Effects of Change orders on Construction Projects Labor Productivity

Parisa Aghamohammadi[1], Mahdi Faraji[2]

Abstract

Changes have long been identified to have a negative impact on construction control. Changes result from the necessity to modify aspects of the construction project in reaction to circumstances that develop during the construction process. The changes may be small, well managed, and have little effect on the whole construction project. On the other hand, changes may be large, poorly managed, and have tremendous negative impacts on the construction project performance in terms of time and cost. While some changes can be predicted, others are unforeseeable. In both cases, it is important to take the correct actions to mitigate the costs. After understanding what change is, the next step is to calculate the potential losses that are attributable to that change. The potential productivity losses will give a more realistic picture of the costs and time that are associated with the change. This paper summarizes various aspects of the existing change cumulative methods can be used to quantify the construction productivity losses due to multiple different changes and provides a comprehensive literature review as well as some comments on possible future directions to aid the contractors in their claim preparation and the owners to better defend against such claims.

Keywords: Change orders, Productivity, Project management.

1. Introduction

Several researchers have worked in the area of quantification of change orders and labor productivity inefficiency damages. They attempted to pinpoint the problem of how to prove that the changes carried out by the owner have led to a negative impact on the contractor's labor productivity. They also included the impact of changes such as delay, overtime, over manning, congestion and other factors, which affect the labor productivity.

The study aims to identify the problem of how most of the change order and loss of productivity studies are tackled from data supplied by contractors. This led to several disagreements between the owner and the contractor regarding the quantification method and hence the value of the change order and the productivity loss. Understanding the problem was achieved through reviewing the most recent literature in this area provided the researchers with global view of the problem. The goal of the study is Analyzing and

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[1] Phd Candidate; Urban Management Department; Kyoto University, 615-8540; pariissa@gmail.com
[2] Postdoctoral Research Fellow; Urban Management Department; Kyoto University, 615-8540; faraji@gmail.com

evaluating all currently available studies, methods, and models for quantifying productivity losses due to changes extensively and intensively so that a reliable body of knowledge is assembled." To achieve the goal, quantitative studies and methods that are currently available are first categorized according to their approach and focus.

2. Background

Change orders are frequently encountered in any construction project. Contract modifications that increase the contract value from 5 to 10% are expected in most construction projects (Finke, 1998a). It is important to understand the types of costs in any construction projects to provide a good estimate of the change costs. There are two types of costs in any construction contract and they are fixed and variable costs. The risks associated with the fixed cost-items can be financial crisis, or a mistake done by the subcontractor that can lead to defective work. The variable cost-items are items such as the labor, equipment and overhead. The major variable risk item in any construction project is the labor as they are frequently the most variable cost for the contractor. The main areas of labor cost increase include schedule acceleration, changes in the scope of work, project management, project location and external characteristics. Each of these areas has main subcategories that can affect the labor cost. Schedule acceleration may lead to overcrowding, stacking of trades, and overtime. Changes in the scope of work may lead to additional quantities of material, learning curve changes, delays, engineering errors and omissions, rework of already installed work, and changes to the plans and specifications. As for the management characteristics, any deficiency in this area might negatively affect the material and tool availability, the coordination between the team members, and the effectiveness of the supervision. Project location and external conditions include weather, altitude, availability of skilled labor and the economic market in the area where the project is constructed (Shawartzkoph, 1995).

Productivity is the units of work accomplished for the units of labor expended in such work. According to Adrian, 1987, the two main problems in the construction industry are the productivity inefficiency and the lack of productivity standards. Statistics on productivity in the United States published by governmental agencies or collected from industry standards showed that over the last ten years industrial productivity has increased at a rate of 2.7% annually. Compared to other countries like Japan, the rate of increase is 5% annually. This is considered a relatively high number that is attributed to the nature of the construction that includes variable physical environment and how the process of construction is unique from one project to the other. Such high percentage of non-productive time affects the construction cost and estimating time. There are several factors that contribute to non-productive time namely industry factors, labor factors and management factors.

2.1 Evaluating the impact of changes on loss of productivity

Owners frequently think that contractors make money on changes because their estimates are too high. In reality, contractors often lose money on multiple changes because their estimates are too low and because they underestimate the administrative effort required to negotiate and process the change. Pricing methodologies for changed work are often weak.

Few contractors maintain adequate job-site records to allow evaluation of impact costs for individual change orders, let alone a multitude of change orders.

