CAUSES OF REWORK IN CALIFORNIA HOSPITAL DESIGN AND PERMITTING: AUGMENTING AN EXISTING TAXONOMY

Peter P. Feng[1] and Iris D. Tommelein[2]

ABSTRACT

Based on the premise that healthcare facility design and construction costs are escalating due to rework in (1) upfront planning, (2) programming, (3) design, and (4) permitting phases, a group of healthcare facility owners, architects, designers, contractors and state permitting personnel conducted a study to understand where the waste occurs. This study identified 158 process waste items. In this paper we categorize these 158 waste items using an existing taxonomy of rework and extending it as needed. The existing taxonomy of rework contains five categories: (1) human resource capability, (2) leadership and communication, (3) engineering and reviews, (4) construction, planning, and scheduling, and (5) material and equipment supply. The extension places waste items into three new categories: (1) planning, programming, and budgeting, (2) design planning and scheduling, and (3) design review.

This research identifies what causes of rework are within the California healthcare facility design and permitting phases. Understanding these waste items provides a foundation on which to build new practices that avoid costly design and permitting delays.

KEY WORDS

Cause and effect diagram, design and permitting, rework, and lean construction.

INTRODUCTION

The delivery of healthcare facilities in California is a complex process. To understand this process the current state of operations were explored. Four hospital owners mapped their facility delivery process and it was determined that each owner had a different way of delivering healthcare facilities in California. These four process maps were consolidated and waste items were identified and documented. The consolidated map and waste items serve as the basis for the work presented in this section (Feng et al. 2009). A team combined the four current state maps and consolidated a list of causes that lead to waste in the permitting phase. This list contained 158 items.

[1] Assistant Professor, Engineering Management Department Air Force Institute of Technology, Dayton, OH 45431, Phone +1 510/292-9786, peter@fengconsultants.com

[2] Director, Project Production Systems Laboratory (http://p2sl.berkeley.edu/) and Professor, Civil and Environmental Engineering Department, 215-A McLaughlin Hall, University of California, Berkeley, CA 94720-1712, Phone +1 510/643-8678, FAX +1 510/643-8919, tommelein@ce.berkeley.edu

METHODOLOGY AND METHODS

Qualitative research explored the causes of rework within the state of California healthcare facility design, permitting, and construction industry. A cause and effect diagram categorizes the causes of rework under Fayek et al. (2004) original five headings and three additional headings. Data was sampled from a series of workshops that developed current and future state maps. The identified waste items were screened for duplication and placed into a two-tiered categorization system.

DATA COLLECTION AND REWORK CLASSIFICATION

Kauro Ishikawa (1982) developed the "fishbone" diagram or cause and effect diagram as a qualitative tool to present cause and effect relationships. In developing process improvements, quantitative tools (such as multiple regression, analysis of variance, and multi-variate charts) can be used to analyze cause and effect relationships. However, use of quantitative tools should be preceded by qualitative analysis to ensure existing knowledge is acquired and quantitative tools are focused in the right direction (Schippers 1999).

Rework has many sources in the construction industry. Figure 1 shows a cause and effect diagram documenting the causes of rework in a facility project. To the right of the dashed line, it shows five categories of rework: (1) human resource capability, (2) leadership and communication, (3) engineering and reviews, (4) construction planning and scheduling, and (5) material and equipment supply.

This taxonomy of rework (figure 1) shows two levels of categories, the first level represents the five main branch headings and the second level the horizontal arrows from each branch of the cause and effect diagram. Fayek et al. (2004) further described the secondary level by a third level of detail (not shown). Their extensive work in the causes of rework lacks causes tied to the design and permitting phases of a project.

Following are our interpretations of the five categories proposed by Fayek et al (2004).

A. Human Resource and Capability focuses on the physical work that is conducted to complete the construction project. It also includes the direct supervision of the field work.

B. Leadership and Communication focuses on the project management team and subsequent communications amongst the team members. It also includes end user buy in, however, it does not include the programming and budgeting process that owners participate in.

C. Engineering and Reviews focuses on the process that occurs between design engineers and how scope changes cause rework. It does not include the interaction that the design engineers have with regulatory agencies.

D. Construction Planning and Scheduling focuses on the execution of field work where designs are implemented. It does not include rework that occurs within the design phase of the project.

