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TYPES, CAUSES, AND EFFECTS OF DEFECTIVE CONSTRUCTION WORKS

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Reviews of performance after construction completion is an important task for enhancing the sustainability of engineering solutions for social needs. This research reviewed and investigated defects in some construction projects of a university. The article analyzed types, causes, and effects of defects in terms of both time and cost dimensions. It collected data through the investigation of how completion certificates and contract documents are issued. It also gathered information on the causes of defects by interviewing project supervisors and those involved projects. The result showed that the majority of defects were in the architectural work, accounting for 57.1% of the total. The chance of having defects depends on the type of project. The main causes were foremen, workers, and working procedures. In the defective projects, defects caused delay in obtaining payment, averaging approximately 26 days. Defects also caused cost increases, averaging 3.3% of the initial contract value. These findings are vital for the construction department of the university to continuously improve and find more sustainable solutions in monitoring and supervising construction projects, so that fewer defects occur.

Keywords: Continues Improvement, Defect, Delay, Risk, Sustainable Solution.

1 INTRODUCTION

Defects in construction work not only damage contractors' reputations, but also impose impacts on time and cost performance. Reviews of the performance in defects after construction completion is an important task for enhancing the sustainability of engineering solutions to meet project owners' needs. This research investigated the types, causes, and effects of defective construction work to provide insightful feedback for continuous improvement to project owners, consultants, and contractors.

2 PREVIOUS RESEARCH

Defects in construction projects can be classified into various categories, such as structure, architecture, safety, environment, etc. (Cheng and Leu 2011). A defect can occur from multiple causes. Some research attempted to identify numerous pathways to detect defects, such as Akinci *et al*. (2006) and Aljassmi and Han (2013). Defects can also occur on post-handover periods (Forcada *et al*. 2012).

Because the performance of a construction project depends on the surrounding contexts, a similar design or type of project in different places can result in different

performances of defects. Identification and quantification of the degree of defects in the residential sector in Klang Valley, Malaysia, and Victoria, Australia, contain some differences (Mills *et al*. 2009, Abdul-Rahman *et al*. 2014). This research analyzed defects based on the context of construction works within an academic institute to seek out their specific types, causes, and effects that could be informative to the involving parties at the institute.

3 METHODOLOGY

3.1 Data Samples

This research gathered defect data of procurement works that were constructed at a university from 2010 to 2012. The procurement works consisted of four types of contract, including construction of new buildings, renovation of existing buildings, construction of campus utilities and infrastructure, and landscaping work. For the purposes of this paper, the surveyed defects were defined as those detected by the procurement committee at the time of site inspection for approving the final payment request. During the specified period, 110 completed procurement contracts were examined; of them, 31 contracts reported defects. In total, 333 examples of defects were found in the 31 completed contracts.

3.2 Data Collection Tools

In each procurement work, five categories of data were collected. The first was general information, including project name, contract identification number, budgetary year, payment schedule, contractor's name, site supervisor's name. The second was the record of quantity and causes of defects. The third was related to types of work and defects, including the description of the work, nature of the work, and characteristics of defects. The fourth was related to the effects of the defects on construction time, including contract duration, final completion date, duration of inspection for approving final payment, duration of correcting defects, duration of inspection for approving corrected defects, duration of final payment process, and remittance date of final payment. The fifth was related to effects of defects on construction cost, including contract sum, related information in BOQ (Bill of Quantity), and the amount of liquidated damages.

To obtain the above five categories of data, two data-collection tools were used. First, the data-collection form was particularly designed according to the five categories. It was filled in after readings formal documents, including contract documents, formal site inspection reports for final payment approval, corrected defects reports, and requests of final payment remittance. Most of data used in this research was obtained by the first tool. Wherever data was not available in formal documents was filled in through the second survey tool: interviews with site supervisors. Causes of defects were mainly obtained from interviews because they were hardly recorded in any formal documents.

