OPTIMIZATION ON SUPPLY-CONSTRAINED MODULE ASSEMBLY PROCESS

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1 Background and Identification of Problem /Knowledge Gap

To benefit from the concept of lean construction, prefabrication and modularization have been utilized to improve the construction cost, scheduling, quality, and safety performance. For the modular construction method, each module, which is a basic building block, goes through off-site fabrication, transportation, and on-site installation. The balance among the three processes needs to be delicately maintained in order to minimize the waste of material, time and effort.

However, due to the low labor cost and convenient sourcing of raw material (e.g. steel), the engineering design and fabrication of modules are usually undertaken by overseas vendors. Any unexpected interruptions to the overseas shipping process can easily disrupt the original plan, even if the module supply is planned based on on-site demands. In this circumstance, decisions should be made in order to mitigate the wastes potentially caused by the disrupted module supply, and in the meanwhile, the module assembly plan must meet on-site demands as closely as practically feasible. The unreliable supply of modules and the temporary nature of the module yard configuration make it difficult for project managers to update plans in a fast and effective manner. Furthermore, decisions resulting from subjective experience often turn out to be less efficient and non-optimal.

2 Research Aim and Methodology

This research aims to propose a systematic computer-aided optimization system to optimally derive and adjust the assembly plan in the module yard in coping with the dynamic supply chain and limited resource availability. In the optimization system, the total waiting time of all small modules is set as the objective function in order to evaluate the effectiveness of a module assembling plan. The smaller the waiting time is, the more effective is the module assembling plan. Constraint programming (CP) is deployed for deriving the optimal assembly plan for a module assembly yard. The proposed constraint programming based optimization framework for module assembly is presented in Figure 1.

In this framework, three data sources are investigated for identifying constraints to optimize the module assembly plan in the framework. They are 1) the logistics management database for overseas module supply information; 2) construction contract documents for on-site demand information, and 3) module yard crew information for the availability of labor resources. After identifying the three constraints, they are entered into the optimization engine in search of the optimum solution resulting in the smallest waiting time averaged over all small modules. There are two outputs of the optimization engine. One output is the optimal assembly plan with the start time and finish time of consolidated large modules. The other one is the total waiting time for each small module, which provides a basis for calculating the additional logistics management cost (e.g., storage cost).

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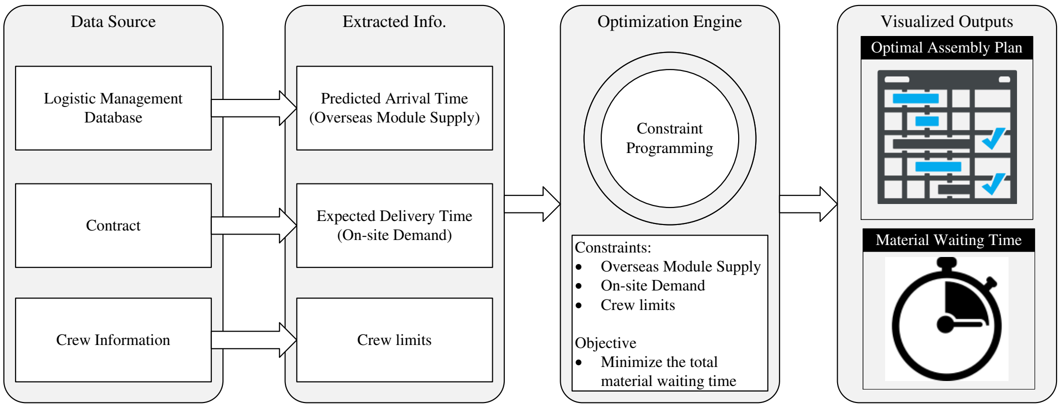

Figure 1: Constraint Programming Based Optimization Framework

3 Research Findings

A case project is abstracted from a modular construction project in Alberta, Canada and used to illustrate the effectiveness of the proposed methodology. In this case, 10 large modules are to be assembled from 40 small modules and have their own expected date on site. The 40 small modules are manufactured off-shore and then shipped to the module yard for further assembly. Two assembly plans (Table 1) with the least module waiting time are generated by the proposed optimization approach with respect to two different inputs on the small modules supply status.

Table 1: Detailed schedule information for each large module

Module ID	Assembly Duration (day)	Expected Delivery Time	Scenario 1		Scenario 2	
			Scheduled Start Time	Scheduled Finish Time	Scheduled Start Time	Scheduled Start Time
M1	5	15	9	14	9	14
M2	3	20	15	18	15	18
M3	4	25	17	21	20	24
M4	3	18	10	13	13	16
M5	2	13	9	11	9	11
M6	3	16	11	14	11	14
M7	5	31	20	25	24	29
M8	4	29	24	28	24	28
M9	4	26	21	25	20	24
M10	5	28	19	24	20	25

For an actual project, the developed optimization algorithm can be run multiple times over the project duration in order to mitigate the potential increase of module waiting wastes given the most recent module supply information. Under the fast-changing logistical conditions, the proposed methodology can provide effective assistance for project managers to make and update module assembly plans, aimed to reduce the waiting waste of materials. In conclusion, the proposed methodology can assist practitioners in (1) interpretation of material supply data and project scheduling data in an integrative fashion and (2) generation of the best crew job plan resulting in the least material waiting time incurred at the module assembly yard.