rework is accepted as an inevitable part of the construction process. This study benchmarks the cost of rework in Australian house construction based on a database on building defects supplied by a government insurance organization and interviews with construction contractors. The results show that type of construction, size of the contacting organization and the use of quality assurance systems effect the cost of rework.

Key words: Rework, Housing construction, Continuous improvement; Benchmark metric.

Introduction

Rework, defined as the unnecessary effort of redoing a process or activity', and is often overlooked by the practitioners in the construction industry. Rework is one of the main features of the construction industry and is caused by many factors.

There is an urgent need for the clients and practitioners in the industry to consider this cost, and to improve the quality of the end product. This is likely to benefit everyone, including; contractors, clients and end-users. It may even assist new home owners by making more affordable. Given the lack or awareness of the rework problem, the identification of rework root causes will help the construction industry better appreciate its significance. Consequently, the aim of this research was to understand the causes of rework in residential construction, and benchmark the cost for various project types, and by the different organizations that construct the homes.

The next section of the research defines the nature of rework in construction and presents the results of other research into its impact on the industry. Also, if is well known that manufacturing has substantially reduced its rework in recent decades as a result, the nature of quality management practices in the construction industry are discussed.

Cost of Rework

Rework results in significant cost to the construction industry which burdens owners, contractors and administrators. However, rework is not necessarily just the cost of rebuilding, for example, in the case of a poorly designed fireplace, there are many other "hidden" costs that are not always considered, such as the cost of consultants to assess the situation, extra time required in thinking of a new solution, disruption to other work tasks and the negative effects on staff the morale of having to redo a job.

Love and Edwards, (2005) describe total rework as the summation of both direct and indirect costs. They investigated the total rework costs in various Australian construction projects and found that the mean direct and indirect cost of rework as a percentage of the total contract were 6.4% and 5.9% respectively. This is a significant amount for the stakeholders to bear, totaling 12.3%. An earlier study by (Love, Mandal and Li 1998) recorded a similar amount, in which rework costs were around 12.4%. Supporting this, a study by (Burati, Farringtn and Ledbetter 1992) analyzed the cost of defects in construction projects and found the cost to be 12.4% of the total project cost.

Quality Management in Construction

From most accounts quality assurance (QA) seems to have been a failure in the construction industry. "The quality assurance 'revolution' unleashed in the construction industry since the early 1990's is not delivering the promised efficiencies and has in many instances degenerated into a paper based formality." (Jaafari 1996) Another view on the process was that "QA is typically viewed as no more than an administrative based burden." (Love et al., 1998)

It was found that paper based QA systems containing elaborate administrative procedures began to emerge quickly in the construction industry with the general feeling being that bureaucratic compliance was the only point of quality assurance practices in construction. (Jaafari, 1996). As a result companies became skeptical, did not realize the benefits of becoming quality focused and sub standard products and services emerged, resulting in rework. (Love et al., 1998) Total quality management is a complete rethink on the issue of quality, however unfortunately the construction industry seemingly approaches it with skepticism due to the negative impacts of the QA approach.

The "present quality revolution has been fuelled by increased global competition" (Love et al., 1998), however this phenomenon seems to have passed the construction industry by. Deming was one of the leading figures in the development of Total Quality Management (TQM) for Japan in the 1950's. TQM is different to regulatory and paper based QA systems as it is a quality philosophy across the organization lead by top management and placing an emphasis on achieving "continuous improvements." (Jaafari, 1996) "Deming stressed that 85% of the problems encountered in manufacturing are with the process and that statistics can be used to control that process" he also stated that "quality cannot be inspected into the project" (Burati et al., 1992)

The TQM effort is companywide and "involves everyone in an organization to improve performance. It permeates every aspect of a company and makes quality a primary strategic objective." (Burati et al., 1992) The "application of TQM on construction projects has two distinct purposes: (i) to satisfy the customer's requirements through a quality assurance (QA) system; and (ii) to achieve continuous improvements (CI)" (Jaafari, 1996)

However, it is stated that similar to QA systems, "total quality management principles have not been implemented effectively in the construction industry. As a result, rework has become an inevitable feature of the construction process" (Love et al., 1998) It is possible, that due to the failure of QA systems to alleviate rework in construction, TQM has been dismissed as just another buzz word. This is unfortunate as over the years, it has had such a large positive affect on the manufacturing industry.

