A Case Study for Visualizing Skipped and Out-of-Sequence Work

William Ibbs[1], L.M. ASCE, Mark Berry, JD[2], and Xiaodan Sun[3]

Abstract

Skipped and out-of-sequence work on construction projects is disruptive to work flow and damaging to labor productivity. It is a condition in which the originally planned, and probably most efficient and logical, work sequence is interrupted and changed. Change is a common reason for such circumstances. It may induce or force a contractor to skip work in an effort to progress the work, and advance the schedule by continuing work efforts rather than demobilizing until the delay caused by the change is resolved. As a result, the contractor may need to re-arrange its work sequences to accommodate change or shorten the work schedule, and that may force workers to change means-and-methods or crew mix. That may in turn may create productivity loss, increase project costs, reduce profits for contractors, and reduce project value for owners.

To recover damages from decreased productivity resulting from out-of-sequence performance, a causal link must be demonstrated between disrupted performance and decreased productivity. Visualization of the disruption helps demonstrate the impact of skips and out-of-sequence work and establish that causal link. This paper presents a way the authors have used to visualize and analyze such out-of-sequence work. This paper is intended for owners, contractors,

[1] Professor of Construction Management, Dept. of Civ. and Environ. Engr., Univ. of Calif., Berkeley CA 94720; and President, The Ibbs Consulting Group, Inc. Oakland CA 94618. Bill@IbbsConsulting.com

[2] President, Delta Construction Project Management, Inc. (Delta CPM), Sacramento CA 95816. MB@DeltaCPM.com

[3] Ph.D. Candidate, Dept. of Civ. and Environ. Engr. Univ. of Calif., Berkeley CA 94720. sxd929@berkeley.edu

and other professionals who are interested in construction change and loss of productivity claims.

Introduction

Skipped and out-of-sequence work on construction projects is disruptive to work flow and damaging to labor productivity (American Association of Cost Engineers, AACE 2004). Out-of-sequence work is a condition in which the originally planned, and probably most efficient and logical, work sequence is interrupted and changed. Change, which has been defined as a variation from the original contract expectation or what would be a reasonable plan, is a common reason for such circumstances (Ibbs 2005). The US Government's Federal Acquisition Regulations (FAR 1984) recognize change may arise from many different sources, including but not limited to changes to the project's specifications, plans or design; furnished facilities, equipment, materials, services or site; time of performance (delay, suspension, acceleration, constructive acceleration); and construction means and methods (U.S. Government 1984).[i]

Such changes may induce or force a contractor to skip a scheduled work activity in an effort to progress the work, and advance the schedule by continuing work efforts rather than suspending work on the scheduled activity or demobilizing until the delay caused by the change is resolved. As a result of continuing to work despite the change, the contractor may need to re-arrange its work sequences to accommodate change or shorten the work schedule. That may in turn create a directed or constructive acceleration condition, which may force workers to change means-and-methods or expected crew mix which may result in productivity loss, increase project costs, reduce profits for contractors, and reduce project value for owners (Lee 2007 and Ibbs and McEniry 2008).

Productivity or efficiency can be impacted in various ways as a result of work performed in a sequence which differs from that originally anticipated. For example, out-of-sequence performance can decrease productivity as a result of additional time expended on the task moving back and forth to it and also indirectly due to transporting employees, retraining employees, reorienting workers to the tasks skipped over, and completing or and correcting deficient work. There is also the phenomenon that without complete unencumbered access to a task workers pace themselves during the day to work as is available. Out of sequence work can also create circumstances where what was originally planned to be successor work is erected and obstructs the originally planned predecessor work. It can also cause demoralization of workers, which in turn also hurts productivity. All this can lead to prolonged time and increased labor hours to compete planned schedule tasks.

Contractors generally have the right to perform their work according to their reasonable bid and schedule expectations as along as it is consistent with the contract intent. A deviation from that plan may result in dispute and even claim. To succeed in proving their claim and rights to compensation, they have to demonstrate causation, liability, and damages.[ii] Of these three elements, causation generally has the strictest standard and is most difficult to demonstrate (Ibbs and Nguyen 2011).

