Applying Computer Simulation to Study a Multi-Modal Transportation Problem

Surapong Sirikulvadhana

Department of Industrial Engineering, Chulalongkorn University, Bangkok 10330
Tel: +662 218 6833 Fax: +662 218 6813 Email: surapong.s@chula.ac.th

ABSTRACT

One of the problems encountered in planning a multi-modal transportation problem is due to the randomness of weather condition. This translates to uncertain transportation time and uncertain schedule of arrival. When the transportation time changes, its effect is ripple throughout the supply chain planning. To make a good plan, the planning procedure should be somewhat adaptive to this uncertainty. Mathematical formulation is very hard and intractable due to the random nature of some parameters and its complexity when incorporating all parameters together. Computer simulation seems to be an outstanding tool of choice under this setup. The goal of a multi-modal transportation problem presented in this paper is to create a feasible schedule in a timely fashion for two types of barges to deliver the product within a time window at the destination and avoid the late penalty. Parameters in this problem are transportation cost for each mode, vehicle availability, transportation time, transferred rate, distribution capacity, weather condition, etc. We model this system and test it using the ProModel 7.0 as the simulation package. Even though data gathering for making a valid simulation model were overwhelming and the model itself was highly sophisticated, the effort was very rewarding. The outcome of this study helps decision makers to understand the actual operation, generate a multi-modal schedule that copes with the changing situation in a responsive and systematical fashion.

INTRODUCTION

The multi-modal transportation problem is one of the most sophisticated problems in the academic as well as in the industrial world. Its primary theme is to allocate transportation modes to accommodate the needs to supply its product(s) to its destination attaining the minimum cost. The variations of this type of problem are subjected to its constraints such as choices of transportation modes, delivery time frame, transit time, loading and unloading capacity, etc. Its complex nature is due to the variety of constraints as well as the randomness in them. Thus, the objective of many researches is to reach a reasonable solution. Traditional techniques such as mathematical programming seem to be highly sophisticated to incorporate all randomness into the model and thus intractable. Computer simulation has been known to suit well with problem of such nature.

LITERATURE REVIEW

The multi-modal transportation problem is an important part of supply chain management and has been studied widely. They sometimes are referred in the problem as carrier selection [3]. Basically, to choose proper carriers to assign to the selected routes from created optimized routes. For example, ProModel is used as an effective tool to study a network of barge fleet [1] and recommend to model a barge as an entity instead of the product itself to avoid exceeding amount of computational resource. A heuristic of steepest descent is used in [4] to find a feasible schedule for carriers with the minimum total cost. By nature of a greedy algorithm as of the steepest descent algorithm, the finding of a solution is very fast; however, the quality of the results cannot be guaranteed to be close to the optimum.

SYSTEM DESCRIPTION

The setup of our problem is to deliver a single product type to a destination within a timeframe at the destination. The reason behind this is the fact that the cost incurred when the delivery is not within the time window is overwhelming. However, the randomness from our transportation mode which is water mode contributes the intricacy to our problem. The transportation is partitioned into two segments; upstream river and downstream river. The problem begins from the production at the upstream river plant, then the product is loaded to small barges and the barges are towed by a small tugboat to its specified destination. The destinations of the small barges are the transshipment point or the destination in the sea. The transshipment point is for the small barges to transfer their product to a large barge which will be grouped and towed by a large tugboat to the sea. The tugboat for the small barges which destined to the sea will be changed at another transit point to a large tugboat. Due to the insufficiency of available barges, some of the small barges which finished unloading its product at the sea will have to make an extra trip to pickup product at the nearby warehouse and deliver at the sea again. Our goal is to study the use of barges and schedule them so they can deliver the required amount of product within the limited time window.

MODEL DESCRIPTION

We model this system using ProModel 7.0. As can be seen in figure 1, the production plant, transshipment point, buffer warehouse, and pier are all defined in ProModel as locations. It is intuitively appealing to define the product as an entity in ProModel. However, even if we define with the largest reasonable common unit, i.e. megatons, there will be large amount of entities in the model. This would translate into large amount of computational consumption. Thus, we define the barge as the entity, instead of the resource as suggested in [2] and [5], so there are two main types of entities, namely small and large barge.