The building industry must stop considering quality assurance as a paper based formality and realize that continuous improvement achieves substantial efficiencies, making a company more competitive, generating benefits to counter the expenditure involved in setting up and running the respective systems. (Jaafari, 1996)

Challenges for the Construction Industry

There are many challenges to the construction industry in terms of rework going forward. Recognizing all rework as detrimental and recording its occurrence is vital to understanding the overall extent of rework. It is stated that many rework incidents are not made formal especially those less than $500 (Love et al., 1998), where the contractor rectifies a problem on the spot instead of involving themselves in excessive paperwork.

Additionally, in terms of training, in the rush to push "quality" along and secure certification, the workforce and their training needs have largely been neglected. (Jaafari, 1996) This is most likely due to the extra time required in generating extensive and some may say "useless paperwork" to comply with regulations and government policies. Companies who go on to implement TQM have considerably "more training efforts than the non-TQM companies." (Burati et al., 1991) However, hopefully over time the investment will pay off in terms of productivity gains.

It is stated that construction, as an industry is different from manufacturing and therefore QA and TQM systems are more difficult to implement due to a number of reasons. These reasons include (Jaafari, 1996):

- the fragmented structure of the industry with the bulk of the construction business being generated by a large number of firms, often small in size and therefore less likely to implement formal quality management processes
- the diffusion of responsibilities across sites and across professions including architects, engineers, consultants, builders and the owner

- projects resembling "prototype" products in the manufacturing industry, often carrying unique design features
- a transient and roving labor force, not trained in QA construction
- the lack of research and development (especially onsite), confined to that undertaken by manufacturers and suppliers

Research Question

The results of past research showed that the cost of rework is very significant. (Cida 1995). Previous research shows that the direct cost can be 6.4% of the building contract value (Love and Edwards 2005). This includes only the direct cost of rectifying the defect and does not include other indirect costs like the cost of redesign.

It has been stated that rework is caused by avoidable faults, errors and omissions occurring at a number of stages throughout the project; during design, construction, the defects liability period or at some stage during the builder's guarantee that require the contractor to make alterations or fix an unforeseen problem at a later date. This can incur significant costs on the owner and the contractor. The magnitude and sources of were examined in the next section of this research.

Based on secondary data provided by the Housing Guarantee Fund (HGF) the aims of this research were to:

- Examine the impact of defects in residential building and ascertain the relative cost and incidence of rework in the Victorian residential construction industry
- Identify incidence and cost of rework by various groups within the industry, including owner builders and general builders.
- Identify the impact of rework on various types of constructions; including new work, renovations and extensions.

The essential question in this research is to investigate extent and impact of rework in residential construction. The following section discusses the research methods that that was used to answer the above research questions.

Methodology

The main data used in this research was information provided by a Victorian Government insurance organization. The role of the Housing Guarantee Fund (HGF) was to provide insurance to owners on newly construct homes and renovations and extensions. Permission was granted by the HGF to interrogate their database which contained records on over 800,000 properties. This was not a sample instead it represented all new houses constructed in Victoria between 1982 and 1997. However, not all homes reported faults so a smaller number (110,000) made claims to the HGF for defective work.

The results in this report are based on a subset of approximately 32,000 records that were extracted from the HGF database. Although the full database contained 110,000 claims; 78,000 records did not contain any information on the defect itself. As a result the records analyzed were only those that contained some information about the nature of the defect.

Preliminary checks of the HGF database were undertaken to determine if missing data seemed to occur on a random basis, or whether consistent patterns occurred that might affect the results. There are a number of procedures for handling missing data. If only a few responses have missing data and they seem to be a random sub-sample of the whole sample, deleting the response is a useful procedure. But if missing values occur extensively throughout the sample, deletion of several cases can mean a substantial loss of information. Another option is to estimate missing values and then use the estimates during data analysis. There are three popular methods for doing so; using prior knowledge, inserting mean values and using regression (Tabachnick and Fidell 1996).In the absence of all other information, the mean is the best guess about the value of a variable. Part of the attraction of this procedure is that it is conservative; the mean for the distribution as a whole does not change and the researcher is not required to guess at missing values.

In this case, the amount of missing data was very large (approximately 78,000 records) and so a subset of 32,000 records was chosen. Random checks were undertaken to ensure that the data was reliable. Every effort was taken to ensure that the conclusions drawn are valid so that the results reported are representative of the industry as a whole.

The data was analyzed using the statistical software package SPSS. Information on the type and nature of defects were identified and their associated frequencies and dollar values were tabulated. This allowed the most common and costly defects to be readily identified.

The HGF data set contained three main columns related to the cost of the defect. 'Claim Value' which was the amount paid to the plaintiff once a defect had been recognized, 'Associated Costs' which were costs related to initial investigation, research and assessment before the defect had been formally recognized and finally 'Total Cost' which was the sum of these two components.

