Responsible Design and Delivery of the Constructed Project
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EVALUATION OF SIMULATION TECHNIQUES FOR MODELING PROGRESSION OF CONSTRUCTION CLAIMS

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The unstructured and dynamic nature of construction projects and the on-site work complexities have been inevitably leading to claims. These evolve according to a staged mechanism set forth in the adopted conditions of contracts. More specifically, claims might progress expeditiously or drag depending on the nature of the applied mechanism and the behavior and interaction among contractual parties. As such, this complex problem of claim progression, which entails a lot of parameters and variables, is addressed in detail in this paper by resorting to three simulation techniques namely: (1) Discrete-Event Simulation (DES), (2) Agent-Based Modeling (ABM), and (3) System Dynamics (SD). The purpose behind this study is two-fold: (1) capturing and visualizing, through three different simulation models, the dynamic and interaction among the different entities as claims are progressing and defining the weak links hindering the efficiency improvement of such a process, and (2) comparing DES, ABM, and SD simulation approaches, using choose-by-advantage technique, and evaluating the advantages and drawbacks of each when studying the progression of claims. Results of all approaches are presented and analyzed followed by a discussion of the effectiveness of each simulation technique and the potential applicability of a hybrid approach in modeling the progression of claims.

Keywords: Discrete-event simulation, Agent-based modeling, System dynamics, Disputes.

1 INTRODUCTION

Claims have become almost inevitable through the course of construction projects. This has typically urged both owners and contractors to adopt effective claim/dispute mechanisms with the aim of resolving arising conflicts. Some mechanisms might be expeditious while others might involve unregulated periods thereby dragging the claims for a long period of time. As such, there is a need to simulate the adopted claim process in order to allow contractual parties to predict the different possible outcomes and take remedial actions when needed. In this case, three simulation techniques could prove promising in simulating the aforementioned process, namely; (1) discrete-event simulation (DES), (2) system dynamics (SD), and (3) agent-based modeling (ABM) (Maidstone 2012). Although several studies compared the applicability of these methods in various fields (Brailsford and Hilton 2001, Tako and Robinson 2009a, Tako and Robinson 2009b, Siebers *et al.* 2010, Maidstone 2012), and some have adopted these tools in dispute resolution (El-Adaway and Kandil 2009, Menassa and Peña Mora 2010), none has evaluated their feasibility in modeling the progression of claims in particular. Therefore, this paper aims at evaluating these three techniques in modeling the progression of claims and identifying the most suitable one.

2 SCOPE AND METHODOLOGY

This research study uses three simulation techniques to model the progression of construction claims. The adopted methodology involves: (1) defining the generic claim/dispute timeline, (2) creating DES, SD, and ABM models to simulate the progression of claims along the timeline, and (3) evaluating the applicability of every simulation method in replicating real-life scenarios.

3 CLAIM/DISPUTE TIMELINE

Claims arising within construction projects are addressed according to the mechanism set forth in the claim/dispute administration and resolution provisions. Based on relevant standard conditions currently in use, the mechanism typically consists of three main modules: (1) the disclosure of claim, (2) the judgment(s), and (3) the final resolution of dispute, as shown in Figure 1.

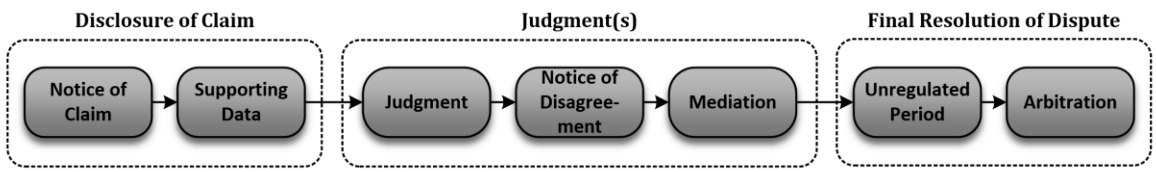

Figure 1. Claim timeline.

