4th Construction Specialty Conference
4e Conférence spécialisée sur la construction

Montréal, Québec
May 29 to June 1, 2013 / *29 mai au 1 juin 2013*

Enhancing Construction Claims Analysis Using Computer Simulation

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Abstract: Construction industry is described as a risky, complex, and multi-stakeholder business. In the domain of construction, on-time and within budget completion is an imperative; but unanticipated delays and its subsequent costly claims remain as an ongoing challenge. Construction claims are usually caused by experiencing alternate scenarios that vary from the project's original baseline. An effective presentation of causal relationships facilitates claim resolution procedure. In fact, the improvement of claim analysis process depends on enhancing the accuracy and the illustration of a claim case. This paper shows the benefits of using modeling and simulation concurrent with traditional claim analysis techniques such as the Measured Mile Method. Furthermore, simulation can be used as a standalone solution, to improve time extension and loss of productivity calculations prior project completion. In addition, simulation improves claim cases legibility for all stakeholders, especially those who have minimum construction knowledge. This objective was illustrated in an actual tunneling construction claim case-study. Simulation was utilized to demonstrate and analyze the conflict between the as-planned and the as-built conditions at the construction site. Simulation model built for the impacted event accurately predicted the time extension required due to unexpected soil condition. Productivity rates were analyzed using two methods: Simulation and the Measured Mile Method. The results exhibited the importance of utilizing simulation in evaluating construction claims.

1 Introduction

Design errors and unforeseen site conditions often lead to costly claims in construction projects. This frequently leads to expansive and exhausting disputes which commonly results in involvement of third party to assess such disputes. In this assessment process, the analyst should deal with a number of complex issues (e.g. illustrating cause and effect, quantifying cost and time caused by delaying events, assigning responsibility of delaying events). To evaluate and assess construction claims, many subjective decisions must be taken by the analyst that result in questioning the validity of claims. In addition, the most difficult part of assessing claim is to present the claim case in a way that will be convincing to the plaintiff and defendant (Minkarah & Ahmad, 1989). Preparing delay claims demands substantial effort, as it requires the detailed review of large stacks of project documentation to classify and establish the causes of delays. This process is tedious, complicated, and costly, partly due to insufficient documentation in construction projects (Alkass et al., 1995). An effective presentation of a complicated delay claim requires both high quality and detailed information. Visual supplements such as computer modeling in the presentation of a delay claim helps to make complex technical issues understandable. Therefore, visual aids have played a significant role in the analysis of complicated cases (Keane & Caletka, 2008).

Claims may be issued for time lost, loss of productivity, price escalation, and interest on any remaining money, additional costs due to change orders, and others. One of the problematic aspects for participants is quantifying the impact costs related to productivity losses (Levin, 1998). Analysis of the loss of productivity has been the subject of considerable research in recent years. Measure mile method, total cost method and learning curve models have been used in productivity related disputes. Furthermore, simulation has been found to be an attractive tool in demonstrating different construction disputes or scenarios configuring resolving productivity losses and delays. In other words, construction simulation techniques can be utilized to measure productivity of construction activities before and after occurred delaying events. With an accurate representation of the activities constituting the process, the analyst can estimate the production of the process and probabilities of meeting a given schedule.

Additionally, simulation can be applied to different types of claims that include productivity loss due to changes, owner or trade-contractor interferences, or unexpected conditions. The contractor often seeks compensation based on loss of productivity or change impact for non-recoverable costs or delays due to conditions beyond his control. Simulation models have been successfully used to provide an accurate representation of the original condition as expected at the time of bid and condition that would have been encountered after the new facts arise. Since productivity loss is derived from factors such as weather, labor skill, and site conditions, the simulator can build the simulation model and introduce the new facts to study and analyze their impact on the productivity, cost or time of the project (AbouRizk & Dozzi, 1992).

This paper examines the application of construction simulation to enhance the understanding of delay and productivity-related claims. For this purpose, two simulation models have been built for a tunneling project. First model has been developed based on the as-planned information and the second model based on the actual gathered information from the site. Thus, the authors can measure the expected productivity based on the developed models.

