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ASSESSMENT ON DEFECTS OCCURENCE AND REWORK COSTS IN HOUSING CONSTRUCTION SECTOR IN SRI LANKA

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Abstract: Defects in building construction are considered to be one of the recurring problems in the construction industry. It has adverse effects on project performance, building performance, and client or end-user satisfaction. The lack of focus on defects leads to negative impacts on cost, duration and resources of projects. Defects may generate controversies among parties involved, not only affecting ongoing construction but also during its operation. Rework cost is another effect of defects, absorbs a significant share ranging from 0.5% to 3.7% of total project costs. This research therefore investigates the most frequent defects and rework cost involved in rectifying the defects in residential buildings in Sri Lanka. A questionnaire survey and subsequent interviews to be carried out together with a detailed analysis of documents will be employed to address research focus. 47 housing projects which exposed to defects were studied. Findings of the study indicates that defects such as bulging of columns, beams and slabs, verticality issues of masonry walls, cracks in plastering and painting, defects in doors and windows are more likely to occur in residential buildings in Sri Lanka. The mean total rework cost as a percentage of the cumulative work done value was found to be 0.92%. For a mean total rework cost of 0.92%, the likelihood that a project exceeds is 37%. Finally, the study proposes strategies such as proper documentation, proper coordination of works and uplift the attitude towards reporting the defects of lower level staff would help practitioners to minimise the defects in building construction in Sri Lanka.

Keywords: Defects, Housing construction, Rework costs, Sri Lanka.

1. Introduction

Building defects and failures are very common phenomena in any kind of construction; either building or civil engineering. Building defects arise through inappropriate or poor design, specification and construction as well as to insufficient attention given to building maintenance. Building defects can be the result of design errors by professionals, a manufacturing flaw, defective materials, improper use or installation of materials, not conforming to the design by the contractor, or any combination of the above [3]. Ransom [17] stresses that the defects in many of the buildings not only due to lack of knowledge but also by non-application and misapplication of knowledge.
On a similar note Ojo and Ijatuyi [14] explains that, defective construction refers to works which fall short of complying with specified descriptions or requirements of a construction contract, especially any drawings or specifications, together with any implied terms and conditions as to its quality, workmanship, durability, aesthetics, performance or design.

1.1 Objectives

With this notion in mind, the objectives of the research are to;

- Identify and differentiate types of defects
- Identify the frequency of occurrence of identified defects
- Analyse the rework cost related to defects

The research identifies most defects occurring elements, frequency of defects pertaining to those elements, probability of rework costs for rectification of defects of residential buildings in the course of construction and defect liability period. For the purposes of this research, rework is defined as 'the unnecessary effort of redoing a process or activity that was incorrectly implemented at the first time'.

2. Definition of defects and different terminologies used in the construction environment

The term 'defect' has been defined differently by researchers. It means the shortcomings in the design and construction practices for some of them, while to others; it implies the inadequacies

that arise from normal wear and tear. Olanrewaju and Idrus [15] indicates that design and construction defects are those that are caused due to wrong methods of construction, poor materials and bad labour practices. "A defect is a shortfall in performance occurring at any time in the life of the product, element or building in which it occurs (BRE Digest 268). It is also a departure from design requirements where these were not themselves at fault" [6, p.49]. However, Table 1 shows that there has been recent increase in research on defects in the house building sector.

Table 1: Definitions of defects in various contexts ([19], p.86)

Context of definition	Definition	Literature Sources
Wider construction environment	Wider construction at any time in the life of the environment.	BRE (1990)
Wider construction	Non-fulfilment of intended usage environment requirements.	Josephson and Hammarlund (1999)
House building environment	Failing or shortcoming in function, performance, statutory or user requirements of a building that manifests itself within the structure, fabric services and other facilities of the building.	Ilozor, et al.(2004)
Wider construction environment	Part of work which is not in accordance with the work's information.	NEC (2005)
House building environment	A final product that does not meet the required quality.	Kim, et al (2007)
House building environment	A component has a shortcoming and no longer fulfils its intended function.	Georgiou (2010)
House building environment	Breach of any mandatory requirement by builder or anyone employed by or acting for the builder.	NHBC (2011)
House building environment	Something that is unfinished, or an imperfection that is inadequate or causes failure.	Beattie (2011)

