CAUSES OF TIME BUFFER IN CONSTRUCTION PROJECT TASK DURATIONS

Marion M. Russell[1], Greg Howell[2] Simon M. Hsiang[3], and Min Liu[4]

ABSTRACT

Due to the inherent nature of the construction industry, all construction projects have some amount and type of uncertainty. Personnel involved with the project compensate for the uncertainty by adding buffers. This research is focused on "time buffers" added to construction task durations. We define "time buffer" as time added to task durations to compensate for uncertainty and protect against variation. Although previous research acknowledges this addition of time buffer, the root causes of buffer have not been thoroughly researched. The research objectives include determining which factors are the most prevalent and severe causes of buffer and determining opinion differences amongst various groups.

A survey was developed and then completed by 180 construction personnel across the United States. The top twelve most frequent and severe causes of buffer in task durations were identified. The factors were analysed in how they are viewed differently by foremen, superintendents, and project managers; trade to trade; general contractors to subcontractors; level of experience; and companies regularly using the Last Planner System® and those who do not.

The findings will help construction managers understand what drives the need for buffer in construction schedules and focus efforts on strategically addressing critical areas of concern or uncertainty.

KEYWORDS

Buffer, uncertainty, time, variation

INTRODUCTION

There exists a natural tendency in construction to add buffer to tasks due to the inherent uncertainty and resulting variability which exists in construction. While there are several types of buffers, the focus of this research is the study of time buffers added to individual construction project task durations by construction personnel to compensate for uncertainty and absorb potential variation. It seems evident that buffers are used in construction, but the underlying causes of time buffers, both the frequency and severity thereof, are unclear. Although we probably cannot

1 Graduate Student, Department of Civil, Construction, and Environmental Engineering, North Carolina State University, Raleigh, NC 27695-7908. PH (757) 218-3425; E-mail: mmrusse2@ncsu.edu

2 President,Lean Construction Institute. PH(208)726-9989; E-mail: ghowell@leanconstruction.org

3 Derr Professor, Industrial Engineering, Texas Tech University, Lubbock, TX 79409, PH (806) 742-3543; E-Mail: simon.hsiang@ttu.edu

4 Assistant Professor, Department of Civil, Construction, and Environmental Engineering, North Carolina State University, Raleigh, NC 27695-7908. PH (919) 513-7920; E-mail: min_liu@ncsu.edu, Corresponding author

eliminate all uncertainty and associated time buffer, understanding and addressing the root causes of time buffer will help us to allocate it where it is needed most and consequently reduce project durations costs. There are two primary objectives discussed in this paper:

Objective 1: Determine which factors are the most prevalent and severe causes of time buffer being included in construction task durations.

Objective 2: Determine the differences in opinion and perception between different levels of management, different trades, different levels of experience, the difference between general contractors and subcontractors, and the difference between contractors using traditional management approaches and those using lean construction techniques.

LITERATURE REVIEW

When addressing a topic such as buffer, there is great importance in first clearly defining it. There are several definitions of buffer in construction literature as well as several types of buffer. Hornby (1974) wrote that a buffer is an apparatus for lessening the effect of some impact. Horman and Kenley (1998) defined buffer as an allowance used to accommodate the impact of unexpected influences and other difficulties encountered in a construction project. Alves and Tommelein (2004) define buffers concisely as resource cushions, i.e., money, time, materials, space, etc., used to protect processes against variation and resource starvation. According to Ballard and Howell, buffers operate to provide a cushion or shield against the negative impact of disruptions and variability (Howell et al. 1993; Ballard and Howell 1995). Ballard (2005) has called construction one type of production system, albeit one of greater complexity and uncertainty, that uses various types of buffer to absorb variation that occurs due to uncertainty in construction projects.

