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USING PROCESS MAPPING IN CONSTRUCTION PROCESS TO REDUCE CHANGE ORDERS

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ABSTRACT: Change orders represent one of the largest sources of cost growth on construction projects, but an efficient change management control system can help the projects steer clear of the constant construction changes. This study was performed to achieve a better understanding of all changes and to develop a new set of Best Practices using process mapping techniques. The project data for this research were collected from case studies of aviation projects implemented in Houston, Texas at Bush Intercontinental Airport. The findings and contributions of this research should help owners and project managers determine and identify major causes that impact project budget and schedule and implement solutions prior to them surfacing.

Keywords: Process Mapping; Change Orders; Change Management; Construction Process; Best Practice

1. INTRODUCTION

Change has always been a very important feature of human life and human history. Change is so invasive, that it affects human notion of cause and time. It is impossible to deny change, but it is possible to understand that change has inspired people throughout the years. The history of the world has been marked and defined by major changes; and so has been the history of every construction projects. Changes are nothing else than milestones through the road of progress.

Construction Industry Institute (CII) has identified and developed 14 best practices that have proven to enhance the value and performance of construction projects. One of the major practices is Project Change Management (PCM) which was developed with the intent of avoiding interruption on the flow of work, delays and schedule impact during the progress of construction projects. When practiced and applied correctly, PCM can improve cost and schedule performance [2]. PCM has been implemented throughout the entire construction industry for many years, generating a positive impact in numerous construction projects.

This study focuses on change orders related to aviation projects. Aviation projects cover a different spectrum in the construction industry, and therefore, require special consideration. PCM will be analyzed and a new set will be developed to directly fit the needs of aviation projects using process mapping techniques. Aviation projects include all activities related to airborne devices known as aircrafts, and takes into consideration organizations, regulatory bodies, and personnel involved in the operation of the aircrafts. For the purpose of this research, aviation projects will encompass all construction projects generated by Continental Airlines and/or Houston Airport System, with the intent to develop or improve areas directly related to the operation of the aircrafts, passengers, personnel, equipment, etc. at Bush Intercontinental Airport in Houston, Texas.

The purpose of this research is to discover changes in aviation projects. Discovering change encompasses a lot more than just acknowledging the fact that changes are part of every construction project. There are many research works that consider project changes and PCM Best Practices, but there are not many that focus primarily on the changes and specific change management techniques on aviation projects.

This study investigates and explains construction change orders in aviation projects with the following objectives:

- Explore the different types of changes that occur in aviation projects;
- Determine the reason why changes in aviation projects occur;
- Develop a set of new Best Practices targeted to the aviation sector; and
- Propose implementation tools that can be used to target root causes that generate the highest percentage of changes in aviation projects.

By using process mapping method, project managers will be able to easily determine, identify, and avoid major potential changes prior to them surfacing during the

progress of the construction project. At the same time, owners will be able to identify major causes that normally impact budget and schedule on aviation projects and implement solutions with confidence.

2. BACKGROUND

2.1 CII Best Practices

"It is estimated that the United States construction industry spends $13-26 billion in 1 year for construction change orders" [10]. Changes are inevitable on most construction projects; it is almost impossible for a project to go through its entire construction process without a single change order.

There have been many studies completed in the past dedicated to analyze, quantify, and determine the impact that change orders have in construction projects. The CII attempted to demonstrate how to apply different techniques into projects in order to reduce losses related to change orders [1], but it was only in 1997 when the PCM Best Practices were included in the CII database. PCM Best Practices were developed by an established research team dedicated to find ways to help construction projects steer clear from changes that can potentially create delays in the project schedule, disrupt the established flow of work, and cause budget overruns. The research was centered on revealing and identifying the root causes of the problems that create the changes. The results obtained by the research team were published and shared with the entire construction industry as a "set of recommended best practices for the effective management of change" [2].

On the other hand, there are other research areas that have focused on productivity losses related to change orders. In general, these studies have managed to provide valuable recommendations to the industry on the quantification, impacts, and importance of change orders in the construction industry [6;7;8;12].