E. Material and Equipment Supply focuses on the physical items that are utilized in the construction effort.

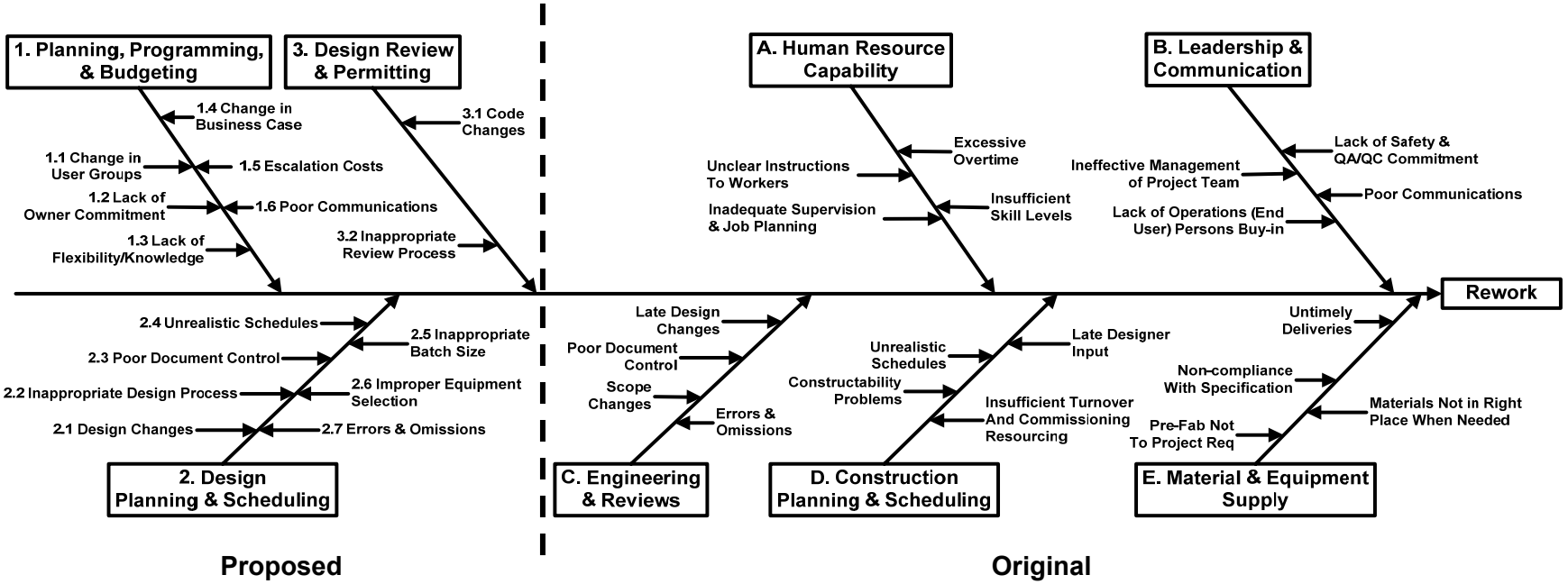

Figure 1: Rework Cause and Effect Diagram

CATEGORIZATION OF REWORK IN DELIVERY OF CALIFORNIA HEALTHCARE FACILITIES

In this paper we propose adding three categories to the existing taxonomy as presented by Fayek et al (2004). In figure 1, our three proposed categories are to the left of the dashed line. The three added categories are located to the left of the original five because the design and permitting phases occur prior to construction.

1. Planning, Programming, and Budgeting (PP&B) focuses on upfront actions including plan validation, a process where major stakeholders verify project budgets, timelines, scope, design, and labor and material costs. This category captures the causes of rework as it pertains to the owner's involvement with the project. This category has six second-level categories.

1.1 *Change in User Groups* causes rework because the design team may have to change the facility layout and functions to accommodate new representatives of the staff. For example, a healthcare facility is trying to persuade a specific doctor to join their staff and promised to provide what he/she wants in a functional space. This leads to late changes in the design and multiple rework iterations because of the long lead time to delivery a facility while staffing occurs in a short lead time.

1.2 *Lack of Owner Commitment* causes rework because the design team does not have clear direction of what user requirements will be. For example, rework may occur because an owner will ask the design team to explore multiple options and then not commit to a specific design because the owner has not committed to a single vision of the facility.

1.3 *Lack of Flexibility and Knowledge* causes rework because the owner will not make concessions on different design options that could support a particular requirement. The design team then makes changes to the design to accommodate owner requirements. For example, an owner initially requests a specific type of medical equipment for a surgical room. The design team accommodates this piece of equipment into the contract drawings. Then, as the facility is in construction, the owner requires a new type of medical equipment and is not flexible in using the original piece of equipment. This issue results in the cycle of technological innovation versus the time it takes to deliver a facility. As the project is being designed and constructed, new medical technology gets developed. Therefore, owners, wanting to provide state-of-the-art medical care will want to decide relatively late in the project to obtain the latest technology, however, this new equipment may require different design requirements resulting in rework. This situation is not unique to healthcare facility construction; Gil et al. (2004) researched this phenomenon in the semiconductor industry. He advocates a judicious postponement of design commitments to reduce waste and increase the reliability of the development process. Design teams can adopt
a wider range of initial design criteria, that accommodates potential technological innovation to prevent downstream rework. However, if not managed properly, an increase in construction rework is likely.