2 Background

The significant increase in the power of microcomputers and their affordability has made it possible for the construction industry to use computers in its daily operations. Over the past decades, computers have been used to help with complex issues in the construction industry, such as claim resolution, negotiation, planning, and scheduling.

Alkass et al. (1995) developed a computer system model for delay claims analysis and preparation, called Computerized Delay Claims Analysis (CDCA). They described how a customized expert system for a particular type of construction expertise claims was used to ease the progress of delay analysis and how it can reduce the cost and time of claims preparation. Hammed (2002) developed a framework to overcome the difficulties related to record keeping and retrieval procedures, called the Construction Project Document Information Centre (CPDICenter). In another study, Baram (1994) described an integrated system to support construction claims and litigation by supplying particular technical support for document control, productivity, schedule analysis, delay, and impact cost calculations.

To instruct and educate inexperienced engineers about the legal consequences of construction disputes, Diekmann and Kim (1992) designed a knowledge-based expert system intended to analyze claims changes. Bubbers et al. (1992) depicted a computerized assistance approach for claims resolution using a “Hypertext Information System”. The system provides relevant information for validating claims, although it has one major drawback compared to other expert systems: it has no decision-making capability. Ren *et al.* (2001) proposed an approach using intelligent agent technology, Multi-Agent System (MAS), to effectively and efficiently perform claim negotiation. Their approach helps the parties reach an agreement quickly, thereby mitigating the drawbacks of human mediator decisions in negotiations. AbouRizk *et al.* (1993) used a computer simulation model to resolve construction disputes arising from the inevitable changes in technical specifications. Simulation models were developed to estimate the cost of operations before and after the modifications.

The delay responsibility, as well as the cost of damages, must be ascertained accurately to the satisfaction of each party. One of the problematic aspects for researchers and project participants is quantifying the impact costs related to productivity losses caused by delays. Analysis of the loss of productivity has been the subject of considerable research in recent years (Moselhi et al., 1991, Hanna et al., 1999). The objectives of process simulation range from productivity measurement and risk analysis to resource allocation and planning. With detailed representation of the activities forming the process, simulation can predict the productivity rates of the construction operations and associated likelihoods of meeting a specific milestone. As resources in construction include costly machinery and labour, various distribution scenarios can be studied to select the optimum solution (AbouRizk et al., 1992).

High repetitive construction projects such as tunnelling applied modeling and simulation to predict realistically projects duration. Tunnelling construction typically consists of three main cycles: excavation, dirt removal and tunnel support. The interdependency of these cycles, and the unanticipated geological conditions makes tunnelling a high risk construction projects. Statistical features of simulating provide more realistic representation of activities duration (AbouRizk et al., 1992).Therefore, simulating tunneling advance rate is significant for predicting the project's completion date, schedule endorsement, equipment selection, and costs estimating (Touran & Asai, 1987).

3 Methodology

In this paper, a construction claim case was studied using a realistic tunneling case-study. The claim analysis was performed using two methods:

First, a stochastic simulation model was constructed to represent the impacted section of the project (i.e. after the cause of the claim occurred). To generate the impacted model, as-planned model was created first to represent the time required to complete the project during planning phase. Later, the impacted activities were added to the as-planned model. The impacted model was utilized to estimate the required time extension to complete the related segment of the project. The simulation model was able to mimic one complete cycle of the tunneling excavation. Each cycle was designed to excavate a fixed length. However, the time required to complete one cycle was variable and it was influenced by delay causes. Construction processes durations were represented by a probability distribution, rather than one single deterministic number. The logic behind this approach is counting for productivity loss by relying on statistical data represented in the probability distribution functions.

Second, Measured Mile method was used to illustrate the problematic areas and their effects on the examined section of the project. The case-study cost reports, working hours, and excavated quantities were utilized to demonstrate productivity rates during the related period. Loss of productivity due to the sudden variation was calculated using Measured Mile method.