Another term that is commonly used is rework. Rework may be defined as the process by which an item is made to conform to the original requirement by completion or correction [4]. Alternatively, rework is doing something at least one extra time due to non-conformance to requirements [5]. A broader definition of rework is unnecessary effort of redoing a process or activity that was incorrectly done the first time [11]. However, Hwang, Thomas, Haas, and Caldas [7] emphasis that all these definitions share a common theme which is to redo work due to non-conformance with requirements or the occurrence of a defect.

2.1 Types of defects

Othman, Jaafar, Harun, and Ibrahim. [16] identifies, building defects can be categorized into two which are patent and latent defects. Patent defects are 'obvious' defects while latent defects are hidden and become apparent at a later date. A patent defect could be something that is visually obvious, for example, the omission of mastic seal in the required areas around a shower or bath unit. Patent defects can be identified during construction's inspection and during Defect Liability Period (DLP) contrast to latent defect that will occur after the building is occupied [8].
Such patent defects are often recorded in snagging or defect lists at the time of practical completion. Latent defects may include those defects that, while not obvious at practical completion, become obvious soon after. If defects become patent during the defects rectification period, most standard form construction contracts contain mechanisms for rectifying them.

2.2 Causes of defects

Ahzahar et. al. [3], have identified contributory factors for defects within the Malaysian construction industry as;

- Faulty Design
- Faulty Construction
- Building Type and Change in Use
- Climatic Conditions
- Lack of Supervision

These factors can be the root causes for many different defects in different ways. Following are origins of defects identified as shown in Table 2 and how they may manifest in a building in general. It lists out the common roots for which results ultimately to spread into number of defects.

Table 2: Origins of defects ([18], p.61)

Origins of defects	Examples of defects
Material failure or component failure	Deterioration of finishes such as paint
	Sulphate attack of ordinary Portland cement in walls and floors
	Metal fatigue in fixings
	Spalling of clay brickwork
	Failure of bitumen felt roofing
Workmanship failure	Joint seals
	DPC laps
	Manufacturing faults
	Absence or incorrect use of fixings and restraints
Design failure	Tolerance faults
	Material combinations and aggressive effects
	Difficult weatherproofing details
	Insufficient sizing of structural elements
External agencies	Impact damage from vehicles
	Vandalism
	Arson
Wear and tear	Natural degradation of materials

Besides those technical aspects, Ågren [2] stated, the causes of defects as lack of documentation, standardisation, knowledge and motivation. Communication issues and insufficient resources have also been eminent. Although concepts are usually related to organisational factors, these studies have been carried out on an operational level, for example, the lack of communication between two individuals and a lack of resources for a given construction task.

3. Rework cost and significance of defects in building construction industry

Rework refers to non-achievement of quality standards within the construction industry. Rework as defined by Love and Li [12] as the unnecessary effort of re-doing a process or activity that was incorrectly implemented the first time. The impact of rework on construction organisation is significant. It can adversely affect an individual's, organisation's and project's performance and productivity [10]. Abdul-Rahman [1] agrees that an organisation's reputation and its profit margin can be affected because the cost of redoing a project that is not up to standard is high. The need to reduce costs and at the same time improve quality standards is mutually supportive for any project. If the building process must achieve the principle of doing things right the first time and every time, it should be appreciated that the occurrence of defects has a price.

To perform rational defect prevention, it is necessary to have knowledge about defects, their causes and associated costs [9]. Previous research efforts have revealed that the rework cost could be result as 5 % to as high as 23 % of the contract value ([13]; [9]).