With each individual change, a contractor will estimate the work-hours required, but because of the inability of project personnel to fully anticipate the consequential effects of multiple changes, the actual final work-hours required may be much greater than originally anticipated. As the number of changes increases, the differential between estimated work-hours and actual work hours widens at an increasing rate. Essentially every construction contract contains a “changes clause” that defines the process for identifying and documenting changes. The two main types of damages encountered by the contractor when the owner issue a change order are namely; delay damages and inefficiency damages. Delay might be the inevitable result of the change order to execute the change.

A schedule delay analysis and a loss of labor efficiency analysis are not the same. With a loss of labor efficiency it means that it takes longer to perform a certain task. There need not to be a work stoppage or delay that is necessary to perform a schedule analysis. Although loss of labor productivity may result in delayed completion, loss of efficiency is not included as an element of delay damages. When permitted by the contract, both the delay damages and losses of labor efficiency can be recovered (Harmonet, 1984). It is not considered double recovery to receive both types of damages (Thomas & Oloufa, 2001). Inefficiency is loss of productivity, expressed as a percentage of the actual or the optimum productivity. It is the difference between what was actually performed and what “would have been” performed in the absence of the impact. The cumulative impact of multiple changes is greater than the sum of individual impacts from each change. Such cumulative impact is reached when the project is experiencing continuous changes that exceed the contractor ability to quantify, estimate, schedule, negotiate and implement any change. The owner’s representative takes time to resolve any pending change order request, thus the contractor experiences a financial burden from the unpaid work (Pinnel, 1998). As mentioned previously, delay and loss of productivity are the two main types of damages experienced by the contractor when the owner issues a change order. Courts have recognized Critical Path Method (CPM) schedule analysis as the preferred method of identifying and quantifying critical delays (Singh, 2002; Crowley and Livengood, 2002). As for the inefficiency damages, there is no way of directly measuring inefficiency due to its qualitative nature. The courts and most owners recognize this and accept a lesser degree of proof for inefficiency damages. It is difficult to link the causation to the damages.

Although there are a few studies (e.g. Borcherding and Alarcon 1991; Thomas and Sakarcan 1993; Thomas and Napolitan 1995; Finke 1998a) which focus on how changes cause losses of productivity, these studies mainly focus on the relationship between changes, disruptions, and lost productivity, not the role of the project parties. For instance, (Thomas and Napolitan 1995) present a factor model which explains that changes themselves do not directly cause productivity loss but cause other disruptive influences to be activated instead. Unfortunately, this model’s neglect of the responsible party makes this model incomplete, especially since “causation,” together with “liability” and “resultant injury,” is a prerequisite for the success of cumulative impact claims.

3. Factors Affecting Labour Productivity

The impacts of changes on labor productivity are extremely complicated to analyze. Quantifying the impacts of changes on labor efficiency is burdensome as there are the interconnected nature of the construction work and the difficulty in isolating factors to quantify them (Hanna et al. 2004).

Improvement of productivity in construction has been a major industry challenge, given its high impact on project results. It has received increased attention from construction researchers promoting different enhancement actions, since analyzing factors affecting labor productivity is an instrumental part in this process. The main findings indicate that the critical areas affecting construction productivity were related to materials, tools, rework, equipment, truck availability, and the workers' motivational dynamics. Rivas (2011) mentioned that labour productivity is a function of various controllable and uncontrollable factors. (Schwartzkopf, 1995) listed these factors under six groups comprising: (1) Schedule acceleration;(2) Change in work;(3) Management characteristics;(4) Project characteristics;(5) Labour and morale; and(6) Project location/external conditions.

As demonstrated in Table 1, there is a significant amount of literature and studies conducted in the field of productivity by identifying factors that can exert influences. In order to depict a rich picture, Allan (2010) endeavoured to outline a table that contains as many factors that may potentially influence productivity from a theoretical perspective. The output can be utilised as a checklist for practitioners to check whether they face similar productivity constraints.

