system for easy access of available records. The investigation covered only the construction phase of the project but problems from design and others that affect construction were considered.

Data collection

The research methodology was based on discussions and interviews with key personnel and recorded information. Background information for the contract is obtained from the discussions with the main contractor's quality assurance manager, quality systems engineer, site agent and project manager. Data on non-conformance events were collected mainly from the defect notices used by the main contractor as part of its quality systems recording procedure while others were from interviews and discussions with staff who participated in this investigation. The latter relied on records from variation orders and other site instructions. The defect notice details each item of work on site that does not conform to the specification or plan of work, i.e. when rework is necessary. Its presence eased the collection of non-conformance information for this case study. Information from the notice is transferred on to the matrix format and later the cost for each item estimated on-site by the site management team which included a quality surveyor. The head office's quality assurance department verified the completed matrix. Site management clarified ambiguities and provided additional information when needed. Delay in communication on certain ambiguities occurred at the end of the project when the project manager and the site agent were transferred to new projects but this was resolved with the appointment of a works agent as the coordinator for the remaining tasks.

Initial findings

A site visit was held in late October 1991 to explain the concept of quality cost and the purpose of the exercise and to discuss the issue of quality cost with site management. The discussion with the site agent indicated that the project had benefited in terms of better and systematic record keeping, minimum dispute and conflict, better cooperation and fewer communication problems at various levels as a result of implementing a quality assurance system by the main contractor. The choice of contract type, i.e. design-and-build has some influence on performance in terms of faster design approval, better communication and early project completion. However, not all the problems disappeared. Site management disclosed some problems which can be considered as major and which hindered smooth work progress. The problems revealed during discussions included the following.

1. Buildability problem: difficulties in constructing the design which caused the reworking of a portion of a wing wall several times, although theoretically this should not have happened in a design-and build contract.
2. Non-compliance by material supplier: poor quality material, i.e. flint, was found in the concrete mix during a pour of a wall section. The result was the concrete had to be flushed and a minor dispute occurred between the site agent and the concrete supplier.
3. Subcontractor problem: complacent attitude of a subcontractor. The main contractor chose to select the cheapest subcontractors for this project though steps were taken to ensure that these subcontractors had reasonably good performance records. Apparently these steps were not sufficient to prevent failures by some of the subcontractors.

The site agent cum QA coordinator and a works agent were responsible for filling in the matrix and grouping each non-conformance under the categories shown in Table 3. The categories listed in Table 3 were a result of a discussion with the quality manager on the types of expected non-conformance. A second site meeting was conducted in early 1992. Discussions were mainly with the project manager to finalize the acquisition of the remaining information.

Findings

A total of 72 non-conformances were gathered by the end of the investigation of which 59 were considered for analysis. The cost of the non-conformance considered was estimated by site management. The rest were omitted mainly because they represented trivial events and did not carry with them any cost but were reported as minor non-compliance.

Analysis shows that rectification of non-conformance can take as little as 'nil' time to as long as a few weeks and the costs of non-conformance ranged from £9 to as high £9989. It is interesting to note the highest cost of prevention was £30 as reported by the site agent. For the period covered by the investigation, it was estimated that less than £100 spent in preventive actions could have saved almost £58 000 in failure cost during construction. This is because all non-conformance could have been avoided by low-cost preventive actions including timely inspection, improved communication and planning and the use of a design review. Not all of the failure costs were borne by the main contractor. A detailed analysis of the information revealed that a total of £28 000 was charged to the respective subcontractors responsible for non-conformances.

Table 3 Classification of non-conformance in construction

Number	Classifications
1	Geotechnical, e.g. misjudgement on risk factors, inadequate site investigation
2	Design/information of temporary and permanent works, e.g. buildability problem, error in design
3	Planning, e.g. inadequate/poor planning
4	Information and communication, e.g. failure in communication
5	Material, e.g. material does not meet specification
6	Construction-related, e.g. setting out error, mistake
7	Plant and equipment, e.g. machine breakdown due to poor maintenance
8	Difficult to work area, e.g. rough terrain
9	Personnel, e.g. attitude problem, lack of motivation and inexperience leading to mistakes
10	Subcontractor and supplier, e.g. poor workmanship/error by vendors supplying service or product to the main contractor
11	Supervision and inspection, e.g. inadequate or untimely inspection/supervision
12	Other problems, e.g. problems which do not fall into any of the categories above including client's policy

Upon receipt of final information it was found that there was more relevant information needed to provide a more comprehensive picture of the cost of non-conformance. These included a problem associated with a concrete supplier who supplied contaminated concrete, the costs of material wastage other than those included in the matrix if any, any cost variance between estimated and actual costs, the cost associated with overtime work, variations and their consequences on project cost and the number of hours the project manager and his team members spent in resolving non-conformances. The last item includes the time spent in meetings, communication, replanning, reporting and decision making. A ball-park figure on total hours spent by each individual and the pay-rate per hour are what is needed in preparing the estimate. The site management responded to each query with cost detail.

It was found that the total cost of non-conformance incurred in the project based on the information obtained was £210 922. This represents 5% of the tender value. Bearing in mind that this project implemented a quality system and that this figure does not include material wastage and head office overheads, it is expected that a project with poor quality management could incur a much higher figure. Tables 4 and 5 show the actual breakdown of cost by type of non-conformance and the frequency of non-conformance, respectively.