The required time extension for the impacted section was calculated deterministically (traditionally), by simply adding the impacted processes to the original duration. The impacted model production rate was analyzed and compared to the as-built (actual) and deterministic production rates. Finally, the results were discussed showing how simulation is utilized to improve claim analysis and visualization. Furthermore, it was demonstrated how using simulation and Measured Mile method together can be a powerful tool in analyzing and presenting construction claims. Figure 1 illustrates the paper's methodology.

4 Case Study and Claim Description

The case study is the construction of a concrete tunnel project in Canada that has been executed and assessed for delay claims. This project experienced various types of delays and also offers access to the related information as the source of inputs for the developed simulation model; thus, it is a valuable practice case for delay claim assessment. Meanwhile, for confidentiality purposes, the source of the information and the parties engaged in this project are not revealed. The tunneling project consists of three main sections: A, B, and C. However, the focus of this paper is primarily on the excavation of section (C). Tunnelling procedure consisted of 26 construction processes falling into five major areas: start up, excavation, steel structure (ripping), concrete work, and demobilization.

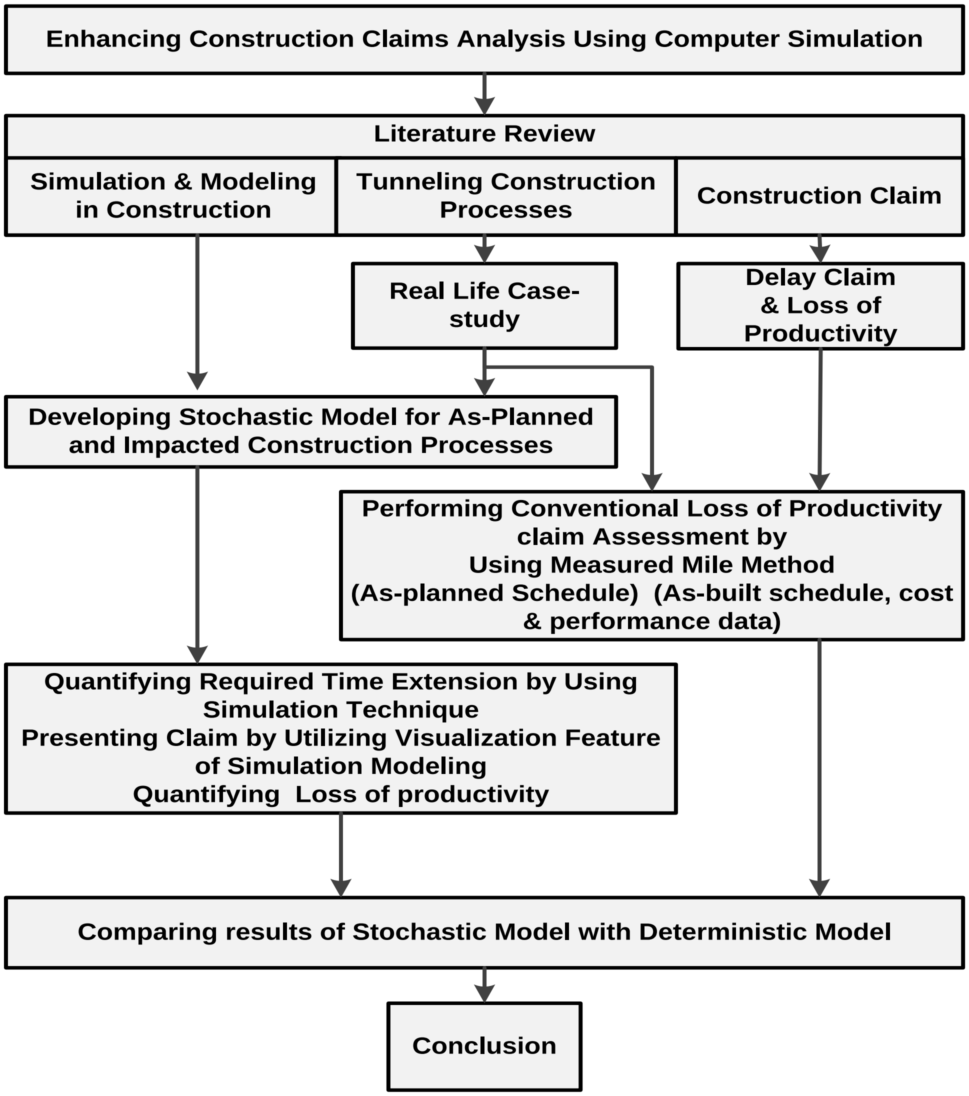


Figure 1: Research Methodology Flowchart

In this case-study, the project documents were used to recover the as-planned and as-built schedules. The loss of productivity assessment is based on the delaying events' information which was extracted from project documents. Unanticipated rock conditions encounter the section course. Consequently, the project's completion date could not be achieved. In fact, section C was scheduled to start on Aug 22, 2001, and to be delivered by Jan 15, 2002. However, it could not have been delivered on the agreed upon date. Section C was delivered on Mar 3, 2002 instead, which represents a delay of 29 working days. Table 1 summarizes the as-planned and as-built durations. The contractor claimed compensation to recover the damages due to the time and cost overrun. The contractor experienced various rock cavity conditions, which were substantially