Table 1: Comparison of identified productivity factors from a variety of studies adopted from Allan, (2010)

Country Ranking	Canada	Iran	Indonesia	Nigeria	Thailand	US(1970s)	US(2005)
1	Planning and Scheduling	Material Shortage	Absenteeism	Lack of Material	Lack of Material	Material Availability	Skill and Experience
2	Equipment	Weather and sit condition	Rework	Inadequate tools	Incomplete drawings	Proper tools	Management
3	Working drawings	Equipment breakdown	Lack of material	Rework	Inspection delay	Rework	Job planning
4	Materials	Drawing deficiencies		Instruction delays	Incomplete supervisors	Overcrowded work	Motivation
5	Motivation	Lack of proper tools		Inspection delays	Instruction time	Interference between crews	Material availability

Borcherding and Alarcon, (1991) present a comprehensive review of quantitative information on factors influencing productivity. In addition, they categorised the major components of productivity loss as waiting or idle, travelling, working slowly, doing ineffective work, and doing rework. Abdulaziz, 2012 ranked the relative importance of factors perceived to affect labor productivity on construction sites in Kuwait in a structured questionnaire survey, comprising 45 productivity factors, classified under the following four primary groups: (1) management; (2) technological; (3) human/labor; and (4) external. Among the factors explored, the subsequent 10 are discerned to be the most significant in their effects on labor productivity: (1) clarity of technical specifications; (2) the extent of variation/change orders during execution; (3) coordination level among design disciplines; (4) lack of labor supervision; (5) proportion of work subcontracted; (6) design complexity level; (7) lack of incentive scheme; (8) lack of construction manager's leadership; (9) stringent inspection by the engineer; and(10) delay in responding to requests for information. Parviz (2012) defined the factors and grounds affecting sub-contractors productivity in Iran and evaluated their overall negative side effects on project productivity via a structured questionnaire. The analysis indicated that the most important grounds affecting sub-contractors productivity in descending order included: Materials/Tools, Construction technology and method, Planning, Supervision system, Reworks, Weather, and Jobsite condition. Abdul Kadir (2005) evaluated the importance, frequency and severity of project delay factors that affect the construction labour productivity for Malaysian residential projects. The five most frequent factors were: material shortage at project site; non-payment to suppliers causing the stoppage of material delivery to site; late issuance of progress payment by the client to main contractor; lack of foreign and local workers in the market; and coordination problem between the main contractor and subcontractor. The most cited factor affecting productivity during scheduled overtime is physical and mental fatigue. Other factors which may contribute to a productivity loss include: absenteeism, accidents; reduced supervision effectiveness; shortage of materials, consumables or tools due to accelerated pace; and tardy processing of engineering questions and requests for clarifications due to greater demand within a given period. (Regula, 2001)

4. Methods of Quantifying Lost Productivity

Proving causality between changes and their impacts is one thing, and quantifying productivity losses is another. When it becomes time for quantification, practitioners have mostly relied on a few traditional methods such as total cost method, industry indices, and measured mile analysis, depending on the amount and quality of available project data. However, these methods have been criticized for their lack of reliability and other limitations. Therefore, the industry has been seeking alternatives and academia has been trying to quantify the impacts of certain factors or develop quantification models.(Ibbs, 2012) when a project suffers from existence of multiple productivity factors, there is no guide for how to combine the effects of multiple factors.

Supporting and evaluating cost overrun claims because a contractor has suffered labor productivity problems are difficult undertakings. Industry guidebooks (NECA 1976; USACE 1979; MCAA 1986) are one source. They are suspect though because parties with vested interests have developed them and their underlying research methodology is unclear.

Hanna (Hanna et al. 1999a,b; Ibbs _Ibbs and Allen 1995; Ibbs 1997; Ibbs et al. 1998, 2003); and Leonard (Leonard 1988) have tried to fill the gap by independently benchmarking projects. The result has been industry standard statistics, which are somewhat useful. These techniques are based on data collected from a large number of projects and deriving regression curves that show the impact that change has on labor productivity. Another approach for computing lost productivity is the measured mile approach (Zink 1986). In this technique, periods of unimpacted production are compared to periods in the same project that have suffered substantial productivity loss strictly because of one party's actions (say the Owner). That party (the Owner) is then assigned responsibility for this difference.

In cases where a pure, unimpacted portion of the project cannot be found, a baseline may be defined (Thomas and Sanvido 2000a). From the claimant's perspective this is a conservative measurement because the baseline productivity may still include some lost productivity. But because responsibility for that lost productivity cannot be easily measured and clearly assigned to the respective parties, the claimant uses the baseline period as a reference, even though some lost productivity may still be intertwined in the baseline rate. There are substantial limitations with these methodologies though. The measured mile method, as defined by Zink, requires that its reference productivity come from a continuous, uninterrupted period. That is not always available though. The baseline method has the shortcoming of using daily output to identify the reference period instead of daily productivity. The result is questionable because daily output may vary because of crew size, not just productivity.