The effects of change orders have been the subject of extensive research and successful results, but these studies have not taken into consideration specific sectors of the construction industry such as aviation projects. In the construction industry, a useful distinction is made between the different types of projects – building construction, heavy/highway construction, and industrial construction. The distinction is relevant because each type of construction project requires a unique team to plan, design, coordinate, construct, and maintain the project. In order to successfully develop and manage construction projects, it is important to identify the project's nature, cause, and intent. Aviation projects are a separate type of project and therefore, require an exclusive set of documents, processes, and plans in order to be successfully established.

2.2 Federal Aviation Administration (FAA)

Aviation includes all activities related to aircrafts such as regulatory bodies, organizations, aircraft operations, and all related personnel. Great progress was made in the field of aviation during the 1920s when aircrafts began to transport people and cargo over great distances. The first commercial airport was built in 1920 in Sydney, Australia (Sydney Airports Corporation 2007), and in 1922 the first permanent airport and commercial terminal built solely for commercial aviation was established in Germany. These two airports started the history of aviation projects and led to futures developments of new designs and approaches required to meet the aircraft and passenger needs. Through the years, aviation evolved and expanded dramatically, impelling all airport infrastructures into one specialized and unique entity. Aviation projects have become on major specialized sector within the construction industry. As of January of 2005, the total number of airports built and maintained in the United States alone reached 19,820 [3].

The FAA estimates that the demand for airport and carrier passenger services will increase dramatically by approximately 50% within the next decade and the air cargo and its related facilities will increase approximately 80% over the same period of time [4]. A large number of airport expansion projects will be required in order to meet the increase in air traffic demand. The expansion projects required to maintain airports and all infrastructure current are either ongoing or being planned, and include the construction of new terminals, expansion and construction of new runways, better taxiway systems, and expansion of existing structures [3].

This research highlights the importance of aviation projects within the construction industry and presents a comparative investigation of change orders and its root causes on traditional aviation projects. In this specific case, the approach taken helps isolate the major issues and conditions that cause change orders and creates an opportunity to propose viable solutions that lead aviation projects away from these changes. The goal is to create a customized set of Best Practices addressing the unique needs and requirements of aviation projects using process mapping techniques. By presenting a new set of Best Practices, the negative effects of change orders will be reduced through implementation of the new techniques and proposed approaches.

3. RESEARCH METHODOLOGY

The data obtained and reported on this study were taken and collected solely from aviation projects implemented at Bush Intercontinental Airport in Houston, Texas. This study consisted of an analysis of aviation projects generated by Continental Airlines from 2005 until 2008 and with budget amounts that range from $100,000 up to $27 Million. Of the projects occurring during this time frame, various projects were eliminated and only 20 significant projects were selected. All selected projects are expected to make the data representative of the actual conditions of projects that occur at Bush Intercontinental Airport: (1) New construction projects were selected as well as major tenant improvement projects. Both types of projects play a vital role within the airport and its operations. They both require meticulous coordination in order to avoid any impact to the scheduled Airport Operations; (2)

Every selected project carries a different number of change orders, and regardless of the implemented number of change orders, only the top 10 change orders of every project were selected and analyzed; (3) The top 10 change orders of every project were selected based on the amount of cost and schedule impact that was generated to the specific project. The selected change orders generate more than 50% of the total change order cost of each project; and (4) All selected projects have an established contingency fund and have been able to execute all change orders without spending more than the allocated contingency amount.

It is also important to mention that the collected data is considered to be homogeneous in nature and posses an equal importance in regards to this study. Every change order, regardless of its amount, was treated uniformly in order to place an emphasis on the conditions and causes that generate changes on aviation projects.

3.1 Research Structure

In order to achieve a better understanding of the root causes that affect change orders and to develop a new set of best practices for aviation projects, it was important to analyze the collected data and to compare it with projects of the same type. Based on the collected data, a framework was introduced that relates the important aspects of the problem areas. Then, the framework is used to explore a number of techniques that could help solve the change order problem in certain situations. The techniques follow from the analysis of existing best practices and all change orders in its context.