4. Research Methodology

A quantitative approach was used as the main research approach to obtain the frequency of defect

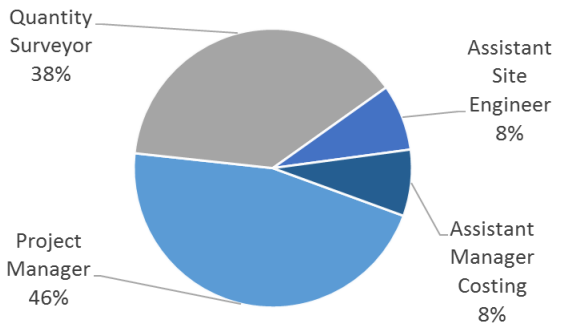

Figure 1: Respondents by profession

occurrence and observe the behaviour of the total rework costs associated with defects. A questionnaire survey along with interviews and document survey was implemented to improve the reliability of the data obtained. The questionnaire had four major focuses: general profile of the project which had defects, types of defects together with their frequency, root causes of the defects and rework costs associated with them. The respondents were asked to consider their experience in projects where they had defects and answer the questions given under the above four areas. In addition, participants were given the list of defects identified in the literature. Where it deviates from the literature findings participants were given the freedom to indicate their own options.

The study sample was selected based on snowball sampling method as there was tendency of the participants were reluctant to furnish some of the confidential information. Respondents included Project Managers, Quantity Surveyors, Assistant Site Engineers and Assistant Manager in costing. The research participants had 5 to 20 years of work experiences in building construction.

For the data analysis, details were obtained from housing projects situated in Western and Southern provinces carried out by different contractors.

Data were collected from construction firms which have C3 to C7 grading and registered with Construction Industry Development Authority (CIDA) in Sri Lanka. Figure 1 provides a breakdown of the respondents based on their professions: projects managers (46%), quantity surveyors (38%), assistant site engineer (8%) and assistant manager costing (8%). Response rate of the data collection is 100% as each and every data collection was personally attended. During the data collection, a detailed questionnaire along with a semi-structured interview was carried out to improve the reliability of the data.

