SIMULATION BASED MODELING OF INVENTORY POLICIES AND OPERATING PROCEDURES IN COMPLEX, LOW-VOLUME ELECTRONICS MANUFACTURING

by

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ABSTRACT

This simulation study considers a low-volume manufacturing system, which produces complex, customized electronics. Modeling demand as a renewal-reward process, the simulation, inspired by the production system and available data from a Canadian company, examine the performance of alternative inventory policies and operating procedures. Performance indicators that measure the responsiveness and inventory on hand show trade-offs between them in order to supply relevant information to decision makers. Experiments compare make-to-order and make-to-stock scenarios with various inventory parameters as well as introducing variability to examine the model's robustness under uncertainty.

The system under consideration consists of three main processes to manufacture a finished product from raw materials. The first process fabricates metal and electrical components from raw materials. Second, a worker assembles components into a semi-finished product. The third requires information from the customer in order to customize the product according to their needs, and test the unit to ensure its quality. The company, known for their well-designed products and exceptional customer service, wants to improve the accuracy of their leadtime promising. The current MRP control system assumes a completely make-to-order environment where every piece of WIP has a customer order attached to it. However, a forecast of orders likely to materialize from the sales quotes allows production to initiate jobs before the actual order arrives.

The approach taken to analyzing this system involves studying the make-to-stock, make-to-order decision at two stock points, components and semi-finished units. The operating procedures examine four possible stocking strategies: holding no inventory, holding only component or semi-finished inventory, and holding both components and semi-finished units. Simulation experiments determine the trade-off between holding inventory and the responsiveness to the customer for each operating procedure. Sources of randomness introduced to processing time, capacity, and demand, show how they respond to added variability.

The simulation experiments indicate that holding no inventory, and waiting for a customer order to initiate jobs, results in unstable performance. In order to achieve a stable make-to-order system, it would be necessary to have a fifty percent reduction in demand or product cycle time, a capacity expansion, or forecasting method. In the absence of an accurate forecast model, holding inventory is necessary for an acceptable level of performance. Component inventory is useful as many components are common among a number of products. Suitable component inventory can lead to customer orders typically fulfilled within two weeks. Adding semi-finished inventory can reduce the customer lead-time to under a week though requires stocking at least a few of each semi-finished unit. Holding semi-finished inventory without component stock is possible. However, it is necessary that the replenishment quantity be three or more units ordered at a time. Otherwise, the setup time for components exceeds the allowable limits and resource queues become unstable, much like the completely make-to-order scenario. Using an order-up-to parameter for semi-finished stock can further decrease the setup time incurred per unit.

The model is robust to randomness in job times, though it is component stock, which provides an effective buffer to this variability. Machine breakdowns begin to affect responsiveness measures if the average time for repair is greater than a week. Reducing the capacity in the assembly and testing processes can provide the same level of service indicating the two resources are underutilized. The analysis of this system shows the current make-to-order model requires some forecast to function in steady state, which is difficult to model without information on the current forecasting processes. Expanding the simulation model to incorporate forecasting or some other means of analysis can improve its accuracy and credibility as a management decision tool.

LIST OF ABBREVIATIONS USED

BOM	Bill of Materials
ConWIP	Constant Work-in-Process
CSL	Customer Service Level
C_V	Co-efficient of Variation
EDD	Earliest Due Date
EOQ	Economic Order Quantity
ERP	Enterprise Resource Planning
FCFS	First-come-first-serve
Hrs	Work-Hours
M/M/n	n-server queue, exponential service and inter-arrival time
M/G/n	n-server queue, general service times, exponential inter-arrivals
MPS	Master Production Schedule
MRP	Material Requirements Planning
MRP II	Manufacturing Resource Planning
MTO	Make-to-Order
MTS	Make-to-Stock
MTBF	Mean Time Before Failure
MTTR	Mean Time to Repair
OQ	Order Quantity
OUT	Order-up-to
NP	Nondeterministic Polynomial Time
QOH	Quantity on Hand
SPT	Shortest Processing Time
WIP	Work in Process

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CHAPTER 1 INTRODUCTION

Over the past century, manufacturing and producing goods with high quality standards at a low cost has become an essential part of many industries. In order to compete, companies devised strategies to produce goods in the most efficient and economical way. One of the earlier approaches developed in the 1960's is Material Requirements Planning (MRP) which allowed companies to calculate the exact amount of material to suit a forecast of demand. Later through the 1970's, MRP began to incorporate capacity planning and elementary job scheduling and was renamed Manufacturing Resource Planning (MRP II.) These types of strategies have become widespread and the basis for modern Enterprise Resource Planning (ERP) systems, although many companies still use MRP software for their operations.

