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IDENTIFICATION OF SOME FAILURE COSTS AND THEIR PERCEIVED ROOT CAUSES IN CONSTRUCTION

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ABSTRACT: In 2008 the total estimated failure costs in the Netherlands was estimated to be 11.4% of the industry's turnover compared to 7.7% seven years earlier. Failure costs can be the consequence of rework as a result of failure to conform to the product requirements and specifications or due to inefficient processes and bad management practices. Many construction companies however are unaware of the exact nature of these costs, their root causes or how to control them. This paper describes work carried out in the Netherlands to identify the different types of failure costs in construction and their root causes. The research described builds on previous findings by another research institution and expands it to include information collected from project cases and a survey of a number of project managers in the construction industry. The paper describes the analysis of the results from cases and the survey to identify the root causes of failure costs. Research shows, for example, that many failure costs are related to the client taking late decisions and making changes to the project requirements.

Keywords: Failure costs, construction, contractors, root causes of failure

1. INTRODUCTION

The construction industry in most developed countries in Europe such as the Netherlands accounts for up to 10% of GDP and provides and maintains the infrastructure to enhance the quality of life. It uses less skilled workers than other sectors of industry do, and the control of cost, time and quality are perceived to be lower than in other industries. In the UK for example both Latham [1] and Egan [2] have criticized the UK construction industry and highlighted the need to improve its performance. Latham [1] estimated that the "real cost of construction" needed to be reduced by some 30 per cent if it were to survive as a competitive UK operation.

The problem described above is compounded by the fact that construction projects are increasingly under pressure to be delivered within target budget, duration and without compromising the quality of their works. This pressure comes at a time when most construction experts are also realising that the industry needs to be more efficient and that significant part of the construction costs are unnecessary and can be avoided. A recent survey study carried out among construction practitioners in The Netherlands has shown that on average these unnecessary costs, often termed "failure costs", range between 8% to 12% of the total project cost. In this paper failure costs refer to all unnecessary costs that are the results of rework due to non-conformance of product requirements and specifications or due to inefficient processes and bad management practices.

To address this problem many studies on failure costs in construction have been carried out worldwide in order to: quantify failure costs, identify their sources, and develop models and strategies aimed at reducing the occurrence of failure costs in construction projects. Some studies have shown that although manifesting themselves in the construction stage, a significant part of these failure costs however originate in the pre-construction or design stage of the project. Despite all the efforts made by academia and industry to identify and measure the extent of this phenomenon there is still no suitable solution offered to the problem. For this reason many construction companies are still unaware of the exact nature of these costs, their root causes, or how to control them.

Problems described in previous paragraphs are not limited to Europe or the Netherlands. Recent research in the US had also shown that inefficient management practices in projects in the construction industry amounted to extra costs of 16 billion dollars per year representing between 3 to 4% of the total turnover of the industry.

Some previous research studies have shown that failure costs may arise due poor planning, design errors, poor communication, construction deficiencies, uncertain ground conditions as well as many other factors. It has also been found that in the majority of the cases failure costs share common causes. However many of the previous studies have addressed failure costs as a management problem that is associated with quality of the product. Very limited research effort has been undertaken to address failure costs related to quality of the construction process or in explaining the mechanisms behind the failure costs adequately.

In investigating failure costs in manufacturing industries, many studies in the past have used PAF (Prevention-Appraisal-Failure) model of the British Standards Institute [3] to analyse costs of quality (COQ). The PAF approach groups non-conformance costs into the following four categories:

- prevention costs
- appraisal costs
- internal failures
- external failures

Many of the studies have concluded that this model is difficult to apply in construction due to the difficulties of separating prevention and appraisal costs from other aspects of the construction task [4].

2. FAILURE COSTS AND QUALITY ISSUES

Most studies on failure costs in the construction industry have set their theoretical basis on quality management theory. This is the reason why many of the terms used to refer to failure originate from a quality management perspective. Some of these terms include quality deviation [5] and [6], non-conformance [7], defects [8] and rework [9]. In some cases these terms have been used interchangeably within the same studies [8] and [10]. Some scholars have argued that one of the shortcomings of existing literature is the lack of a common definition of failure costs [11]. In response to this Love & Edwards [11] argued that terms such as errors, omissions, changes, failure, damage, and defects are all attributes of rework, hence proposing that rework encompasses all previous constructs. To a certain extent the wide array of terms referring to failure costs that are found in the literature has contributed to blur the boundaries of what encompasses failure costs and what does not. Certainly what this implies is that the findings of previous studies are not entirely comparable as the scope of the failure construct differs from one another.

