The Development of A Reusable Simulation Model for the Modular Housing Industry Using ProModel and Visual Basic

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Abstract

Developing a simulation model can be a time consuming process. Often multiple simulation models are built to simulate similar systems with small differences. The Housing Constructability Lab at the University of Central Florida has developed numerous models of modular housing manufacturing operations, both existing and planned. While the physical configurations differed considerably, the underlying manufacturing processes and relationships were remarkably similar. As a result, the research team recognized the opportunity for a generic modular manufacturing simulation system. This paper describes the common structural elements that are likely to be found in a modular manufacturing simulation model and outlines an approach for developing a generic simulation system based on this structure.

Keywords
Simulation, housing, generic modeling, reusable simulation

1. Introduction and Background

The modular housing industry is an industry characterized by complex manufacturing operations that combine extensive precedence activity relationships with flow line product movement and constraints. The modular housing industry is currently seeking innovative approaches to enhance quality and increase profitability within their housing manufacturing processes. The Housing Constructability Lab (HCL) at the University of Central Florida is presently helping to address these needs. Due to the complexity and dynamic nature of the manufacturing operations, simulation was used as a decision analysis and design tool. Simulation provides insight into improving productivity in both new and existing manufacturing facilities. Simulation helps housing manufacturers address concerns such as [4]:

- How changes in factory technology, procedures, staffing and layout will impact operations
- Correcting bottlenecks on the production line
- Optimizing new facilities and products during the planning stage to ensure efficiency and profitability once they are developed.

Noting the early success of HCL researchers in addressing these needs using simulation, modular home manufacturers are embracing the technology. As a result, HCL researchers were asked to develop several models, two for existing operations and two for the two newest plants in the industry. Regardless of previous experience with similar models, developing a simulation model is a time consuming process. According to Mackulak et al [2], simulation development time takes about 45% of the total simulation project effort. With the rapid growth that simulation is experiencing in the housing manufacturing arena, it has become unreasonable to develop unique models for all possible scenarios. Furthermore, with constantly changing needs, complete and incomplete models frequently have to be modified to reflect new requirements and innovative design concepts. These changes also take time to model. An alternative to creating a unique simulation model is to reuse an existing generic model that can be reconfigured for individual projects. Mackulak *et al* define a generic model as a model that is applicable over some large set of systems, yet sufficiently accurate to distinguish between critical performance criteria. The model becomes specific when the data for a particular system is loaded. In their research, Mackulak *et al* state that there exists a need for generic/reusable models that are properly structured to provide sufficient accuracy and computer assistance. "Their primary advantages are that they eliminate major portions of the upfront model design process, they are bug free, they have been code optimized for fast run times, and they can be consistently applied throughout the corporation". Furthermore, in their study they demonstrate that a generic model can be constructed to meet the needs of reuse for a situation with a reasonably small set of unique components and that when properly constructed a special purpose reusable model can be more accurate and efficient than new models individually constructed for each application scenario. In their study, simulation reusability resulted in an order of magnitude improvement in design project turnaround time with model building and analysis time being reduced from over six weeks to less than one week.

2. Problem Description

The HCL at the University of Central Florida has developed numerous models of modular housing manufacturing operations. Until 1999, the HCL used a consistent, but complex modeling approach to develop unique models for each factory. This approach yielded consistent and reliable models, but challenged the modeler:

1. It took a long time to code and then modify the code for alternative scenarios. This limited the number of different scenarios that could be explored.
2. The complexity of the approach made it difficult to train new simulation analysts. This was very important given the transient nature of student research assistants.

HCL researchers also noticed that, although there is a considerable difference in the physical configurations of the modeled manufacturing processes, the underlying processes and relationships were remarkably similar. Consequently, the research team recognized the opportunity for a generic modular manufacturing simulation system.

3. Design Approach

3.1 Model Description

The process of manufacturing modular homes takes place in a production line environment. Homes are produced in major sub-assemblies called modules that move from workstation to workstation. Line length ranges from 12 to 20 serial workstations, depending on the overall capacity of the facility. Throughput is determined by the line cycle time, which ranges between 1 and 4 hours per cycle.

At each workstation, specialized teams perform fabrication and assembly activities. Each activity requires an amount of time that is a function of the unique module design. Precedence relationships constrain the sequence of activities (e.g., walls cannot be set until the floor is assembled). If an activity cannot be completed within the line cycle time at the desired workstation, and the activity can be performed in the next station, the module is moved to the next workstation and the activity is resumed. Certain activities can only be performed in specific workstations (e.g., a roof can only be set in the roof set station that is linked to the roof assembly station via bridge crane). If the activity can only be performed in the current workstation, the module must remain in the station until the activity is completed.

Moving large modules between workstations is a non-trivial task in the modular factory. Each movement consumes up to several minutes per module and disrupts value-added production activity. Many higher volume modular manufacturers use a unique batch movement protocol to reduce interruptions associated with line movement. For example, a manufacturer producing eight modules per day (with a one-hour line cycle time) may choose to move modules in pairs every two hours instead of individually every hour. Thus, modules visit every second workstation on the line and reside there for double the overall line cycle time. The generic simulation model reflects these aspects of the home manufacturing environment. The animation screen for the simulation model is shown in Figure 1.

