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A CUSTOMIZED ROOT CAUSE ANALYSIS APPROACH FOR COST OVERRUNS AND SCHEDULE SLIPPAGE IN PAPER-MACHINE-BUILDING PROJECTS

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Abstract

This study presents a customized root cause analysis approach to investigate the reasons, provide improvements measures for the cost overruns, and schedule slippage in paper-machine-building projects. The proposed approach is an analytical-survey approach that uses both actual technical data and experts' opinions. Various analysis tools are embedded in the approach including: data collection and clustering, interviews with experts, 5-Whys, Pareto charts, cause and effect diagram, and critical ratio control charts. The approach was implemented on seven projects obtained from a leading international paper machine supplier. As a result, it was found that the main causes behind cost and schedule deviations are products' related; including technical accidents in the Press section, damaged parts, design issues, optimization of the machine and missing parts. Based on the results, prevention measures were perceived.

Keywords

project quality management, project evaluation, paper industry, paper-machine-building projects, root cause analysis, big machines.

Introduction

The success of any project can be evaluated by multi criteria including completion within scheduled time, cost and scope [1–3]. It is so rare that a project does not undergo any kind of plan changes or challenges, thus resulting in cost overruns, or schedule slippage, or both [4]. Cost overruns and schedule slippage are in fact mutually non-exclusive; when projects' schedule is unmet it's either extended or crashed, therefore, incur additional cost [5]. Reported statistics show that high percentage of projects, with increasing trend, experience cost overruns [4, 5], but with significant variation in these percentages due different reasons including project type, size, country of implementation, and reference point for measuring cost overruns [6]. For example, cost overruns percentages were reported between −12 % to 70 % in construction projects [7], about 20% in transportation construction projects [8], 45% in large IT projects [3], and 87% for international development projects [1]. In due course, cost overruns and schedule slippage cause dissatisfaction to all stakeholders, particularly the projects client.

Several studies have been undertaken to study projects' cost overruns and schedule slippage. Majority of these studies are related to construction projects. Order changes, unrealistic contract duration, shortage in labor, poor technical and material resources management, poor risk management and supervision, unforeseen site conditions, and slow decision making; were found to impose most significant effects on cost overruns and schedule slippage in construction projects [4, 9–12]. Technical issues, plant availability, and labor and raw material availability were found significant in influencing pharmaceutical projects delay [2]. For international development projects, the major causes of delays were recognized as long contract duration, consultant recruitment, civil works and land acquisition, and host country bureaucracy [1]. Scarce literature can be found on cost and schedule performance of big machines building projects such as airplane and naval ships building projects; design errors, project life, and complexity were found to be crucial factors for cost overruns in such projects [13, 14].

Paper industry is a multi-billion industry that deals with commodity products. Although digital devices are partially replacing it nowadays, paper will remain a need for many uses in our houses, businesses and various places. Depending on the intended usage and characteristics (gloss, smoothing, size, etc.), paper is classified into four main grades, namely: printing and writing (P/W) (also called graphic), tissue, packaging (or board and packaging) and specialty grade [15]. Some grades have further classification, for example, tissue includes toilet paper, napkins and wipes, kitchen towels, and tablecloths [16]. With the increase of the world population in the past 16 years, paper's overall consumption, including recycled paper, has steadily increased with one exception in 2009 because of the recession [15]. Except for graphic paper, which has seen consumption declining due to the technology developing in digitization and the wide use on the internet; all other paper grades have grown steadily.

Building the paper-machine (PM), which is the fundamental component in any papers' production line, is a 10's up to 100 million dollars' budget project. The life cycle of a paper-machine-building (PMB) project can be classified by the typical 4 phases of initiation, planning, execution (including monitoring & controlling), and closure. The initiation phase, including negotiating customer requirements and identifying suitable machine, identifying customer involvement in the execution and termination phases, and specifying and accepting the quotation; and the planning phase, including activities of planning, scheduling, costs' estimating, and resources allocation; are all occurring off-site from where the PM will be built. On the other hand, the execution and termination phases are on-site phases. Normally, the execution phase includes the installation of the machine on site and the start-up of the machine. Closing final points, handling the machine over to the customer and the warranty activity are the main activities of the termination phase. Alternative to the above multi-phase's classification and in conjunction with construction projects, the life cycle of PMB projects can be classified into two main phases: the pre-construction phase and the construction phase.

