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SIMULATION OF PRODUCTION HOMEBUILDING USING SIMPHONY

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ABSTRACT

Production homebuilders operate in a sales-driven environment characterized by a varying demand for homes that is at odds with the homebuilders' and their trade contractors' requirement for work flow consistency. This paper presents a simulation-based approach for studying the production flow issues that production homebuilders face. Seven scenarios, representing different practices and possibilities that the homebuilders have, are simulated using Simphony, a simulation platform intended for building Special Purpose Simulation (SPS) tools. The results of this study indicate that simulation can indeed be used to shed light on the work flow issues that production homebuilders face.

1 INTRODUCTION

By virtue of its preponderant importance in satisfying the basic human need for shelter, the U.S. homebuilding industry has developed into a significant contributor to the U.S. economy. Today, homebuilding employs more than 3.5 million workers and produces approximately 1.5 million new homes (NAHB 2001), worth about $225 billion, every year. Indeed, housing investment and consumption contribute one-fifth of the US gross domestic product (Joint Center for Housing Studies, 1997) and the US housing stock has developed into the nation's largest single assets with a total value that exceeds that of the US equity markets. However, despite its importance and significance, the U.S. homebuilding industry is confronted with a multitude of persistent problems ranging from little innovation and production management difficulties, due to a fragmented nature of the industry, to regulatory hurdles and constant sales fluctuations.

The U.S. Homebuilding industry is characterized by an immense fragmentation and complexity. It is composed of hundreds of thousands of small, medium, and large companies ranging from material suppliers and product manufacturers to homebuilders, and trade contractors, linked by complex and ill-defined supply chains and communication links. Variations in housing affordability due to economic and regulatory factors result in business cycles that affect the homebuilders' ability to perform R&D (NAHBRC, 1998) and introduce consistency and quality into its labor relations and production process. This is due to the fact that most homebuilders operate by subcontracting most of the construction work of a home to a large number of specialty trade contractors that have to perform approximately 100 interrelated activities – the successful coordination and completion of which requires consistency. This consistency, however, is difficult to obtain because the amount of homes being produced at any given time is sales driven and may vary widely. On the other hand, building homes on speculation is kept to a minimum to avoid being caught with large inventories of unsold homes as during the last recession during the late 1980's.

The 1990's have produced a large consolidation process in the residential construction industry and resulted in a significant growth in the number and size of production homebuilders. Indeed, a 1994 survey by the NAHB indicated that although production homebuilders building more than 100, and in many cases several thousand homes nationwide, represent only 7% of all homebuilders, they produce more than 70% of all homes (Willenbrock et al., 1998). Figure 1 represents this breakdown of homebuilder sizes and homes built.

These large production homebuilders have been attempting to find solutions to production management problems. For instance ways to create assembly line processes at the construction sites have been studied with the intent of implementing processes that capitalize on efficiencies inherent in such processes. Motivated by these developments and interaction with several production homebuilders, the authors of this paper decided to use discrete event simulation to study these production flow issues.

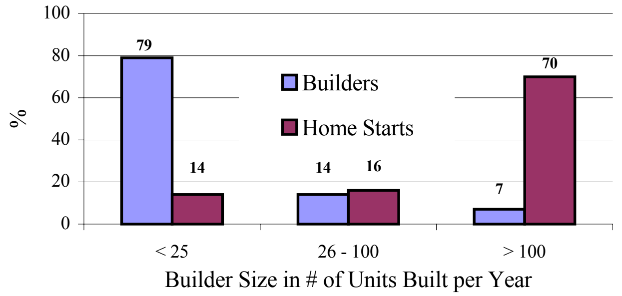

Figure 1: Homebuilder Sizes and Respective Percentage of Homes Built

2 APPROACH: SPECIAL PURPOSE SIMULATION USING SIMPHONY

Given that most practitioners in the homebuilding industry are not knowledgeable in simulation, it was decided to use Special Purpose Simulation (SPS) to create models that are more intuitive to these practitioners. SPS allows to model a project within a given domain by using symbols, model specifications, navigation schemes, and reporting in a format that is native to that domain (AbouRizk and Hajjar, 1998).