different from what was anticipated in the geological soil report; hence, extensive ribbing and ongoing soil investigation were required. The contractor had to continuously install extra ribs in many locations all through the tunnel length. Unlike the geological soil report, this installation demonstrated the existence of a serious rock cavity in section C, rather than a slight one. The client considered the situation an excusable delay. Nevertheless, the client calculations indicated that only fifteen additional days were required to complete the related excavation. The contractor failed to submit an accurate time estimate when the claim cause was introduced. Quantifying the damages caused by the misleading geological soil report accurately, was only possible after the job was completed.

Table 1: As-Planned Vs. as-built Durations

Schedule	Section (C) Dates		Total working days
	Start	End	
As Planned	August 22,2001	Jan 15 , 2002	96 working days
As built	August 22, 2001	March 3, 2002	125 working days
Difference			29 days

Introducing unforeseen situations to a construction project (e.g. Change Order) may cause unclearly defined delay causes in additional to the direct time related delays .Vague delays are usually considered to be productivity related delays that is hard to illustrate and verify. Both delays are referred to as Impact delays (Moselhi et al., 1991). In this paper simulation will be employed to verify and even predict the impact delay. In conjunction with simulation, Measured Mile Method was used to demonstrate how productivity can be influenced by unforeseen events.

5 Development of Simulation Models

The claim described earlier consists of two main components: (1) As-planned tunneling process. (2) Impacted tunneling process. EZstrobe software was utilized to construct a discrete event simulation model for the impacted tunneling process. Constructing the required model was by two phases: (1) Constructing as-planned model to represents the base line of the project. (2) Adjusting the as-planned model to introduce variations (i.e. impacted model). The models were based on the tunneling process shown in Figure 2. Construction processes employed in the models were extracted from project documentation; missing information such as probability distributions, were adopted from similar tunneling projects studied by Lin et al., 2009