To recover for decreased productivity resulting from out-of-sequence performance, a causal link must be demonstrated between the disrupted performance and the decreased productivity. Visualization of the disruption helps to demonstrate the impact of skips and out-of-sequence work and establish that causal link. There is a need for such a visualization tool.

The purpose of this paper is to introduce a way the authors have used to visualize and analyze such out-of-sequence work. The methodology is not necessarily based on the presumption that the originally-planned work sequence is an efficient approach to the work and consistent with the contract requirements. If the original plan is deficient, the presented methodology can still work on a corrected plan by first correcting such deficiencies.

This paper is intended for owners, contractors, consultants, and other professionals who are interested in construction change and loss of productivity claims. The methodology introduced does not prove productivity loss in an ironclad manner but when presented with labor data that indicate a productivity loss and the inclusion of all known impacts from the project records, the plaintiff can better demonstrate inefficient out of sequence work occurred and illustrate an association between the skips, their causes, and diminished productivity.

Previous Work

Academic and Industry Studies

Disruptions resulting from work skips can be inefficient and impair labor productivity (Ibbs and McEniry 2008). When crews or tradespersons are demobilized from an area or schedule activity before its anticipated completion and mobilized to another activity, non-productive labor is expended. This is true because no permanent work is installed while time is spent demobilizing, mobilizing on to another activity, then remobilizing back to the originally skipped activity. This out-of-sequence disruption is compounded when the skipped-to activity is also not completed and the initial activity is returned to or another new activity is started. These decisions are sometimes schedule-driven but are also driven by considerations of keeping crews engaged on work that may be available.

Field experience is such that when crews encounter a change, they very likely may slow down to contact supervision to determine if an immediate solution is available. If not they may decide or seek direction to move to an alternate task, relocate equipment, tools and materials to the new task location, review and become oriented to the plans and field conditions for the new task, and finally commence work on the new task as productively as possible.

A proper out-of-sequence work analysis depicts the demobilization, mobilization, demobilization and remobilization among activities on perhaps smaller (piecemeal) portions of the original tasks. Work performed in this manner is typically less productive due to the higher percentage of demobilization and remobilization time (labor hours) expended per productive time worked on the task. Because out-of-sequence events cause contract work to be piecemealed into shorter intervals than planned, losses arise from the time lost on associated unplanned demobilizations and remobilizations. As a consequence, the project's rhythm may also be interrupted. Of course, a certain number of demobilizations and mobilizations is normal and generally included in a contractor's estimating units. However, when the number of out-of-sequence moves from one activity to another increases abnormally, the productivity loss for each demobilization and remobilization from the activity will exceed that anticipated by the parties at the time of contracting.

Numerous researchers have written about skipping and out-of-sequence work and its negative effect on labor productivity. AACE (2004) listed out-of-sequence work as one of common cause of lost productivity and gave an example that crews moving around the site haphazardly might negatively affect efficiency. The Mechanical Contractors Association of American listed change of sequence as one of sixteen types of changes that might result in productivity loss (MCAA 2016). It noted that crew congestion, trade stacking, and error and omissions might also result from such skipping. The National Electrical Contractors Association (Hanna et al 1997), has also addressed the subject.[iii]

Long (2005) listed out-of-sequence work as one of the site environment changes that the contractor should record. He suggested comparing as-planned and as-built schedules to understand which activities were performed out-of-sequence. Comparing schedules though only presents the timing and duration of a change; e.g. Activity B was started ahead of Activity A or took longer than anticipated. It does not fully present the labor-dimension as clearly; e.g. workers had to move from Activity A before they were finished so as to work on Activity B for a period of time, and then back again, perhaps multiple times.

Many previous studies have tried to develop approaches quantifying the impact of out-of-sequence work without graphically demonstrating it occurred or quantifying the number, extent, timing and duration of out-of-sequence moves from one activity to another. McLeish (1981) studied two projects and compared the number of times workers visited a house under construction and the average number of man-hours required to construct a house. He found a strong association between an increased number of visits and diminished productivity. Thomas and Smith (1990) cited two studies conducted at Penn State (Bilal and Thomas 1990 and Bennett and Thomas 1990). Their statistical analysis of data collected from those projects indicated that loss of productivity arising from out-of-sequence work was severe, ranging between 40 and 80 percent.