From a general perspective, the process of failure costs occurrence includes a failure source or a set of failure sources, an erroneous action, a manifest defect, its consequences and corrective action. Within this context every failure can be traced back to one or more sources which are the condition or interrelated set of conditions triggering an erroneous action. The erroneous actions consequently lead to the manifest defect which is the non-desired condition in a product or process. The non-desired condition refers in fact to non-conformance to established product or process requirements or specifications. Consequently non-conformance condition will have effects on both the product and the process that will require corrective measures for remedying the manifest defect. According to [8] the extent of the consequences and corrective measures expressed in monetary terms is what constitutes failure costs. In fact these terms represent different stages that occur in the generation process of failure costs. This contrasts with [11] argument that all failure costs are the resulting consequence of rework. The authors disagree with this argument as rework does not fully represent the whole spectrum of events of how failure costs can be manifested in a construction project.

Davis & Ledbetter [5] and Burati & Farrington [6] referred to failures as quality deviations, where quality is defined as the ‘conformance to establish requirements’ and deviation is used to indicate ‘a product or result that does not fully conform to all specified requirements. In this context [5] distinguished between three types of erroneous actions that trigger a deviation: error, omission, and change. Error is defined as any item or activity in a system that is performed incorrectly resulting in a deviation. Omission is defined as any part of the system left out which results in a deviation. And change is defined as a directed action altering the currently established requirements. Furthermore, [5] had also distinguished between three degrees of deviations (i.e. failures): imperfection, defect, and non-conformance. Imperfection refers to a deviation which does not necessarily affect the use or performance of the product or process. In their work, Davis & Ledbetter [5] stated that in practice imperfection are deviation which are tolerated. A defect refers to a deviation of a severity sufficient to require corrective action. Finally non-conformance is a deviation that occurs with a severity sufficient to consider rejection of the product or process. According to all these definitions the main criterion for determining failure is set on the conformance of established requirements. Abdul-Rahman [7] considered the term of non-conformance as inefficiency within the specified process, i.e. over-resource of excess costs of people, materials and equipment arising from unsatisfactory inputs, errors made, rejected output and various other modes of waste. Furthermore the costs of non-conformance are those related to the inefficiencies found in processes and the costs of conformance are those incurred when operating a particular process with 100% efficiency (i.e. with respect to specified procedures). It is worth mentioning here that the 100% efficiency does not imply that the process is the optimal process to produce a certain product. In addition defect is defined by [8] as a non-desired condition in a product or a process. Finally rework is defined by [9] as the unnecessary effort of redoing a process or activity that was incorrectly implemented the first time.

In summary all these definitions make reference to failure as a state or a condition of not meeting a desirable or intended set of requirements. One aspect that has been disregarded in previous studies is the contextual subjectivity of the term failure. Determining what is and what is not a failure is greatly dependent on the definition and interpretation given to this set of established requirements. In principle all project stakeholders share the common goal of delivering the product according to the project requirements defined by the client. However, as construction projects are characterized by being temporal organisations that include many parties who individually translate and adapt the overall project requirements to fit their own needs means that what may be considered as a failure by one project stakeholder may not be for the other. A good example of this is the case in which a change order for the contractor issued by the client may represent a failure to conform to the original budget for the latter and additional work and profit for the former.

3. OVERVIEW OF PREVIOUS STUDIES

3.1 Basis of Assessment of Failure Costs

As stated earlier, previous studies have set their theoretical basis on quality management theory. In most studies the prevention-appraisal-failure (PAF) model has been considered. In this model prevention costs are those incurred to reduce, eliminate and prevent defects (errors); appraisal costs are those incurred to detect errors and to evaluate the quality of the work done. In the case of failure costs, these are divided into internal and external failure costs, where failures are all those costs incurred when it's necessary to correct products or processes that fail to satisfy the quality specifications [10], [4] and [12]. Internal failures are those which occur before the delivery of the product including scrap, rework, retesting and time spent for corrective action; and external failures are those which occur after the delivery of the product including costs of repairs, returns, dealing with complaints and compensation. Authors that have used this model for measuring failure costs have found some limitations in its applicability to the construction industry. The main limitation is the difficulty in estimating the prevention and appraisal costs for each project [13]. The second limitation is that the focal point of analysis is set on the quality of the product and not on the process. To overcome the second limitation other authors have used process cost model in which the project costs are quantified as cost of conformance and cost of non-conformance. In their seminal work, Aoieong and Tang [14] and [15] proposed the usage of the process cost based model for the quantification of the cost of conformance and cost of non-conformance in a concreting process of a construction project.