Schedule slippage and budget overruns are visible symptoms for projects' troubles; to be able to address and eliminate them, a deeper understanding of what is causing them is needed. This study presents a customized root cause analysis (CRCA) approach to investigate the reasons behind cost overruns and schedule slippage in PMB projects. Accordingly, recommendations for solving these causes are proposed and projects risks in such projects can be reduced. To our knowledge, no previous research has evaluated PMB projects in terms of time and cost performance. As mentioned above, related cost and time performance research can be found for construction [4, 11], aircraft [13], and shipbuilding [14] projects. For PMB projects, the major cost overruns and schedule slippage instances occur in the construction phase; hence, it will be the focus of the current study.

The rest of this paper is arranged as follows. In the next section, the papermaking cycle and production process is described. In section three, the proposed CRCA approach is presented while section four demonstrates the implementation of the approach. Section five discusses the results obtained and, finally, conclusions and recommendations are presented in section six.

Paper making cycle and production process

Paper is a commodity; it requires a minimum level of design efforts and is produced in mass amounts. Despite the different types of grades, the papermaking cycle is similar for all grades. Figure 1 illustrates the complete paper making cycle from the start till the end (stages 1–8); including papers' recycling (stages 6–8). There are two sources of paper pulps (stage 1): 1. Coniferous and deciduous trees, which are the major source of paper pulp; and 2. some plant fibers (secondary sources) such as: bamboo, cotton, rice, wheat, etc. Recycled paper can be considered as a third source. After obtaining the wood/fibers and removing bark from the wood using debarking machines (stage 2), pulping (stage 3) is conducted through three methods: mechanical, chemical, or a mix of both (semi-chemical pulps). The fibers/pulp is then washed and bleached in the cleaning stage (stage 4). The fifth stage is the paper production line/processes (which is the scope of the study) that delivers the finished paper product. After consumption, paper is recovered for recycling (stages 6–8). Ideally, sorting (stage 6) is first made to separate different types and grades, and then the recovered paper goes through pulping (stage 7) with the possibility of virgin fibers being added to the pulping process. Finally, papers are de-inked (stage 8), through a flotation process (raising ink to the surface to be removed using small bubbles), before being cleaned and transferred to the PM again.

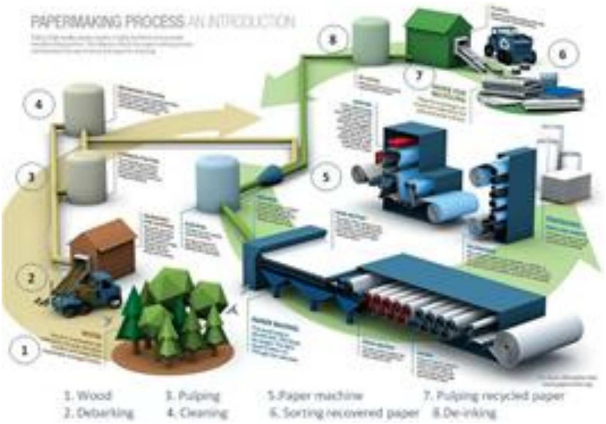

Fig. 1. Papermaking cycle [17].

The paper production line consists mainly of stock preparation, PM and winding systems (Fig. 2). The stock preparation is a prolongation of the cleaning stage in the papermaking cycle explained before. The PM is constructed of several sections; each is responsible for a function in the production process [19]. The first section is the 1. Forming wire or the wet end process (WEP) section, where paper sheets are formed (sometimes WEP is considered independent from the PM). The WEP minimizes stock's fluctuations, in terms of composition, flowrate, and pressure; and evenly distributes the pulp stock over the wires, performed by the headbox. After forming, the sheets are dewatered in the 2. Press section, by going through nips between a series of rolls. The dewatered paper is then transferred to the 3. Drying section, where the paper is dried using steam-heated cylinders. Prior to the last section of the PM, comes the 4. Coater and 5. Calendar sections that are responsible for various paper surface characteristics. These two sections are required for certain types of grades and can be online; part of the machine, or offline; detached from the PM. The coater section is responsible for the coating applications; to close the pores, cover the surface (coloring for example) and sizing; making them less ink-absorbent to maintain the print, hence enhancing printing properties of the paper. The calendar section is made of multiple rolls arranged on top of each other under pressure, forming nips where the paper goes through. High pressure and heat are applied to the paper to give smoothness and gloss characteristics for the paper surface, similar to the ironing principle. Finally, in the last section reels wind the paper on reel spools forming jumbo rolls. It is worth mentioning that a tail threading mechanism is responsible for the transportation of the paper throughout the PM through shooting the paper between the sections. After the PM, winders transform obtained paper jumbo rolls to smaller sizes by longitudinal slitting of the web [19].