Though the effect of out-of-sequence work has been recognized by many people in the industry, a consistent and efficient way to demonstrate skips and out-of-sequence work is still needed (McLeish 1981). Classical schedule delay analysis in which planned and as-built schedules are compared is most informative when a contractor is completely stopped from performing all work from one date to another date, meaning that the planned, work flow is delayed, not altered or disrupted. However, sometimes the need to keep working to meet a project deadline precludes convenient halts of some portions of the work until issues were resolved (resulting in directed or constructive acceleration), allowing other portions to continue causing out-of-sequence work, possibly at a reduced speed and with impaired productivity. In such cases the schedule delay analysis will only depict part of the picture, and may not be able to identify and explain fully the disruption itself.

Legal Cases Involving Change of Sequence Work

Numerous disputes concerning the impact of out-of-sequence work have been heard by courts, arbitrators and appeal boards. Such change-of-sequence work disputes are commonly seen as a consequence of an owner’s design changes, deficient performance by another contractor, or defective work or specifications. Disruption or out of sequence work has been described as "work anywhere possible", "work everywhere at once" and "bounce its crews all over the job" (*Hoffman Construction Company of Oregon v The United States*) or "work off schedule" on a "stop- and-start basis" (*Appeal of International Builders of Florida, Inc.*). Without a method to demonstrate out-of-sequence work and the casual relation to delay issues these narrative descriptions have often been the only probative evidence available in such cases. They are frequently insufficient.

Out-of-sequence work has been claimed to cause many problems including dilution of supervision and crew size inefficiency[iv]; higher material cost due to piecemeal and deferred purchasing in a rising market and additional movements of materials[v]; additional learning or extra time to get familiar with the areas again[vi]; and extra mobilization and remobilization and equipment usage stretch-out and extra standby.[vii]. It may also lead to trade stacking and crew congestion, logistical bottlenecks, unanticipated shift and overtime work, and other frustrations to the effective performance of work tasks. Those problems may consequently cause productivity loss and project delays.

As mentioned, owner-caused delay is frequently seen as one reason why a contractor works out-of-sequence. Even though the effect of out-of-sequence work is well recognized by many people in the industry, it is not easy to get reimbursed for such disruptions. First, some disruptions are not reimbursable because the contract between the owner and contractor may allow some amount of reasonable delay on the part of the owner.[viii] In addition, it is important for the contractor to provide evidence to prove the existence of such loss and that loss was "proximately" caused by the change, which is not an easy task.[ix] With out-of-sequence work this may be particularly true as the scheduled activity impacted by a change is not be the activity onto which the contractor mobilizes in an out-of-sequence manner as a result of the change. With out-of-sequence work the contractor demobilizes from the impacted activity to a new activity and then later remobilizes back to the originally impacted activity. A contractor may mobilize on to an activity out-of-sequence activity due to a delayed planned activity merely because that activity is available to do some work, albeit not in schedule sequence.

In *Appeal of International Builders of Florida, Inc.*, the Board evaluated all the details provided by the contractor and only accepted some of the reasons provided (extra movement of materials and extra mobilization and demobilization) and rejected others (labor inefficiency allegedly caused by working around the partially completed partitions). The court in this case was adamant that that the contractor failed to visually show a clear linkage between causation and loss of labor productivity.

Improved methodology for demonstrating the impacts of skipped and out-of-sequence work are thus clearly needed.[x] Simultaneously visualizing the skips and productivity loss is one such improvement. The following case study presents our methodology that has been utilized on projects. It has been used in formal claims and claim negotiations and utilized as demonstrative evidence for mediations, trials and arbitrations.