A major problem with both these methods is that they use subjective methods to identify the unimpacted reference periods. The baseline method, as described by Thomas, multiplies the duration of a project by 10% (say 10% of a 100 day project duration=10 days). Then the productivity of those "top 10%" days is computed by averaging the productivities achieved during those days. The basis for using 10% is clearly arbitrary. To overcome these shortcomings a new statistically based methodology for baseline calculation is proposed by Ibbs (2005). The measured mile and a variant, the baseline method, were analyzed and compared to a new, proposed statistical clustering method. The approach was advocated because it determined its reference period using objective criteria. A case study was included to show how the three methods work, and advantages and disadvantages of each method were presented.

Table 2. Comparison of the Measured Mile and Baseline Calculation Methods(Ibbs, 2005)

		Baseline	
	Measured mile	**Thomas`s**	**Statistical method**
Purpose	Find periods where there are no own caused impacts	Find contractor's best performance	Find contractor's best performance
Causes of delay	Contractor	Owner/Contractor	Owner/Contractor
Consecutive time periods?	Yes	Not necessary	Not necessary
Record of delay causes needed?	Very detailed	Somewhat detailed	Somewhat detailed
Sample size	Reasonable	10% of project duration	Depends on project characteristics

Table 2 summarizes the important differences between the measured mile and the baseline period methods. According to the definition of measured mile (Zink 1986), the purpose of measured mile calculation is to find periods without owner-caused impacts. A measured mile has to be a consecutive set of time periods. Thomas's baseline method does not require it to be a consecutive period. But it specifies the baseline size, 10% of project duration.

The construction industry has developed and employed a number of methodologies for estimating lost labour productivity. Based on the appropriate data input, these methods can be classified into three major groups;(1) Project practice based; (2) Industry based; and (3) Cost based methods. The detailed data requirements and corresponding judicial acceptance generally increase as the approach adopted moves from cost based to project practice based methods.

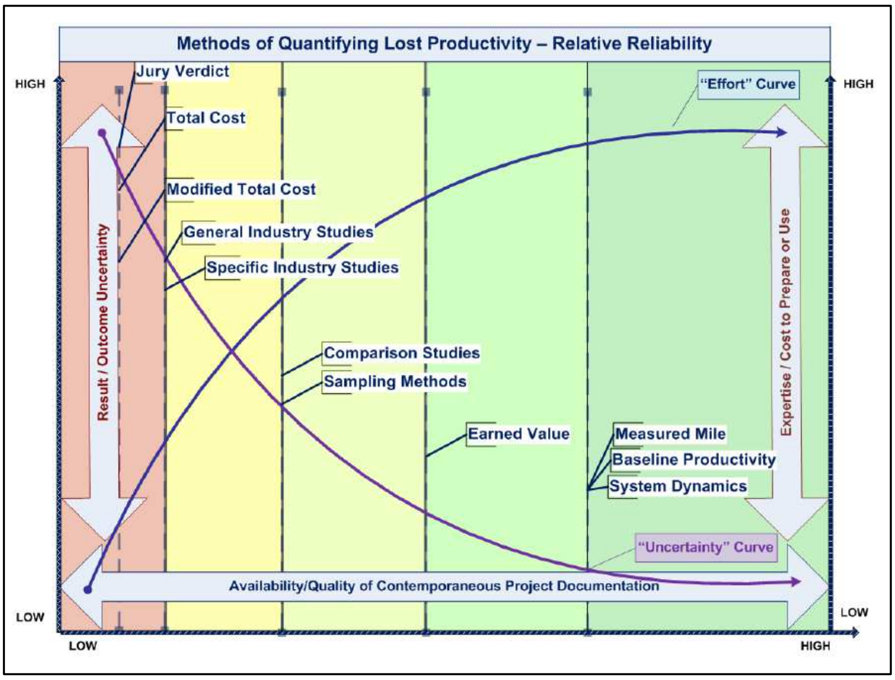

Figure 1 - Comparison of Cumulative Methods adopted from (Ibbs, 2007)

The above figure outlines the relationships between the availability, quality and providence of the contemporaneous project documentation. To successfully utilise one of these methods, the claimant generally has to overcome some difficult legal hurdles. But, if these challenges can be met, then these techniques may be allowed as a measure of lost productivity. The different set of procedures and assumptions required by each methodology, have resulted in them producing different results of staggeringly different levels of accuracy for any given claims situation (Cuningham, 1998; Stumpf, 2000). In addition, there is currently no industry-wide agreement on which is the most appropriate methodology to use for quantification of lost productivity. This is evident by the diverse views among researchers and practitioners on four common methodologies as shown in Table 3 (compiled by Braimah, 2008).