4 ANALYSIS

4.1 Types of Defects

From 2010 to 2012, 110 procurement contracts were completed; 31 contracts reported defects. In these contracts, 333 items of defects were recorded, classified into 5 groups as follows:

- Defects in structural work: 11 (3.3%)
- Defects in architectural work: 190 (57.1%)
- Defects in electrical and mechanical work: 47 (14.1%)
- Defects in sanitary work: 37 (11.1%)
- Defects in landscaping work: 48 (14.4%)

The data revealed that defects occurred mostly in architectural work (see Table 1):

Table 1. Top-three defects in each type.

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Rank	Description of Defective Work	Number of Occurrence	%
Defects in structural work			
1	Welding of steel structure	4	36.4
2	Connection joint in reinforced-concrete structure	2	18.2
3	Crack in structure	2	18.2
Defects in architectural work			
1	Doors and windows	39	20.5
2	Painting	22	11.6
3	Wall plastering	21	11.0
Defects in electrical and mechanical work			
1	Air-conditioning	9	19.1
2	Lighting appliances	9	19.1
3	Installation of electrical conduits	5	10.6
Defects in sanitary work			
1	Cover sheet of drainage system	11	29.7
2	Installation of pipes	10	27.0
3	Drainage structure	7	18.9
Defects in landscaping work			
1	Pedestrian block	11	22.9
2	Cleaning	10	20.8
3	Waste clearance after work	7	14.6

More insights were found when the defects were considered in different types of contracts. The 31 contracts were classified into 4 groups as follows:

- Construction of new buildings: 5 contracts (16.1%) with the average contract sum of 41.9 million Baht.
- Renovation of existing buildings: 17 contracts (54.8%) with the average contract sum of 1.8 million Baht.
- Construction of campus utilities and infrastructure: 5 contracts (16.1%) with the average contract sum of 2.9 million Baht, and
- Landscaping works: 4 contracts (13.0%) with the average contract sum of 0.8 million Baht.

In sum, for the construction of new buildings and the renovation of existing buildings, the majority of defects were architecturally-related. The reasons why these were common for these types of contract could be that the owner's representatives had no construction background, and defects of architectural work could be visually detected. For the construction of campus utilities and infrastructure and the landscaping work, the majority of defects were landscaping-related work. The reasons why the landscaping-related defect was common for these types of contract could be that the works were under weather conditions that might affect either the quality of work during construction, or the appearance of the finished work while waiting for the final completion certificate. Why structurally-related defects were rarely detected could be because the complexity of academic building structures was not so high that the quality of work could be satisfactory achieved; or else the structures were covered by finishing work, and their defects could not be detected visually. This data is useful for both owners' representatives and contractors to focus their attention on reducing defects.

Table 2. Causes of defects in each type of defects.

No	Description		Total	Causes					
				Worker	Supervisor	Material	Working Procedure	Tools & Equipment	Coordination
1	Defects in structural work		11	11	11	1	10	0	0
		%	*100*	*100.0*	*100.0*	*9.1*	*90.9*	*0.0*	*0.0*
2	Defects in architectural work		190	165	182	19	117	2	22
		%	*100*	*86.8*	*95.8*	*10.0*	*61.6*	*1.0*	*11.6*
3	Defects in electrical & mechanical work		47	36	44	10	25	1	6
		%	*100*	*76.6*	*93.6*	*21.3*	*53.2*	*2.1*	*12.8*
4	Defects in sanitary work		37	29	36	3	23	0	4
		%	*100*	*78.4*	*97.3*	*8.1*	*62.2*	*0.0*	*10.8*
5	Defects in landscaping work		48	31	45	4	23	1	17
		%	*100*	*64.6*	*93.8*	*8.3*	*47.9*	*2.1*	*35.4*
	Total		333	272	318	37	198	4	49
		%	*100*	*81.7*	*95.5*	*11.1*	*59.4*	*1.2*	*14.7*

4.2 Causes of Defects

Table 2 illustrates the causes of defects in each type. Potential causes of defects included workers, supervisors, materials, working procedures, tools and equipment, and coordination. It should be noted that a defect can occur due to several causes simultaneously. The analysis revealed that the perceived top-three causes of defects were engineers' and foremen's poor supervision, workers' insufficient skills, and improper working procedures, respectively. It was interesting that the priority of causes did not change even if the types of defects and types of contract were taken into consideration.