Out-of-sequence Analysis and Skip Analysis: A Case Study

The case study presented herein was part of a long and complicated litigation that resulted in a favorable resolution through mediation for the subcontractor's out-of-sequence work disruption claim. This same approach has subsequently been used on other projects by two of these authors. By using this methodology the subcontractor was able to demonstrate causation and link damages and liability.

Utilizing the out of sequence work graph the issue of disruption was never meaningfully challenged. It was graphically demonstrated. Testimonial and anecdotal recollections did not need to be presented or tested by those with a differing recollection. Once the out of sequence work methodology was demonstrated and its foundational evidence explained it was basically accepted that the subcontractor was detrimentally disrupted. With the out of sequence work graph and using the skip analysis the subcontractor was able to demonstrate the number and time duration between each skips. The subcontractor was able to associate the timing of the skip with particular delay issues linking liability for the out of sequence move. The ability to demonstrate this data assisted with the quantification or damages calculations. Three damage methods were considered. The first was a modified total cost type approach that enabled the subcontractor to link schedule tasks disrupted to actual job cost categories. The second quantification method utilized the MCAA guidelines for minor, average and severe impact conditions. The third method was a measured mile analysis that was available to depict the labor hours expended on relatively uninterrupted times to that on tasks the subcontractor was clearly able to demonstrate it was disrupted simultaneously with the delay issues occurring at or near the time of the skip. In this manner the labor hour cost overruns were substantially resolved in the mediated settlement. Some other issues of disputed change orders entitlement and an unabsorbed home office overhead claim were discounted in the mediated settlement.

Case Background

This paper documents the experiences of a mechanical subcontractor on a three-story healthcare facility near San Francisco, California. The project began in 2010 and was scheduled to be complete in 2012. Due to numerous changes and design issues, the project was delayed 22 months, more than doubling its original contract duration. In addition to a notable delay, there was a substantial amount labor cost overrun attributed to disruption of the project's scheduled work sequence. There was a 170% increase in direct labor hours attributed to changes and another 100% increase in labor hours due to the disruptive out-of-sequence work inefficiencies. To help understand the cause of the labor overrun and demonstrate the impacts caused by the changes and out-of-sequence work, one of the authors of this paper utilized a methodology of visual tools to demonstrate and quantify the resulting impacts to labor productivity. Those tools are described in detail later in this paper.

Shortly after the Notice to Proceed of the project, the general contractor (GC) claimed it experienced substantial delays and impacts that disrupted the scheduled activities during specific periods of time. Its claim was based upon review of the approved baseline schedule and subsequent schedule updates. Those project delays and disruptions had direct and consequential schedule impacts to the mechanical subcontractor.[xi] That mechanical subcontractor, the focus of this paper, had bid the job in way that would have allowed it to perform its work in a manner consistent with the sequenced flow and durations of schedule activities represent in the contract schedule.[xii] Its original contract schedule was consistent with industry standards and reasonable expectations regarding the timing, durations, and sequence of activities to perform the specified work, as verified by the Construction Manager's review and approval of the project's baseline schedule.

While the subcontractor was provided schedule updates that documented scheduled activity changes and directed changed project priorities, changes to the project led to multiple delays and impacts to the subcontractor's expected sequence of activities which in turn led to disruptive, out-of-sequence work. Most of the changes were added design scope, delays to owner-furnished equipment, and changes to the mechanical subcontractor's means and methods because of deficient work and design changes affecting other subcontractors.

When "added work" changes are identified in time and can be properly planned and performed, production flow may be effectively managed and cost controlled. However, on this healthcare facility changes were implement late, untimely, and out-of-sequence, a condition widely recognized as disruptive to productivity (Ibbs 2005). The added work changes not only required more time and cost to perform the task, but they were done out-of-sequence and piecemeal. Scheduled work was also left incomplete due to delayed responses to Requests for Information (RFIs), incomplete predecessor work, and pending changes. The scheduled work activities of many trades could not be completed as planned and the mechanical subcontractor was forced to skip over previously-scheduled work and move to other work in an effort to stay busy.[xiii]

In addition, other follow-on subcontractors began work in areas of the mechanical subcontractor's incomplete predecessor activities. When the mechanical subcontractor returned (remobilized) to restart work on a skipped activity, the material, equipment and operations of ongoing work by other trades interfered with the mechanical subcontractor's work. Therefore, not only did the return to the skipped locations result in additional out-of-sequence moves to schedule activities, but the work area for the mechanical subcontractor's earlier scheduled activity had become congested because of installed work and ongoing or partial operations of these other successor trades. As a consequence the workflow and means and methods anticipated by the mechanical subcontractor under the planned baseline schedule were no longer applicable and original productivity levels were no longer achievable.