Once the data had been checked, the SPSS analysis was performed. It was decided that in order to answer the research question, the incidence of each defect would be tabulated and all costs, including Total Claim would be analysed. This was chosen because it represents the cost paid for the rectification of the defect, plus the administrative cost of investigating and handling the claim.

In addition to the data analysis a number of informal discussions were conducted with HGF staff in order to understand how the process was managed. This became a valuable opportunity because it allowed the researchers to identify the areas where the significant defects occurred. As a result of these discussions the defects associated with footings and water ingress were examined in detail.

Results

The results were split into a number of areas to allow easier interpretation. Firstly, a count of particular defect types in the result set was prepared, following which total costs were expressed in terms of average value. This gave an indication of the most costly individual defects.

The claim value tables indicate the amount claimed and paid to the plaintiff (where a payment was made), the associated cost tables indicate the "other" or "indirect" costs associated with investigating the claim, such as the use of specialists, consultants, extra labor and loss of time. Finally these figures were aggregated into Total Claim Paid tables to give an overall figure.

Cost of Rework in Residential Construction

Past research has suggested that rework is a very significant problem in the construction industry. Some research suggestion that direct cost can be as high as 6.4% of the contract value. The results of this research show (Table 1) that the on average defect accounts for about 4% of the contract price but houses where defects were reported. This included both the direct cost of rectification and the associated cost borne by the HGF to examine the claim. The total cost of rework associated with defects accounted for an average of $4,245 for each dwelling where a claim occurred. This comprised the value of the approved claim plus associated costs.

The results (table 1) shows that during the first three years the start up claims exceed the average value of the projects; however this quickly rectified itself after 1985. This was due to some external residual liabilities that were initially covered in the scheme. It was also worth noting that from the beginning on 1997 the Victorian government ceased the operation of the HGF. However, a run off period allowed claims to be made until 1999, even though no new insurances contracts were issued during this period.
It is likely that the actual cost is rework is higher than amounts recorded in HGF data. This is because the direct cost of rework is only calculated on properties where the

builder could not be recalled to fix it at their own expense. For instance, defects to properties for owner builders and building companies that have gone out of business. Nevertheless, the results were based on 10,548 properties where the builder could not be recalled, and it has been assumed that the sample is sufficiently large to be representative of the housing industry as a whole.

Table 1 : Average Value of Total Claim Costs by Year

Year Approved	Count	Contract Value (Average)	Total Claim Paid (Average)#	Rework Average %
1982	203	$570	$2,484	435.7%
1983	100	$461	$2,782	604.1%
1984	53	$1,844	$2,581	140.0%
1985	119	$30,851	$2,639	8.6%
1986	228	$48,875	$2,845	5.8%
1987	350	$46,528	$2,572	5.5%
1988	421	$52,068	$2,658	5.1%
1989	574	$64,130	$3,555	5.5%
1990	931	$85,593	$5,836	6.8%
1991	1190	$111,092	$4,129	3.7%
1992	1096	$124,494	$3,744	3.0%
1993	958	$124,821	$3,820	3.1%
1994	921	$134,550	$4,243	3.2%
1995	1219	$117,271	$4,236	3.6%
1996	1367	$127,033	$3,910	3.1%
1997	625	$122,083	$6,410	5.3%
1998	136	$108,919	$11,951	11.0%
1999	57	$105,366	$11,830	11.2%
Group Total/Average	10548	$104,055	$4,245	4.1%

Total costs included Claim Value and Associated Costs

Type of Rework

The results of interviews with HGF staff suggested that defects in footings and water ingress were major sources of rework cost. However, most dwellings with defects had more than one problem and it was not possible to distinguish the cost of rectification for each defect separately. As a result the HGF database was sorted to include properties where only a single defect code was recorded.

Table 2 : Total cost of footing defects*

		Total Claim Value	
		Count	Mean
Defect Code	No Footing Code	11109	$967.91
a	Footing Heave	213	$3,692.43
d	Footing Subsidence	129	$5,256.87
f	Trees	127	$3,424.05
B	Site Drainage	57	$2,158.56
E	Footing Design	17	$7,793.04
Group Total/Mean		11652	$1,107.75

* Single Codes Only

The results show that there were 11,652 dwellings with a single code; the average cost of single defects was $1,107 (Table 2). The cost of footing defects varied between $2,158 for Site Drainage and $7,793 for Footing Design.

The results show (Table 3) that T- Pier and Beam footings ($1,549) and UV-Strip Footing & slab ($1,541) had the highest average defect costs. However, there were relatively few of them, and the highest incidences of footing defects occur in the more common construction method like V-Slab and U-Strip Footings. As expected this suggests that when more robust designs like in pier and beam construction fail; the cost of rectification is higher.