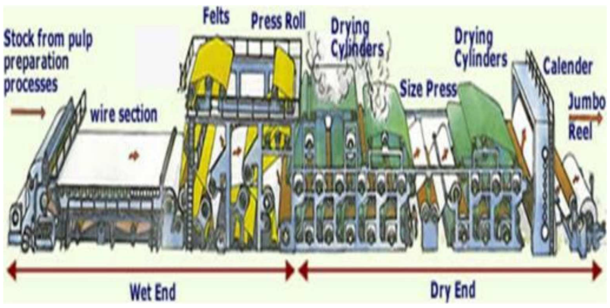

Fig. 2. Paper machine [18].

In addition to the main steps within the paper production process, there are also supporting systems that support the papermaking process; automation and auxiliaries. The automation system combines the machine, process, distribution, quality, motors and drive control systems. Auxiliaries (air system and lubrication) provide and withdraw levels of steam and condensate, air, water and oil to maintain them at the right level.

The proposed CRCA approach

This study proposes a customized CRCA approach for cost overruns and schedule slippage in PMB projects [20]. The four-stage approach of define, collect data & organize, analyze and prevent stages, aims to identify the sources of the cost overruns/schedule slippage problem and the actions necessary to eliminate them [21]. The define stage defines the problem, identifies its objective, and reviews related background and past knowledge from similar applications. The latter is required to specify the steps to further carry out the study, based upon which, required data are collected in the Collect data & Organize stage. Organization of data is important prior to analysis, especially when data is available in an interrelated qualitative and quantities form, as in the case of this study presented in section four. Through brainstorming, the suitable tools for data management and analysis are chosen. In the analysis stage, the tools from the brainstorming stage are applied to the data for analysis. In the case for interrelated qualitative and quantitative data, data is classified and arranged in a suitable form for the analysis. For example, the 5-Whys tool can be used to classify qualitative data into different levels and categories, and then plot it on Pareto charts with their corresponding quantitative data [22, 23]. The results from the Pareto charts are considered for further investigations to identify the root causes, that are then mapped using a Fish-bone diagram [20]. In parallel to Pareto analysis, Earned Value Analysis (EVA) and Critical Ratio (CR) control charts are applied to test the performance of the phases of the projects in reference to cost and time [24]. Interviews with experts provide additional suggestions for improvement based on their long field experience. Finally, prevention measures are perceived based on the analytical analysis results and advices of experts. Figure 3 demonstrates the proposed CRCA approach.

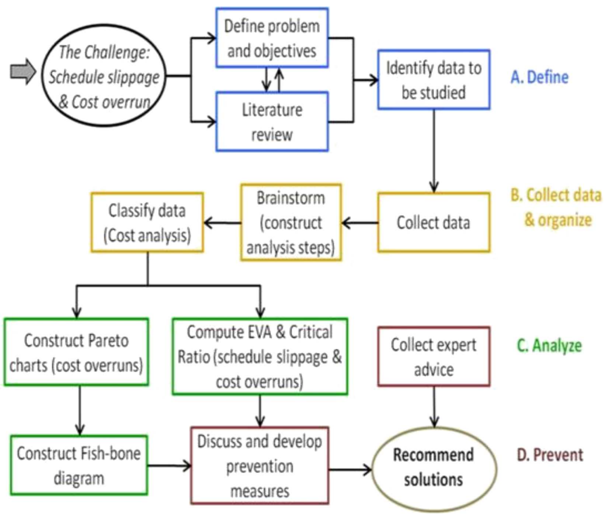

Fig. 3. The proposed CRCA approach.