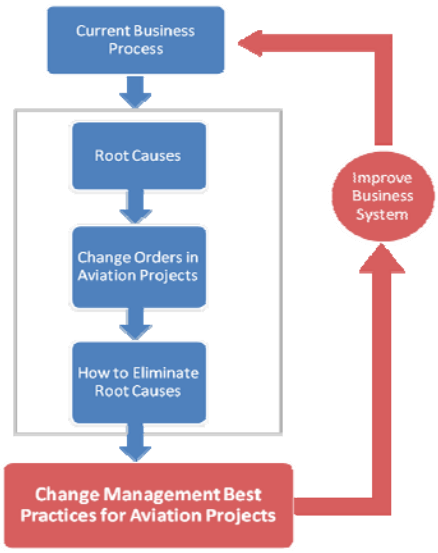

Figure 1. Process Mapping

As can be seen in figure 1, the new set of aviation best practices is based on the data analysis of existing change orders that occur repeatedly in aviation projects. By analyzing the data, an established set of root causes is identified and addressed case by case. The set of aviation best practices focuses on how to avoid and control changes, how to improve the existing system, and how to deliver successful projects.

3.2 Data Preparation and Analysis Procedures

A total of 328 change orders were identified on the 20 projects included in this study. Data preparation, sorting, and interpretation are important elements that play a critical role in the development of the new set of best practices. The collected data was first sorted and organized per project. Change orders were identified, described, and mapped to the root causes that generated the changes. The identified and selected root causes were then analyzed and used as the basis for the development of an action plan targeted to address every root cause. A small set of root causes is capable of producing significant impacts on the construction projects.

Data analysis consists of three steps. First, the top 10 change orders of every project were investigated; second, the root causes were selected and mapped to the changes; and third, a new set of best practices was developed based on the identified root causes. By addressing the root causes, change orders will be reduced or eliminated and aviation projects will be able to take advantage of the proposed improvements by saving money, improving schedule, quality, and safety, increasing productivity, and minimizing rework.

4. DATA ANALYSIS

4.1 Identify Root Causes

Through the process of investigating all different types of change orders, it was concluded that there is only a small group of root causes that generate the most impact on cost and schedule on change orders. Table 1 illustrates all identified root causes at Bush Intercontinental Airport in Houston, Texas. As an example, change order No.1 of project No.1 carried a cost of $12,441.00 for the material and labor required to paint the guardrail, fire sprinkler lines, and exposed red iron throughout the building. After carefully analyzing the change and the responsible parties, it was determined that this change was approved as an owner requirement item and was caused due to a design omission by the architect/engineer. This change order was mapped directly to root causes No. 2 and No. 3.

Change orders and root causes play different roles in construction projects. Change orders are commonly identified as the main causes of negative impact on cost and schedule in every project, but in reality the root causes are the ones that generate change orders. It is important to highlight that the root causes are different from the change orders and are the ones fully responsible for the creation of every change order. Once the root causes are identified and analyzed, it becomes possible to understand the exact cause of the change orders and develop an implementation plan capable of addressing and reducing changes in construction projects.

The mapping of all change orders and root causes was possible with the help of the project managers involved in the selected projects. The project manager on each project was asked to identify the root causes that produced each change. The top 10 change orders were selected based on the cost impact generated on each project from highest to lowest. Not all selected projects have more than 10 change orders on record; in those cases all the change

orders were included in the analysis.

Table 1. Identified Root Causes

Root Causes No.	Identified Root Causes
1	Communication Issue
2	Design Omission – Architect/Engineer
3	Owner Requirement
4	Construction Issue
5	Design Change / Revision
6	Owner's Mistake
7	Schedule Conflict / Issue
8	Work Force / Man Power Issue
9	Unforeseen Existing Condition
10	Temporary Structure Requirement
11	Additional Scope of Work
12	Weather Related Issue
13	Required for Inspection

It was also expected that differences would exist between the selected projects due to the significant difference in size and scope of work; but all collected data and identified change orders were treated equally, assuming that all managerial supervision and interaction on each project was the same, regardless of the project cost or scope of work. Every project owned by Continental Airlines requires close communication among all team members as well as the owner. The assumption made was that every project is equally relevant to the owner.

4.2 Frequency Rate and Cost Impact

A small set of root causes is capable of producing significant impact on aviation projects. A set of 13 root causes were identified as the role players and originators of 42% of all change orders that occurred at Bush Intercontinental Airport during a period of 3 years. All analyzed change orders were mapped directly to the root causes, generating different frequencies for every root cause. Figure 2 shows the rate of occurrence of every root cause.

