# SIMULATION-BASED DEVELOPMENT FOR UNCERTAINTY IN ENVIRONMENTAL FACTORS ON PROJECT DELAY

**Zirawani Baharum**<sup>1,a</sup>, Fathan Jamil<sup>1,b</sup>, Hairulnizam M.<sup>2,c</sup>, Azliza Yacob<sup>3,d</sup>  

<sup>1</sup>Technical Foundation, Universiti Kuala Lumpur, Malaysian Institute of Industrial Technology, Jalan Persiaran Sinaran Ilmu, Bandar Seri Alam, 81750 Johor Bahru, Johor, Malaysia  
<sup>2</sup>Faculty of Computer Science and Information Technology, Universiti Tun Hussein Onn Malaysia  
<sup>3</sup>Faculty of Computer, Media & Technology Management, TATI University College, Teluk Kalong, 24000, Kemaman, Terengganu, Malaysia  

Email: *zirawani@unikl.edu.my, fathan.jamil@unikl.edu.my*, hairuln@uthm.edu.my, azliza@tatiuc.edu.my

**Abstract**  
Costs, schedule and planning overruns due to late delivery in project completion or project delay have become issues for construction companies. These companies know there are uncertainties but they are not aware of the specific factors and the degree of impacts of these factors that can actually cause delay in projects completion. This paper aimed to identify the environmental factors that contributed towards project completion late delivery through literature review and integrating them with the business processes of the case study. A simulation-based model was developed using ProModel software. The methods involved were identifying the problem of project completion delay and collecting data relating to the business processes. Design analysis was then conducted to determine the input, process and output using Promodel before the simulation model was created and conclusion was being finalized. The development of simulation models will allow construction companies to monitor and minimize project completion delay.

**Keywords**— Promodel, uncertainty, simulation, environmental, uncertainty

## THE INTRODUCTION

Most construction companies are more concerned on the impacts caused by uncertainties such as human and equipment factors, rules and policies, agreement and economic issues [1-9]. Nevertheless, this research paper focuses on environmental factors as it is deemed to be necessary and contributive in terms of project findings.

This project is conducted to develop a simulation-based model for environmental factors that contribute to project delay or project completion late delivery (PCLD) at Syarikat Air Joroh Holdings (SAJ). Uncertainty can be defined as risk and complexity during the planning and construction activities [10].

Projects in construction industry have the possibility of being affected by uncertainty. The term uncertainty is used interchangeably with the word factor, which refers to the same meaning as the former and this research paper will focus on the environment.

Environmental factors are seen as to play certain pivotal roles in PCLD, which some construction companies including SAJ Holdings overlook them. Uncertainty may be noticed in unclear decision-making concerning the selection of construction methods, activity dependence relationships, inspections, and activity execution.

Duration of completion of construction projects is also seen to play pivotal roles in measuring the performance of companies. It is to be understood that the performance of a construction project in terms of time, cost, and quality is subject to a large degree of fluctuation due to the presence of uncertainty [11].

On time project delivery within proposed budget and meeting clients’ requirements is an indicator of a successful delivery. Uncertainty can create certain influences on construction projects as factors such as poor weather conditions as well as activity and facility constraints take places.

The uncertainties are the environmental factors that would cause late delivery in projects completion. Therefore, PCLD can be defined as execute later than intended plan, or particular period, or later than specific time that all concerned parties agreed in construction project [12].

There are four environmental factors that are discussed in this paper namely; rain, flood, hot and dry, as well as cold and snow [13-15]. These uncertainties are identified to exist worldwide and are believed to affect the project’s completion of construction companies.

## PROJECT DELAY FOR CONSTRUCTION INDUSTRY

SAJ is a water supply company that manages the process of water treatment and distribution of treated water to consumers in the state of Johor. This can be done upon identifying the reasons behind the delay of project construction involving piping activities in Johor Bahru (JB) that caused by underlying of uncertainty. Pipes construction is one of the business activities conducted by SAJ together with assigned contractors at domestic, commercial and institutional sites.

This construction of pipes involves 14 business processes (as shown in Figure 1), which require systematic planning and execution.