1.4 *Change in Business Case* occurs when an owner revises the business plan which changes the services that the healthcare facility will provide, in response to market forces. For example an owner may change areas to support an additional surgical ward because a nearby hospital closes.

1.5 *Escalation Costs* cause rework. For example, when an owner does not adequately plan for cost escalation, as the project progresses, changes to design have to occur because the current budget cannot support the future facility and the revised business plan.

1.6 *Poor Communication* causes rework. For example, when the needs of the owner are not conveyed to the design team, the design team then has to make assumptions in order to proceed, likely resulting in rework later when owner needs are revealed.

2. Design Planning and Scheduling (DP&S) focuses on the design team and how they process information to complete the facility design. This category captures the rework associated with the design team, and any additional players such as contractors and specialty contractors. This category has seven subcategories.

2.1 *Design Changes* cause rework because the discipline engineers have to rework their designs to accommodate them. These design changes do not include owner driven changes which are a focus of another category.

2.2 An *Inappropriate Design Process* causes rework when information is not properly obtained by discipline engineers. For example, in mechanical design, there is pressure to submit design drawings before they are completed for two reasons (1) to obtain regulatory agency approval and (2) to allow the sheetrock contractor to provide an estimate for their work. Regulatory agency approval is required before a construction permit is granted. Delays in obtaining this permit ultimately delays project completion. The sheetrock estimate is provided to the general contractor and owner to determine the project budget. Then, as the mechanical design is finalized, the completed design can differ from what was shown in previous design iterations which in turn will require another regulatory agency review and rework of the sheetrock estimate.

2.3 *Poor Document Control* causes rework because discipline engineers are not working off the latest set of design assumptions and criteria. For example, in foundation design, a geotechnical report can provide many seismic loading scenarios. Rework occurs when the structural engineer does not have the latest loading scenarios to design the foundation.

2.4 *Unrealistic Schedule* is likely to occur when the design team and other project members do not complete a well thought-out reverse phase schedule. A reverse phase schedule works backward from required intermediate and schedule completion dates. All project members participate in understanding how long each of their design and construction requirements will take. This information is then posted for all to see and information handoffs are clarified and agreed upon. A final schedule is then developed by all project members. A poorly planned reverse phase schedule results in poorly defined handoffs of information between design engineers; which causes rework.

2.5 *Inappropriate Batch Size* refers to the number of drawings that are transferred between discipline engineers or a regulatory agency. For example, a regulatory agency will review any and all drawings that are submitted, so if the design team submits a large batch of drawings that have incomplete information, they may receive comments that require extensive rework. Therefore, if the designers have a smaller set of drawings that are more accurate and complete, only those drawings should be

submitted for agency review, rather than, submitting a large number of drawings that contain errors or lack of information.

2.6 *Improper Equipment Selection* is a cause of rework because medical equipment may require specific design requirements. For example, if the design team or owner selects improper equipment that does not meet user requirements, the discipline engineers will have to rework the design to accommodate the correct type of equipment.

2.7 *Errors and Omissions* cause a cascade of errors in the design leading to rework. For example, an incorrect column size is placed in the design. This error is used to calculate the required eight-foot corridor width in a healthcare facility. Later on in the design, it is discovered that a larger column size will be required resulting in less clearance in a healthcare facility corridor. Since healthcare facility corridors must be at least eight feet wide with no exceptions, if the requirement cannot be met due to the larger column size, then the entire floor space may have to be redesigned.

3. Design Review focuses on rework that occurs within a regulatory agency. This category has two subcategories.

3.1 *Code Changes* cause rework in many situations. Design code changes frequently as new testing and techniques are discovered to provide better quality facilities. For example, a code change may force a structural design change when a new geotechnical analysis is developed that is technologically advanced to calculate seismic loadings. The national geotechnical code requires a geotechnical report for a healthcare facility use the latest analysis techniques. However, the state review code will not adopt the new geotechnical analysis until 2012. This situation causes confusion which leads to the design team not knowing which code to use and ultimately having to conduct rework to analyze the structure using the correct code requirements.