3.2 Common Structural Elements

When modeling different modular home manufacturers, it is very evident that many of the processes and their precedences are similar, but not identical. The primary difference between different manufacturers is often a different physical configuration or layout. Common structural elements include:

- Activities that represent manufacturing processes.
- Precedence relationships that dictate the sequence in which activities are performed
- Workstation constraints that specify the range of workstation where an activity can take place.
- Activity-based teams.
- Design-specific cycle time.
- Batch line movements

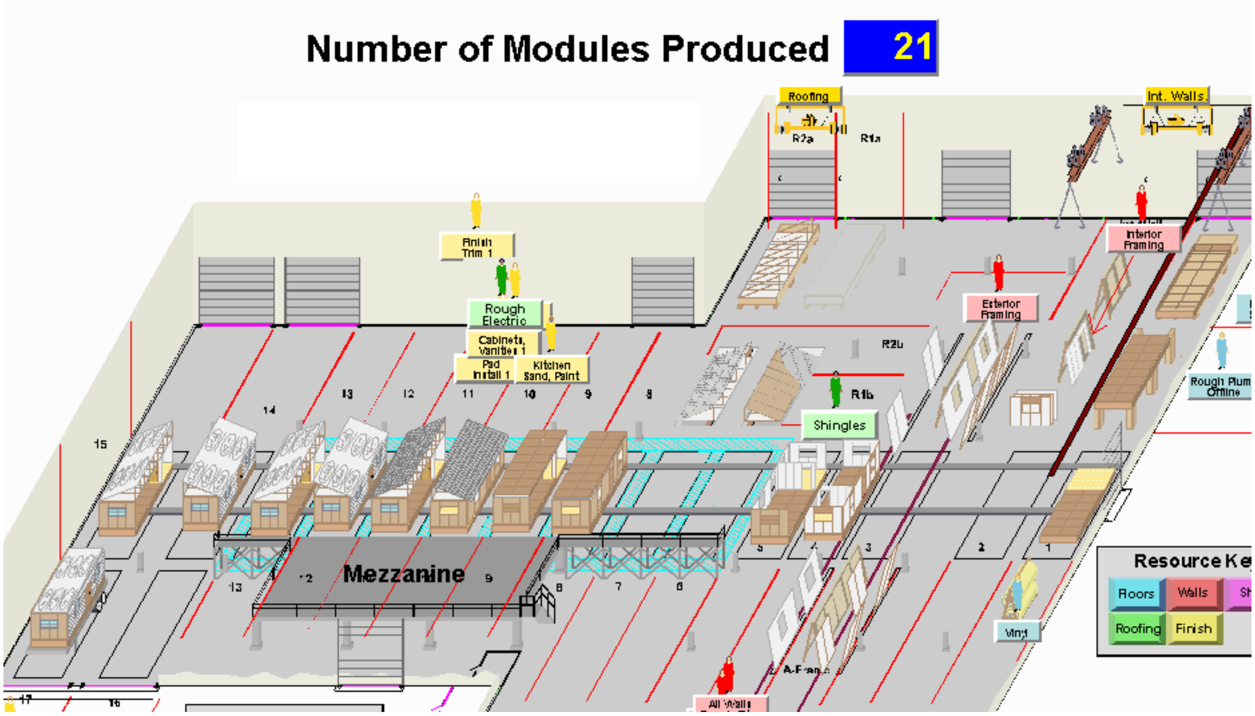

Figure 1. Simulation Model of a home manufacturing facility

The unique elements that differentiate one model from another are often the details and specific characteristics that describe the common structural elements mentioned above and the physical characteristics of the plant.

3.3 Development of the Generic Simulation Model

The implementation of a reusable model involves the use of spreadsheets for data input and macros for post processing report generation. A Microsoft Excel platform was utilized using the embedded Visual Basic for Applications. Figure 2 describes the overall design of the generic model. Section 3.3.1 describes the Excel input file structure and Section 3.3.2 summarizes the Visual Basic application. Section 3.3.3 describes the simulation scenario creation process using the reusable modeling approach.

3.3.1 Building the Excel Data File

The Excel data file consists of two spreadsheets:

1. Process spreadsheet: This spreadsheet contains information about the manufacturing processes that take place on the manufacturing floor. For each process, the mean processing time, resources required for completion, precedence relationships, and graphical representation in the simulation model are provided. The range of

stations where the process can take place is also specified. Table 1 gives an example of the first five processes in the process sheet (the process sheet typically contains information for 40 - 60 processes). Note that a process may have up to five precedence relationships.

2. The production forecast spreadsheet: The production forecast spreadsheet contains information about the expected future production schedule. The processing time for each process is dependent on a set of key design characteristics of the module, termed key drivers. The values of the key drivers are used to modify the value in the mean processing time field in the process spreadsheet.