Simphony, a simulation platform for building SPS and other simulation tools – in this context commonly referred to as Simphony templates – was used to build the home-building SPS template used in this study. Simphony was developed by AbouRizk and Hajjar at the University of Alberta and was chosen because it provides a structured approach to building these types of templates and offers a comprehensive set of services under its framework including a discrete event simulation engine, a trace manager, statistics collection, graphing, random number generation, and report generation (AbouRizk and Hajjar, 1998). Of importance in this context is another concept, which is at the heart of Simphony, - the concept of a modeling element. A modeling element is a class that encapsulates the functionality of the system of the intended domain. For instance, in the case of homebuilding, it is possible to design a modeling element that encapsulates the construction of a home, i.e. all activities needed to build a home. Every instance of use of this modeling element in a larger model, i.e. the model of the construction of a subdivision with several homes, represents another of the same type of home being built. For more information on Simphony and the development of simulation tools, the interested reader is referred to Lueke et al. (1999), AbouRizk et al. (1999), Hajjar and AbouRizk (1999), and Hajjar and AbouRizk (2000). Figure 2 presents the Simphony Designer's main user interface – the end-user's view of a SPS tool.

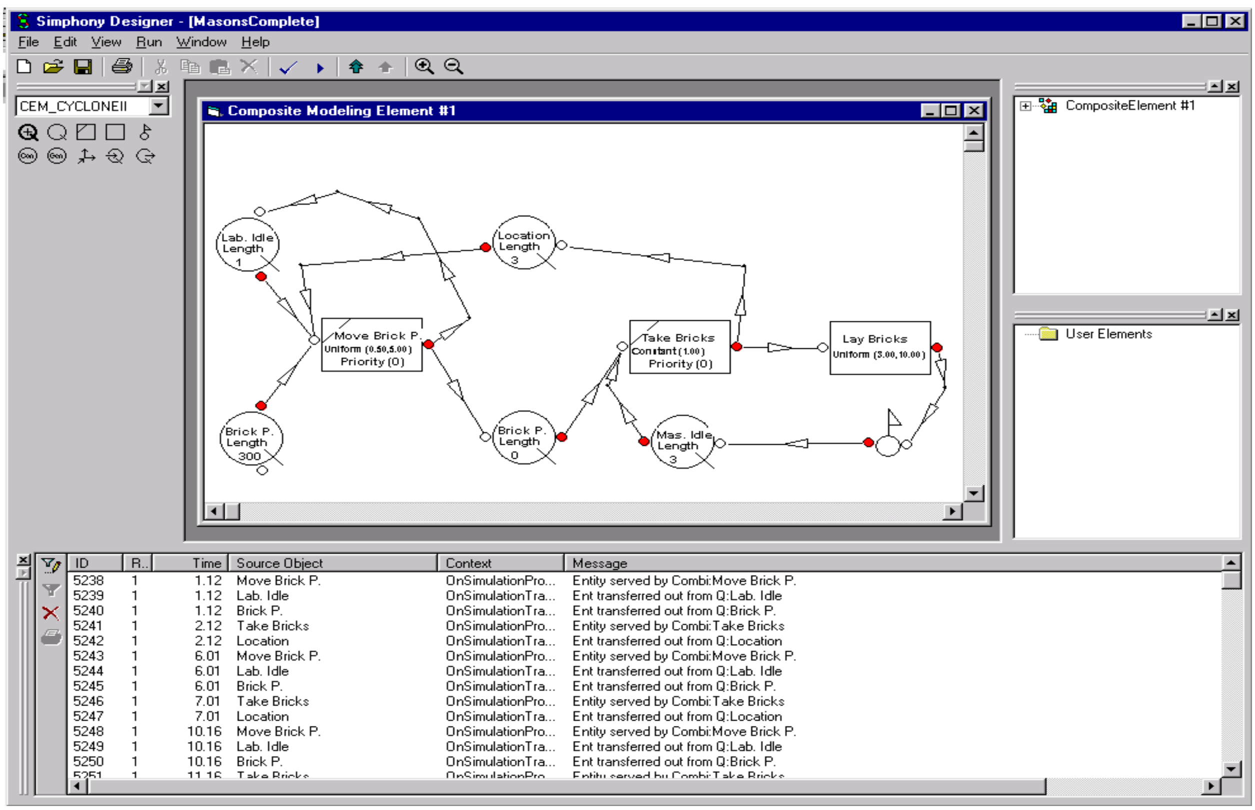

Figure 2: Simphony Designer Main User Interface

3 SIMULATION OF PRODUCTION HOMEBUILDING USING SIMPHONY

3.1 Simulation Scenarios

A subdivision of 90 homes of three different types or models was selected by the authors to serve as a basis for the study of the above-mentioned production flow issues. Thus, in essence, by simulating the construction of all homes in the subdivision according to different scenarios in terms of weekly numbers of starts and types of homes built, it would be possible to gain a better understanding of the complexities and interactions at work. The effects on production of these complexities and interactions could then be studied to determine the best practices for the production homebuilders. Seven (7) scenarios, briefly described below and summarized in Table 1, were selected for the study:

1. Scenario 1: 30 homes of each type were to be built with a random number of weekly starts following the pattern of an actual subdivision (sales-driven). Three deterministic schedules, i.e. different deterministic durations for all home types. Homes types to be built selected randomly.
