Delay Mitigation in Tall Building Projects

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Abtract: The rise of tall buildings in urban centres across the globe has been attributed to the need to create more urban space for an imminent population explosion and urbanization crisis. Despite the potential of this building typology as a sustainable alternative to urban design, it has become notorious for being delayed, and sometimes abandoned. The research domain is saturated with numerous studies on the causes of construction delays, however inadequate effort has been channelled towards the development of prescriptive tools with the potential to mitigate construction delay. The desired solution is one that would employ innovative methods to arrive at problem solving strategies for the ultimate purpose of delay mitigation. Today, the fourth industrial revolution (IR 4.0) offers the construction industry a unique opportunity to solve its many woes, such as delays, through leveraging the capabilities of digital technologies such as artificial intelligence and machine learning. Thus, it is the purpose of this book to describe a delay mitigation framework proposed for tall building projects based on the application of machine learning. The application of machine learning is considered in three major areas of project delay risk mitigation including “reliable cost estimates”, “reliable duration estimates”, and “delay risk assessment”. Interestingly, the concept of the delay mitigation framework can be extended to other project types, besides tall building projects.

Keywords: Cost, delay, Industry 4.0, risk, schedule

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This book is dedicated to all who have inspired and motivated our journey in life

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Preface

Over the last decade, the number of tall building construction around the world has increased significantly. This increase has been attributed to the need to create more urban space for an imminent population explosion and urbanization crisis. Unfortunately, construction delay and non-completion have become major issues when managing tall building projects.

This book highlights the research that has been conducted on delay in tall building projects, with the specific focus on the development of a framework for mitigating delay. The book also emphasizes the rise of technology in the modern construction industry driven by Construction 4.0, which is a phenomenon triggered by the fourth industrial revolution. Therefore, the main idea behind the development of the framework for mitigating delay is the adoption of machine learning, which is considered as one of the leading technologies driving the fourth industrial revolution. Among the main topics included in this book are construction delay, cost and duration estimation, delay risk assessment, and delay mitigation framework development.

The book allows the readers to understand the key factors that contribute to delay, and the potential mitigation strategy to overcome such delay. The content of this book has been carefully designed and arranged to enable an in depth understanding of the development process of the delay mitigation framework, hence can serve as reference to stakeholders in the construction industry. Furthermore, the book provides more understanding on issues related to construction delay from a broader perspective.

In preparing the book and implementing the related research, many important inputs were obtained through the experience of the authors and contribution of ideas from various parties. Without the support and contributions of these people a book such as this would not have been possible.

Acknowledgment

This research book would not have been completed without the support and assistance of numerous persons and organizations. Though, they cannot all be listed here, their contributions are sincerely appreciated and recognized.

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Chapter 1

INTRODUCTION

1.1 ORIGIN AND EVOLUTION OF TALL BUILDINGS

Traditionally, humankind has always been fascinated with tall buildings. Ancient structures such as the Tower of Babel, Colossus of Rhodes, the pyramids of Egypt, Mayan temples of Mexico, the Kutub Minar of India, and many more were built to show power, pride and economic strength (Chew, 2017). Even today, tall buildings are still the fascination of many nations globally. The origin of tall buildings in the urban context can be traced to the world's oldest metropolis in Shibam, Eastern Yemen (see Figure 1.1). Also referred to as the "Manhattan of the desert", Shibam is a third century mud brick city with a density of around 300 per hectare, where most buildings are 8 storeys high (Newman, 2001).

The evolution of the modern skyscraper is however attributed to the invention of the elevator by Elisha Graves Otis in 1853, and technological advancements in building materials in the late 1800s. The Home Insurance Building (see Figure 1.2a) was built as a 10-storey in Chicago in 1885, two stories were later added in 1890, to make it 12 stories tall with a height of 55 m (180 ft). In succession, the 16-story Monadnock Building (see Figure 1.2b) was constructed in Chicago, in 1891 to reach a height of 60 m (197 ft). Still in Chicago, the 15-story Reliance Building (see Figure 1.2c) was built in 1895 to a height of 61.6m (202ft). In the late 1920s, and early 1930s, the tall building boom was extended to other urban centres outside Chicago. The Chrysler Building in New York (see Figure 1.2d) was built in 1930, and was surpassed one year later by the Empire State Building (see Figure 1.2e) as the tallest building in the world, at a height of 382 m (1252 ft).

The tall building boom witnessed some paucity due to the Great Depression and World War II, and re-emerged in the 1960s. Hence, the Empire State Building remained the tallest building in the world for 41 years, until the World Trade Centre in New York (see Figure 1.2f) in 1972 (Sarkisian, 2016).

Chapter 2

CONSTRUCTION DELAYS

2.1 DEFINITION

The construction industry for many decades has been plagued by the occurrence of schedule delays as a major source of productivity losses. According to the Merriam-Webster Dictionary, a delay is defined as *"the act of postponing, hindering, or causing something to occur more slowly than normal"*. The following technical definition of construction delay also occurs in the literature (Aibinu and Jagboro 2002; Trauner 2009; Sanni-Anibire et al., 2020):

> *"A situation where a project's completion time is postponed due to causes that may be related to the client, consultant, or the contractor."*

> *"Situations where an event occurs at a time later than expected, or to be performed later than planned; or not to take timely actions; or occurring beyond the agreed date specified in the contract."*

2.2 TYPES OF CONSTRUCTION DELAYS

Construction delays can be categorized based on various perspectives including the liability of the stakeholders, effect on the project's critical path, as well as the simultaneous occurrence of the delays. The major types of construction delays are illustrated in Figure 2.1, and subsequently described.