It is worth noticing that most literature studies regarding cost overruns and schedule slippage are questionnaire-based associated with the implementation of some mathematical analysis tools [5], or researchers-experience based [25]. Contrarily, the proposed approach is an analytical-survey approach that uses both actual technical data and surveyed data (experts' advices). The actual data were obtained from internal post-project reports of a leading international PM supplier. Within the project and operations management area, research based on such data is very promising and offers great opportunities for new studies [1, 26].

The CRCA approach implementation

This section describes the implementation of the proposed CRCA approach on a multiple PMB case study. A multiple case study is implemented as it provided more reliable results than a single case study [27].

Define; topic understanding, problem & objective definition and identifying sample of study

Past literature in addition to problem and objective definition were discussed earlier in this paper. After the latter was achieved, seven cases were chosen from a PM manufacturing company (whose name will remain confidential), to be the sample of the study and are summarized in Table 1. These seven cases consist of the most recently completed PMB projects at the source company. The sample contains three board grade machines, two graphic grade machines, two tissue grade machines and one packaging grade machine. Complexity, rated on a 1 to 4 scale with 1 being the least complicated; is related to the machine size in paper width (typically, the wider the paper-width the larger and more sophisticated the PM), paper grade (graphic paper grades being the most complex, then Board & packaging, and specialty and tissue grades come last), and project's duration (lengthy projects are considered more complicated).

Table 1
The PMB studied projects.

Project	Machine type	Complexity	Cost overruns, % of cost overruns from the risk budget	Schedule slippage, ratio of actual over planned used hrs
P1	Board machine	3	87%	1.65
P2	Graphic paper	4	249%	1.18
P3	Board machine	4	42%	1.05
P4	Graphic paper	2	98%	1.15
P5	Packaging paper	3	312%	2.19
P6	Tissue paper	1	410%	4.48
P7	Board machine	3	202%	1.72

Data collection and organization

This step of the approach consisted of obtaining data on projects' cost overruns and on schedule performance of the projects. The data was then revised to check whether it could be directly applied onto the tools for the analysis. If not, data was organized as such.

Table 2
Example of the "5-Whys" tool implementation.

Why?[1]	Why?[2]	Why?[3]	Why?[4]	Why?[5]
Need for extra fund/Cost overrun	Unexpected problem	Problem in section X	Product issue	Product design issue
	Unexpected problem	Problem in section Y	Product issue	Damaged parts
	Deviation from plan	Problem in section Z	Personel issue	More workers needed
	Deviation from plan	Problem in section Y	Cutomer issue	Customer damaging

I. Data collection – cost overruns & schedule slippage data; the data was collected from the on-site activities (construction phase of PMB projects). The on-site activities represent the majority of the work and timeframe in PMB projects and are responsible for the actual erection and commissioning of the PM. Data sources for Cost and schedule slippages are as follows:

Schedule slippage data was obtained from the total hours used for the project from the start of the installation of the machine until the handing over to the customer. For Cost overruns: for each problem arising during the execution of the project, a report is made with the description of the situation and the corresponding impact on cost. Therefore, these reports will be used to investigate the causes of the cost overruns. However, project reports contained interrelated quantitative and qualitative data, therefore data management was required in order to analyze this information. In the fourth column in Table 1, cost overruns are calculated as a percentage of the total risk budget value; hence, a value over 100 % indicates that a project exceeds its risk budget value. Likewise, in the fifth column, schedule slippage is calculated as a percentage of planned hours over actual used hours in the project.

II. Organization and classification; to plot the data from the reports onto the Pareto charts, the descriptions of the problems were classified into different clusters of data. Using the 5-Whys tool, a set of whys questions were asked to be able to classify a problem into the different clusters of data. Each why question, gives more detail than the preceding one, consequently clusters can be arranged into different levels. Examples are shown in Table 2.

Around 340 project reports were studied and classified from the seven projects. The data was found to include three types of general information: field of problem, location of problem in PM, and further descriptions of the problem from which a general factor was extracted. Consequently, the data was classified into three levels: Level 1 – Segment (field of problem), Level 2 – Section (location in PM), Level 3 – Factor (general, group of similar situations). In each level, data was also clustered into different categories. Classification levels with the corresponding categories (listed alphabetically) are listed in Table 3.