SAJ Holdings manages the construction of pipes and to assist it in resolving the delay problem, developing a simulation model using ProModel software is believed to be the most ideal and effective way to replicate and study its piping activities as to obtain inclusive understanding of the degree of the uncertainties that affect SAJ Holdings business operations.
Simulation-based Development for Uncertainty in Environmental Factors on Project Delay

However, construction activities can be delayed due to environmental uncertainties. Construction companies lack of concern on environmental factors that can actually affect their project deliveries. They also still lack the abilities to properly plan, estimate, and execute projects in a consistent, efficient, and reliable manner. Moreover, lack of appropriate techniques and technologies to handle the natural disasters are causing construction projects to be completed not on time or outside the targeted timeframe. These eventually result in poor performance by the companies. Moreover, there is no software system being developed yet using ProModel to measure the impacts of these environmental issues that contribute to PCLD as well as monitor these uncertainties. It is important to note that the uncertain factors are believed to affect SAJ construction projects in terms of planning, schedules, costs, and delivery of services. [16] explained that the impacts of delay can be seen in terms of time and cost overruns and disputes among others. It has become a norm that when projects are not completed on time as planned, project completion schedules are extended and additional costs are incurred. The delay leads to higher costs due to longer working time, labor cost increase and higher fabrication costs [12].

SAJ incapability to follow its pipes installation operations based on its plans and schedules can be detrimental to its business progression. Furthermore, this will also cause SAJ operational costs to be out of its initial capital allocation. As a result, SAJ cannot provide the best water utility services due to late delivery of project completion that occurs and this would incite SAJ customers to be unsatisfied with its services. SAJ has the knowledge of the existence of the environmental issues. Nevertheless, it is not aware of the specific factors and their impacts that can significantly affect its projects completion. Thus, the development of simulation model is important as to enable SAJ to monitor these environmental factors. In addition, a discrete event simulation software known as ProModel will be used in this project for planning, designing and analyzing the business model.

Simulation-Based Model Design

The first step in conducting this research paper is identifying the problem faced by construction companies such as SAJ. A comprehensive review on several journals gives some insight on the late delivery issue in the construction industry. Several significant uncertainties concerning environment proved to cause delay in projects completion yet construction companies do not have inclusive understanding of the explicit factors and their degree of impacts contributing to PCLD. A thorough literature review is carried out and four environmental factors that are rain, flood, hot and dry as well as cold snow are identified. In addition, 14 business processes of SAJ are obtained are site clearance, excavation, pipe delivery, filling, valve delivery, metaled road, fitting and special, testing, tapping and meter stand, connecting, concrete works, verification and validation, commissioning and tidy up/hand over [5],[15]. The conceptual model of factors is integrated with the business processes and data collection is executed based on these models. Figure 2, Figure 3, Figure 4, Figure 5 and Figure 6 show some of elements of ProModel being used to represent the business processes.
Thirdly, design analysis is conducted to determine the input, process and output using ProModel software. Modeling elements such as locations, entities, resources and processing are inserted and defined based on the four environmental factors that have been integrated with the 14 business processes of SAJ. Suitable modeling elements are to be chosen in line with its capability to personify each process in the real piping activities situation. After that, operations and rules of these ProModel elements are required to be defined as how it should process, from one destination to another using the routing network. Time of operation might also be set-up. The inputs are completely put into their positions and it will receive command in future as when it will be run by clicking the ‘Play’ button. Figure 7 and Figure 8 shows the operation and defined that use in this simulation.

Next is the development of simulation model. As has been stated earlier, when all modeling elements are in their positions, the simulation model has been successfully created. ProModel is used in this paper, which provides discrete-event simulation (DES) ability. DES utilizes a mathematical/logical model of a physical system that portrays state changes at precise points in simulated time. Both the nature of the state change and the time at which the change occurs mandate precise description [19]. As a result, conclusion is being finalized with reference to the simulation model that has been created.