Table 4 Percentage breakdown of cost into types of non-conformance

Type of non-conformance	% of cost
Subcontract	48.2
Construction related	21.0
Design related	12.1
Materials	11.7
Supervision/inspection	4.1
Planning	2.4
Other problems	0.2
Personnel	0.1
Communication	0.1
Plant and equipment	0.1

Table 5 Frequency of non-conformance by type

Problem category	Frequency
Construction related	18
Subcontract	18
Supervision	9
Materials	7
Design related	3
Planning	1
Personnel	1
Communication	1
Plant and equipment	1
Other problems	1

Discussion

The implementation of quality costing affects the contractor's site management in several ways. Probably the most significant effect was the change in attitude. Personnel became more conscious of the non-conformance events and the impact of non-conformance on project time and cost. Although this increased awareness was difficult to quantify, observations and feedback from the quality assurance department showed that personnel became interested in how each major problem could have been avoided and in allocating responsibility to each non-conformance. In most instances, the information gathered provided the opportunity for the site engineer and foreman to reconsider what could have been done to prevent the problem – a learning experience. For construction activities, site personnel agreed that most of the non-conformances could have been avoided by timely inspections and the use of experienced and skilled labour. In design, personnel were more concerned with furnishing the project teams and accurate data and in responding to or managing a change/instruction timely.

In this case, the variation orders issued out of design error or omission constitute a non-conformance because the structure would not be complete without the variation order issued and the cost is borne by the joint-venture.

The time required to rectify a non-conformance varies but the main concern is its anticipation and management to minimize any deviation to the programme of work. Failure to control critical activities will result in additional on-site cost apart from the cost of rectifying the problem.

As indicated earlier, the preventive cost from any of the problems encountered was minimal when compared to the amount spent in correcting a non-conformance. Attention should be paid so that the cost of any preventive measure does not exceed the cost of expected failure(s). To be selective in its choice of expending time and resources in preventive measures efficiently a firm requires knowledgeable and experienced personnel.

The extra paper work generated from the quality cost exercise may not provide benefit to this contract but could prevent repetition of non-conformance on another job – but only if the message is publicized within the firm and employees are motivated to use this information.

The quality cost information collected enables, in this case, the contractor to identify failures and their causes with cost attached to them. Such information is hidden or spread elsewhere in the accounting system and is not shown when comparing an original estimate to the final cost. Non-conformance information can be used to prioritize problems and to eliminate or reduce quality-related failures. It is impossible to achieve this by comparing the estimated cost with the final one without first sourcing the problems encountered during construction, apart from, maybe, material wastage. The accuracy of the data obtained from the site was verified by the quality assurance department.

In the author's opinion, an area of concern is the extent of non-conformance caused by the subcontractor in this project. This is a major problem as most construction works are sublet to specialized subcontractors. Though specialized these subcontractors demonstrated that they were not able to take the necessary precautions to avoid failure. If most subcontractors suffer the same fate as those in this project, then the mark-up cost of construction would have to be high or they would be out of business.

Potential use of quality cost information in construction

Measuring quality cost is often difficult due to differing perceptions amongst individuals, especially when the concepts of quality and its management are not properly understood. Its use has been proven beneficial to improve weaknesses that lie within a company or an operation in terms of quality production or service rendered.

The use of prime cost as a control is limited due to its overall character (Gobourne, 1973). It merely exposes loss figures and does not address its nature. Cost control, an important function in construction project management, goes further. The objectives of cost control include the detection of potential cost overruns before they occur to enable corrective or cost-minimizing action, to act as an expenditure versus budget indicator, to establish a cost-conscious environment and to minimize the overall project cost (Clark and Lorenzoni, 1985). It enables the project team and the client to be aware of cost trends for the project and forms a basis for timely corrective actions whenever unfavourable variances are found, usually, by comparing the actual cost of an item of work with a known standard cost or budget. If the analysis shows potential losses then immediate action would need to be taken either to reduce expenditure overall on the individual item/activity or project overheads. Variances (the difference between estimated and actual cost or time figures) exist because more money is spent on resources during production than anticipated and/or there is an increase or decrease in the amount of resources used to achieve the required output (Pilcher, 1985). Traditional cost control systems in construction do not consider the quality function and variances resulting from, for example, rework due to poor quality. This is probably due to top management's reluctance to establish a rework account (Clark and Lorenzoni, 1985). Mistakes are buried and the extra costs incurred are treated as poor productivity. This act reflects a poor management attitude and prevents room for improvement. On the contrary, quality costing allows cost quantification of failure events. Current cost control procedures need to accommodate quality costing because the latter can help management identify unnecessary costs.

Quality cost can be used to assess the performance of quality management and to identify potential weaknesses in a firm or a process. When the prevention and/

or appraisal cost is known and placed along the failure cost of an activity the matrix can show the ratio of prevention to failure cost for that particular activity.

Conclusions

This paper demonstrates the applicability of the quality cost matrix in the construction phase of a motorway contract. The flexibility and simplicity of the matrix could be extended to building and other construction works. The following are the main findings from the case study.

1. The quality cost exercise has a positive effect on the attitude of the project team involved.
2. The preventive cost of any non-conformance is found to be minimal compared to the cost of its rectification because the relevant non-conformance could be prevented with low-cost preventive measures.
3. Information on the cost of non-conformance from the matrix can be used to highlight source(s) of problems for management to prevent the repetition of similar failures.
4. The cost of non-conformance arising from subcontractor's failures is significant indicating the need for them to exercise better quality management.
5. A breakdown of additional costs into activity, time-related, other and prevention costs identifies the origin of the additional costs.
6. The cost of the non-conformance concept illustrates the importance of prevention rather than handling failure or 'fire-fighting'.

This case study shows that quality has to be managed at all project levels and stages and that the responsibility of providing a high quality construction lies with the integration and cooperation of project teams and the quality of their personnel. The implication of any decision taken early in the project will influence the fulfilment of requirements and the cost of quality for that project. Thus, how quality cost information can be used effectively in construction industry needs to be addressed.

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