3.2 An *Inappropriate Review Process* causes rework. For example, the fire, life, and safety reviewer requires the design team to provide explicit information on the door hardware, when designers are not yet ready to provide it. If the design team provides that information to accommodate the plan reviewer and the door hardware has to be changed, rework for the design team and the plan reviewer will occur.

ANALYSIS AND RESULTS

We categorized the 158 waste items and developed figure 2 to show the relative contributions of each of the rework categories. For example, planning, programming, and budgeting resulted in 28% (42 items) of the 158 waste items.

Figure 2 shows six categories, three from the original taxonomy framework and the three extension categories. The two original categories of (1) human resource capability and (2) engineering and reviews were not necessary in categorizing the causes of rework in California healthcare facility design and permitting because no occurrences met those category descriptions. The three original taxonomy categories used in this research are (1) construction, planning, and scheduling <1%, (2) material and equipment supply 3%, and (3) leadership and communication 1%.

Figure 2 shows the largest contributors of rework in the design and permitting phase of a project are (1) *Design Planning and Scheduling* 51%, (2) *Planning, Programming, and Budgeting* 28%, and (3) *Design Review* 17%.

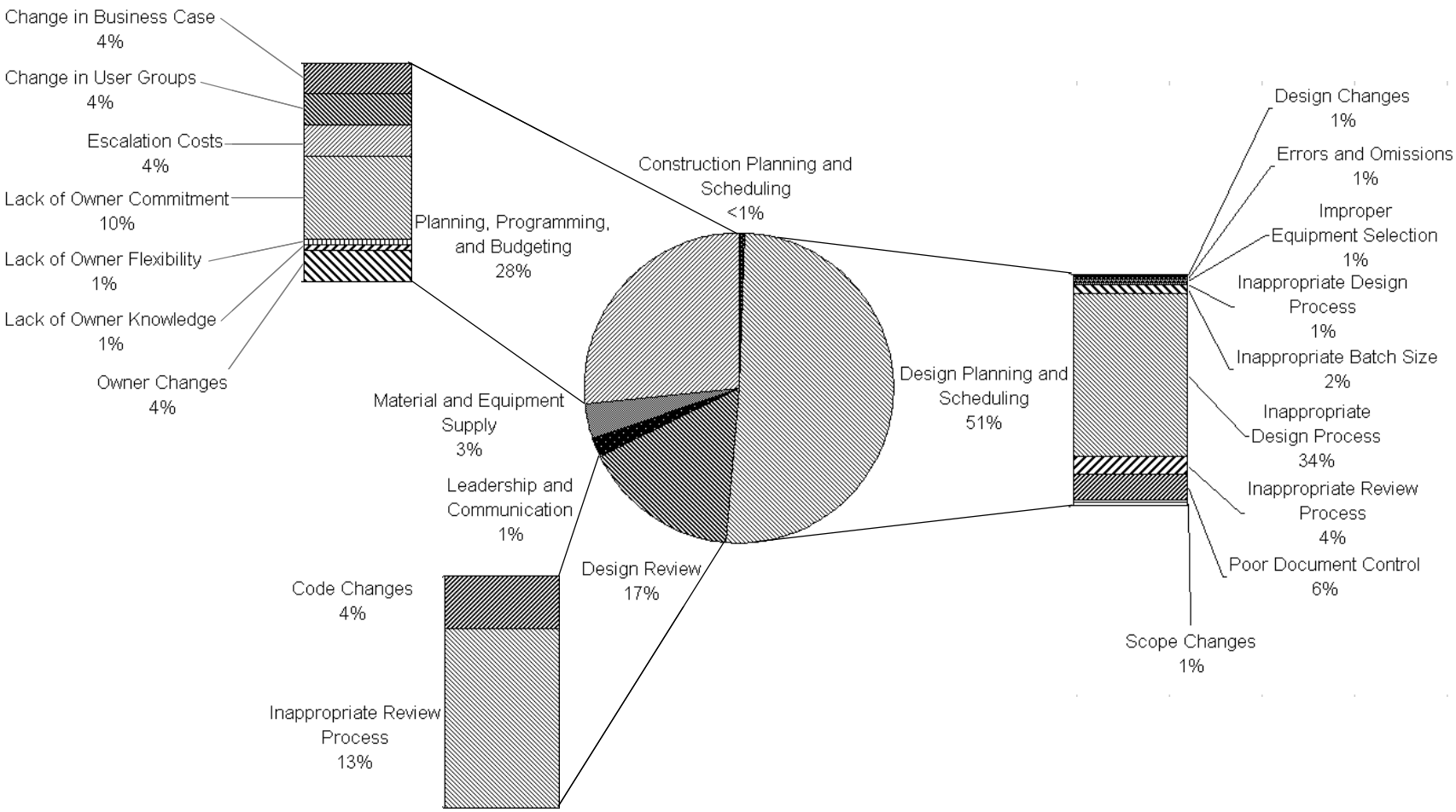

Figure 2: Relative Contribution of Rework

This figure reinforces industry comments in regards to rework, "we do it to ourselves," because much of the rework is in the control of the design team. Controlling the *Planning, Programming, and Budgeting* aspects of facility construction are directly attributable to facility owners, yet there is always a need or want to allow for flexible programs. We do not propose that business case programs be inflexible, in fact, we support flexible programs that will ensure state of the art healthcare services, nevertheless, owners must understand there can be a price for program flexibility such as increases in rework, project cost, and project delay. However, the impact of program flexibility may be reduced if proper set-based design techniques or delayed commitments strategies are applied. *Design Planning and Scheduling* is responsible for 51% of the causes of rework. The design process contains many areas where waste can be eliminated.

Design Review makes up 17% of the rework causes. An effort by a state regulatory agency to improve the review process that will remove causes of rework from all three proposed categories is currently underway. However, improving *Design Planning and Scheduling* may have the greatest effect in reducing rework in the process of permitting healthcare facilities. Improving can occur if owners take the time to properly plan, program, and budget for their facilities, (which will reduce the time to permit).

RELATIVE CONTRIBUTION ANALYSIS

The relative contribution analysis mirrors the process, analysis and results conducted by Fayek et al. (2004). The analysis is based on the contribution of each rework cause to the overall number of rework occurrences (158). The sum of all rework percentages is equal to 100%. Figure 2 shows the percentages of the second level causes that contribute to the first level cause of rework. For example in figure 2, *Planning, Programming, and Budgeting* (PPB) contributes 28% to the total rework causes. We attributed 10% of the 28%, to *Lack of Owner Commitment*, 4% to *Owner Changes*, 4% to *Change