Table 1 shows the differences between planned and actual start and finish dates for this subcontractor. This type of schedule analysis compares the Planned and Actual Start dates and Planned and Actual Finish dates to show the magnitude of the duration of the delays to each task or activity, expressed in calendar days. Most activities started later than planned, and all but one finished much later than anticipated. A few activities started earlier than planned, which is not always a good thing. That is, starting work before it is planned may be disruptive to work flow and productivity because resources may be missing, predecessor work may be incomplete, the work season may be inappropriate, and so forth. In other words, out-of-sequence work can be triggered by starting too early as well as too late.

Insert Table 1 about here

Delays that Disrupted the Subcontractor's Work

Following a delay to its first fieldwork on the project, the subcontractor was directed to proceed with its deck layout and insert work on the first floor. Thereafter the mechanical subcontractor's deck layout and insert work on all levels was further delayed and disrupted.[xiv] It was not able to proceed in a timely sequenced manner from floor to floor in a continuous flow of work as represented in the planned baseline schedule.

After the GC completed placement of structural concrete and removed its formwork the mechanical subcontractor was able to start the critical interior overhead Mechanical/Electrical/Plumbing (MEP) rough-in work.[xv] However, time was critical and no formal time extension was granted. The project was therefore constructively accelerated and all the MEP subcontractors were forced to work on all floors simultaneously.[xvi]

Figure 2 is a delay analysis of the subcontractor's mechanical rough-in work from planned baseline schedule to the actual as-built schedule that shows the time impact to the mechanical subcontractor's performance.[xvii] These data are compared in this figure with Proposed Change Orders (PCOs) and Delay Issues (Impacts), which will be discussed in more detail later in this paper. The "count" entry in Table 2 represents how many times each impact was mentioned in the superintendent's daily diary. "Dur" in this table refers to the duration in calendar days.

Of course work may not have been continuously pursued for every one of those duration days. Also, out-of-sequence work may reflect a contractor "pacing the schedule" to mitigate the delay impacts to its cost and schedule. Such nuances need to be evaluated on a case-by-case basis and reflected in the method of analysis proposed herein.

Insert Table 2 about here

Out-of-sequence Analysis

To understand the extent of this project's out-of-sequence work, Figure 1 was developed to compare the planned and actual sequences of work. The planned scheduled work is represented in an efficient sequence, as shown in left-hand side of this figure by the dashed line climbing from lower left (lower level floor early in time) to upper right.[xviii] Each planned schedule activity is represented by its planned mobilization, sequence, and duration.

The length of the horizontal axis represents duration or time. The Figure 1 graphic shows the activities from the planned scheduled work perspective, organized as sequenced in a manner that shows one area or task being completed before moving on to the next area or task. It represents the planned logical flow of work showing the number of moves, their logical relationship (height of vertical axis) and duration (time or horizontal axis) of each activity in sequence. This order may be the same type of work performed in another area (e.g. drywall area A; then drywall area B) or the logically successor activity (e.g. after drywall, then tape drywall). Therefore, in typical construction scheduling the planned graphic represents the same activity in the next area or adjacent location or the successor work task for completing the installation.

The vertical axis represents the next activity in planned order from the prior activity. On Figure 1 this is represented by the vertical axis (amplitude). The height of the activity correlates to the activities planned position in sequence.