Starting with the disclosure of claim module, the claimant has to submit a notice of claim (NoC) to the other party to notify him of the arising issue. In addition, the claimant has to provide supporting data (SD) to justify the eligibility and/or quantum of the claim. In this study, it was assumed that the time-bars of these two stages are sequential whereby the time-bar of the supporting data stage is not activated unless and until the notice of claim is submitted. However, upon submitting the supporting data, the claim moves to the next module whereby an engineering professional shall act impartially to render a judgment. The rendered judgment is binding upon both parties with the possibility of turning final if not revoked within a specified period. In this case, either party shall submit a notice of disagreement (NoD) in order to revoke the judgment and initiate mediation. If the mediation process is not initiated, then the judgment becomes final and both parties waive their rights in pursuing mediation or arbitration. It is worth mentioning that this judgment acts as a condition precedent to mediation unless it was not issued in the first place within a specified period, allowing thereby either party to unilaterally initiate mediation at any time. When mediation is pursued, both parties shall endeavor to reach an agreement. If the mediation is deemed unsuccessful, the mediator can conclude the mediation at any time. Moreover, either party may terminate the process after a specified period. The end of the mediation process signals the start of the final resolution of dispute module. Within this module, either party can refer the matter in dispute to arbitration at any time, thereby dragging the claim within an unregulated period, as shown in Figure 1.

4 SIMULATION TECHNIQUES

The following subsections model the claim mechanism using each of the DES, SD, and ABM simulation paradigms within the anylogic environment (Borshchev and Filippov 2004).

4.1 Discrete-Event Simulation

DES is one of the most popular simulation techniques used to model a process (Maidstone 2012). This technique adopts the top-down modeling approach whereby it focuses on modeling in detail a system and not entities. Furthermore, the entities flowing through the process are passive and they cannot act independently since their behavior is affected by that of the system. Figure 2 depicts the anylogic model simulating the progression of claims using DES.

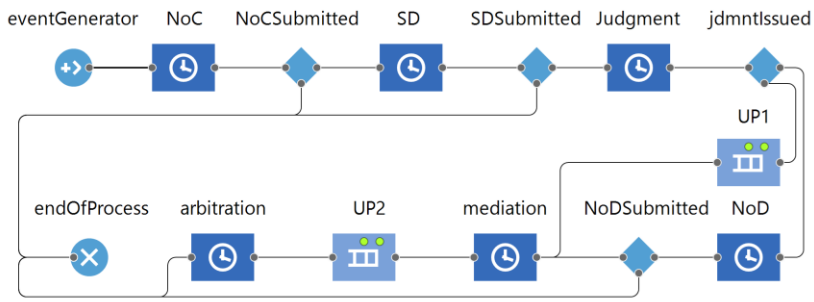

Figure 2. Simulating claim/dispute timeline using DES.

The model starting point is the source "eventGenerator" that generates the entities into the system. These entities are the events that give rise to a claim. All states within the claim/dispute timeline were modeled as tasks (i.e. dark blue rectangular shapes) except for the two instances of unregulated period. Once an entity flows into a task, an action is taken. For illustration, the event triggers the claimant to submit a notice of claim upon entering the "NoC" task. Upon exiting the "NoC" task, the claim entity is faced with two options through a "NoCSubmitted" select-output (i.e. diamond shape). In this case, if a notice of claim is not submitted within the specified period, the process ends, thereby shifting the claim entity to the "endOfProcess" sink where it leaves the system; otherwise, the claim entity moves to the supporting data stage (i.e. "SD" task). The claim entity proceeds through the claim/dispute timeline as explained in Section 3 and can possibly face two instances of unregulated periods (UP), modeled as queues in Figure 3. The first occurs when a judgment is not rendered within the stipulated time, then allowing contractual parties to initiate mediation at any time. This moves the claim entity through the "UP" queue to reach the "mediation" task. On the other hand, the second occurs when either party may refer the dispute to arbitration at any time. In this case, the claim entity stays in the second "UP" queue for an unregulated period of time before it moves to the "arbitration" task.

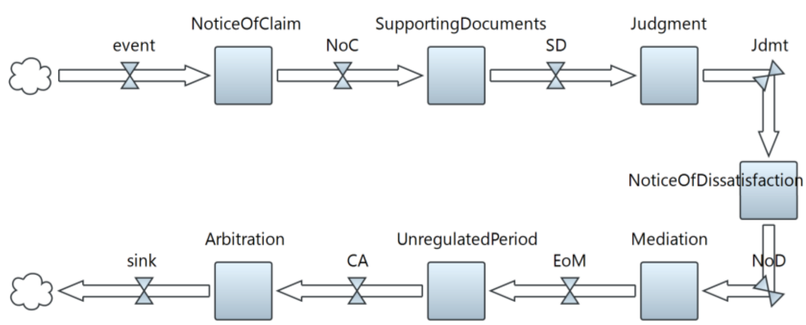

Figure 3. Simulating claim/dispute mechanism using SD.