However, there should be caution about interpreting this data: Causes of defects were rarely recorded in formal documents. They were derived from interviews involving parties in the owner's side. The contractor was the main party missing in the interviews due to some reasons, so the data should be interpreted with some caveats.

Nevertheless, the data set provided insights into causes of defects from the viewpoint of the project owner's side. This data is very insightful for contractors who want to work with the owner.

4.3 Effect of Defects on Time

Table 3 illustrates the administrative procedures starting from the request of final inspection to the remittance of final payment. Without any defects, procedures took an average duration of 43.7 days. Whenever defects occurred, procedures took an additional average duration of 26.4 days. This was the quantifiable risk that defects could have regarding impacts on project time.

Table 3. Duration of defect-correction procedure.

No.	Types of Contract	Average Duration in Each Step (days)					
		Step1: waiting duration for arranging final inspection day	Step 2: duration spent for defects correction	Step 3: waiting duration for arranging inspection of corrected defects	Step 4: duration spent by owner's representative in preparing payment request	Step 5: duration spent by financial section in remitting final payment	Total duration
1	Construction of new buildings	18.2	40.0	11.0	20.6	13.6	103.4
2	Renovation of existing buildings	19.2	12.5	5.4	19.9	8.5	65.5
3	Construction of utilities and infra	14.4	7.2	13.4	8.2	8.8	52.0
4	Landscaping works	15.0	29.2	10.5	7.8	8.2	70.7
	Weighted average	17.7	18.2	8.2	16.6	9.3	70.1

4.4 Effect of Defects on Cost

Table 4 shows that the impact of defects ranges from 0.23% to 15.90% of initial contract value. It should be noted that the studied projects were constructed in different years. It meant the cost might be different due to inflation, market conditions, etc. In this research, the estimates of expenses in correcting defects were estimated by using the cost data in 2012 so that all projects could be compared in term of expenses. Some errors remained due to the initial project sum not being adjusted by any inflation rate or cost index. However, the analysis results are helpful for contractors to foresee their potential cost-risk in their work quality. They can utilize the figure in planning and controlling their budget for quality supervision at sites.

5 CONCLUSION

The article illustrates the types, causes, and effects of defective work using a 3-year historical data set of constructed projects at an academic institution. The research performed analysis based on recorded data in formal documents. By the nature of documentation in construction projects, some facts were not formally reported. Interviews with some involving parties provided additional data for analysis. Some

limitations of analysis and their interpretations are noted above. The authors expect that this analysis will provide some insights for both owners and contractors.

Table 4. Additional expenses in correcting defects.

No	Types of Contract	Average Contract Sum		Percentage (%)		
				(Expenses in correcting defects) / (Initial contract sum)	(Liquidated damage for delay) / (Initial contract sum)	(Expenses in correcting defects + Liquidated damage for delay) / (Initial contract sum)
1	Construction of new buildings	41,915,600	Avg	2.38	3.00	5.38
			Max	7.71	11.8	19.5
			Min	0.30	-	0.30
2	Renovation of existing buildings	1,874,170	Avg	4.80	1.32	6.12
			Max	15.90	8.57	19.7
			Min	0.23	-	0.23
3	Construction of utilities and infra	2,943,310	Avg	1.06	-	1.06
			Max	2.49	-	2.49
			Min	0.26	-	0.26
4	Landscaping works	805,407	Avg	4.90	2.58	7.48
			Max	9.27	9.00	18.27
			Min	1.02	-	2.32

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