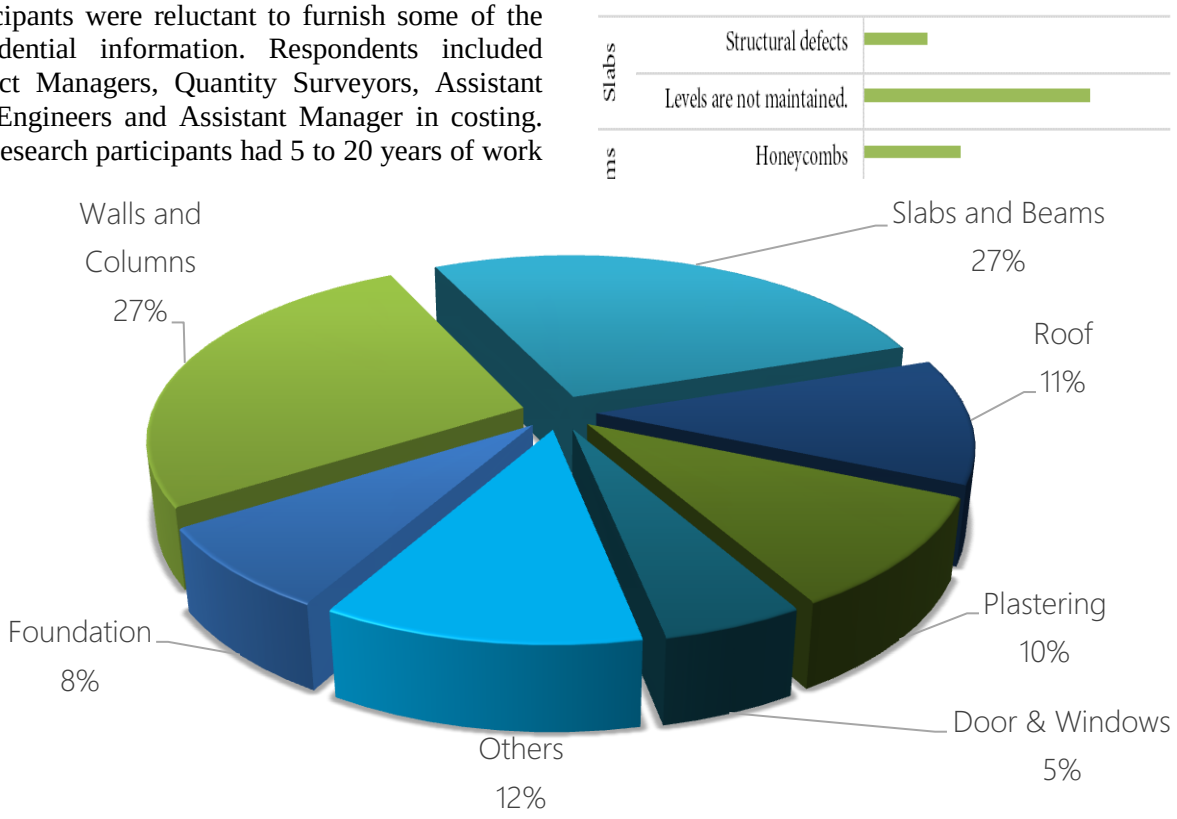

Figure 2: Frequency of occurrence of defects pertaining to elements

4.1 Data analysis procedure

Quantitative data collected from the questionnaire and document survey where required were encoded using the Statistical Package for the Social Science (SPSS) v.20 and results were analysed using both descriptive and inferential statistics. Additionally, EasyFit Professional 5.6 were used to analyse the probability of distribution of rework costs.

5. Research findings and discussion

Defects and Contribution factors for defects

The questionnaire asked participants to provide details on a current project or any past projects where defects have occurred during the course of construction and the defect liability period. Likert scale 5-part type questions (1-Less occurred, 5-Mostly occurred) were asked on each defects listed out in the questionnaire which was identified through literature survey and preliminary survey. According to the data collected, defects were identified under following elements. Figure 2 depicts the frequencies of defects occurrence pertaining to a particular element group. Most of the defects occurred in the elements of slabs, beams and columns as an account of 54% of total defects. Where others category has been introduced by including the elements in which the frequencies reported below 5%. Others category can be elaborated as follows;

- Painting defects 4%
- Plumbing defects 4%
- Floor finishes defects 3%
- Waterproofing defects 1%

Nature of the defects occurred in the concrete works are shown in the Figure 3. Most of the defects such as alignment issues and bulging of columns, beams and slabs are due to inadequate formwork supplied and lack of supervision of the responsible parties. In general practise honeycombs are not recognised as defects unless otherwise it will create a structural issue. Deep honeycombs are considered as defects in the industry practitioners and generally they are rectified with specialized sub-contractors.

Roof defects which is of 11% are due to the leakage of the ridge and the fading of paint of the valance boards and other components. All of the roof defects pertaining to water leakages have been reported during the defects liability period.

Cracks formation of the plaster due to chemical reactions of substances and inadequate curing is the third most occurring defect in the residential buildings pertaining 10% of the whole. Sometimes these cracks have emerged after the painting was done, so therefore it affects the painting as well. Foundation defects have been identified during the construction and they account to design defects most of the time and only at one scenario has been reported due to bad workmanship under the study.

Door and windows defects are reported due to unmatching of sizes due to carpenter's erroneous production and usage of not properly seasoned timber.

Table 3: Descriptive statistics of total rework costs

Statistic	Value	Percentile	Value
Sample Size	47	Min	0.049
Range	3.646	5%	0.0956
Mean	0.91791	10%	0.122
Variance	0.73983	25% (Q1)	0.214
Std. Deviation	0.86013	50% (Median)	0.583
Coeff. of Variation	0.93705	75% (Q3)	1.292
Std. Error	0.12546	90%	2.2286
Skewness	1.3163	95%	2.7658
Excess Kurtosis	1.3442	Max	3.695

Figure 3: Types of defects occurred in the concrete works

Defects in floor finishes accounting to 5% are occurred due to poor workmanship and the chipping of the tiles and terrazzo due to careless handling of equipment and poor organizing of work sequence.

Rework costs

Table 3 presents the descriptive statistics for the total rework costs used in determining the probability of rework in the sampled project. The mean total rework cost as a percentage of the original contract sum was revealed to be 0.91% and the standard deviation was 0.86%. The data indicate that the total rework costs ranged from 0.05% to 3.7%. Evidently, the total costs of rework vary considerably among projects. Love [10] argued that the degree of variability in the estimates specified by the respondents suggests that many respondents may be unsure about the actual costs of rework incurred in the projects.