4.2 System Dynamics

SD is another popular simulation technique used to model a system. Figure 4 shows the SD model of the claim/dispute mechanism. Similar to DES, a top-down modeling approach is adopted, but the system is modeled as a series of tanks or stocks (i.e. rectangular shapes) connected by pipes or flows (i.e. arrows), and entities are viewed as a continuous quantity flowing through this system. The rates of flow are controlled by valves, and accordingly the time spent in each stock or system state is modelled by fixing the rates of inflow and outflow (Brailsford and Hilton 2001).

In this case, the stages of the claim/dispute mechanism were modeled as the stocks, and the transitions between the stages were modeled as flows. Within the SD model, the claim entities flow from one stock to the other based on the flow rates set through direct and indirect variables. This approach allows modelers and practitioners to identify causal loops that show the impact of the system's variables on the flow of entities.

4.3 Agent-Based Modeling

Unlike DES and SD, ABM adopts the bottom-up modeling approach and aims at mainly modeling agents and the interactions among them (Maidstone 2012), and while focusing on both passive and active entities. This technique relies on state-charts to model the different agent states. For illustration, Figure 5 shows the state-chart of the claim agent, in particular.

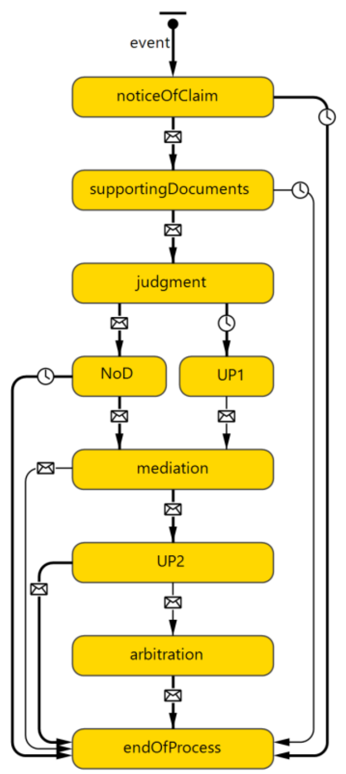

Figure 4. Simulating claim progression using ABM.

The various stages within the claim/dispute timeline were modeled as states that are connected using different types of transitions. For illustration, the claim agent transitions from the "noticeOfClaim" state to the "supportingDocuments" state upon receiving a message from the claimant agent indicating that the notice was submitted. On the other hand, the "noticeOfClaim" state is connected to the "endOfProcess" state using a time transition and not a message transition. In this case, if the time transition stipulated period expires prior to receiving the message of submitting the notice, the claim moves automatically to the “endOfProcess” state.

It is worth mentioning that other active agents such as the contracting and other involved parties (i.e. owner, contractor, judgment engineering professional, mediator, etc.) are part of the ABM model, and their interactions throughout the claim/dispute timeline contribute greatly to the overall emerging system behavior.

5 DISCUSSION

In this section, the choose-by-advantage decision making tool (Suhr 1999) was used to determine the most suitable simulation method for modeling the progression of claims, as shown in Table 1.

Table 1. Choose by advantage of the three simulation techniques.

Factors	DES		SD		ABM	
Nature of Problem (Applicability)	Process-Oriented **Highly Applicable**	85	System-Oriented Least Applicable	0	Individual-Based Moderately Applicable	60
Method's Goals vs. Problem's Goals (Similarity)	Comparison of Scenarios, predictions, and/or optimization More Similar	45	Understanding feedback dynamics and long-term system behavior Less Similar	0	Examining the system behavior that emerges from the interactions of agents **Most Similar**	100
Modeling (Ease)	1) Stochastic 2) Tasks and queues 3) Transition to the next stage is time-based Difficult	20	1) Deterministic 2) Stocks and flows 3) Transition to the next stock depends on flow rates Most Difficult	0	1) Stochastic 2) Agents and States 3) Transitions to the next state are time-based and/or action-based **Moderate**	70
Total		**150**		**0**		**230**

Starting with the nature of the problem, the claim/dispute mechanism is a process that has a queueing network. As such, the DES method fits in that regard and is highly applicable in modeling the progression of claims. However, the ABM method is considered moderately applicable (Siebers *et al.* 2010) since the mechanism is modeled as a state-chart of the claim agent. The SD technique is considered the least applicable as the aim behind modeling the progression of claims consists of focusing on the entities rather than on the system (Tako and Robinson 2009a).