Table 3 : Total cost of footing defects by construction type*

		Total Claim Value	
		Count	Mean
House/Job Code		1032	$1,922
Description	UV - Strip Footing & Slab	60	$1,541
	TV - Pier & Beam/Slab	75	$879
	UT - Strip Footing/Pier & Beam	200	$842
	T- Pier & Beam	245	$1,549
	U- Strip Footing	4801	$1,104
	V- Slab	5239	$938
Group Total/Mean		11652	$1,108

* Single Codes Only

The next area identified by the HGF staff as being important was water ingress. The results of the analysis showed that the average cost of water ingress defects varied between $374 for Water Hammer to $1754 for Leaking Windows (Table 4). The results of the this research support the previous work by (Georgiou, Love and Smith 1999) who suggested that the most expensive rework occurred in areas of window sill gaps, cracking, water hammer, and dampness.

Table 4 : Total cost of water ingress defects*

		Total Claim Costs	
		Count	Mean
Defect Code for Water Ingress	No Water Ingress Code	7056	$1,209.40
	2 - Leaking Roof	1185	$774.56
	4 - Leaking Shower Base	910	$864.22
	6 - Ext. Water Penetration	752	$1,343.83
	3 - Plumbing	473	$753.29
	5 - Leaking Shower Cubicle	426	$963.13
	7 - Drainage	246	$1,048.61
	0 - Leaking Windows	239	$1,754.82
	1 - Leaking Spouting	222	$501.77
	8 - Flashings	92	$920.69
	9 - Water Hammer	51	$374.02
Group Total/Mean		11652	$1,107.75

* Single Codes Only

The next section of the research looks at impact of construction type. It should be noted that Extension and Renovations were not covered by the HGF prior to 1988. As a result the database was resorted and only records after that date were included in the analysis. The results show (Table 5) that Extensions and Renovations appear to have higher rework costs. This type of construction is more complicated than the construction of new housing and it is therefore not surprising to see high defect costs.

Table 5 : Total Cost of All Defects (Multiple Codes)

	Total Claim Costs	
	Count	Mean
	83	$4,689
A- New residence	7749	$4,340
B- Extension existing dwelling	808	$6,264
C- Renovation of existing dwelling	119	$5,566
D- Site works involved in relocating an existing residence	4	$2,913
E- Attached garage, carport, pergola, veranda or patio	49	$2,245
F- Door/window replacement	2	$3,277
H- Brick-veneering works or chimney	1	$5,700
I- External cladding	23	$2,454
J- Improvements to sub-floor	112	$5,730
K- Improvements to the roof	13	$1,811
L- Improvement to kitchen or bathroom	87	$2,501
O- Completion of dwelling-house	19	$2,207
R- Rectification of dwelling after a claim paid	5	$2,301
Group Total/Mean	9074	$4,504

Past research also suggested that in many cases it may be important to analyse not only the cost of defects but their incidence. The research undertook preliminary analysis of the number of defects that occurred in each class. Unfortunately due to the cumbersome manner in which the HGF database was designed it became very difficult to draw any firm conclusions.

The HGF database was sorted into defects that contained only one defect code; there were 11,652 records included in the analysis. The results showed that Leaking Roofs have the highest incidence comprising 10.1% of the sample. However, approximately 20,000 records were excluded from the analysis and it is already known that the Leaking Roof defect coded occurs in a further 31 other code combinations. As a result it is not clear if theses other multiple code combinations impact on the outcome. As a result this line of research was not taken any further. Instead the next section of the research compared the defects that occurred by type of building organization.

Type of Building Organization

The HGF also had a responsibility to register the building organization that was licensed to undertake the construction work. After 1988 the HGF kept records three classes of builder in their database. They were:

The largest group of builders was General Builders who had an unrestricted license to construct as many dwellings as they wanted. This included a full spectrum of firms from small contractors who constructed only a few houses each year, to Volume Home Builders who constructed thousand of new homes annually.

Owner builders who were limited to a few construction projects per year. The limits were placed on those organizations because of the view that these individuals did not possess the qualifications and experience to undertake a large number of projects at once.

Restricted Builders were those organizations who were under some form of sanction by the HGF. In most cases these were firms that had high numbers of claims made against them in the past. They were restricted for a period of time until they could prove that their defects record improved. If those builders exceed their quota they were subject to severe penalties.

The research results show (Table 7) that the average total cost for defects (after 1988) were $4,504. This comprised; $4,706 for General Builders, $3,672 for Owner Builders and $4126 for Restricted Builders. It was not surprising to find the Restricted Builders had the highest claims made against them because they were the groups with the worst track record. However, it is somewhat surprising that Owner Builders appear to have lower value claim than General Builders.

