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# SIMULATION OF A NEW PRODUCT WORKCELL

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## ABSTRACT

As part of an ABB training program, two manufacturing engineers introduced a manufacturing facility to the benefits of modeling and simulation. The project goal was to evaluate a proposed manufacturing cell for a newly developed product. The engineers identified numerous layout improvements, but the analysis showed significant improvements in cycle time would still be needed to meet aggressive throughput targets. In addition to illustrating the use of deterministic modeling as a precursor to simulation, this paper also highlights lessons learned by these first-time simulation users.

## 1 INTRODUCTION

The Power Transmission and Distribution segment of ABB sponsors an Advanced Manufacturing Program (AMP) for selected manufacturing engineers. As part of the program requirements, pairs of participants must perform a project to apply the tools and methods presented in the training sessions. As participants, we decided to use simulation and modeling techniques as the focus of our project. This paper presents our first time experiences and the results we gained while evaluating a proposed manufacturing cell designed to produce a new product.

The facility we selected produces medium and low voltage switchgear for customers in the power generation industry, as well as commercial, industrial, and OEM market segments.

A dedicated assembly area was designed to produce a new product line that incorporates technological features not yet available to the competition. With an anticipated head start, it is important to maximize the competitive advantage by planning and executing the design of the new manufacturing cell quickly. Also, designing the cell optimally was viewed as a critical step to minimizing the manufacturing costs immediately. The lack of previous experience with this kind of workcell and product, coupled with the importance and timeliness of the project, led us to believe that the cell represented an ideal opportunity to showcase the strengths of simulation.

## 2 THE SYSTEM DESCRIPTION

A new product line of medium voltage switchgear entered production in late 1995. The new product consists of a number of frames (cabinets) that contain various combinations of circuit breaker, PT (Potential Transformer), instrument, low-voltage, and rear bus compartments. This facility operates as a make-to-order business with significant design engineering required. Because of their size (each frame has dimensions of roughly 36" wide x 92" deep x 95" tall), an order is often broken up into groups (called splits) of two to four frames for shipping purposes.

Figure 1 illustrates the general cell layout as originally designed. The product flow is from left to right and starts with subassembly and module assembly, then proceeds to stacking modules into frames, frame assemblies into shipping splits, final wiring, mechanical assembly, test, and then shipping.

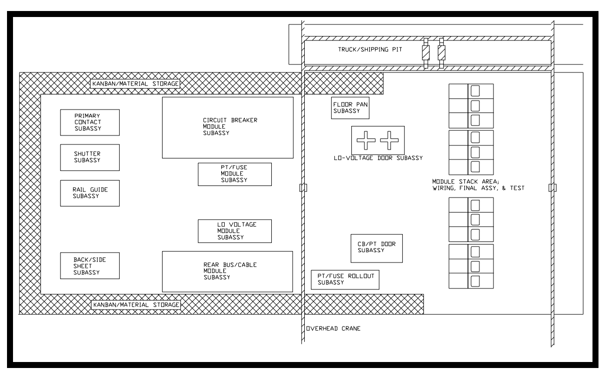


Figure 1: Original Cell Layout Design

# 3 THE DETERMINISTIC MODEL

## 3.1 Method Overview

As a first step, a deterministic model was developed for capacity analysis using Microsoft EXCEL Version 5.0c (1994). A spreadsheet model offered the following advantages:

1. it is based on a software product that is widely used and readily accessible;
2. it enables simplified modeling that is easy to understand;
3. it facilitates the definition of data requirements;
4. it has the potential to yield reduced data requirements, and
5. it allows quick turnaround which means quick feedback, and it provides a quick check for obvious data problems.

The spreadsheet provides static as opposed to dynamic analysis because the spreadsheet does not consider random behavior in the system (e.g. arrival frequencies and variable processing times, movement and queue times). By ignoring random behavior, we gained simplification but sacrificed accuracy. In general, the static estimates are idealistic; however, knowing an upper bound on performance is useful information.

The capacity analysis served two purposes. For system designers, the spreadsheet offered a simple analysis tool to help acquaint them with a modeling perspective. Its different viewpoint offered immediate benefits by targeting potential improvement opportunities and trouble spots. For us, it acted as a validation check on the supplied data. Each time the designers judged the analysis results unrepresentative, we reviewed the data for accuracy.