As a contrast, the actual sequence of work is plotted as the solid line. If the actual sequence followed the planned sequence, the plots of the planned and actual lines would coincide. If the plots do not match, a change in the sequence of planned work is indicated. If the actual plot is stopped before the duration of the planned plot the activity was not completed per the planned duration. When this occurs the out-of-sequence work graph depicts the next activity in actual sequence with a vertical line. The stops and starts on the horizontal line represent demobilizations and remobilizations. The greater the vertical distance from one activity to another the greater the change in sequence. Therefore, the vertical amplitude of the lines is an indicator of the distance traveled by the crews when they moved from one work front to another or a change in the task from what was planned. Because the job incurred many more disruptions than planned the “actual” curve is more erratic and complicated than the “planned” curve.

If the actual plot is to the left of the planned plot the activity was performed earlier than planned. If the actual plot is to the right of the planned plot the activity was performed later than planned. If the actual plot is longer than the planned activity then the activity took a longer duration to perform.

Some vertical lines may be expected as no project ever proceeds perfectly uninterrupted in a bottom-to-top manner, but the number and density of lines in the actual work sequence plot in this figure demonstrate the project was gravely disrupted. This is especially true for vertical lines jumping from one task to another on the same day. This approach treats crews as "unsplitted"; if they were split, this approach could be modified to accommodate such.

Again, if the actual plot was to the left of the planned line, the activities were performed out-of-sequence early, and if the actual plot was to the right of the planned plot, the activities were performed in an out-of-sequence late manner or returned to manner, requiring remobilization efforts. Even more disruptive are the activities that are stopped and restarted again in an out-of-sequence manner. These planned activities are first on the schedule and are often the priority activities or perhaps even controlling work. Figure 1 shows that as a planned activity is stopped the crew is demobilized from the planned activity and mobilized on to another "available" activity which was scheduled to be less of a project priority. Later the crew will demobilize from the activity it moved to in order to "stay busy" and remobilize back on to the skipped activity. When the crew remobilizes back to the original activity, it has to reorient itself to the task it was already performing and re-lay out and re-set up materials, equipment and tools. The longer the horizontal distance on the graph the longer the time duration from demobilization. Typically, the longer the duration to return to an activity the greater the loss of learning curve and job rhythm.

The usefulness of Figure 1 is that what was once typically verbally described in testimony or project correspondence as the problem of out-of-sequence work has now been graphically depicted. In addition, the testimony of moving to unrelated activities (vertical moves) and returning to them later (horizontal moves) is graphically depicted and proven. Once the foundation is presented as to the source of the data and the methodology to graphically represent it, the fact of disruption is evident.

Insert Figure 1 about here

As a next step, causation for the out-of-sequence move is provided. By way of example the authors will show one Impact's effect on the work analyzed.

Figure 2 shows the work performed during the time Impact #1 (Need Complete Drawings/Need information) was active. It can be seen that 1) Impact #1 might have contributed to several jumps between January 2012 and July 2012, and 2) Impact #1 also happens frequently between September 2012 and April 2013, which might contribute to the large amount of disruptions during that period. Admittedly, this is not irrefutable evidence of causation, but it does present a solid circumstantial argument that Impact #1 may have caused or at least contributed to the out-of-sequence work. In making this statement two premises may be assumed. The first is that the contractor does not purposefully engage in inefficient out-of-sequence work on its own, and the second is that there is no evidence that the contractor caused or contributed to the out-of-sequence moves itself. For example, by performing defective work, unavailable materials or equipment or hiring unskilled work force, it did not impact its own work.

Insert Figure 2 about here

Figure 2 shows that the work performed on a specific task can be reviewed and the Impacts recorded during that work identified. It clearly shows disruption to work flow.

Figure 3 shows the Impacts recorded during the time Activity #149 was being performed. It can be seen that Activity #149 was interrupted by seventeen Delay Issues (Impacts) during its performance. The recorded Impacts are possible reasons for those interruptions. After the available data are analyzed and incorporated into the methodology, it may reasonably be surmised that the out-of-sequence moves were caused by the known impacts related to the activity being performed during that duration depicted in the analysis. In other words the methodology may provide more specific data explaining why a particular activity is impacted in a manner that causes the out-of-sequence move(s) depicted in the Figures.