On the other hand, comparing method’s goals to that of the modeled problem reveals different results (Table 1). In this case, the DES goals are considered to be more similar to the problem’s goals than the SD goals. However, the ABM goals are considered to be the most similar ones because this technique examines the behavior of the system that cannot be predicted automatically and emerges from the various agents’ interactions (Klügl and Bazzan 2012).

Moving to the ease of modeling, SD is considered the most difficult. SD models tend to be deterministic, which is not representative of the case of claims progression. Furthermore, stages are modeled as stocks, where the flow rate between the stocks cannot be easily evaluated. In the case of DES, modeling is considered difficult as the progression of claims is modeled in a stochastic fashion due to the variability of time needed to take the corresponding action at each stage. Furthermore, the transitions between the stages are mainly time-dependent and not action-based moving the claim entity to the next stage upon an action being taken by the concerned party. It can be argued that the time needed for an action to be taken can be modeled as the time needed for the claim entity to move to the next task, which is not easy to model. Similar to DES, ABM models are stochastic in nature (Maidstone 2012), but the transitions between the states are not only time-based but also action-based whereby a claim moves to the next state based on a taken action, which facilitates modeling the problem at hand. As such, the ease of modeling level of the ABM method is considerate moderate. Consequently, the points assigned to each factor, based on their corresponding advantage, showed that the ABM approach is the most suitable one to model the progression of claims with a total of 230 points.

6 CONCLUSION

Attempting the simulation of the claim/dispute mechanism can greatly help the contracting parties in predicting the effectiveness of the adopted mechanism and its potential applicability when resolving arising conflicts. Therefore, in this paper, three different simulation techniques, namely DES, SD, and ABM, were evaluated in modeling the progression of claims throughout the claim/dispute timeline. As such, a generic timeline was first generated for use under each simulation method environment. Although all three techniques present their own pros and cons, the ABM one outweighed the other two, scoring the highest using the choose-by-advantage decision making tool. It was found that the ABM method is moderately applicable with respect to the nature of the problem, has the most similar goals to that of the studied model, and is moderately easy to model.

References

Brailsford, S. C., and Hilton, N. A., A Comparison of Discrete Event Simulation and System Dynamics for Modelling Health Care Systems, *Proceedings of the 26th meeting of the ORAHS Working Group 2000*, 18–39, Glasgow, Scotland, 2001.

Borshchev, A., and Filippov, A., Anylogic—Multi-Paradigm Simulation for Business, Engineering and Research, In *The 6th IIE Annual Simulation Solutions Conference* 150, 45, March, 2004.

El-Adaway, I. H., and Kandil, A. A., Multiagent System for Construction Dispute Resolution (MAS-COR), *Journal of Construction Engineering and Management*, *136*(3), 303-315, 2009.

Klügl, F., and Bazzan, A. L., Agent-Based Modeling and Simulation. *AI Magazine*, *33*(3), 29, 2012.

Maidstone, R., Discrete Event Simulation, System Dynamics and Agent Based Simulation: Discussion and Comparison, *System*, *1*(6), 2012.

Menassa, C., and Peña Mora, F., Hybrid Model Incorporating Real Options with Process Centric and System Dynamics Modeling to Assess Value of Investments in Alternative Dispute Resolution Techniques, *Journal of Computing in Civil Engineering*, *24*(5), 414-429, 2010.

Siebers, P. O., Macal, C. M., Garnett, J., Buxton, D., and Pidd, M., Discrete-Event Simulation is Dead, Long Live Agent-Based Simulation!, *Journal of Simulation*, *4*(3), 204-210, 2010.

Suhr, J., *The Choosing by Advantages Decision Making System*, Greenwood Publishing Group, United States, 1999.

Tako, A. A., and Robinson, S., Comparing Discrete-Event Simulation and System Dynamics: Users' Perceptions, *Journal of the Operational Research Society*, *60*(3), 296-312, 2009a.

Tako, A. A., and Robinson, S., Comparing Model Development in Discrete Event Simulation and System Dynamics, *Proceedings of the Winter Simulation Conference*, 979-991, December, 2009b.