Construction literature focuses on four main types of buffer. Hopp and Spearman (2008) list inventory, capacity, and time as three types of buffer. Ballard and Howell (1995) introduced a fourth type of buffer called plan buffer. The focus of this research is the “within activity” time buffer that is an amount of extra time added to individual task durations to compensate for uncertainty and protect against variation.

In addition to research group discussions, direct input from construction personnel, and pilot study feedback, an extensive literature review was conducted to develop a baseline of factors that may cause time buffer to be added to task durations. The literature review included factors considered in the planning stage and those factors which affect construction productivity. One area reviewed dealt with factors resulting in the addition of cost contingency to a project budget. Cost contingency is defined as an amount of money reserved to pay for unforeseen design or construction costs in the project (Risner 2010). Smith and Bohn’s (1999) investigation of contract contingency included factors such as scope changes, specifications, design quality, damaged or late materials, resource availability, site access, delays in addressing problems, quality problems, poor productivity, weather, and construction methods. Mak and Picken (2000) used risk analysis to determine site conditions, access, additional client requirements (scope changes), contract period, and project coordination as contributing to uncertainty associated with a specific project. Harbuck (2004) documented cost variation associated factors such as design errors and changes, specification requirements, differing site conditions, delays, scope changes, and permits. Günhan and Arditi (2007) listed project complexity, inherent uncertainty in the performance of the parties involved, design and scope changes, permit issues, differing site conditions, schedule constraints, and constructability issues as examples of contingency driving factors. Chan and Au (2009) studied factors relevant to our study of time buffer such as project size, project complexity, construction method, degree of difficulty, labor reliability, labor availability, project duration (contract period), and site constraints. Risner (2010) discusses design errors and omissions, scope changes, and unforeseen field conditions as factors driving cost contingency. Just as cost contingency considers the impacts of uncertainty and potential variation related to these factors, construction personnel may too consider many of the same factors when determining time buffer to add to their task durations.

Factors which affect construction productivity are equally important in developing a thorough list of factors for investigation. There has been a significant amount of research done in reference to factors affecting construction productivity. Borcherding and Gardner (1981) identified material and tool availability, rework, overcrowded work areas, inspection delays, foreman incompetence, crew interference and turnover, and foreman changes as the top factors affecting productivity. Researchers in the 1990s identified scope, work content, work complexity, design features, specifications, rework, materials, tools, construction equipment, information, weather, site congestion, crew size and skill, design accuracy, degree of repetition, working conditions, and site access as factors affecting productivity (Thomas and Sakarcan 1994, Portas and AbouRizk 1997, Somnez and Rowlings 1998). In the last decade, research has found additional factors to include scheduling, manpower experience and motivation, scope changes, lack of detailed planning, inadequate supervision, lack of information, lack of foreman planning and communication skills, poor communication between foremen and project managers, engineering drawing management, lack of craft level technical training, poor quality of plans and specifications, slow response to questions, and lack of qualified labor (Rojas and Aramvareekul 2003, Liberda et al. 2003, Dai et al. 2009, and Kimpland 2009). Wambeke (2011) completed a thorough literature review of productivity factors including the factors previously mentioned to identify 166 factors. He cross-referenced and reduced those factors to 50 causes of variation which were also used to help develop a baseline of time buffer factors for the survey in this research. Current literature does not address the perceived frequency and severity of the root causes for the addition of time buffer.

METHODOLOGY

A survey was developed to study which causes of uncertainty or concerns about potential for variation result in the most frequent and severe addition of time buffer in construction task durations. Through a combination of the literature review and research team discussions with construction project managers, superintendents, and foremen, 47 individual factors related to time buffer in construction tasks were identified and included in the survey. Emphasis in determining the final list of factors was placed on selecting the most relevant factors from a prospective view during the planning or pre-task time frame. In other words, which factors construction personnel are concerned about or perceive as potential for problems due to uncertainty as they assign task durations. The seven categories that impact productivity established by