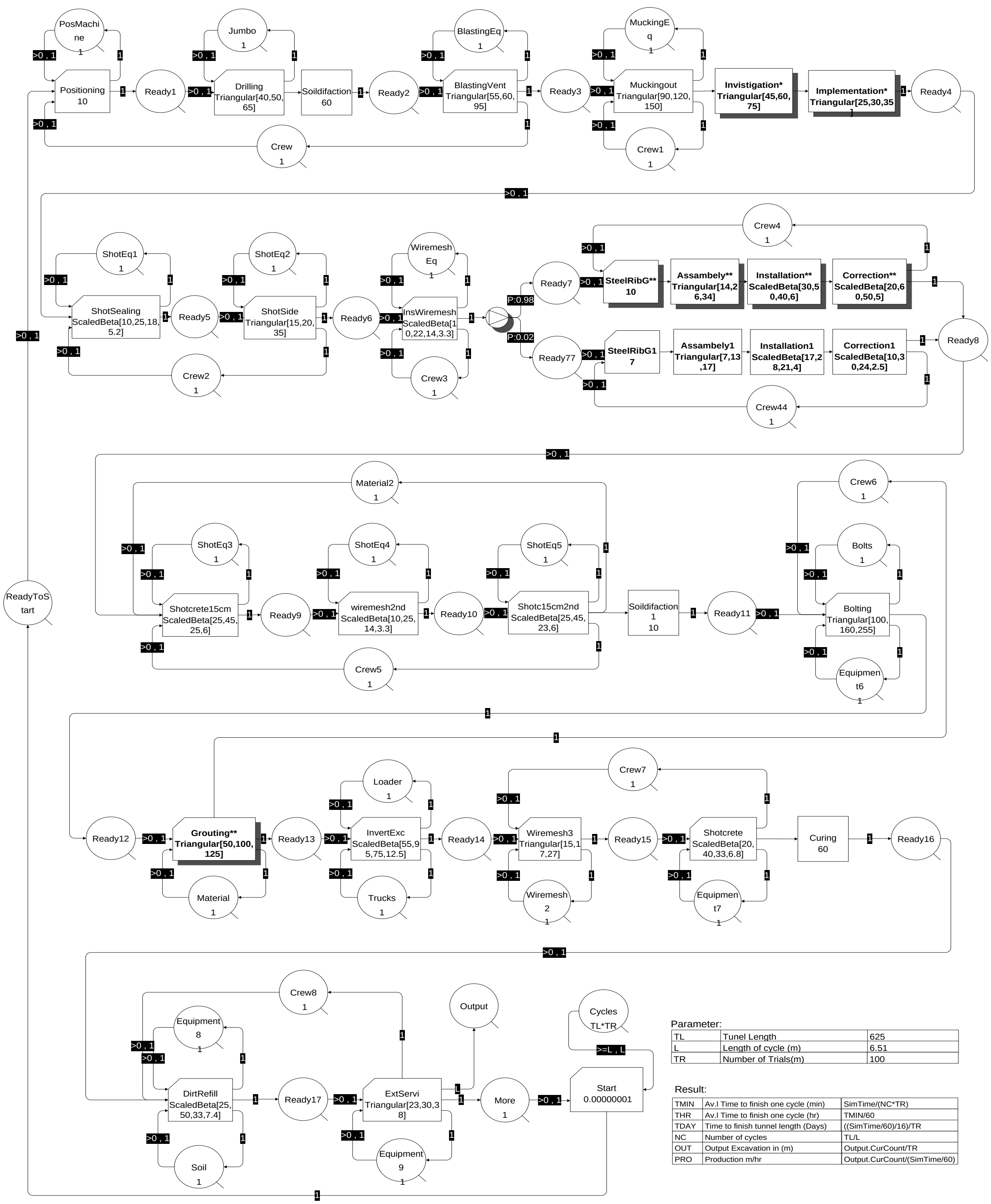
The as-planned model was established by applying the project's deterministic construction processes durations. It was activated to simulate the excavation of 625 lm for 100 trials. This length represents the impacted section of the tunnel. Table 2 illustrates productivity rate as per Ezstrobe simulation and the original contractual production rates as anticipated during the projects planning phase. As-planned model was primarily constructed to be used as the basis of the impacted model, which is the main focus of this paper As-planned model was validated by comparing it to the original as-planed schedule as demonstrated in Table 2.

Table 2: Comparison Between Contractual and Simulation Model Production Rates

AS PLANNED		
Items	**Contractual**	**(EZstrobe) deterministic durations**
Av. Time for a complete cycle (min)	960	949
Av. Total excavation duration (days)	96	95
Av. Production rate m/hour.	0.407	0.411

Figure 2 shows the impacted Ezstrobe Model. This model was constructed by adding the delay sources, represented by additional or modified processes. Impacted processes are highlighted in Figure 2. In order to simulate the project realistically, the deterministic processes durations were replaced by probability distribution functions. Statistical credibility and discrete event simulation were combined into one model to improve productivity measures accuracy. The intention was counting for unclearly tangible factors such as productivity loss and workers efficiency in the proposed model.