Uncertainty Factors and Progression of Business Process

Table 1 shows the progression in terms of percentage of processes for each factor. There are a total of 14 location activities and 13 environmental factors. The activities progression refers to the advancement of works conducted by the workers at the piping site. There are 13 factors with each having its own code. The following terms explain the terminology. For rain factor; RAIN 1= Drizzle, RAIN 2= Intermittent rain at P.M., RAIN 3= Intermittent rain at A.M., RAIN 4= Heavy rain. For flood factor, FLOOD 1= no warning, FLOOD 2= yellow warning and FLOOD 3= red warning. Moving on, for hot and dry factor, DRY 1= Hot, DRY 2= Hot and dry and DRY 3= Extremely hot and dry. The last factor is cold and snowy. SNOW 1= Mild cold, SNOW 2= Cold and snowy and SNOW 3= Extreme snow and wind. Each factor has its own unique attributes and characteristics which directly affect the results of PCLD.

| PROCESS | 1    | 2    | 3    | 4    | 5    | 6    | 7    | 8    | 9    | 10   | 11   | 12   | 13   | 14   |
|---------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| RAIN1   | 95   | 80   | 90   | 1    | 80   | 85   | 90   | 50   | 90   | 90   | 80   | 50   | 100  | 100  |
| RAIN2   | 50   | 50   | 50   | 50   | 50   | 50   | 50   | 0    | 50   | 50   | 50   | 50   | 100  | 50   |
| RAIN3   | 0    | 0    | 25   | 25   | 25   | 10   | 25   | 50   | 50   | 50   | 0    | 50   | 100  | 100  |
| RAIN4   | 0    | 0    | 25   | 25   | 25   | 10   | 25   | 50   | 50   | 50   | 0    | 50   | 100  | 100  |
| FLOOD1  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  |
| FLOOD2  | 75   | 75   | 50   | 50   | 50   | 50   | 50   | 50   | 50   | 50   | 50   | 100  | 100  |
| FLOOD3  | 10   | 10   | 0    | 0    | 0    | 0    | 0    | 0    | 25   | 20   | 0    | 0    | 25   | 25  |
| DRY1    | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  |
| DRY2    | 75   | 75   | 50   | 50   | 50   | 50   | 50   | 50   | 50   | 50   | 50   | 50   | 50   |
| DRY3    | 10   | 10   | 25   | 25   | 25   | 10   | 25   | 50   | 50   | 50   | 0    | 50   | 100  |
| SNOW1   | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 75   |
| SNOW2   | 75   | 75   | 50   | 50   | 50   | 50   | 50   | 50   | 50   | 50   | 50   | 50   | 100  |
| SNOW3   | 15   | 15   | 5    | 5    | 5    | 0    | 5    | 25   | 20   | 10   | 0    | 50   | 100  |

*SC= site clearance, EXC= excavation, PD= pipe delivery, F= filling, VD= valve delivery, RM= road metaled, FIT= fitting, TEST= testing, TAP=tapping, CON= connecting, CW= concrete works, VV= verify and validate, COM= commissioning, TU= tidy up
RESULT AND FINDING

Through the completion of this research paper, it enables the development of a logic simulation model using ProModel software. The simulation model is to be examined and validated through DES, a process of codifying the behaviour of a complex system as an ordered sequence of well-defined events. In this context, an event comprises a specific change in the system’s state at a specific point in time. The first benefit of doing this project is the ability to determine the environmental factors that cause project completion late delivery (PCLD). Moreover, SAJ will be able to deal with PCLD, through the development of simulation model as Figure 9. The examination and analysis of the simulation model will provide valuable data on the negative impacts of environmental factors towards SAJ project operations. The delay of piping installation activities can be significantly minimized.

In addition, this model will provide a medium for construction companies, primarily SAJ to monitor the effects of the uncertainties and be more prepared to encounter them in future. These environmental issues can be systematically and properly dealt by SAJ as the model is utilized to act as a useful tool for SAJ to predict future natural disasters that would occur at its construction sites. In addition, with the on time delivery of water utility service, SAJ customers’ complaints can be alleviated, as they will be satisfied with its business performance.

Data collected from activities progression of the 14 business process are transmitted to SPSS software. In this research, automatic linear modelling analysis of SPSS is used to determine the degree of environmental effects on SAJ piping activities. There are two results that are successfully obtained through this analysis. Firstly, the 13 environmental factors that causes the most delay to the project are able to be determined and ranked accordingly. Secondly, location activities that are mostly affected in terms of delay by these factors can be detected genuinely. The result produced by Automatic Linear Modelling analysis shows that the data gained and utilized throughout this study is 100% reliable as the confidence level set-up is 95%.