Koskela (2000) to include connected work, detailed construction design, components and materials, workers, equipment and tools, space, and external conditions, along with Wambeke's (2011) added eighth category of management-supervision-information flow were used as a framework to separate the 47 buffer factors. Based on the nature of some of the identified buffer factors, the researcher also felt it was necessary to add one additional category: project characteristics. The nine categories are listed and described below:

1) Project Characteristics: Pertains to concerns/uncertainty about characteristics specific to the project and one's trade.
2) Prerequisite Work: Pertains to items that must be completed before one can start their task.
3) Detailed Design / Working Method: Pertains to concerns/uncertainty about having an accurate and available design and a feasible working method.
4) Labor Force: Pertains to concerns/uncertainty about availability, reliability, and capability of the labor force to complete the required task.
5) Equipment and Tools: Pertains to concerns/uncertainty about the availability, reliability, and capability of required equipment and tools.
6) Material and Components: Pertains to concerns/uncertainty about receiving the correct and necessary materials from the supplier.
7) Work / Jobsite Conditions: Pertains to concerns/uncertainty about the physical space available to perform one's job.
8) Management/Supervision/Information Flow: Pertains to concerns/uncertainty about the management system regarding issues related to communication, trust, changes, and getting questions answered when they arise.
9) Weather: Pertains to concerns/uncertainty about the climate at the location of the project and what weather conditions are prevalent.

The 47 potential reasons for adding buffer to construction task duration estimates were assigned to the appropriate category above. Table 1 displays the entire list of buffer factors and to which of the nine categories they belong.

A contractor general information survey and a time buffer survey were developed to answer the research questions. The contractor general information survey collected information such as the company type (subcontractor or general contractor), company size, annual revenue, average project size, backlog or pending work, and whether or not they use the Last Planner System©. The time buffer survey collected responses from construction personnel at three different levels of management: project managers, superintendents, and foremen. Participants were asked to provide background information such as their trade, position, and experience. For each factor, the respondent was asked how frequently the factor influences their duration estimate by circling one of the following seven frequency responses: never, rarely, occasionally, sometimes, frequently, usually, or always. Next for each factor, the respondent was asked to consider a two week (10 day) activity and estimate how much time (days) they would include or allocate for the given factor in their duration estimate to protect against the effects of uncertainty. The respondents chose one of the following seven severity responses: 0, 0.5, 1, 2, 3, 5, or 7. The decision to use seven choices for both frequency and severity was made to balance having too many choices with still being able to capture just noticeable differences.

Table 1: Time Buffer Factors

1. Factors Related to Project Characteristics: Contract delivery method Contract period Size of project Complexity of the project (interdependency of activities) Complexity of the task for your trade (degree of difficulty/inherent nature of your work) Size of your company
2. Factors Related to Prerequisite Work: Delays in obtaining permits for a specific part of task Completion of prerequisite work (work before you is not done yet) Rework being required due to quality of prerequisite work Delays in inspections for previously completed work
3. Factors Related to Detailed Design / Working Method: Design constructability Quality of documents (Design errors/omissions, differing site conditions, & dsn issues requiring additional time or RFI) Poor performance due to unfamiliarity with the scope of work Strict specification requirements Quality control requirements Low degree of repetition in your tasks (inability to develop efficient system due to task constantly changing)
4. Factors Related to Labor Force: Reliability of your labor force (concerns about absenteeism, people arriving late and/or leaving early) Availability of your labor force (crew size limited or inadequate possibly due to other tasks/projects) Inefficiencies in your crew due to lacking experience/skills Concerns about being pushed into using more manpower and creating inefficiencies Low morale or lack of motivation Language barrier among workers/supervisors
5. Factors Related to Equipment and Tools: Reliability of your trade's equipment and/or tools (tendency to breakdown, old/worn out inventory) Availability of your trade's equipment and/or tools (inventory maintained by your company) Capability (productivity) of your trade's equipment and tools Time required to repair equipment if breakdown occurs Time required to replace equipment if breakdown occurs
6. Factors Related to Materials and Components: Receiving incorrect quantity of materials Receiving incorrect material type or damaged materials Receiving materials for task later than expected/planned
7. Factors Related to Work / Jobsite Conditions: Overcrowded or cluttered work area/jobsite congestion Difficult access to work area Method of material transfer required from receiving area to task location (i.e – crane, construction elevator, hand carry) Distance of material transfer required from receiving area to task location (i.e – one story versus ten story project)
8. Factors Related to Management / Supervision / Information Flow: Confidence in request for information (RFI) process Liability pressure (liquidated damages, contractual deadlines, etc) Preparing for duration negotiation (knowing management will request the task be done in shorter duration) Positive company recognition Trust in superintendent (based on their reputation, experience, knowledge, and/or experience you have had with them) Trust in project manager (based on their reputation, experience, knowledge, and/or experience you have had with them) Trust in owner (based on their reputation, experience, knowledge, and/or experience you have had with them) Required coordination with other trades Changes in scope of work (tendency of owner to make changes) Communication between owner/engineer and project manager Communication between project manager/superintendent and foreman Communication between foreman and workers
9. Factors Related to Weather: Climate – weather conditions such as temperature, rain, and wind associated with the location of the project