Choosing the appropriate strategy depends on the business environment and customer expectations. Regardless of the software used for controlling production, the policies for releasing jobs into a system need to be determined based on acceptable customer lead-times and customer involvement during the ordering process. For example, Make-to-Order (MTO) policies release jobs when an order arrives, which allows the customer to customize the product as desired and eliminates stocked inventory; however, this could result in long lead-times depending on the production process. Make-to-Stock (MTS) policies release jobs based on the removal of inventory, which could improve lead-times, however requires a larger investment in inventory, especially with high product variety.

1.1. Company History and Environment

The Canadian company of interest sells high-end, technologically advanced electronic equipment worldwide. This medium-sized production facility manufactures six products, each with hundreds or thousands of parts and subcomponents. The facility's production area, which consists of twenty-two workstations, fabricates all components from raw materials. Semi-finished products begin construction in the final assembly area when all required components become available. The testing of semi-finished products ensures the quality of the equipment and involves a customization procedure unique to the customer's order. As a result, making a completely finished product in advance of the order arrival is not possible.

The company was founded several decades ago and started with only a few electrical engineers designing and building products by hand. As a small business, they grew popular for their customized products and exceptional customer service. Over time, the electrical designs changed, more products began to use similar components, and the company expanded to keep up with the growing interest. However, as the demand for their products evolved, the ordering and production process remained relatively unchanged.

1.2. Current Procedures and Practices

The current ordering process heavily relies on forecasting and human planning. The sales and marketing team produce a forecast of the orders likely to occur from the customer quoting process, which specifies the product, quantity, costs, and a lead-time estimate or constraint. The production facility receives the forecast and plans how to build the necessary components before the actual sales order arrives. Although the company likes to think of its process as make-to-order, the current manufacturing strategy is a combination of a make-to-order and make-to-forecast policies under MRP control systems. Building components to a forecast reduces the setup time by combining the jobs among common components.

Many problems associated with forecasting demand include the inherent error and the impact of this error on the production system. As products are rather large and expensive, a small error in the forecast can prove costly to the production system and customer satisfaction. With the sales forecast however, planners determine how to build the necessary components and semi-finished products. When an order actually arrives, the customer receives an estimate of the lead-time. If some of the forecasted orders do not materialize, the work completed up to that point is set aside and used later, though if more orders arrive than forecasted, planners expedite the necessary jobs. This can create inconsistencies between the actual customer lead-time and the initial estimate and as a result, the accuracy of the lead-time promise is highly dependent on the accuracy of the forecast. A difficulty for using statistical forecasts is the small level of demand. The average rate might only be a fraction of units sold per month; there may be some months with no sales of a product and other months with several units sold. Because of these complications, the actual lead-time frequently exceeds the quote given to customers by a number of weeks.

The company would like to examine alternatives that permit more accurate leadtime predictions to quote customers. Creating an alternate system requires straightforward modifications within their existing MRP software without a costly investment in complex computer systems. Although a sales forecast could still aid decision-making, the company would like to reduce their reliance on forecasts in favour of a more robust approach capable of meeting uncertain demand in a responsive manner.

1.3. Measurements and Data

Information from this Canadian company, obtained in 2010, provides insight into the complexities of this system. Though information that is more recent exists, it is unavailable for this research. Past data and sampling were used to determine the duration and distribution of each element in the production process. Testing times are generally consistent by product though sometimes rework is necessary which can cause small delays. Final assembly times for products appear more variable, though a random sample has revealed that only sixty percent of the process time is value-added as it is a time-consuming, complex task, dependent on the experience and skill of the worker. The remainder of the time is typically lost due to acquiring missing components and technical troubleshooting. Although the standard time could represent the fastest possible build time, the duration of final assembly is often longer and varies from build to build.

The production department fabricates each component. For every workstation in its routing, there exists an associated standard setup and unit run-time measurement. Standard times typically indicate a minimum effective processing time and often serve as an indicator of performance rather than actual processing time. This allows decision makers to observe the performance of their production process by comparing the difference in the overall processing time and the expected standards. Computerized or automated tasks, however, do not have much variation and the standard time would be a suitable estimate of the actual process time. The standard process times are stationary and relatively small for production jobs. For simplicity, these times are assumed to be the exact duration for production jobs. However, due to the complicated nature of final assembly and testing, their processing time can be thought of as a random variable to model its natural variation.