Impacted - two shift day simulation cycle



Parameter:

TL	Tunel Length	625
L	Length of cycle (m)	6.51
TR	Number of Trials(m)	100

Result:

TMIN	Av.I Time to finish one cycle (min)	SimTime/(NC*TR)
THR	Av.I Time to finish one cycle (hr)	TMIN/60
TDAY	Time to finish tunnel length (Days)	((SimTime/60)/16)/TR
NC	Number of cycles	TL/L
OUT	Output Excavation in (m)	Output.CurCount/TR
PRO	Production m/hr	Output.CurCount/(SimTime/60)

Figure 2: Impacted EZstrobe Model.

* Additional processes. ** Modified processes

The impacted stochastic simulation model was activated to excavate the disputed portion of the tunnel (625 m) for 100 trials. To establish good basis of comparison, the impacted duration was calculated deterministically in a convention manner. Table 3 shows the production rates as per Ezstrobe model, deterministically, and as-built (actual).

Table 3: (Impacted event) - Comparison between as-built, deterministic and stochastic production rates

IMPACTED			
Items	**As Built**	**Deterministic**	**Stochastic (Ezstrobe)**
Av. Time for a complete cycle (min)	1250	1147	1261.8
Av. Total excavation duration (days)	125	114.7	126.8
Av. Production rate m/hour.	0.312	0.340	0.308

The simulated model showed an accuracy of +1.44%. Deterministic method showed an accuracy of -8.24%.

6 Implementation of the Developed Models to Case Study

Recovering Loss of productivity claims may be considered as one of the most challenging types of claim. Although practitioners agree on the theory of loss of productivity, it is very difficult to reach an agreement on this issue either during the course of the project, or through meditation to litigation phases (Long & Carter, 2012). Several techniques are available for determining cumulative impact costs due to loss of productivity, but are not limited to: Total Cost Method, Modified Total Cost Method, and Measured Mile Method. Among the above-mentioned techniques, Measured Mile Method is considered the most accurate one by owners, contractors, and court. Since this method uses the actual data of contractor's performance, it brings more creditability to its calculation. Utilizing this technique may increase the contractor's chance of verifying loss of productivity claims. This method requires comprehensive cost reports, utilized man-hours, and installed quantity to implement the calculation. Before utilizing measure mile method, two criteria should be met (Long & Carter, 2012):

- Loss of productivity is caused by the owner and contractor does not contribute to this situation.
- Contractor suffers from cost and time overrun due to loss of productivity

The two main drawbacks of this method are :(1) the reliance on excellent project cost, man- hours and performance documentation and reporting. Unfortunately, many projects may not have such advanced documentation system. (2) This method can only be used when the project is completed. However, contractors usually calculate delay cost prior to project completion. Submitting early realistic delay costs to the client will minimize claims and helps in early resolutions of resulting disputes. Furthermore, it is difficult to utilize this method for the following reasons

- Difficulty to establish un-impacted period of work
- Difficulty to distinguish contractor's performance problem in impacted period of work from client-caused events.

Table 4 and Figure 3 demonstrate the application of Measured Mile Method for the claim case-study. It is conspicuous that productivity rates did not recover to its original status when the effect of delay is omitted. Moreover, productivity rate before problematic period started is higher than as-planned rates. The simulation model discussed in section two demonstrated a very similar result to Measured Mile Method. However, such model can be constructed prior the entire completion of the project. Furthermore, simulation doesn't require comprehensive cost reports; still it requires historical data of similar projects that are usually available at the contractor's database.