## 3.2 Assumptions

Assumptions relate the model behavior to the physical system behavior by serving two purposes. The first purpose is to identify system details not included in the model because they do not influence performance. The second purpose is to define how the included details are represented in the model. The following is a list of the key assumptions made for this deterministic model:

1. there are only three product types (configurations),
2. no material handling times are included, and
3. rework is not included.

## 3.3 Model Data

The deterministic model uses two sets of information to estimate system performance. The first, shown in Table 1, lists the volume by product type, the yearly production hours per person available, and the performance rating, sometimes known as PF&D (personal, fatigue and downtime). The second table (not shown for data sensitivity reasons) lists the average processing times (in hours) for each task performed by product type based on historical labor records.

We define the Labor Capacity as the fraction of an operator’s time needed to perform an operation for a specified product volume and performance rating. It is calculated using the following equation:

$$\text{Labor Capacity} = \frac{(\text{Standard Processing Time})(\text{Total Volume})}{(\text{Performance Rating})(\text{Total Production Hours})}$$

Table 1: Volume Data

| | | | |
|---|---|---|---|
| **Total Volume/Year** | XXX | | |
| **Total Production hr./year** | 2000 | | |
| **Actual performance rating** | 90% | | |
| **Product Type** | 1 | 2 | 3 |
| **Arrival Percentage** | 0.4 | 0.3 | 0.3 |
| **Volume** | XXX | XXX | XXX |

## 3.4 Results

The results from this modeling effort split into two categories: those that resulted from the analysis and those that resulted from the process.

The analysis results confirmed the fact that the current processing times were not adequate to produce the designed throughput goal even under ideal circumstances. Further it pinpointed the bottleneck areas and let us gauge the manpower requirements.

The process results included the discovery of the three dominant product types. Previously, everyone believed that there were innumerable custom product types. This insight led directly to the consideration of kanbaning as an option to be considered in the simulation model analysis.

## 4 THE SIMULATION MODEL

Once the static analysis was completed and accepted, we built a simulation and animation model to show how the tool could be used to validate the design and understand the impact of proposed changes. The system description, assumptions, and data used in the construction of the deterministic model served as the basis for the model built to analyze the proposed layout design.

### 4.1 Objectives and Measures of Effectiveness

This project needed to address two basic issues. First, would the current design meet the production goals if current processing times were reduced 40%, and if not, what changes would be needed to achieve the goal? Second, could we identify and evaluate the effect of several possible improvements based on World Class Manufacturing ideas?

### 4.2 Assumptions

As with any model, a number of assumptions had to be made. Many assumptions were needed because there was limited historical data available on processing times, order frequencies, product type variety by customer, etc. Also, there were no written standards for the assembly operations and experimentation is ongoing. This section highlights the nine key assumptions:

1. there are three product configurations that comprise over 85% of all customer orders;
2. 63% of all customer orders contain six frames,

9% of all customer orders contain nine frames,
and 28% of all customer orders contain twelve frames;

3. all processing times are normally distributed with a standard deviation of 10%;
4. upon completion of an order, it is immediately shipped;
5. movement of parts between workstations were assumed to take between one and two minutes;
6. the system will run 2000 hours per year;
7. the labor by skill code is:
    - mechanical assembly operators,
    - electrical/wiring assembly operators, and
    - test technicians;
8. rush orders are not considered, and
9. all parts necessary to build subassemblies are always available.

### 4.3 Analysis

The cell analysis was designed to address the identified project objectives, but no formal experimental design was used. Instead, scenarios were defined as ideas were generated by the analysts and management.

Thirty-six sources of variation in the model were made independent of each other by assigning each a separate random number stream. No formal warm-up analysis other than animation observation was done; however, with a throughput volume typical of this product, a warm-up period of three months was considered conservative.

Initial pilot runs indicated each scenario needed to be replicated 120 times using arbitrary, but common random number seed values to generate a mean throughput estimate with a precision of 10% of the mean. The following scenarios were evaluated.

1. Existing: used the current processing times. The results were validated against historical data, and then used as a baseline to measure the effectiveness of tested improvements.
2. Kanbans: certain subassemblies were controlled using kanbans instead of ‘by job order’ to simplify production control;
3. Cross-training: considered all mechanical and electrical operators to be completely cross-trained;
4. Process time reduction: a 40% processing time reduction goal was set by management. A 20% reduction was also tested.
5. Product rework: a 67% reduction in product rework was tested; and
6. Combinations of kanbans and processing time reductions were run to test the combined impact on performance.