2. Scenario 2: 30 homes of each type were to be built with one (1) start per week. One deterministic schedule, i.e. same deterministic durations for all home types. Home types to be built selected randomly.
3. Scenario 3: 30 homes of each type were to be built with two (2) starts per week. One deterministic schedule, i.e. same deterministic durations for all home types. Home types to be built selected randomly.
4. Scenario 4: 30 homes of each type were to be built with one (1) start per week. Three deterministic schedules, i.e. different deterministic durations for all home types. Home types to be built selected randomly.
5. Scenario 5: 30 homes of each type were to be built with two (2) starts per week. Three deterministic schedules, i.e. different deterministic durations for all home types. Home types to be built selected randomly.
6. Scenario 6: 30 homes of each type were to be built with one (1) start per week. Three stochastic schedules, i.e. different stochastic durations for all home types. Home types to be built selected randomly.
7. Scenario 7: 30 homes of each type were to be built with two (2) starts per week. Three stochastic schedules, i.e. different stochastic durations for all home types. Home types to be built selected randomly.

3.2 Experiment Setup

Using the above-described features of Simphony, the authors developed a special purpose simulation (SPS) template for residential construction by production homebuilders. In essence, three Simphony modeling elements – one for each type of home in the subdivision – was designed and implemented. These modeling elements encapsulated the activities needed for the construction of the respective type of home. Instances of these modeling elements were then used to simulate the above-described scenarios, with each instance of a modeling element representing the building of one home of the respective type. Figure 3 shows the modeling element developed for home type 1. In this context it should be noted that the use of only 10 activities for the completion of the home is a simplification that was made to reduce the computational overhead and to improve the traceability of the data. The basis for this simplification was input from various homebuilders that clearly indicated that the home building process falls into these ten stages. As such the modeling elements for the two other types of home present on the subdivision are similar, only denoting differences in the durations of the activities or stages. Table 2 provides an overview of the activity durations used in the three modeling elements developed for the SPS template for residential construction by production homebuilders.