Table 4: Productivity analyses using Measured Mile Method (Tunnel Excavation Section C)

Weeks	Dates	Weekly labour cost ($)	Working Hours per week	Working Days per week	Performed Work (m)	labour cost ($) per (m)
A	B	C	D=C/16.5*	E	F	G=C/F
1	Aug 22-26	$29,620	1795.2	5	34	$871
2	Aug 29-Sep2	$29,510	1788.5	5	35	$843
3	Sep 6- 9	$22,512	1364.4	4	41	$549
4	Sep12-16	$29,298	1775.6	5	35	$837
5	Sep 19 -23	$28,508	1727.8	5	33	$864
6**	**Nov 14 - 18**	**$31,420**	1904.2	**5**	**9**	**$3,491**
7**	**Nov 21- 25**	**$28,612**	1734.1	**5**	**8**	**$3,577**
8**	**Nov 28- Dec 2**	**$28,608**	1733.8	**5**	**23**	**$1,244**
9**	**Dec 5 -9**	**$28,503**	1727.5	**5**	**12**	**$2,375**
10**	**Dec 12 - 16**	**$30,319**	1837.5	**5**	**10**	**$3,032**
11**	**Dec 19 - 23**	**$29,512**	1788.6	**5**	**16**	**$1,845**
12**	**Jan 9 - 13**	**$30,303**	1836.5	**5**	**19**	**$1,595**
13**	**Jan 16-20**	**$29,498**	1787.8	**5**	**15**	**$1,967**
14	Sep 26- 30	$26,476	1604.6	5	20	$1,324
15	Oct 3-7	$29,210	1770.3	5	27	$1,082
16	Oct 11- 14	$27,810	1685.5	5	28	$993
17	Oct 17 -21	$22,810	1382.4	4	29	$780
18	Oct 24 -28	$26,504	1606.3	5	26	$1,019
19	Oct 31- Nov 4	$28,512	1728.0	5	31	$920
20	Nov 7 -11	$29,202	1769.8	5	27	$1,082
21	Jan 23-27	$29,499	1787.8	5	23	$1,283
22	Jan 30 -Feb 3	$28,613	1734.1	5	24	$1,192
23	Feb 6 - 10	$28,293	1714.7	5	31	$913
24	Feb 13- 17	$28,721	1740.7	5	29	$990
25	Feb 21 -24	$28,912	1752.2	5	30	$964
26	Feb 26- Mar 3	$11,302	685.0	2	10	$1,130
Total	-	**$722,087**	**46,126**	**125**	**625**	-

* $ 16.5 is the average labour cost. ** Problematic weeks

Productivity rates were analyzed throughout all the related excavation period as illustrated in Table 5. Column A describes the excavation phase at the beginning of the project, where no rock cavity was found. Average productivity at that point was in its highest levels. Column B indicates the most problematic part of the tunnel, where unanticipated rock cavities were found mostly. During this phase average productivity rates dropped to its lowest levels. Column C illustrates the average productivity levels after the surprise was contained. Even though extra ripping was required in some locations during period D, the productivity was not as low as in period B; still productivity rate did not return to its original levels as in period A. Column D shows loss of productivity, which is the average productivity of period A and C (Semi-normal period) subtracted out from the average productivity of period B (problematic period). Column E is the average productivity rates for all the related period (26 weeks or 125 working days). Period E is simply the as-built tunneling productivity rate for the disputed portion of the project. Finally, column F shows the productivity rate generated by the stochastic simulation model. This demonstrates the accuracy of the model when it is compared to actual productivity rates shown in column E.

Table 5: Summary of productivity analysis using Measured Mile Method & Simulation

Measured Mile Method – Average Productivity Rates										**Simulation**	
Max productivity Period (24 days, 178 m) (A)		Low productivity period (40 days,112 m) (B)		Medium productivity period (61 days,335 m) (C)		Loss of Productivity (D)		Total Period (125 days, 625 m) (E)		Total Period (128 days, 625 m) (F)	
(m/hr)	($/hr)	(m/hr)	($/hr)	(m/hr)	($/hr)	(m/hr)	($/hr)	(m/hr)	($/hr)	(m/hr)	($/hr)
0.464	**$783**	**0.175**	**$2,114**	**0.344**	**$1,032**	**-0.202**	**-$946**	**0.313**	**$1,155**	**0.308**	**$1,234**

It's important to note that Simulation Method is not a replacement for Measured Mile Method. Both methods can be utilized simultaneously to illustrate claim analysis & productivity measures. More importantly, the uniqueness of each claim case drives the selection of the optimum method to be used. Factors such as type of construction, available data, and arbitration characteristics may govern the decision making process.