A pilot study was conducted with a construction company in Colorado as well as a local construction company to help avoid potential problems associated with the length, clarity of the questions, and the instructions provided for completion of the survey. A total of 175 different companies across 37 states received the survey and request for completion during the summer of 2011. The survey period ran approximately 10 weeks from 1 August 2011 until 14 October 2011.

SURVEY RESPONSE

The final count of useable surveys was 180 surveys from 36 different companies including both general contractors and subcontractors. General contractors made up 28% of the participating companies and subcontractors the other 72%. Project managers accounted for 51% of the responses, superintendents completed 27% of the surveys, and foremen the other 22%. The trades were separated into four trade groups for comparison. The utilities category includes the mechanical, electrical, plumbing, and fire protection trades and accounted for 44% of the responses. The structural category includes the steel, concrete, masonry, roofing, and earthwork trades and accounted for 22% of the responses. The finishes/surfaces category includes carpentry, drywall, ceiling, painting, and glazing and accounted for 17% of the responses. The last category was for the general contractors who are responsible for multiple trades. This category accounted for the remaining 17% of responses.

SURVEY ANALYSIS

The top twelve (i.e the top 25%) frequency factors and severity factors are summarized in Table 2. A few of the top ranked factors are consistent with previous research. Lee et al. (2006) found that design errors (quality of documents) and changes (tendency of scope changes) are two of the main factors that cause uncertainty in construction. Chan and Au (2009) found project complexity to be one of the most important factors that contractors consider when they are pricing time-related contract risks. Through the results of a case study, Wambeke (2011) found material delivery (late materials) to be a severe cause of task variation. Additionally, one factor just outside the top twelve at thirteen, the request for information process, is consistent with Kimpland's (2009) finding that "slow responses to questions" was one of the top external factors that impacted productivity and led to uncertainty. The top three factors, project complexity, complexity of trade task, and quality of documents, are the same for both frequency and severity, but in a slightly different order. The factors of required coordination with other trades, contract period, material transfer distance, material transfer method, and work area access are highly ranked frequency factors that do not show up in the top twelve severity factors. Conversely, the factors of strict specification requirements, quality control requirements, low degree of repetition, and late materials are highly ranked severity factor that are not included in the top twelve frequency factors.