Table 1: Overview of the Scenarios Simulated

Scenario	# of Homes Type 1	# of Homes Type 2	# of Homes Type 3	Selection of Build Order	# of Schedules	Type of the Schedules	# of Starts per Week
1	30	30	30	random	3	deterministic	random
2	30	30	30	random	1	deterministic	1
3	30	30	30	random	1	deterministic	2
4	30	30	30	random	3	deterministic	1
5	30	30	30	random	3	deterministic	2
6	30	30	30	random	3	stochastic	1
7	30	30	30	random	3	stochastic	2

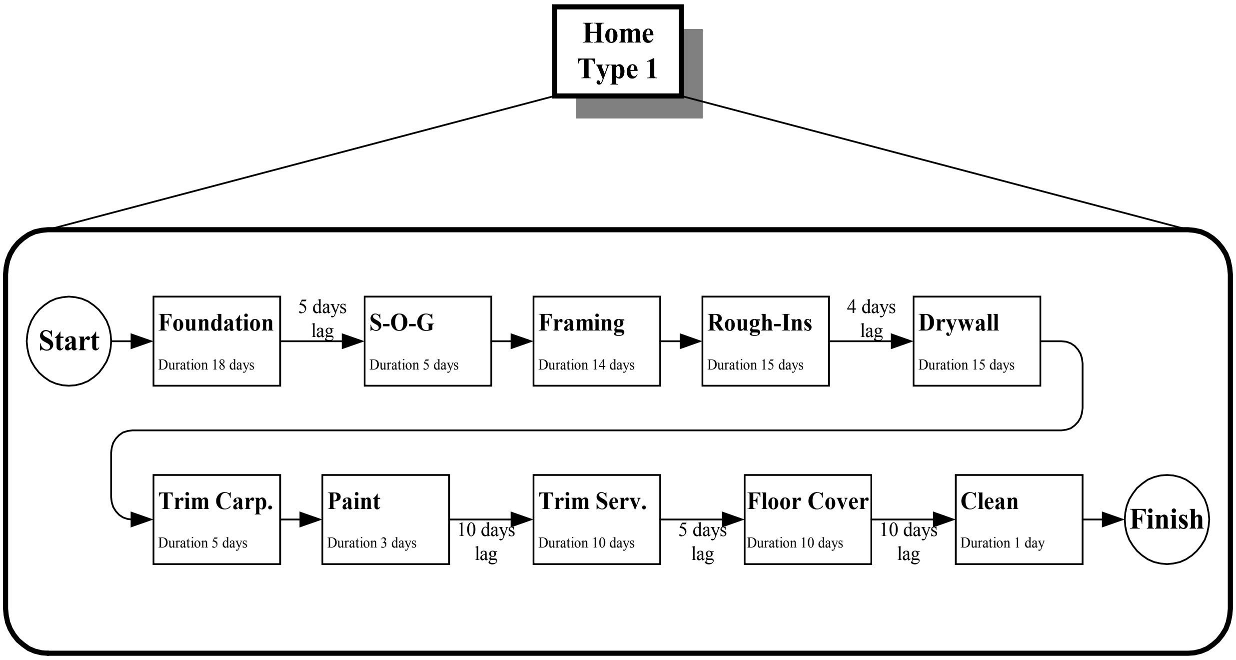

Figure 3: Modeling Element for Home Type 1

Table 2: Activity Durations for the Three Home Types

Activity	Home Type		
	1	2	3
Foundation	18 days	16 days	14 days
Slab-On-Grade	5 days	5 days	6 days
Framing	14 days	10 days	8 days
Rough-Ins	15 days	13 days	10 days
Drywall	15 days	12 days	8 days
Trim Carp.	5 days	14 days	13 days
Paint	3 days	3 days	3 days
Trim Serv.	10 days	8 days	6 days
Floor Coverings	10 days	7 days	4 days
Clean	1 day	1 day	1 day

To model the seven scenarios, seven models were built in Simphony using the previously described modeling elements. The models were built by including the appropriate amount of each of the modeling elements in the model and by setting the start dates for each according to a table generated in Microsoft® Excel. The Microsoft® Excel Tables contained the number of starts per week if fixed in the scenario or generated a random number of starts if the number of starts per week was random (Scenario 1). A random order for the 90 homes - 30 of each type - on the subdivision was also generated for each scenario, thereby guaranteeing that the types of homes started followed a pattern as would be the case in a sales-driven environment.

Figure 4 presents one of the scenarios as seen when modeled in Simphony. The various modeling elements for the three types of homes are clearly visible on the main work area, where they were placed according to the order specified by the respective Microsoft® Excel table for the scenario.