Table 7 : Total cost of defects by builder classification*

Total Claim Costs		Count	Mean
Builder Classification	General Builder	8078	$4,587
	Owner Builder	735	$3,672
	Restricted Builder*	178	$4,126
Group Total/Average		9074	$4,504

* Restricted Builders were those under some form of sanction by the HGF

It should be mentioned that faults that occurred in Owner built homes were the responsibility of the owner to fix. It is likely that much of the rework that occurred immediately after the end of construction was remedied by the owner and therefore not captured by the HGF database. However, the owner of the house could sell off the property during the period of the insurance. Under those circumstances, the HGF legislation require owners to commission an inspection report if they wished to sell their own home within seven years of the Certificate of Occupancy.

These raises a number of other potential issues arise from the owner commissioned reports. The guarantee issued by the HGF only covered defects that were identified in the report. If an item was missed or overlooked it would not be covered under the policy and therefore did not become the responsibility of the HGF. It is possible that many claims were rejected due to incomplete reports undertaken by owner builders intending to sell their own property. It is therefore possible that the amount of defects in Owner built homes is much higher than what was recorded in the data.

The next stage of the research further analyzed the category of General Builder by the number of projects that they undertook. The results of High Volume Builder-Top 20 are significantly better that all other classes of builder. These firms constructed at least hundreds and in some cases thousands for homes each year. These firms are likely to have relatively sophisticated quality management systems compared to smaller contractors. This research shows (Table 8) that houses built by Volume Home builders have fewer defects and are of higher quality

Table 8 : Total cost of defects by builder classification*

			Count	Mean
Builder Volume	High Volume Builder-Top 20	Total Claim Costs	437	$2,344
	General Volume Builder	Total Claim Costs	7643	$4,706
	Restricted Volume Builder*	Total Claim Costs	179	$4,439
	Owner Volume Builder		735	$3,672
Group Total/Mean			8994	$4,502

* Restricted Builders were those under some form of sanction by the HGF

This research has identified a number of significant issues that impact on the extent and impact of rework in residential construction. The next section of the paper discusses the many threads that have been examined throughout the research.

Conclusion

This research shows that the total cost of rework in housing built between 1983 and 1997 was $4,245 for owners that reported defects. This represented 4% of the contract value of the new dwelling or renovation. Considering the annual turnover of Victorian residential construction industry was $60.4 billion in 2005/2006, and if rework cost was multiplied by the total number of house produced in Victoria the cost to industry and end user is in the hundreds of millions of dollars per annum..

Past researchers have lamented that construction quality has not changed significantly in recent decades. Instead, rework has become an "accepted part of the construction process" (Love et al., 1998), which is unfortunate given that there is the potential for rework to be avoided. However, the amount of direct rework found in this study of housing appears to be lower than research in construction. This research shows that less than 4% of the contract value of dwellings reported defects resulted in defects; a somewhat positive finding.

The most frequent defect was Leaking Roofs, albeit based on a limited sample from the HGF database. The most expensive water ingress claims occurred in the Leaking Windows and External Water Penetration categories. In addition, it was not surprising to find that value of defects on New Houses were less than Renovations and Extensions.

Past research by the same authors (Georgiou, Love and Smith 1999) suggested that no significant difference between the quality of housing constructed by owner builders and registered builders. The results of this study seems confirm that finding; Owner Builders appear to be no worse than registered General Builders based on the HGF database. This would suggest that owner builders produce satisfactory quality house construction and that increasing regulations was not likely to improve overall quality.

Past research highlighted that the industry is still fragmented and may not have improved much in the last 30 years (Georgiou, Smith and Love 2003). Poor quality construction has plagued the industry for a long time due mainly to the fact that builders and sub-contractors do not seem to be able to improve service and quality to the end user. However, the houses constructed by the Top 20 firms appear to be significantly better than those constructed by other builders. Past research has suggested that these firms are better organized, and have a more professional approach to quality management

Past research suggested that many housing defects were the result of supervisors not inspecting work on completion and before payment was made to subcontractors. It may be difficult for small volume builders to force subcontractors to return and carry our rectification before the house is handed over. However, this research seems to suggest that this is not the case for large contractors who may be described as volume home builders and will more likely have sophisticated quality management processes.

In conclusion, rework is a significant contributor to unnecessary cost in the Victorian residential construction industry. As discussed, the Quality Assurance industry stereotype must be overcome to allow a focus on the benefits of Total Quality Management. It is hoped that the identification of causes will lead to minimize negative rework impacts and result in productivity gains.

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