The survey results do not allow us to determine a specific frequency or buffer amount for each factor as participants were asked to consider the factors one by one and independent of each other. Construction personnel likely consider multiple factors at once when estimating task durations. However, the survey responses do allow for a comparison of the average frequency and average severity among different groups. The first comparison made was between the different levels of management – project managers, superintendents, and foremen. A total of 17 factors were required to capture the top twelve most frequent causes and a total of 18 factors were required to capture the top twelve most severe causes for each level of management. The top twelve (~25%) were included to highlight the differences in perception for causes outside of the top five. The top five most frequent and the top three most severe causes were nearly identical aside from occurring in a slightly different order. Beyond those, there were some noticeable differences amongst the

Table 2: Overall Top Twelve Most Frequent and Severe Causes of Time Buffer

FACTOR	AVG FREQ	CATEGORY	FACTOR	AVG SEV	CATEGORY
Project Complexity	3.90	Project Characteristics	Quality of Documents	2.14	Detailed Design/Working Method
Complexity of Trade Task	3.79	Project Characteristics	Project Complexity	1.93	Project Characteristics
Quality of Documents	3.54	Detailed Design/Working Method	Complexity of Trade Task	1.91	Project Characteristics
Size of Project	3.32	Project Characteristics	Tendency of Scope Changes	1.61	Management/Supervision/Info Flow
Required Coordination w/ Other Trades	3.23	Management/Supervision/Info Flow	Weather/Climate	1.56	Weather
Contract Period	3.11	Project Characteristics	Design Constructability	1.44	Detailed Design/Working Method
Design Constructability	3.01	Detailed Design/Working Method	Size of Project	1.41	Project Characteristics
Tendency of Scope Changes	2.93	Management/Supervision/Info Flow	Work Area Access	1.35	Work/Jobsite Conditions
Material Transfer Distance	2.90	Work/Jobsite Conditions	Strict Specification Requirements	1.34	Detailed Design/Working Method
Material Transfer Method	2.88	Work/Jobsite Conditions	Quality Control Requirements	1.24	Detailed Design/Working Method
Work Area Access	2.84	Work/Jobsite Conditions	Low Degree of Repitition	1.24	Detailed Design/Working Method
Weather/Climate	2.84	Weather	Late Materials	1.24	Materials and Components

levels of management. In regards to frequency, foremen ranked required coordination with other trades as 3rd most important; however, superintendents and project managers ranked this factor 4th and 6th respectively. This difference is possibly a result of the foremen being more involved in those coordination efforts than higher management levels. Perhaps for a similar reason, material transfer distance and method were ranked higher by the foremen than superintendents or project managers. Another big difference between foremen and the superintendents and project managers was in the factors of overcrowded jobsite and request for information process. Foremen ranked these 10th and 11th respectively while overcrowded jobsite came in at 16th for superintendents and project managers and request for information process came in at 25th for superintendents and 22nd for project managers. The tendency of scope changes ranked 7th among foremen and superintendents, but only 15th for project managers. Conversely, work area access was more important to project managers (8th) than superintendents (12th) and foremen (14th), perhaps due to their responsibility for the entire construction site rather than smaller work areas. Liability pressure was a much greater concern for superintendents (10th) and project managers (18th) than foremen (36th).

The severity or magnitude of buffers due to uncertainty related to scope changes was the #1 most severe factor for foreman and ranked 6th for superintendents and 8th for project managers. Also, required coordination with other trades was again a high emphasis factor for foreman coming in at 4th, while superintendents ranked it 24th and project managers ranked it 15th. Overall the results indicated a perception of larger frequency and severity of uncertainty as you move from project manager to the superintendent to the foreman. One area not highlighted by the top twelve most frequent or severe causes is the much greater emphasis put on materials, equipment, and labor by the foremen than the superintendents or project managers. For example, foremen ranked the frequency of crew inefficiencies, labor reliability, and labor availability 14th, 15th, and 17th respectively. Superintendents ranked those same three factors 32nd, 31st, and 27th, while project managers ranked them 36th, 40th, and 23rd. Here, those actually doing the work are most concerned about the resources it will take to complete the work.

The next four comparisons are summarized in the following discussions. As discussed previously, the trades were organized into groups of similar nature or scope.