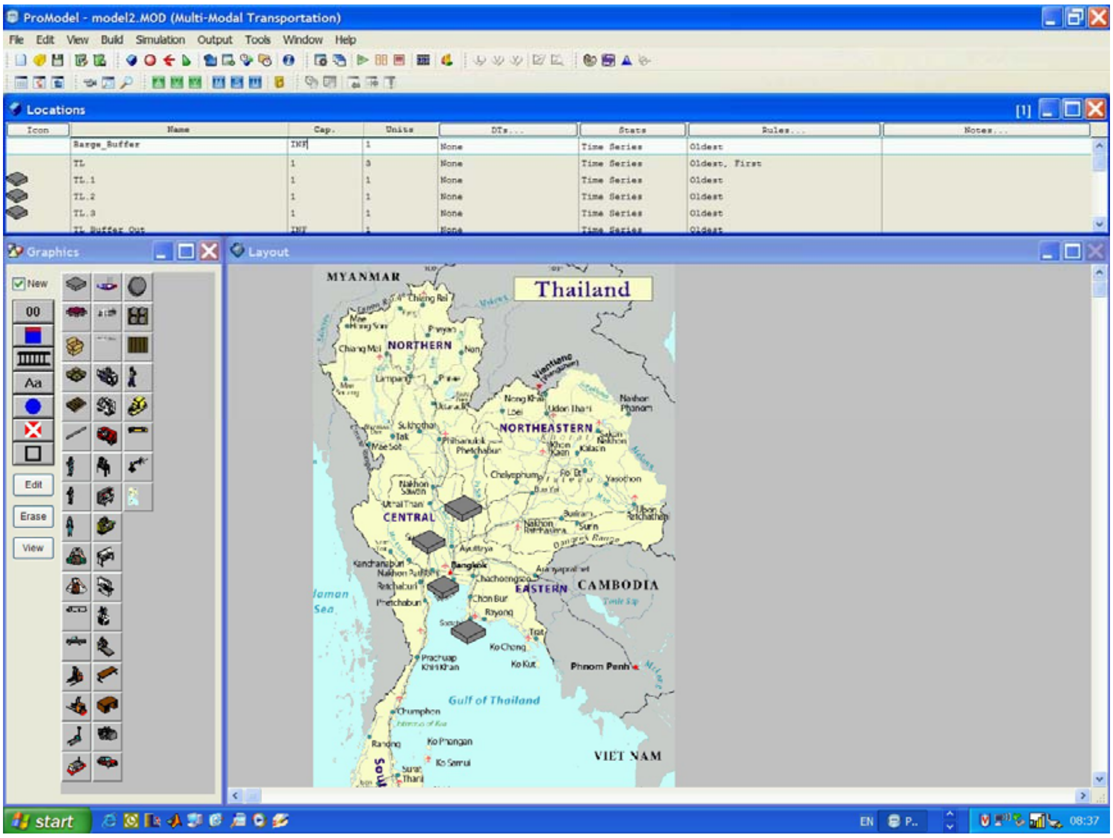

Figure 1: Layout of the System

In order to accommodate the amount of product, an attribute to represent the capacity of each barge is defined. Furthermore, the small and large tugboats are defined as resources. One of the difficulties in manual planning of this system is the synchronization at the transshipment point. This is to guarantee that the right quantity of both small and large barges will be at that location in the same period for transferring product. This can be achieved effortlessly in ProModel by limiting the capacity of the transshipment location as well as utilizing the group operation [5].

The setup of this model is quite similar to the setup in [1] in the sense that both systems are based upon water transportation mode. However, we not only model the system and analyze the average output data, but we also exercise the trace option to track individual activities occurring at each time as shown in figure 2 below.