Some studies have put the emphasis on the dissatisfaction with the product and its rectification (rework) in order to fulfil the specified requirements. Other studies have changed the emphasis to the inefficiencies in the processes as well as the product. The common denominator in all of these studies is the non-conformance of established requirements either at product or process level.

In the work described in this paper failure costs are taken to represent all avoidable costs resulting from product and process non-conformances including all consequences and corrective measures. These non-conformances may be triggered by inefficient processes, or erroneous human actions.

3.2 Approaches Used

Two basic and contrasting approaches have been followed to measure and analyze failure costs in construction projects. One approach pushes in favour of measuring failure costs as accurately as possible while the other relies in the subjective measurement and analysis of the problem. Both approaches have provided significant insight into the subject. Previous studies have found that many failure sources are originated in pre-construction stages of the project while failure costs themselves have occurred in later stages. Some scholars argued that at least 50% of the failure costs are generated in the pre-construction stages of the project [6], [16] and 17. Other studies have found that up to 85% of the failure costs share common causes [8], [9], 12] and [13]. These same studies have also pointed out that relationship between failure sources and costs follow Pareto logic, in which 20% of the failure events contribute to 80% of the failure costs in the project.

Despite the effort put into these previous studies to analyze the problem of failure costs, these studies have experienced barriers that are worth discussing. Studies that have tried to measure failure costs in construction projects in a holistic manner have encounter the problem of involving all members of the project organization. This is due to the fact that each project member has a different perspective about failure costs. To overcome this, researchers have relied on observational approaches to collect available data. This has proved to be labour intensive and despite the effort it was not possible for the observers to collect all failure events in a project. It is extremely important that all parties are committed to the efforts of reducing failure costs in projects and contribute in the work of identifying events leading to them. However one of the main barriers for the measurement of failure costs in a project is the fact that the parties involved are not willing to share the information about the sources or the amount of failure costs with each other.

In addition studies based on surveys have faced the problem of bias in the assessment of failure costs due to the subjective judgment of practitioners. Scholars have found that in some cases different project parties tend to hide their own mistakes which reduce reliability in the data being collected. In other cases practitioners tend to highlight failure events which are attributed to other parties but themselves. Atkinson [18] referred to the attribution theory drawn from psychology to explain this phenomenon. The theory suggests that an individual tend to blame external circumstances and failures of others for his/her own errors.

The construction industry is under great pressure to engage strategic practices that will improve its performance over time. One indicator of this improvement is the reduction of failure costs; hence the importance of measuring and analyzing failure costs. Nevertheless, as literature shows the measurement and analysis of failure costs is not embedded in the industry's practices.

The following sections of the paper describe the work carried out in this research to identify some of the failure costs and their root causes.

5. RESEARCH METHODOLOGY

The research methodology into failure costs described in this paper involves designing and conducting a survey and a limited number of interviews. A typical engineering and consultancy firm was selected as a case for this study and three infrastructural projects were also used as additional source of information for the study. The engineering firm was selected because its activities involve all project phases and, because of the management, consultancy and supervision services the firm provides, these activities are also related to the works of contractors and clients alike. This is believed to be very appropriate to cover all aspects of failure costs experienced by the main parties of any construction project and to see whether the causes of these failures are interrelated.

5.1 Design of the Survey

A survey on the sources of failure costs was designed and distributed to a number of experts within the engineering firm to find out the relationship between failure costs experienced by the organization in the past and the elements and issues provided by the survey. The survey is structured based on the main elements of failure costs that have been identified in an earlier study carried out by the Foundation of Building Research (SBR) in the Netherlands [19]. The main sources and root causes of failure cost identified by the (SBR)'s study are shown in Table 1. The survey has 10 sections in total. The first section contains general information about the respondent, affiliation and his function within the organization. Sections 2-9 are related to the main sources of failure cost that are associated with the work of the engineering consulting firm on the basis of the SBR study.