The expectation was for the utilities trades to have greater frequency of concern for the uncertainty caused by the 47 factors and greater magnitude of time buffer in their task durations. Upon examining the survey results by trade group, the utilities trades were found to have the largest frequency and severity for the time buffer factors. The structural trade groups were second and the finishes trade third.

The researchers also hypothesized that the experience level of the participants may result in different perceptions. Specifically, the least experienced (grouped by 5 years or less) participants would be concerned about more of the factors more frequently and buffer with greater magnitude. The least experienced group was compared to a group of 5-25 years of experience and a group of greater than 25 years of experience. The survey results found that there was not a large percentage difference between the least experienced and the more experienced in regards to frequency, but the least experienced group buffered with nearly 30% more magnitude (severity) than the more experienced groups. General contractors as well as subcontractors participated in the survey. The scopes and areas of responsibility are different for these two entities in the completion of construction projects. Overall, the frequency for general contractors and subcontractors only differed by about 8% with the subcontractors buffering slightly more frequently. The general contractors buffered more frequently for all project characteristics factors. This finding is expected as the general contractors are responsible for the entire project scope and all of the involved subcontractors. The subcontractors on the other hand were more frequently concerned about the materials, equipment, labor, and work/jobsite condition factors than the general contractors. Subcontractors perceived the need to buffer with 30% greater magnitude than the general contractors.

A goal of using the Last Planner System is to reduce variation that occurs as a result of uncertainty and unreliable planning. Reducing the variation should also lead to a reduced need for time buffer in construction task durations. The survey results showed that those using LPS on their construction projects had a lower frequency on 72% of the factors and a smaller amount of buffer on 85% of the factors. This result is interesting and merits further investigation into the effects and benefits of using LPS to achieve reliable planning and reduce buffer amounts in task duration estimates.

CONCLUSION

This research addressed two main objectives, and the results have led to further questions for investigation. First, the overall top most frequent and severe causes of time buffer were identified. The top twelve most frequent causes of time buffer were: project complexity, complexity of the trade task, quality of documents, size of the project, required coordination with other trades, contract period, design constructability, tendency of scope changes, material transfer distance, material transfer method, work area access, weather/climate. The top twelve most severe causes of time buffer were: quality of documents, project complexity, complexity of trade task, tendency of scope changes, weather/climate, design constructability, size of the project, work area access, strict specification requirements, quality control requirements, low degree of repetition, and late materials. Most of the top overall factors are associated with such intangibles as information and communication. In fact only “late materials” is directly a resource (materials, equipment, labor) concern. Galbraith (1977) and others have long pointed out the requirement for increased and improved information flow under conditions of uncertainty such as those in the construction industry. Howell et al. (1993) noted that construction can be thought of as a process of reducing the aforementioned uncertainty through effectively communicating and processing information and making decisions. Based on the survey results, there is a need for emphasis on improving this communication and information flow in construction.

The second objective involved comparing the differences in opinion and perception between different survey groups. Overall, the frequency and severity increases as you move from project manager to the superintendent to the foremen. Acknowledging and understanding this difference in perceptions is important for construction managers as they plan and carry out their projects. The survey analysis also highlighted larger frequency and severity of time buffer perceived by trades with more complex tasks and greater interdependency such as mechanical, electrical, and plumbing. Experience was also shown to impact how much time buffer is included in construction task durations. Limited experience (5 years or less) resulted in adding a larger amount of time buffer. Due to the differences in scope and responsibilities, general contractors and subcontractors were compared to expose the differences in their perceptions. A final comparison between construction personnel who use lean construction techniques such as the Last Planner System© (LPS©) and those using traditional construction planning techniques was made.

Uncertainty inherent in construction results in variability in the work flow and also a tendency to protect against such variability by the use of buffers. This research studied one such buffer: time buffer in construction task durations. Identifying these root causes and their frequency and severity is an important aspect for construction managers in revealing potential problem areas and inefficiencies in their construction processes.

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