Level 1 is the most general level to which the problem can be directly allocated. There were nine direct responsible parties for most of the issues that occurred in the seven studied projects as the following: commissioning and machine start-up activities, customer activities, performance guarantees (final acceptance test runs), installation (installation phase activities), logistics, personnel, products malfunction or problems from sub-supplier products. Everything else is listed under "Other". Level 2 categories are mainly machine-related issues, in addition to the categories "Site management"; which relates to management issues of the site where the machine is built, "Project management" and "Workers". Finally, in level 3 the factor was identified. In some cases, some of the categories in level 2 and 3 relate to a specific higher-level category, this is presented by similar colored categories in Table 3 between the different levels.

Table 3
Classification levels categories.

Segment/level 1	**Section/level 2**	**Factor/level 3**
Commissioning	Automation	Sales agreement
Customer	Auxiliaries	Customer damaging
Guarantees	Calendar section	Customer demand
Installation	Coater section	Damaged parts
Logistics	Drying section	Design issue
Other	Headbox	Engineering
Personnel	Press section	Extra work
Products	Paper machine	HSE
Sub-supplier	Project management	Lost material
	Reel section	Maintenance
	Site management	Manufacturing
	Threading	Material wear
	WEP-line	Missing parts
	Winder	Not delivered
	Wire section	Not mentioned
	Workers	Optimization
		Press crash
		Product recall
		Sales and application
		Technology
		Test run
		Transport damages
		Wrong delivery

In some cases, little information was documented to conclude results for level 2 and 3. Therefore, "Paper machine" and "Not mentioned" were assigned to cases where no information was available in level 2 and 3 respectively. "L1", "L2" and "L3" will be used further to reference the "level" of the mentioned category.

Analyze

Data collected was analyzed through Pareto charts for the cost overruns, to compare the different categories and evaluate their resulting cost overruns. Highest-ranking categories were investigated into further levels, and then Fish-bone diagram is used to list the root causes of the most significant occurring problems. Lastly, CR analysis was used to evaluate the performance of the projects using the schedule slippage and cost overruns data.

I. Pareto charts analysis for cost overruns data; data classification results were plotted on Pareto charts to prioritize the categories from the different levels and their significance, to be investigated for the root cause. Starting from level 1, the highest category was chosen to be investigated further in level 2. In level 2, categories causing 80% of cost overruns were investigated in level 3. The classification results for the seven projects were plotted on Pareto charts for level 1, 2 and 3. Figure 4a, shows that for level 1, "Products/L1" caused almost 70% of the total cost overruns in all the seven cases. Therefore, "Products/L1" is chosen to be investigated in level 2. Figure 4b shows the overall results for level 2, from which "Press section/L2", "Drying section/L2", "Paper machine/L2", "Wire section/L2" and "Winder/L2" were the sections in the PM where the problems that caused 80% of the cost deviations occurred. 19% of the total cost overruns in level 2 were allocated to "Paper machine"; unknown sections due to lack of information. Level 3 was also plotted on Pareto charts (for each level 2 category/section) and the outcomes are summarized in Table 4; were the level 3 categories responsible of causing 80% of the cost overruns in the particular level 2 category are listed, with the corresponding percentages (level 3 category cost overrun/total level‘ 2 category cost overruns). Results were as follows: Press section's main factor was "Press crashes". In the "Dryer section"; "Damaged parts" and "Design issues" were the main factors of the cost overruns respectively, similarly in "Wire section", but in the reverse order. "Winder section" had mostly "Optimization issues". In addition to the mentioned factors, other major factors were: "Missing parts", "Manufacturing and Technology", in order. 13.8% of the total cost overruns in level 3, were allocated to "not mentioned"; due to lack of information, therefore these problems could not be identified.