4 RESULTS AND DISCUSSION

Table 3 summarizes some of the main results obtained from simulating the seven scenarios. Clearly, Scenario 1, where the number of weekly starts was random, had the most variability. In any given week there where anywhere between zero (0) and four (4) starts, the average being 1.11 and the standard deviation 1.14. In contrast, for all other scenarios there were either one (1) or two (2) starts per week and the standard deviation for the starts was zero (0).

Table 3: Summary of Simulation Results

Data Item	Scenario						
	1	2	3	4	5	6	7
Total Duration (In weeks)	109	115	70	115	69	113	68
Week of Last Start	81	90	45	90	45	90	45
Min. Starts/Week	0	1	2	1	2	1	2
Max. Starts/Week	4	1	2	1	2	1	2

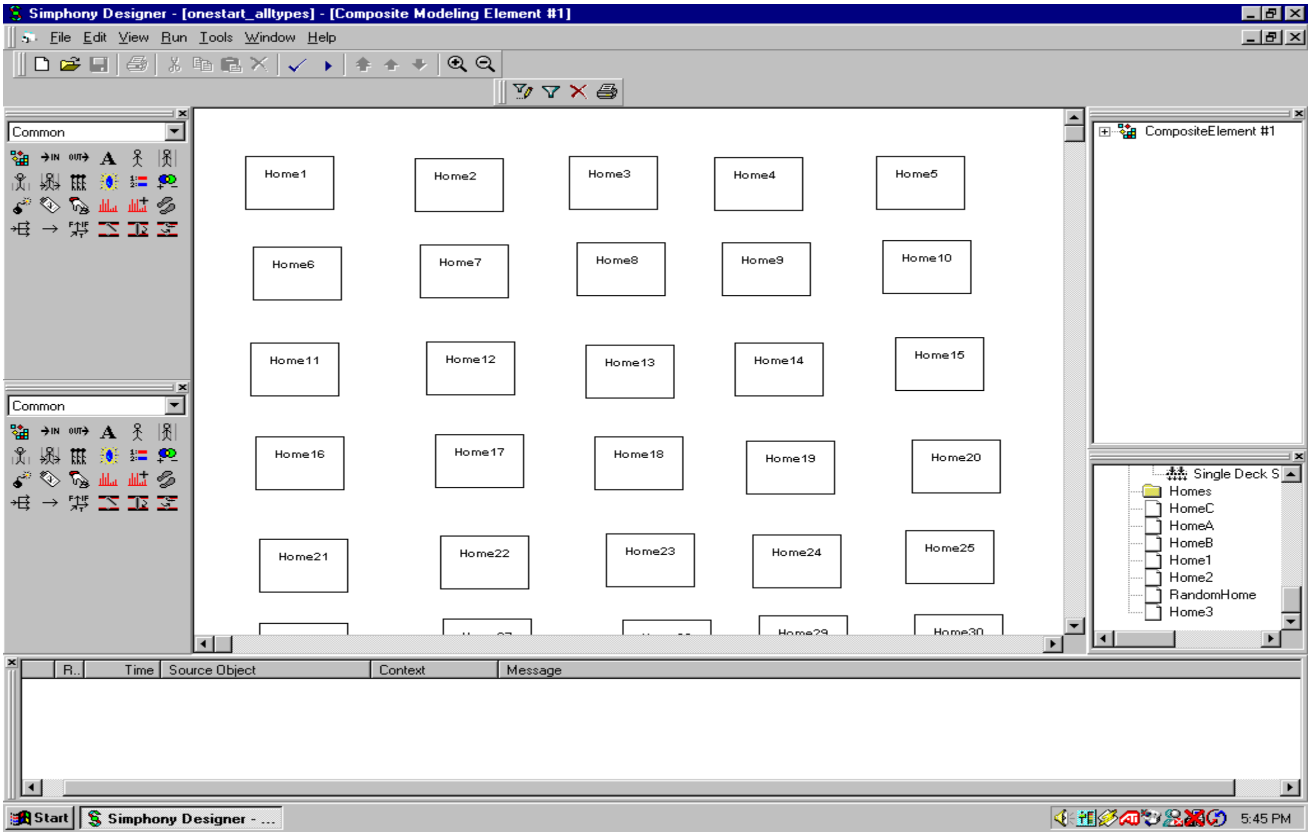

Figure 4: Simphony Designer Main User Interface with Model of Scenario 2

The lower start rates of one (1) home per week were found to be closer to the actual sales pattern, which in this case indicated the last sale taking place around week 80 (see Scenario 1: construction start in week 81). In the scenarios with one (1) start per week the last home was always completed between week 113 and week 115 – 4 to 6 weeks later than in a scenario with sales driven starts. This amounts to a possible 4 to 6 week extra wait for a potential homebuyer when compared to the sales driven starts scenario and may thus contribute to reduced customer satisfaction. Similarly, in all scenarios with two (2) home starts per week, the homebuilder finished the last home between week 68 and week 70. Since it was already established that the last home could be expected to be sold around week 