Within each of the above sections a number of positive statements about issues related to the specific subject of the section were formulated to be evaluated by the respondents. Evaluation is based on a 6 point subjective scale that consists of "completely disagree", "somewhat

Table 1 Identified sources of failure cost by the SBR study

Source of failure costs	Causes
Design related	Design changes due time pressure
	Design changes due to change of business needs
	Design changes requested by the end-user
	Design changes because project budget is too high
	Design changes because budget is exceeded the tender
	Design changes because design not functional
	Design changes because construction system is not efficient
	Lack of knowledge of architect
	Design is not made by skilled professionals
	Lack of knowledge about implementation by the architect
	Contractor and special subcontractors are not involved during design
	Design is not cost effective
Change in the process	Change in process because owner changes the team
	Change in process due to unexpected change
	Change in process because parties interests are affected
	Change in process due to changes in top management
Time pressure	Not sufficient time
	Occurrence of quality failures
	Delay on previous phase
	Too late initiation of works
Culture problem	Lack of culture and attitude towards teamwork
Planning and coordination	Poor planning and coordination
Motivation problem	Lack of motivation
Poor communication	Information is lost as the project advances to following phases
	Execution orders are sent too early
	Insufficient allocation of responsibilities and procedures
	Insufficient monitoring of responsibilities and procedures
Poor supervision	Poor supervision during construction
Workmanship	Poor workmanship

disagree", "neutral", "somewhat agree", "completely agree" and "don't know". The total number of statements in all sections of the survey is 79. Table 2 shows an example of such statements related to one issue within the failure source, in this case "Planning and coordination".

The last section of the survey is provided for the respondent to add any remarks and comments about the various issues provided or additional sources of failure costs experienced by him or her in the past.

The number of experts who responded to the survey within the organisation was 19. They represent various functions across the organisation.

5.3 Interviews

In addition to the survey within the selected engineering firm, a number of senior managers from contracting companies (total of 5) who were working on three large infrastructural projects that the engineering firm was involved in had also been surveyed and interviewed. The interviews were intended to provide practical experience of the projects with failure costs and to complement the information collected through the survey.

6. RESULTS AND DISCUSSION

6.1 General Results

The results of the survey and interviews have been put together and summarised. The analysis has produced the following main observations:

- In relation to the issue of communication, the main sources of cost failures according to the experts were linked to ambiguity in the project problem definition and the specification of project requirements by the client. 64% of the people surveyed have disagreed with the positive statement that the project requirements are usually well specified by the client. 69% of the respondents also attribute failures to lengthy and unclear design procedures. Many of the respondents (48%) indicate that this causes loss of information in the interfaces between the various project phases.

Table 2 An example of issues related statements in relation to project planning and coordination

Source of Failures	Issues- related statements
Project Planning and coordination	1. Construction method is well planned by the engineering and consulting firm and/or the contractors 2. Planning process and logistics are sufficiently controlled by the company 3. The contractors anticipate and adjust to actual problems in planning in time 4. There is enough compatibility between the actual work and the plan 5. Construction site is laid out well 6. Estimates of the costs of work undertaken by the contractors are realistic 7. Construction work on site is coordinated between all parties involved

- 100% of the respondent disagree either completely or somewhat with the positively formulated statement that decisions taken by the client are timely. As consulting engineers as many as 69% of them attribute failure to time pressure due to insufficient preparation time provided by the client for the design and construction. This in many cases lead to starting construction before design is fully complete.
- With regard to the issue of constructability, 74% of the respondents think that an important root of the problem of failure costs is related the fact that the contractor does not get involved in the project during the design process. Also 48% of the experts participated in the survey disagree with the statement that designers have sufficient knowledge in matters related to the construction stage.
- Another important attributes to reducing failure costs is good project planning and coordination. 79% of the respondents think that one of the problems in this area is related to insufficient flexibility of the project plan. As many as 63% of the respondents thought that project plan deadlines often needed to be adjusted to accommodate usual delay during design and preparation of the project. Failure to do that often brings projects under time pressure to finish in an unrealistic time that can lead to failures costs.
- In the case of the contractor managers interviewed on the three projects, 63% of them disagreed with the statement that the client requirements of the projects were sufficiently worked out. %54 of them indicated that the architects have insufficient knowledge about the details of construction. They also pointed out in the interviews that very often the contractors do not react and anticipated changes to the work programme speedily and efficiently.

8. CONCLUSIONS

This paper has shown that there are many definitions and interpretations of what failure costs are. Some estimated failure costs to be as high as 30 to 40% of total project cost. In reality however some of these are related to the increase in the estimated costs due to changes in the project scope rather than inefficient work. The exact percentage of failure costs in projects is difficult to assess.

The study has also shown that there are many factors that are attributed to failure costs. Many of the participants in this study have associated the occurrence of failure costs with late decisions, unclear requirements and changes to the scope of the projects by clients. They have also associated failure cost with failure of designers to consider constructability issues during design. Time pressure and inefficient planning by contractors are some of the main factors considered to be the causes of failure costs during construction.

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