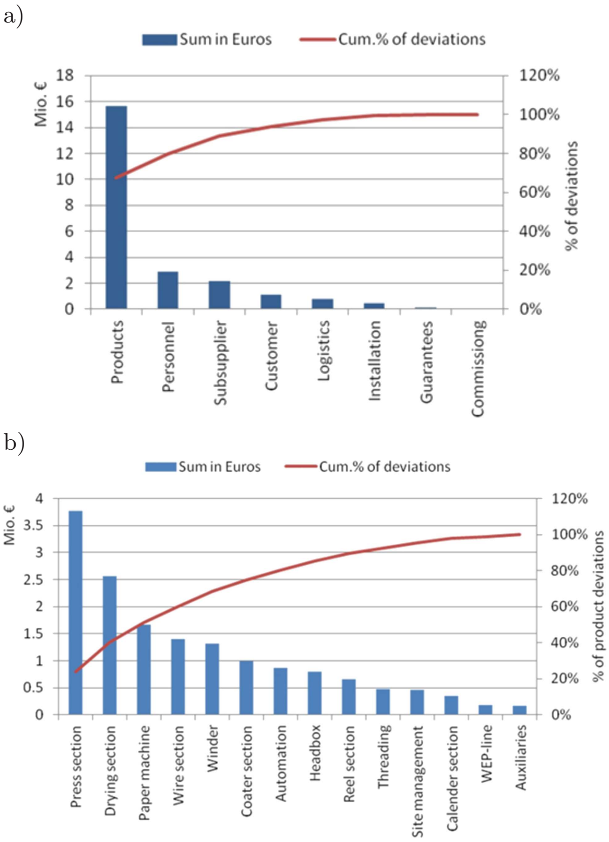

Fig. 4. Pareto chart for: a) Level 1, b) Level 2 for "Products/L1".

II. Fish-bone diagram; the Pareto charts analysis shows the results for levels 1, 2 and 3 – priotrizing the main factors that result in cost overruns. Results from level 3 were then taken to be investiagted further by studying the project reports descriptions (reports related to the categories chosen in Table 4) in detail for a deeper understanding and identification of the root causes of the most significant cost overruns. The results are plotted on Fish-bone diagrams in Fig. 5, were level 3 is presented as the effect, and skeleton lists the most occuring root causes, as explained in the project reports.

In Fig. 5, level 3 categories are presented in order of impact, with 1 having the most impact on cost overruns. No furthur information was found on the causes of Press crashes since they are hard to detect and each case requires its own investigation. All root causes in "Design issues", "Damaged parts", "Optimization", "Missing parts" and "Material wear" can be allocated back to either Machine/products designs or Material management. Material manage-

Table 4
Pareto charts summary.

Level 2 categories	Press section	Drying section	Wire section	Winder section
Level 3 Categories that caused 80% of cost overruns. In addition to the corresponding %'s of the total	*Categories (%)*	*Categories (%)*	*Categories (%)*	*Categories (%)*
	Press crash (68)	Damaged parts (26.4)	Design issue (31.4)	Optimization (33.9)
	Not mentioned (10)	Design issue (22.6)	Damaged parts (20.6)	Not mentioned (22.1)
		Optimization (14)	Material wear (19)	Missing parts (11.7)
		Sales agreement (13.3)	Not mentioned (12.7)	Damaged parts (10.6)
		Missing parts (9)		Design issue (8.4)

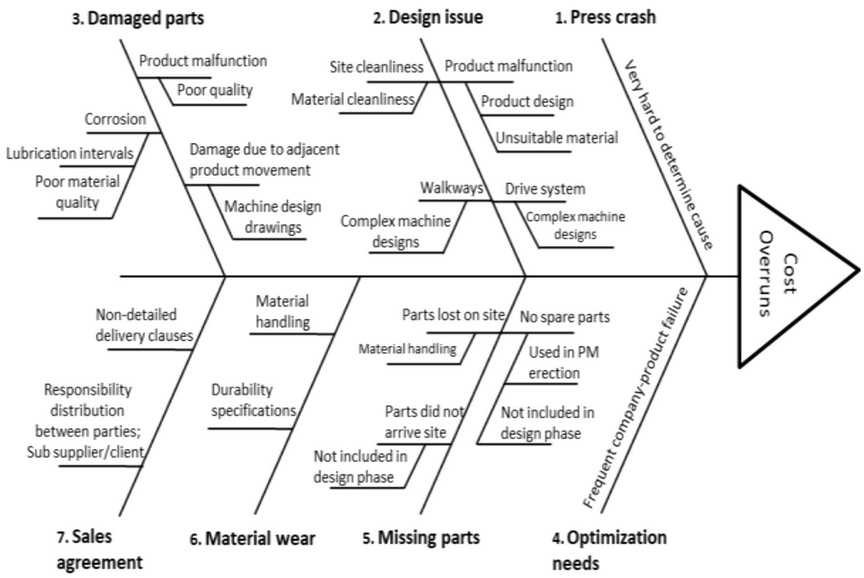

Fig. 5. Fish-bone diagram.