5. Comparing Loss of Productivity Quantification Methods

Within the past years there has been a vast amount of research carried out that provides empirical data for the effect of various factors on labor productivity. The main methods that are used to measure labor productivity inefficiency are: Total Cost Method, Modified Total Cost Method, Industry Standards, Learning Curve, Measured Mile, Baseline Productivity, Statistical Approaches, and Neural Network.

Based on the extent of information available in a particular case, all ways of estimating cumulative impacts try to be as objective as possible (Gulezian and Samelian, 2003). Thus, a guideline on which method should be adopted for inefficiency claims is necessary. The framework recommends the most favored approach rather than a set of possible ones. This means that, for example, an earned value analysis can also be used in case a measured mile study is not available. However, the measured mile method is most favored in that circumstance and hence is recommended. In addition, comparison studies do not appear in the possible outcomes of the framework since much more credible methods such as baseline productivity analysis and system dynamics modeling are preferred when time, available documents, and resources permit.

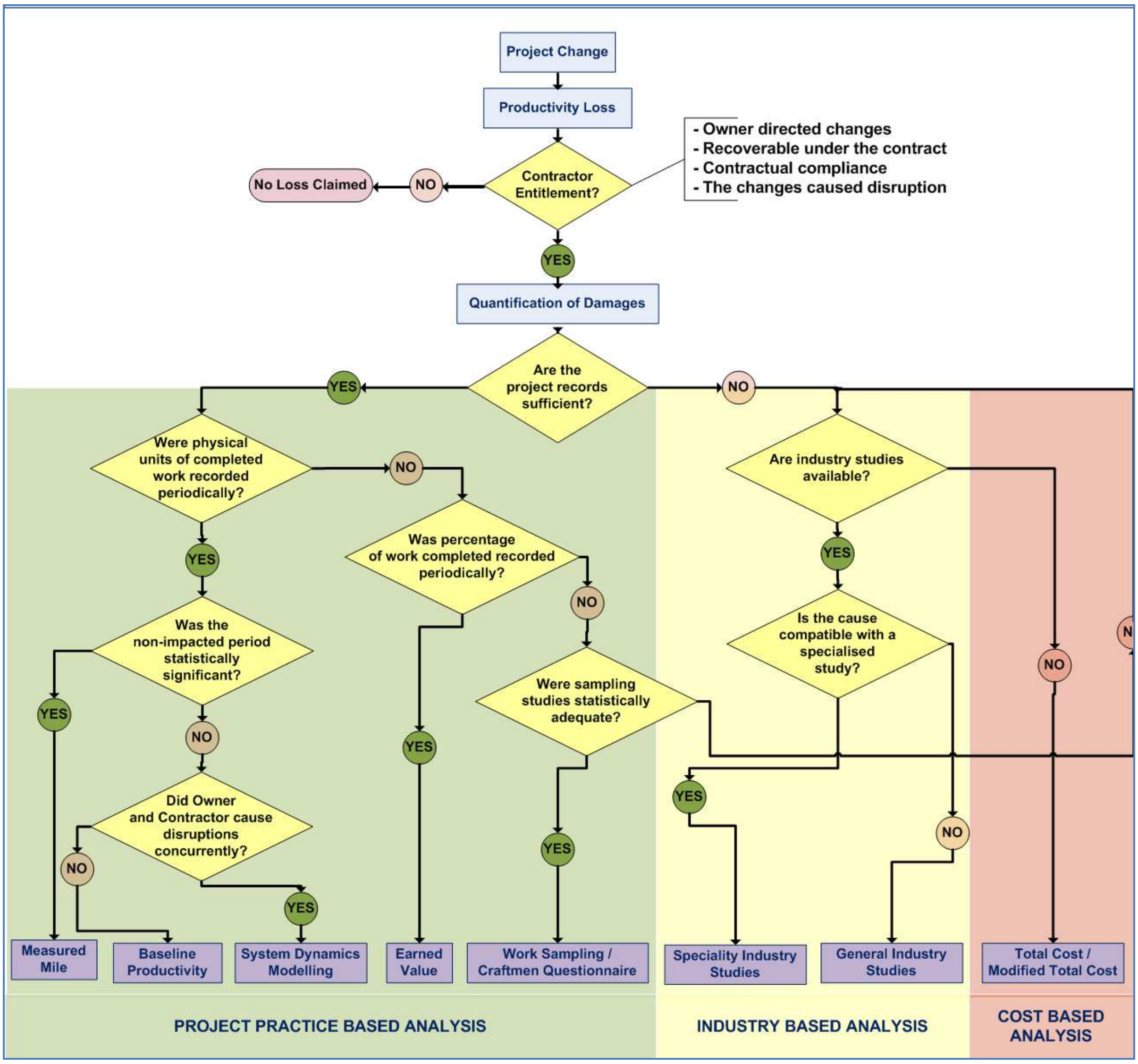

Figure 2 - Adapted from Quantified Impacts of Project Change, Ibbs, 2007

The common aim of all the methodologies is to determine among others the reduction in productivity from what a contractor would have achieved but-for an employer caused delay and/or disruption. However, the various methods attempt to accomplish this by different approaches as discussed in the previous section. The approaches vary mainly base on different sources of information they rely on for the analysis as indicated in Figure 2.

Table 3 – Comments on lost productivity methods adopted from literature review

References	Lost Productivity Quantification Methods				
	Total Cost	Modified Total Cost	Measured Mile	Industry Studies and Guidelines	Jury Verdict
Thomas and Napolitan (1995)	To be used as last resort	More accurate and preferable to Total Cost	Most acceptable method	Not as accurate as measured mile but useful in proving the existence of productivity losses	Acceptable if court finds claimants approach to be Unacceptable
Moselhi (2005)	Generally viewed with skepticism and acceptable by the courts under strict conditions	More credible than Total cost method	Most acceptable method	Acceptable if its use is supported by corroborative evidence	Educated guess based on available information in the absence of more reliable evidence
Gulezian and Samelian (2003)	Do not consider causal factors for which the owner is not responsible	Considers causal factors	Based on actual cost data	Not based on the project about which a claim is made	Useful if contractor is clearly entitled to cost compensation but has no basis for the amount that is claimed.
Finke (1998b)	Major weakness but preferred by contractors	N/A	Preferred over total cost but can only be used retrospectively	They typically do not yield activity-specific results	N/A