The following steps were adopted to determine the probability of rework. First, the probability density functions (PDFs) were developed using EasyFit Professional 5.6 software. The PDF is a mathematical expression that analyses a continuous random variable and defines the shape of the distribution. The 'best fit' probability distribution was examined using Kolmogorov-Smirnov and Anderson-Darling goodness-of-fit tests.

- Kolmogorov-Smirnov statistic (D): Based on the largest vertical difference between the theoretical and empirical CDF (Cumulative Distribution Function)

- Anderson-Darling statistic (A^2): A general test to compare the fit of an observed CDF to an expected CDF. The test provides more weight to a distributions tails than the Kolmogorov-Smirnov test.

As observed from Table 4, the results of the goodness-of- fit tests revealed that generalised Exponential distribution provided the best fit for the dataset for total rework costs. The histogram presented in Figure 4, depicts probability distribution function for rework costs based upon the distribution parameters. For instance, Figure 4 shows that likelihood that a project will exceed a mean total rework cost of 0.92% is 37%.

Table 4: Goodness-of-fit details for total rework costs

Kolmogorov-Smirnov					
Sample Size	47				
Statistic	0.072				
P-Value	0.953				
Rank	3				
α	0.2	0.1	0.05	0.02	0.01
Critical Value	0.153	0.175	0.194	0.217	0.233
Reject?	No	No	No	No	No
Anderson-Darling					
Sample Size	47				
Statistic	0.356				
Rank	1				
α	0.2	0.1	0.05	0.02	0.01
Critical Value	1.380	1.929	2.502	3.289	3.907
Reject?	No	No	No	No	No

6. Conclusions

The research presented the types of defects and its frequency of occurrence during the course of construction and throughout the defect liability period. Required data from 47 housing projects were obtained through questionnaire survey along with interviews and document survey.

Research has uncovered most occurring defects types during construction and throughout the defect liability period. Considering the findings presented in this research, approximately 54% of the defects have been recorded in the concrete works during the structure construction. Most of the roof defects are due to water leakages and they were only reported within the defect liability period. As an overview, contribution factors for defects have been identified as lack of supervision, unfavourable working conditions, design errors, poor coordination of works, construction materials and poor workmanship. However, it was revealed that there was a lacking procedure in documentation and proper management of defects of most of the sites from the interviews conducted. As identified in the research, organizational practices have more influence on this aspect, as being some have established quality objectives to control defects and some have not had much consideration on defects.

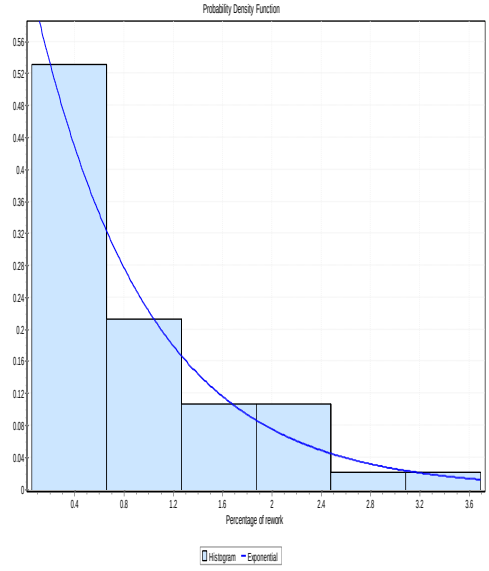

Figure 4: An exponential histogram of rework

The analysis of rework costs revealed that, the total rework costs as a percentage of the total work done value varies from 0.5% to 3.7%. During the statistical analysis, using Kolmogorov-Smirnov statistic and Anderson-Darling statistic, it has been observed the distribution of rework costs follows general Exponential distribution. The mean total rework cost as a percentage of the cumulative work done value was found to be 0.92%. For a mean total rework cost of 0.92%, the likelihood that a project exceeds is 37%.

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