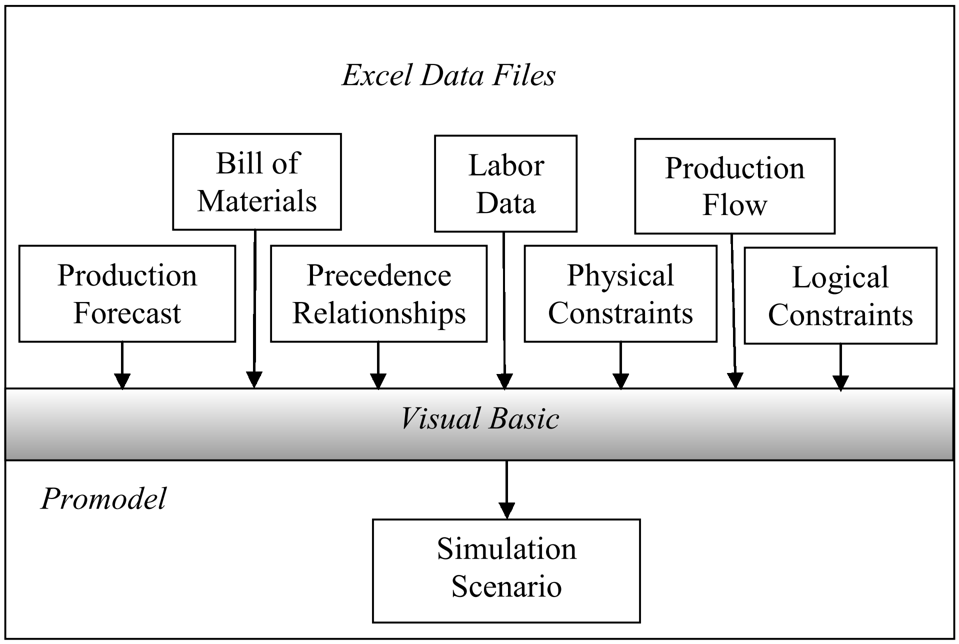

Figure 2. Generic Model Design

Process Number	Process Name	Mean Processing Time (hrs)	First Feasible station	Last Feasible Station	Precedence					Graphics Number
					1	2	3	4	5	
1	Mark Rails	2	*Offline*		6					
2	Framing Floors	4	1	1	1					
3	Rough-in (plumbing)	2	*Offline*		2					
4	Decking	4	2	3	2	3				
5	Mark Floors	0.8	2	3	4					

Table 1. Sample Process Sheet

3.3.2 The Visual Basic Code

The reusable model uses two Visual Basic (VB) scripts:

1. Code Generator Script: The Code Generator Script takes information found in the Excel sheet and creates Promodel simulation code. It first prompts the user to specify the production cycle time and the number of modules to be moved as a batch. It then creates a code sheet for each production station. For example, the simulation model found in Figure 1 contains 17 production stations. The Code Generator creates 17 sheets of code, one for each of the production stations. The simulation code is then manually cut-and-pasted into the simulation model.
2. Output Analyzer Script: The Output Analyzer Script is run after the simulation model is run to completion. The script takes the data in the simulation model output files and transforms it into information that can be used for decision-making. The current report is used primarily to locate potential manufacturing bottlenecks.

3.3.3 Creating the Simulation Model (The User's Point of View)

In order to create a simulation scenario, the user enters the scenario specific information into Excel spreadsheets (i.e. production forecasts, bill of materials, labor data, production flow, precedence relationships, and physical and logical constraints). The fields in the Excel spreadsheets prompt the user to input all data needed for a complete model. After the entire scenario data is entered, the user runs the Visual Basic scripts to generate the simulation model code. The code is then manually cut-and-pasted into the actual Promodel model and integrated with the screen animation constructs. The user then runs the simulation model. Upon completion, the simulation model generates output data files. The user can then run Visual Basic scripts to extract relevant data from the output files and put then into an Excel spreadsheet for further analysis.

The advantage of using this methodology is evident when debugging the simulation model. If earlier assumptions about the model are found to be incorrect, they can be corrected by changing the appropriate values in the Excel spreadsheet. The Visual Basic scripts are then rerun and, in a matter of minutes, the user will have an updated model.

Another advantage is the development of alternative designs for the same operation. Significant modifications, such as changes to the precedence relationships and flows, can easily be implemented using this methodology. Consequently, several simulation scenarios can be created in a short amount of time.

4. Results and Conclusions

Using a generic simulation approach, the Housing Constructability Lab has observed a significant reduction in model development and maintenance times and a corresponding increase in model quality. This permits new manufacturing systems to be modeled faster and more design alternatives to be evaluated using simulation. In addition, modelers can now decrease the time required to become proficient in modeling modular manufacturing systems, since knowledge transfer has been significantly improved.

Future research directions are likely to include the validation of model results using actual production data and the integration of the model with scheduling tools.

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