Even though figure 2 provides valuable information on the rate of occurrence for every root cause, the information obtained with the frequency chart is not enough to stand alone and support the importance of every root cause for implementation purposes. Along with the frequency of every root cause, the cost amount carried by each root cause will generate weight in the prioritization of root causes. As can be seen in Figure 3, all 13 root causes engender a substantial cost impact on aviation projects. The cost impact generated by the root causes on all analyzed projects ranges from $550.00 to $885,510.48. It should also be noted that by addressing one or various root causes, projects will experience less change orders, and the owner will be able to obtain significant savings on all future aviation projects.

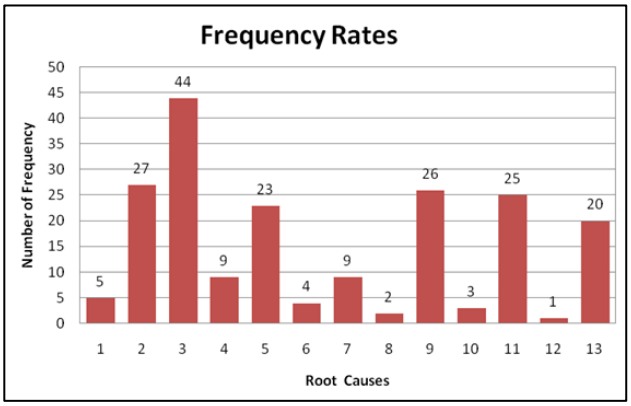

Figure 2. Frequency Rates of Root Causes

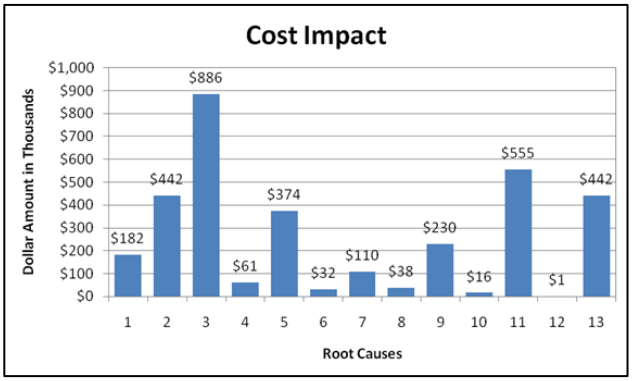

Figure 3. Cost Impact of Root Causes

5. BEST PRACTICE ELEMENTS

As this study was limited to a selected group of implemented aviation projects and to the root causes that impact this type of projects, it is inappropriate to take the results of this study and make broad assertions about the entire construction industry. However, the best practice elements shown below were developed based on the actual needs of aviation projects and carefully propose concise solutions to eliminate or minimize change orders. At the same time, all presented results are convincing in nature and permit some conclusions to be drawn in regards to the many possibilities that exist for implementation of best practice elements and reduction of root causes in aviation projects.

Table 2 summarizes the key findings from the data collected in this study and applied to every root causes. First, the root cause number and its description is presented in column 1. Column 2 presents all applicable best practice elements to be implemented per root cause. All information summarized on this table should be used by the owner to establish an implementation schedule and determine the priority for every root cause.

With the growth on size and importance of aviation projects, owners are scrutinizing the appropriate and