The visual evidence provided by Figures 2 and 3 can be supplemented with information from job diaries, photographs, and correspondence to further strengthen the causation argument.

Insert Figure 3 about here

Skip Analysis

While the above out-of-sequence work analysis and corresponding graphics visually demonstrate project disruption, a quantitative skip analysis provides data to quantify the out-of-sequence moves by the number of mobilizations and remobilizations. More skips (mobilizations and remobilizations) are generally associated with more disruption to a project's plan and productivity loss.[xix]

Table 3 presents a detailed analysis of the mobilizations that were planned and occurred. For example, this subcontractor planned to have eleven mobilizations to the work activities studied here but it had 159 mobilizations. That is, one mobilization per activity was planned but 7.7 occurred. The combined duration of all this subcontractor's work stretched from 85 days to 4,133 days. The duration associated with each actual mobilization was 27.6 days versus a planned duration of 7.7 days.

Insert Table 3 about here

The plan anticipated that eleven of the eighty-five days of work would be devoted to mobilization (thirteen percent). In actuality, only four percent (159/4396) of the actual duration involved mobilizations over the extensively delayed actual duration. Much less work was achieved on each activity and for each actual mobilization than was anticipated in the baseline schedule. In other words, more time (duration) was devoted to orientation of the task, layout and checking, setting up tools, stocking materials, and moving equipment in order to perform each installation of work on an activity than as represented by the planned activity on the schedule. By demonstrating more labor was expended on demobilizations, remobilizations, and reorienting the crews to the work, a stronger argument can be made that loss of productivity was incurred.

Conclusions and Limitations

Skipped and out-of-sequence work is disruptive to project workflow and labor productivity. Previous researchers have written about the negative effect that out-of-sequence work has on labor productivity. However, none of the prior studies reviewed as part of this research has introduced a way to visualize and quantify the number of planned and actual skips.

This paper presents such an out-of-sequence analysis and skip analysis visualization technique to fill this gap. It provides a way of observing the number of out-of-sequence moves, and their magnitude (vertical amplitude) and length (horizontal duration) of activities that experience out-of-sequence disruptions. It also introduces metrics such as the Skip Ratio and the Number of Extra, Unplanned Skips which should be useful for understanding the extent to which out-of-sequence work occurred on a project. By utilizing this methodology, a change analyst may observe whether the disruption was minor, average, or severe. Furthermore, this methodology may be effectively used with a measured mile analysis to compare an efficient period with relatively few disruptions to a period when more out-of-sequence moves occur. When this methodology is presented in conjunction with a traditional schedule delay analysis, a more persuasive case for causation can be made, especially when a project delay does not result in a suspension of work activities.

The methodology presented in this paper will hopefully help contractors and owners more clearly analyze and demonstrate the cause, liability and consequence of disruptive out-of-sequence work.

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[i] For a condition to be deemed a change, the project and contract requirements must be fully considered. For example, a condition that occurs in a design-bid-build project may be deemed a change whereas in a design-build project that same condition might not be.

[ii] Servidone Construction Corp., Eng. BCA No. 4736, 88-1 BCA ¶ 20,390. "The contractor must prove for either claim the elements of liability, causation, and resultant injury."

[iii] The US Army Corps of Engineers Modification Guide also recognizes that out-of-sequence work is disruptive and may have deleterious impacts on productivity. The guide was rescinded by the Corps in 1996

without explanation, but is still occasionally cited by industry practitioners.

iv In *Hoffman Construction Company of Oregon v. The United States*, Botting (plaintiff's subcontractor) claimed that "its crews would be 'bounced' all over the job trying to cover all the bases and get back to the schedule." Botting was "faced with stacking of trades, dilution of supervision, crew size inefficiency and a ripple effect from excessive revisions and/or clarifications." The plaintiff was successful in its claim.

v In *Appeal of International Builders of Florida, Inc*., Spellman (the plaintiff) claimed that one of the impacts of delay is "disruption of its work and logistic plan, causing increases in Spellman's direct costs; the higher labor cost of performing work out-of-sequence, off schedule, on a stop-and-start basis, with smaller crews; the higher material costs of piecemeal and deferred purchasing in a rising market."