Schwartzkopf (1995)	Acceptable based upon certain conditions	Next to measured mile in terms of reliability and judicial acceptance	Most acceptable approach	N/A	Least favoured; useful if causation is established but amount of damages cannot be ascertained with certainty
Ibbs and Liu (2005)	N/A	N/A	Some limitations; proposed improved version	Somewhat useful	N/A
Ibbs (2012)	Significant shortcomings so should be a last resort method	Significant shortcomings so should be a last resort method	Most reliable	Has certain inherent problems but has positive applications	Useful if other methods are not available but entitlement is clear

The strengths of the various methods differ depending on the nature and sources of the data relied on. As a result their use in a given claims situation generate different results of different levels of accuracy (Schwartzkopf, 1995). According to Schwartzkopf et al. (1992), no method is generally acceptable for use in all cases, although some are preferred over others.

6. Conclusion

Cumulative impact is not just a theoretical concept but a real occurrence on construction projects suffering numerous changes, the impact of which is difficult to recognize as individual change orders are issued and priced. This is a result of difficulties in quantifying and pricing the impacts and also resistance on the part of owners to recognize such impacts in the change order.

This article combined the work of two notable studies by Ibbs and Leonard to quantitatively measure the impact project change actually had on construction labor productivity. The results of this comparison clearly demonstrate that increasing amounts of project change will have significant and progressively worsening impact on labor productivity. The courts and various boards of contract appeals have recognized a general entitlement to an equitable adjustment for the cumulative disruptive impact of multiple owner-directed changes, whose effect on productivity and cost exceed the direct costs of the changed work associated with each underlying change order.

None of the methodologies is perfect as each has its own strengths and weaknesses. The more sophisticated methodologies are regarded as more reliable than the simplistic ones, though the former requires more expense, time, skills, resources and project records to operate than the later. Availability and characteristics of information and degree of credibility of the quantifying methods are focused for the matching process. Together with employing qualified experts, the framework proposed herein can be used to find the most favored quantifying method in accordance with its circumstance to effectively recover the damages. The review covered many aspects of these methodologies including: their differences, how they are use, their strengths and weaknesses and factors affecting their use. Under appropriate circumstances, all of the methods set forth herein are technically acceptable. Of all the methods identified above, the most reliable are those reliant upon the analysis of factual, contemporaneous information drawn from the specific project in question.

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