80, these scenarios result in the homebuilder having unsold speculation homes that he would only be able to sell 10 to 12 weeks later – a situation that production homebuilders naturally try to avoid if at all possible. At the activity level the impact of the various start scenarios was clearly perceptible as well. This is useful to study the influence of the various start scenarios on the production process of the trade contractors. Figure 5 depicts the starts for Foundations, Slabs-on-Grade, Drywall, and Floor Coverings in Scenario 1 (random home starts) and Scenario 2 (one home start per week).

Finally, it should be noted that there were no significant differences, in terms of the total duration to complete all 90 homes and in terms of the start week of the last home, between the various scenarios with one (1) weekly start as well as between the various scenarios with two (2) weekly starts.

5 CONCLUSIONS

The present preliminary study indicates that simulation can be effectively used to shed light on the complex production flow issues of production homebuilders. In this context, a simulation platform for building SPS and other simulation tools, such as Simphony, proved especially useful to build the homebuilding SPS template used in this study. Clearly, however, further research in this area is needed to determine the best practices for balancing customer satisfaction and the desire of the production homebuilders to avoid building too large a number of speculation homes.

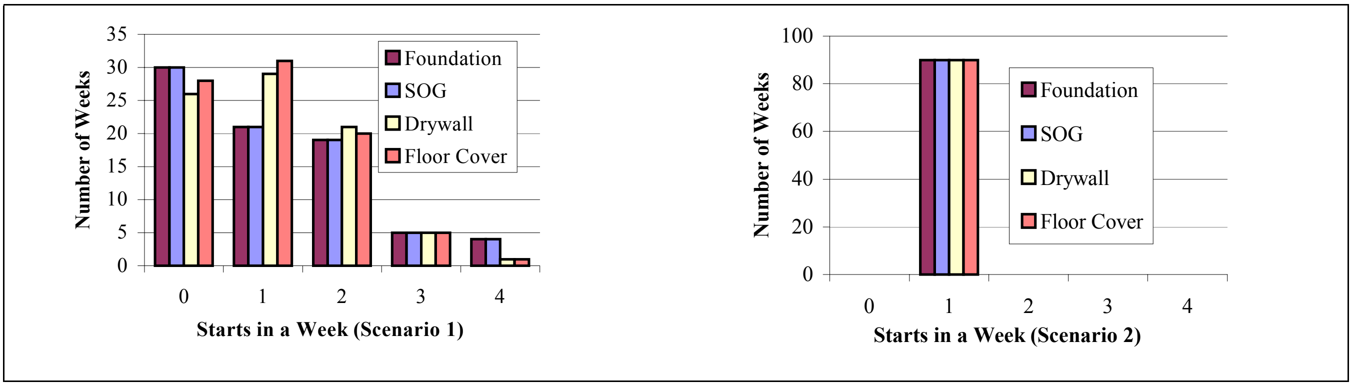

Figure 5: Activity Starts in Scenario 1 and Scenario 2

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