Table 2. Comparison of Main Features between Mixed-use and Single-use Projects

Root Cause	Best Practice Elements
Root Cause #1 Communication Issue	• Ensure key points are communicated during weekly meetings. • Information overload can hurt the communication process. Keep messages simple and to the point. • Reduce the number of communication links • Distribute information and generate project records in a timely manner. • Establish a communication plan and reinforce project communication during the progress of the project.
Root Cause #2 Design Omissions A/E	• Create a design checklist that contains items common to every project using a particular design. • Ensure architects and engineers visit the site several times during the design process. • Ensure architect and engineers verify existing conditions to avoid or minimize design problems. • Architects/Engineers to be required to review lessons learned documents from previous projects.
Root Cause #3 Owner Requirement	• Identify the basis for the change – is it required or is it elective? • Always asses the effect of the change on the project schedule prior to deciding if it will be implemented. • Determine the effect of the change on other disciplines of the project. • Owner rep to encourage beneficial change and discourage detrimental change when reviewing changes
Root Cause #4 Construction Coordination Issues	• Encourage contractor to identify construction issues ahead of time. • Identify all milestones before construction starts. Track and discuss milestone progress during meetings. • Include owner supplied product as part of the milestone schedule and track accordingly to avoid impact on the contractor's schedule.
Root Cause #5 Design Change/Revision	• Architect to be required to keep track of all design changes and revisions. Identify the cause of the change/revision. • Incorporate tracking log as part of the "lessons learned" document for the particular project. • Owner to discourage architect to propose abrupt changes. Encourage design alternatives.
Root Cause #6 Owner Mistake	• Owner rep to be required to create and maintain a "lessons learned" document for every project.
Root Cause #7 Schedule Conflict Issues	• Include permit process as an unavoidable activity in the construction schedule. • Owner rep to encourage owner to be realistic about schedule. Set realistic goals. • Take contractor's input on how long a project activity would take. • Include unforeseen conditions into the schedule such as weather. • Always include equipment delivery dates into the construction schedule. • Construction schedule should be reviewed by another person besides the project manager to verify logic. • Use Cost Schedule Control System methods to track cost/schedule status of the projects.
Root Cause #8 Work Force / Man Power Issues	• Contractor to be required to verify the available resources and training of the selected subcontractors. What is the subcontractor's current load? Have they performed similar jobs in the past? • Owner to discuss with contractor the project schedule requirements prior to awarding the job. Ensure the contractor will be able to provide all resources necessary for the project.
Root Cause #9 Existing Conditions	• Owner to include as-built drafting responsibilities into the A/E contract. Architect to be required to compile and deliver to the owner a complete set of record drawings. • Owner rep to ensure the contractor is maintaining as-built drawings up to date during the construction process. • A/E to be required to verify existing conditions during the design process. Do not assume, verify.
Root Cause #10 Temp. Structure Requirements	• Architect to include in the construction set of drawings the required temporary structures that have already been identified. • Track milestone schedule to ensure timely deliver of required equipment.
Root Cause #11 Additional Scope of Work	• Asses the effect of the additional scope of work on cost and schedule. • Determine priorities and importance of additional scope of work. • Determine the number and availability of resources to be assigned to the additional scope of work.
Root Cause #12 Weather Issues	• Owner and contractor to discuss and include weather days into the construction schedule.
Root Cause #13 COH Requirements / Inspection Requirements	• Owner to include a standard clause on every bid form. "Contractor is responsible for all permit and inspection costs." This will avoid confusion on responsibility of permit costs. • During project planning, determine who will be responsible for permit revision costs. • Create and maintain a checklist with all COH Requirements. • For every project, determine if COH Requirements are applicable and address accordingly. Include requirements during pre project planning stage.

available ways of making projects more effective and profitable for the aviation industry. This research lends insight into the different options available to minimize and eventually eliminate a significant number of change

orders from the construction process, and in particular, from the aviation industry.

6. CONCLUSIONS

Change is a serious and expensive problem for the construction industry. This study lends insight into the changes that occur in aviation projects, and in particular, the impact that they generate in the construction process. The research presented in this study and other studies [9;11] reaffirm that project change is disruptive and not only affects the project budget; it affects the project schedule, employee productivity, project quality, safety, and performance. In this study, 20 projects and 137 change orders were carefully identified and analyzed in order to produce a new set of best practices that could solely be implemented in aviation projects. It was found that the root causes responsible for all change orders were only a small group of 13 items.

The results of this research provide a simple tool that includes a set of best practice elements for every identified root cause, and a weight allocation system that allows the owner to easily determine which best practices need to be implemented first. It is the owner's single source of responsibility to implement this tool in order to reduce and eventually eliminate a significant number of root causes and improve project schedule, budget, performance, and productivity. The analysis of data provides significant evidence that it is possible to provide an improved control of cost growth during the construction process of every aviation project, and reduce the number of change orders.

It is expected that this study would assist owners and project managers throughout the aviation industry in their understanding of how change orders affect construction projects and how it is possible to control and minimize changes with a structured set of project change management best practices. The results of the presented set of best practice elements targeted to aviation projects and identified in this study will only be made possible through a corporate commitment to embracing the procedures presented and implementing all required steps to eliminate all active root causes.

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