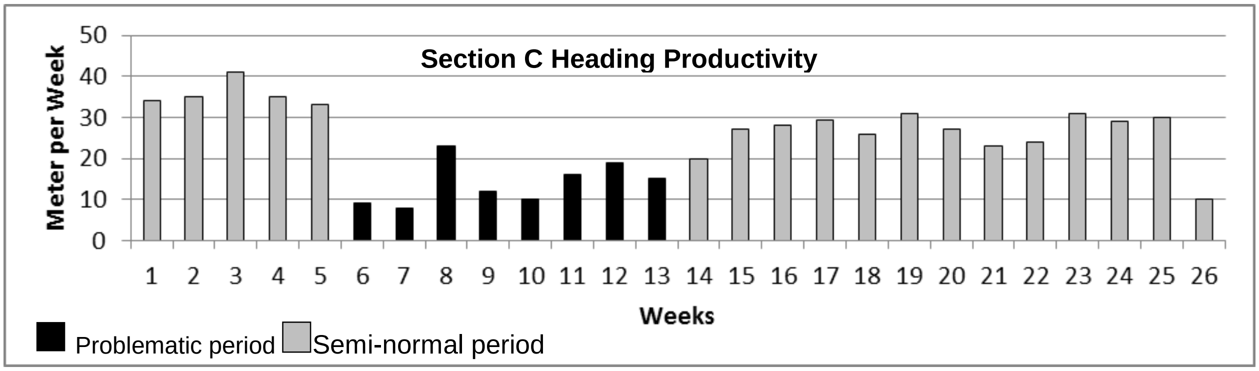


Figure 3: Illustration of productivity rates during the excavation period.

In addition to simulation evident accuracy, it is an excellent tool to visualize complicated construction activities. This feature may be mainly beneficial when claims are explained to non-construction related stakeholders. On the other hand, Measured Mile Method can be hard to comprehend, because it requires a full understanding of the project's cost reports, man-hours, and accomplished quantities. The graphical capability of simulation and modeling software are constantly improving to enable a more realistic visualization of impacted events.

The constructed model capability is not limited to its stochastic features and statistical reliability. By adjusting the model, "What-If" scenarios can be presented and analysed. This can be utilized widely in assessment of different claim scenarios. For instance using deterministic durations in the same model will give similar results to the client's point of view. This is mainly because the loss of productivity was not represented in such a model.

7 Conclusion

Using simulation is useful in analyzing different aspects of construction processes prior and following commencing in construction activities. Simulation has been utilised for: resource allocation, scheduling, site planning, decision making, equipment selection and productivity calculations (Halpin & Martinez, 1999). Nevertheless, simulation potentials have not been utilized completely in claim analysis, claim avoidance and disputes resolution.

Simulation can assist in establishing a realistic productivity rates during the planning phase. Consequently, cost estimating and scheduling accuracy would improve significantly. Additionally, simulating unexpected construction events can be beneficial in predicting required time extension and consequent costs. Knowing such information in early stages during construction can considerably avert construction claims. Simulation utilizes statistical data in mimicking construction processes realistically. This could be particularly helpful when schedule, cost and manpower information is insufficient.

Presenting construction disputes has been a constant challenge for claimant and defendant. Simulation supports visualizing inter-dependency between complex construction processes; it can also assist in visualizing the impact of variations to the project's initial plan. Cause and effect illustration procedure can be improved, especially for personals not directly related to construction activities. Simulation can be used concurrent with Measure Mile Method to quantify the loss of productivity impacts. More clarification in quantifying the loss of productivity damages may be achieved by utilizing construction simulation modeling techniques.

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