in Business Case*, and 4% to *Change in User Groups*. A *Lack of Owner Commitment* occurs when the design team is waiting for owner decisions and approvals. Healthcare facility owners want to provide the best, most appropriate healthcare facility and may require additional effort in making final design decisions; however, this delay can impact project design. For example, conflicts between multiple owners on space use decisions can cause rework. This conflict may arise, for example, from an unresolved business program, poor project definition, and lack of commitment to facility scope.

Design Review resulted in 17% of the rework causes, 13% is due to *Inappropriate Review Processes,* and 4% to *Code Changes*. Some examples of *Inappropriate Review Processes* are incomplete reviews, inappropriate coordination of review, lack of documentation and agreements on code interpretation, and reviewer preference of solutions. An inappropriate review process also includes lack of consistency in review staff, interpretation of code by field staff, and gaps between reviews (loss of knowledge or familiarity).

Design Planning and Scheduling resulted in the majority of rework causes at 51%. Of this 51%, 34% is due to *Inappropriate Design Processes*, 6% to *Poor Document Control* and 4% to *Inappropriate Review Processes* of drawings prior to regulatory agency submission.

An *Inappropriate Design Process* includes incomplete designs, e.g., where drawings are not complete due to a lack of coordination between design team members. It also includes exploring design options outside of project scope and failing to identify alternative methods of compliance. An alternative method of compliance is where the design team feels they can meet a code requirement using a different method from a prescribed standard design solution, however, the approval process for an alternative method of compliance can take up to one year. In California, depending on the situation, an alternative method of compliance can require additional regulatory agencies to review the proposed design solution for code adequacy. These additional regulatory reviews add time to the design and permitting process. However, during this regulatory review time, the design team continues to design the facility. If the alternative method of compliance is determined inadequate, the design team must find another design solution. Therefore, failing to identify alternative methods of compliance early in the design and permitting process is a major cause of rework. Other causes falling under an *Inappropriate Design Process* are improper timing of equipment selections, undefined information needed by team members, and incorrect drawings provided for a desired purpose.

SUMMARY

Process waste items identified from the design and permitting process for healthcare facilities in California were categorized using an existing rework taxonomy. The existing taxonomy lacked categories to capture causes of rework in the design and permitting phase. This paper proposed three additional categories (1) *Planning, Programming, and Budgeting*, (2) *Design Planning and Scheduling*, and (3) *Design Review and Permitting*. Industry practitioners can use this research to better understand where rework is caused in the design and permitting of healthcare facility projects. Improved management techniques can be developed using this research to involve regulatory agencies earlier in design to avoid the embedding of errors in design, which in turn reduces rework and permitting time.

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