Figure 10 above displays the total delays at each location activity caused by the 13 environmental factors. FLOOD 3 causes the most delay with 432.06 minute (min.) of delay. The second spot is RAIN 4 with 351.49 min. of delay. SNOW 3 is the third with 315.50 min. of delay. The fourth factor that causes the most delay is RAIN 3 with 305.21 min. DRY 3 is the fifth factor that causes the most delay with 252.04 min. Next is RAIN 2 with 240.09 min. of delay. The seventh spot is SNOW 2 with a record of 217.80 min. of delay, followed by FLOOD 2 (137.19 min.), RAIN 1 (109.40 min.) and DRY 2 (85.72 min.). The eleventh rank of the factor that causes the most delay is SNOW 1 with 25.72 min. of delay. FLOOD 1 and DRY 1 are the least factors that causes delay to SAJ piping construction activities with zero minute of delay recorded.

Figure 11 presents the piping activities at each process that are delayed due to overall environmental factors; rain, flood, hot and dry, cold and snow. The more the graph moving to the right, the more important it is. This means verification and validation is the most critical process affected by the environmental factors with a record of 20.2%. This indicates it is the most delayed process out of the total 14 activities. Pipe delivery is ranked the second with 0.146 delay criticality. Moving on, both testing and excavation activities are affected at 0.124 of delay due to the environmental factors. Valve delivery records 11.9% criticality followed by site clearance and tidy up with 0.114 and 0.109 importance respectively. Commissioning is ranked the eighth with 4.4% criticality. Filling has the least importance of delay problem with 1.8% record.
Figure 12 clarifies the processes that have the highest delay levels. It further proves the reliability of analysis of Figure 4. Verification and validation process records 0.202 or 20.2% of delay criticality. Pipe delivery is on the second spot with 14.6% delay criticality. Both testing and excavation activities are affected at 12.4% of delay due to the environmental factors. Valve delivery records 0.119 criticality followed by site clearance and tidy up with 0.114 and 0.109 importance respectively. Therefore, there are nine out of 14 processes that are critically delayed due to environmental factors. The reasons to this scenario are might be due to the attributes or characteristics of each process. Different process has different or unique activity. Verification and validation process is at the top of the list due to the activity cannot be conducted when environmental issues interrupted its operation at the construction site. Other processes that are fitting, road metaled, tapping, connecting and concrete works are not affected or in other words, critical due to the 13 environmental factors.

CONCLUSION AND FUTURE WORK
The construction industry is considered as a complex sector worldwide. PCLD is one of the factors that degrade the performance of construction companies including SAJ. In order for SAJ to run its piping installation processes effectively and efficiently without being affected by issues such as low quality of planning, schedules, and costs, it is an ideal strategy to analyze the simulation model as to allow SAJ to monitor the effects of environmental factors. Therefore, the development of a simulation model will create an opportunity for SAJ to improve its business model and deliver better water utility service for its customers.

The future work will be to examine as well as validate the simulation model. The data produced after the model is being run will be analyzed critically in order to determine how the 14 business processes will be affected. Then, this will enable the determination of which of the four environmental factors will cause the most PCLD towards the piping operation. It will give a transparent and holistic view of the degree of the factors causing the delay, as it will be recorded at the same time. This eventually allows the four uncertainties to be ranked according to the degree of impacts, from the highest to the lowest degree. Furthermore, other interrelated simulation software should be utilized to continue this kind of study. Besides ProModel software, there are numerous simulation software such as ASCEND, MapleSim, MATLAB, SimEvents, SimScale, SimPy and VisSim. With the utilization of these software, additional and unique information can be obtained because each simulation software provides different insights and results to be studied upon which can create more inputs for this kind of research study. Lastly, other natural disasters such as earthquake, hurricane and soil condition would be studied and be considered to be part of the uncertainties so that PCLD issue can be resolved in the construction industry worldwide through DES technique.
ACKNOWLEDGEMENTS

This work is supported by the Research and Innovation, Universiti Kuala Lumpur under the VOT: str17034

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