Each scenario was tested using three different scheduling rules. The first rule, ‘release next job after current job finishes’ was the previous practice because of low order volume. The second, ‘release next job after current job finishes final mechanical assembly’, was proposed based on watching the animation and noting how the assemblies and subassemblies moved through the cell into the final assembly area. The last rule, ‘release jobs based on a “push” system’ was included because it is the method currently used at the facility.

### 4.4 Results

This section highlights the significant results obtained from the simulation model and analysis.

A visual representation of the cell provided us the ability to check different layouts and how they would perform under space and product flow requirements.

Since the animation was drawn to scale, this was done visually. Our observations led us to the now seemingly obvious understanding that although straight-line or u-shaped flows are often optimal, the nature of this assembly process lends itself more to a central assembly point with the subassembly stations surrounding it. Based on this visual analysis, a modified layout for the mechanical assembly and module stacking was proposed as shown in Figure 2.

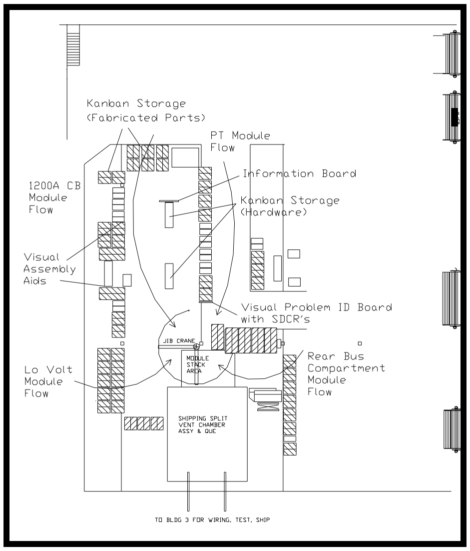


Figure 2: Final Proposed Cell Layout

Another important result was the discovery of an improved scheduling system. The simulation output data consistently suggests that the second scheduling rule (release the next job after the current job finishes final mechanical assembly) is more desirable than the "push" system currently used. Even though the cycle times and throughputs are similar, the work-in-process and labor requirements are substantially reduced.

An additional result was the confirmation that significant process time reductions were needed to meet the expected demand volume. The quantitative nature of the simulation results is helping us implement visual management supported teams because the need for improved methods is now concrete. The management and the simulation team believe a 20% process time reduction can be achieved immediately simply by implementing dedicated teams inside a dedicated work area.

The cross-training scenario demonstrated a "wave effect" through the process when mechanical and electrical operators were completely cross-trained. This undesirable effect can be eliminated by zoning operators. However, zoning requires a line balancing tool to aid shop-floor supervisors to better utilize their "cross-trained" employees. Such a tool is in development and will be an extension of the deterministic model previously developed.

### 4.5 Implementation

The cell was installed with the module assembly and stacking in a separate area from the electrical and testing functions due to budget constraints. As product orders increase in the future, electrical and testing functions will be moved to this workcell. When this takes place, cross-trained and "balanced" employees will prove to greatly increase the capacity of the workcell.

The model estimates for labor requirements have been confirmed, as were the system bottlenecks. The recommendation to release the next order only after the current order completes final mechanical assembly has been partially implemented, and being observed for validity. Also, the implementation of a visual management supported team environment has begun.

## 5 SUMMARY

An important aspect of the work performed is the amount of insight and value the simulation modeling brought to the design process even though little data was available and many assumptions were made. We believe our circumstances are by no means unique when applying simulation in industrial applications. It is the modeling process more than the specific results that are useful.

By applying simulation to a real world problem, we learned a number of things that we would pass on to other first-time users of simulation.

1. Ideas such as order release timing need "buy-in" from key plant personnel, and their inputs need to be involved during the modeling process.
2. Changing requirements and constraints (e.g. budget and location) in mid-project were very disruptive to the modeling process. Make sure key personnel are involved with budget and location decisions up front in the planning stages.
3. It would benefit all to involve other internal and/or external simulation resources to tap their expertise and knowledge in past simulation exercises of this type. The analysis portion of the project provided an excellent information base for future planning, and as such, deserves additional time spent on its own planning up front.
4. It is obvious that much worthwhile information and insight was obtained as part of the modeling process, as well as the actual output analysis.

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