Chapter 3
COST AND DURATION ESTIMATION

3.1 INTRODUCTION

In the previous chapter, the research theory confirmed that effective delay mitigation strategies can leverage the latest digital technologies in construction planning to more reliably estimate the cost and duration, and performance of projects associated with delay risks. Accordingly, this chapter describes the application of machine learning to construction planning in terms of cost and duration estimation. Generally, "planning relates to developing the logic of how a project will be constructed, while scheduling consists of integrating that plan with a calendar or a specific time" (Hinze, 2004). In construction planning, relevant activities include selecting appropriate construction methods, developing a Work Breakdown Structure (WBS), estimating durations, costs, equipment needs, human and material resources (Hendrickson et al., 1987a). The planning process is connected with the project scheduling, which is instrumental in managing the delivery of the construction project. Project scheduling helps to determine and illustrate the start and finish times of various tasks listed in the WBS (Pultar, 1990). A poorly developed project schedule is a causative factor for delays, and consequently cost and time overruns. The ensuing sections discuss the traditional methods used in estimating construction duration and cost, as well as the application of machine learning for the same.

3.1.1 Estimating Project Durations

The duration of an activity is simply the length of time or time span it takes to complete that activity, and which could typically be measured in hours, days, weeks, months or years. Typically, the duration of construction projects is usually estimated based on historical data from past projects, a "guesstimate" usually made by experienced schedulers, or by means of detailed analysis. Determining task durations by means of detailed analysis is dependent on the required human and material resources, as well as the productivity rates of these resources. Available reference guides are consulted to obtain productivity estimates for various tasks. This will entail unit productivity rates for equipment, while unit production times are applied to labor (Bielefeld, 2017). Published standard rates such as the R.S. Means publications are usually adjusted by regional or project-specific factors.

Chapter 4

DELAY RISK ASSESSMENT

4.1 INTRODUCTION

This chapter describes the application of machine learning for determining project risks related to the identified causes of delay. This is an extension of the prior theory that effective delay mitigation strategies can leverage the latest digital technologies in construction planning. Specifically, construction project risk is an uncertain event or condition that, if it occurs, has a positive or negative effect on one or more project objectives such as scope, schedule, cost, and quality (Hossen et al. 2015). Effective risk management practices in construction are crucial to mitigating undesirable events such as schedule delays. ISO 31000: 2018 define risk as "the effect of uncertainty on an organization's ability to meet its objectives". Hence, risk assessment entails identifying events that have the likelihood to cause deviation in a project's objectives, which in the case is the project delivery time. As given in ISO 31000:2018, the risk level is the product of an events' consequence and its likelihood expressed mathematically as follows:

$$\text{Risk Level (RL)} = \text{Consequence (C)} * \text{Likelihood (L)}$$

The consequences of not estimating the risk of project schedule delays is damaging to clients, contractors, and consultants including issues of claims, disputes, and disruption. The ensuing sections discuss the methods used in estimating construction project schedule delays, as well as the application of machine learning for the same.

4.1.1 Estimating Construction Project Schedule Delays

The extant literature on schedule delay analysis has flourished since the 1990s, and continues to flourish. There are various schedule delay analysis methods used in the present construction industry. Delay analysis methods may include: "as-planned vs as-built", "impacted as-planned", "as-planned but for", "collapsed as built", "windows analysis", "Time Impact Analysis", and "global impact technique". As-planned vs. As-Built method determines the difference between the as-planned and as-built completion dates as the time amount for which the claimant will request for compensation. Impacted As-Planned method uses only an as-planned or baseline schedule for delay

Chapter 5
DELAY MITIGATION FRAMEWORK

5.1 INTRODUCTION

This chapter describes the framework proposed to mitigate delays in tall buildings based on the application of machine learning in three potential areas supported by the relevant literature. These include a reliable estimation of duration; reliable estimation of cost, and delay risk management (Abdul-Rahman et al., 2006; Gondia et al., 2020). The Cross-Industry Standard Process for Data Mining (CRISP-DM) was adapted as the vehicle to convey the graphical format of the proposed delay mitigation framework as shown in Figure 5.1. The delay mitigation framework covers five phases including business understanding, data understanding, data preparation, modeling, evaluation, and deployment which are described in the ensuing sections.

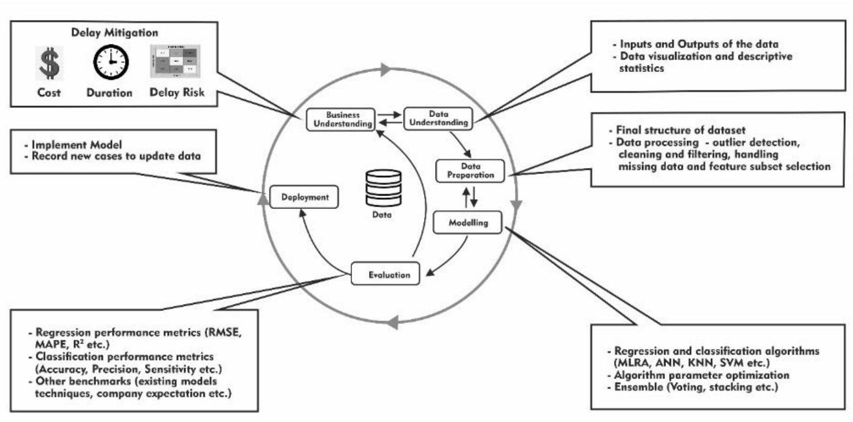

Figure 5.1 Proposed Delay Mitigation Framework based on CRISP-DM

5.1.1 Business Understanding

This entails defining the problem from a business perspective (i.e. cost, duration and delay risk) and obtaining relevant data. As stated earlier, the problem of delay could be mitigated through three key areas including: reliable estimation of cost, reliable estimation of duration, and delay risk assessment. Thus, relevant data required for machine learning application in these domains was obtained.

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