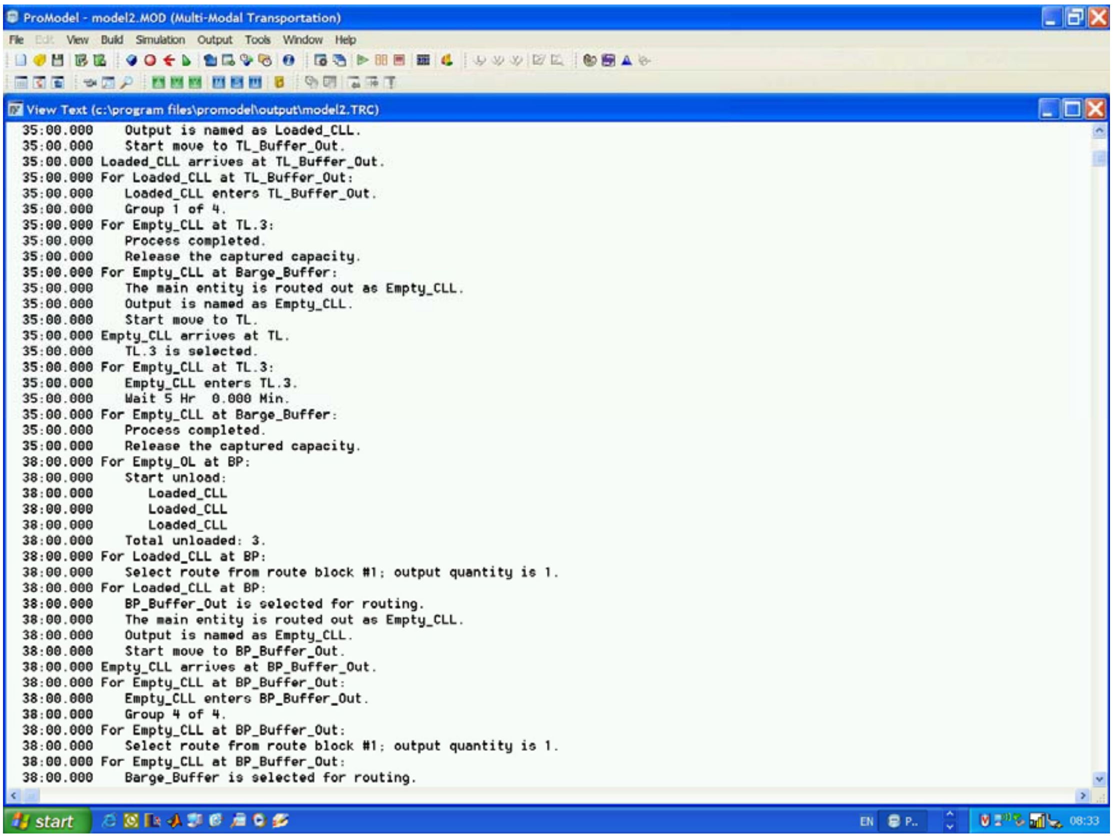

Figure 2: Detail of Activities Presented by Trace Option

The trace option was generally designed for the modeler as a tool to debug the model. Nonetheless, its detailed information of activities is used as a guideline for the practitioners to deploy their corresponding tasks according to the proper schedule. In the traditional manual procedure, the planners must either unavoidably often change their plan or extensively elaborate all possible scenarios to cope with the randomness of weather condition of the river and sea. This technique helps the planner cut the planning time and promotes more accurate result than the traditional manual planning procedure.

Moreover, this simulation provides a critical amount of time to prepare and deliver product, i.e. the total amount of time from loading product to the first barge at the plant to deliver the last required product to the sea. If this critical time is shorter than the available time after the ETA (expected time of arrival) of the ship in the sea is known, then the schedule of deliver will follow the plan. However, if the critical time is longer, then the implication is that the resource available is not feasible to deliver all amounts within the available time. Thus, the truck delivery which is a more expensive alternative will be introduced to make up the amount left to fill by barges.

Conclusion

The study in this paper is to understand and make a good feasible plan for the system to transport a single product type by choosing two transportation modes and deliver the product to its destination within the time window. We use the trace option to help the modeler to visualize activities with respect to the time dimension. This translates to an adjusted action plan for the practitioners at the job site when the given parameters change. Due to the frequent change of weather condition that reflects the changes in transition schedule, the use of this simulation model helps the planners adjust very quickly; thus, making this tool robust and more comprehensible than traditional mathematical programming models.

References

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