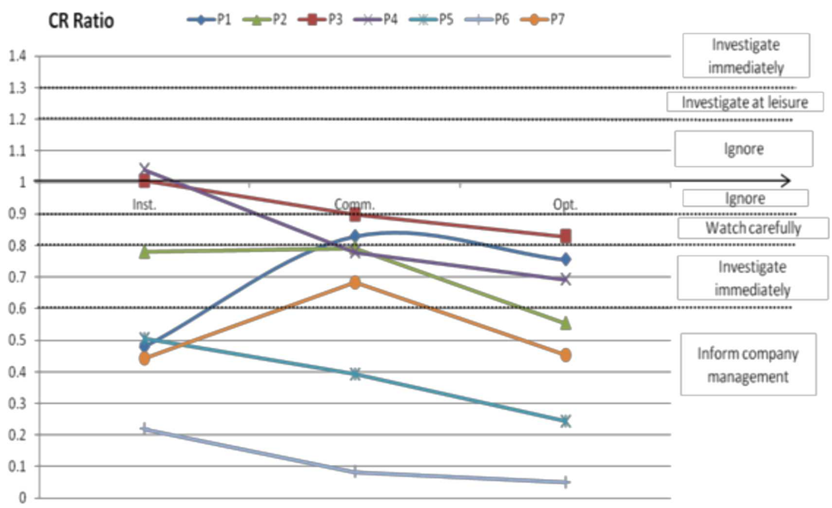

Fig. 6. Critical Ratio control chart.

ment includes all material handling practices such as: cleanliness, maintenance, onsite movements... etc. Contracts lack of clarity and specifity between all participating parties are the main causes for Sales agreements issues.

III. CR and EVA calculations; due to unavailable data, EVA analysis could not be applied. "Hours used" data was used to compute CR. This tool is normally used in real time, however in this study it was used to interpret the cost, time data with respect to the project phases. The outcome of this method gave an indicator of the performance along the phases of the projects. Figure 6 plots CR values for three stages (installation, commissioning, and optimization) of the construction phase for the seven PMB projects considered.

Almost all phases show a value under 1 but not all are serious situations. P3 had a quite on-target start, however, it then proceeded into lower regions, yet remaining in an "OK" region. P1 and P7 both had a rough start, but then improved, though remaining in the region of below 1. P4 started well, with a value above 1, indicating a good performance, but then the CR ratio went into a region indicating a serious situation. P2 had a steady start but not at the best performance though, and like the others, ended with a poorer performance as the previous phases. Project P5 and P6's performances were alarming all through the project phases and continued to drop.

Referring to Fig. 6, the CR ratios show that the optimization phase suffers from the poorest performance compared to the previous two phases. Due to limited availability of information on schedule slippage, project managers input was obtained regarding this matter. According to project managers, this is mainly attributed to the time required for solving the open points during optimization to gain the acceptance of the customer, passing the guarantee tests for the full takeover of the machine, and complete the final acceptance of it.

Prevent

Previous analysis provides an understanding of the root causes of the cost overruns and schedule slippage in PMB projects. An additional step taken to improve understanding for improvements was gaining experts' advice. Based on the results of the analyses and experts' advice, prevention measures were perceived:

- Enforce faster Press crash detection techniques: Due to the high complexity of the Press section, focus on developing early Press crash detection techniques is a more cost-effective solution than any correction technique.
- Advance material handling and on-site management logistics: Damaged parts can be traced back to improper personnel handling and/or site management. By improving material handling whether during logistics or on-site, parts are less likely to get damaged or lost/missing, which in return will decrease the cost overruns in a measurable degree.
- Improve project design: "Design issues/L3" was the third highest cause of problems; the PM industry often has new developments and technologies, and thus; new knowledge. With the latter, technical deficiencies (which are inherent in design developments) because of new designs can occur. Moreover, reviewing and improving project designs can reduce bill of material mistakes that comes along with technical deficits or other reasons.
- Pay more care for follow-up for guarantee tests: In order that the machine can be handed to the customer, guarantee tests operated by customer should be passed. Otherwise, customer cannot be handed over the machine leading to schedule slippage.
- Clarify customers' contracts: including issues of technology warranties vs. performance guarantees and risk of special conditions; this will ensure proper responsibility roles in the case of unplanned events and will avoid misunderstanding.
- Conduct more prototyping tests for new technologies before implementation and follow-up on product developments in practice.
- Consider customer type and country in budgeting.
- Enhance documentation: A large percentage of the issues reported in the project reports, could not be studied due to insufficient information. To avoid this situation, a more detailed description/classification in the project reports should be developed to ease future studies. Frequent updates and reflection of performance will increase the pace at which improvements can be made.

Discussion

Press crashes were found the most significant cause of cost overruns. The Press section is a highly sensitive section in papers machines, where eliminating a Press crash is very hard, a good detection technique of a Press crash before it causes severe damage is favorable. Previous research has found similar results related to the impact of technical issues and poor technical performance on the project cost overruns [11], and schedule slippage [2]. Machine/products design came as the second most significant cause. Design issues are very important point to consider. As authors of reference [14] suggested, for projects with high complexity, completing the design fully, needs more time than what it is actually given, therefore design issues are one of the main factors of cost overruns and/or schedule slippage. In the current study, design issues include non-ordered material; this is similar to reference [11] results, where material resourcing was found to be a factor in project overruns. So did authors of reference [13] concluding that effect of constructional faults on project overruns, where design issues is one form of constructional faults.

A potential correlation between machine complexity and projects' size, from one side, and cost overruns is observed in Table 1. This finding is similar to several researchers' [13, 14, 28, 29] findings that inherited complexity in projects is one of the main root causes of projects overruns, and conclusions of the correlation between the size of the project and project delays and cost overruns [28, 30]. As indicated by the author of reference [6] defining projects' complexity is not the challenge, but determining its influence on overruns and developing solutions that can accommodate it is; in PMB projects, standardization and/or modularization (construction of the machine is deconstructed into modules to a degree where components may be separated and recombined) of PM sections will decrease the occurrences of failure and technical deficiencies.

Interestingly, experts' advices revealed some overruns causes which was not clarified by the analytical analysis, including unclear contract issues. The author of reference [31] mentioned contract consideration as one of the broad project success factors) and customers' type [30] stated project ownership as a key factor to consider in cost escalation analysis).

Finally, it is worth mentioning that the quality of the documentation in project data and incomplete information caused some challenges in the study and hindered the analysis process; for example, the "Paper machine/L2" category appeared as one of the main categories in level 2, however, was not chosen for further investigation in level 3.

Conclusions

In this research, a customized root cause analysis approach for cost overruns and schedule slippage for the on-site activities of PM building projects was presented and implemented on seven cases obtained from a leading international PM supplier. It was found that reasons behind these deviations are mainly products' related. The causes of these problems were found to be Press crashes, Machine/products designs, material management and sales agreements issues. Based on results, measures to be taken on how to improve performance of future PMB projects were found as:

- Imply faster Press crash detection techniques.
- Pay more care on follow-up guarantee tests.
- Explore shared responsibility agreements in machine optimization with the customer.
- Revise contracts in issues of technology warranties and performance guarantees.
- Revise standards of machine drawings.
- Standardize and modularize machines components, especially complex sections.

Additionally, the following are more improvement measures for PMB projects and similar complex machines' building projects:

- Improve material handling.
- Follow new product developments techniques and gain related feedback.
- Review and control sub supplier's products quality.
- Review contracts for clarity and contract risks.
- Implement more real-time projects monitoring and control techniques.
- Develop and update failure mode and effect analysis during and as post project documentation for the benefit of future projects performance.
- Involve workers and employees in the project management and control process.
- Modify and improve project-documenting techniques.

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