vi In *Appeal of Dawson Construction Company, Inc.*, the plaintiff's project manager claimed that "If during any time in that operation, in that process, your work is stopped or disrupted, that confuses you. It causes loss of labor. Because at that point you've got to stop, put your people in other areas ... [and] when you come back you're losing labor, losing time, because your people have got to get familiar with the areas again."

vii In *Appeal of Saudi Tarmac Company Ltd and Tarmac Overseas Ltd (JV)*, impacts included de- and re-mobilization; loss through relearning, imbalance of crews, longer hours and overtime; disruption of working rhythm; equipment usage stretch-out and waiting; and extra supervisory.

viii In *Appeal of International Builders of Florida*, Inc., the Board stated that "by virtue of the standard 'changes' clause in the contract, and the 'pay-for-delay' clause, the government had a right to suspend work for a reasonable time. It thus had the right, reasonably, to alter the planned sequence of work - and we find that, with respect to the outside utilities work, considering the changes to be made, the government's initial exercise of its right to suspend work was reasonable."

ix In *Appeal of Dawson Construction Company, Inc.*, *Appeal of International Builders of Florida, Inc.*, the contractor was rejected because it failed to establish even "proximate" causation.

x The court in *Luria Bros. v. United States* expressed the need for concrete, factual evidence that disruptions and out-of-sequence work impaired the contractor's productivity when it wrote "we cannot ignore the fact that the percentages testified to were merely estimates based on (the contractor's witness) observation and experience … Taking these things into consideration and in view of the fact that no comparative data, no standards, and no corroboration support his testimony, we are constrained to reduce his estimates based on the record as a whole and the court's knowledge and experience in such cases …." Likewise, the Wunderlich court wrote "Broad generalities and inferences to the effect that defendant must have caused some delay and damage because the contract took … longer to complete than anticipated are not sufficient … It is incumbent upon plaintiffs to show the nature and extent of the various delays for which damages are claimed and to connect them to some act of commission or omission on defendant's part …."

xi None of the alleged critical path delay issues were the mechanical subcontractor's responsibility, nor was the mechanical subcontractor ever fully informed of these schedule impacts.

xii The subcontractor bid its work and executed its subcontract based upon the contract schedule, which was a contract document attached to the its subcontract and represented to be the GC's planned schedule.

xiii Contract time extensions were not granted nor requested by the GC, supposedly because none would be granted. The work was therefore constructively accelerated and the mechanical subcontractor was threatened with allegations of breach of contract if it suspended work and demobilized from the project.

xiv The GC's critical path delays and disruption impacted subcontractor's layout and insert work on the first level, second level, and the sloped and flat roofs.

xv The GC planned to continue this work in accordance with its updated critical-path sequence by proceeding with the overhead MEP, framing, primary/high-early drywall, in-wall MEP rough-in and interior finish drywall work on Level two before starting the finishes work. The GC stated the impacts were primarily the result of design changes directed by the owner and approved through the State's regulatory agency (Office of Statewide Healthcare Planning and Development, OSHPD). The GC also asserted that many of the impacts had a ripple effect that carried through the remaining work activities, and that its subcontractors were subjected to multiple periods of work stoppages for design holds, inspection delays and intermittent installations of added work.

xvi The subcontractor's labor loading graph is consistent with the accelerated approach to the project. Under the changed job conditions the trades were stacked and distributed on all floors simultaneously.

xvii The GC and its subcontractors could not execute their work as planned in the contract schedule due to the volume, nature and timing of owner-initiated changes. They were required to work where work was available while waiting for owner direction and finalization of design changes.

xviii The planned work sequence was scheduled so that the movement of labor from one task or area to another was kept to a minimum for cost effective performance. In reality the true planned sequence was slightly more complicated than shown in this figure; we have simplified it for purposes of exposition in this paper.

xix A skip only occurred if a work day was missed before returning to an activity.