The process times only identify the value-added time for the component production process. With the bill of materials and component routings, it is possible to create a complete and detailed interpretation of how components transform from raw materials into a finished product. Many other factors are present in the real system, though not as well understood, such as machine breakdowns and maintenance, component turnover rates or expiry, supplier lead-times, and other sources of natural error.

1.4. Relevant Approaches

When a manufacturing system uses MRP, or 'push' based methods, they require a demand forecast with deterministic supplier lead-times to calculate the order time and quantity for necessary supplies. A 'pull' based system, where the removal of inventory triggers orders for stock replenishment, shows some advantages in controlling WIP over push based production strategies. Some pull systems implement push policies for some processes, referred to as hybrid strategies, such as the conventional "*Constant Work-in-Progress*" or *ConWIP* approach, where the removal of inventory triggers the release of work-orders to push jobs through the system. Pure pull strategies like 'KanBan' require stock points and inventory between each step of the process (Hopp & Spearman, 2004).

Literature on other production techniques has expanded over the past few decades as operations research and computer simulation become prevalent in industry. Well-documented manufacturing strategies, like push and pull, have not been as pervasive in their commercial application since neither strategy generally out-performs the other, as it is highly dependent on the manufacturing environment and industry conditions. Other techniques, to examine alternative methods of analysis in industrial systems have recently gained acceptance and are the focus of rigorous research. Such methods include, but are not limited to, operations research and job scheduling (Van Nyen, Bertrand, Van Ooijen, & Vandaele, 2005), capacity analysis and expansion (Ahmed, King, & Parija, 2003), simulation modeling (Sanchez, 2006), delayed differentiation (Gupta & Benjaafar, 2000), and process re-design (Lee, 1996).

For the company under consideration, information on machine maintenance, purchasing and installation costs is not available and any dollar value associated with these facility resources would require cost estimates in order to compare alternatives. Process re-design requires a holistic understanding of the fabrication process. Indeed many model parameters are subject to the accuracy of the associated empirical measurement. Thus, data from the facility is limited to the current production process. The production data available pertains to components and their jobs; therefore, this research focuses on inventory policies and lead-time as buffers of demand and variability.

1.5. Problem Statement and Methodology

This research attempts to identify the trade-off between inventory held in stock and the responsiveness to the customer without a forecast from recent quotes. Applying inventory parameters to an MRP control system involves simply changing the job release and ordering policies so that pre-determined inventory levels or customer arrivals trigger work orders and not the forecast. A simulation model of the system can identify the trade-off between holding inventory and the responsiveness to customer demand. By testing each scenario, the company can judge the performance and acceptability of each policy. When introduced to sources of randomness, these tests reveal the consequences of such variation on the measures of performance.

Placement of inventory stock in the system determines the operating procedures. In the absence of stock on hand, the system becomes a completely make-to-order scenario where each component exists with a particular order attached to it. With a completely make-to-stock system, orders initiate the testing process by removing semi-finished units. If only a particular section of the system keeps stock on hand then the ordering process and job release policies require appropriate operating procedures. Holding only component stock enables orders to begin in final assembly by removing component inventory. Holding only semi-finished stock allows customer orders to commence at testing. However, in this case stock replenishment begins with raw materials, only making the necessary components to fulfil the semi-finished stock requirement.

To complete the objectives set forth, a review of the existing literature in Chapter 2 details the background and conventional approaches of analysis. Chapter 3 describes the specific details of the system under consideration, while Chapter 4 documents the steps taken in the analysis of the system, the parameters and operating procedures. Chapter 5 develops the simulation processes and model of the system. The results detailed in Chapter 6 identify the trade-offs in various performance measurements. The results of the simulation experiments, generalized in Chapter 7, show how managerial decisions affect the performance of the system. This can allow managers to identify further areas of research that could continue to improve their system.

CHAPTER 2 LITERATURE REVIEW

While there is extensive literature on manufacturing strategies, no general approach exists as each manufacturing and business situation has unique challenges. Even well respected strategies such as Toyota's KanBan strategy may be less successful in other manufacturing systems (Hopp & Roof, 1998). Literature on Make-to-stock and Make-to-order systems has been documented by Arreola-Risa and DeCroix (1997) and Rajagopalan (2002) for some typical manufacturing environments. The conditions necessary to prefer one particular strategy depends heavily on customer expectations of lead-time and the company's allowable investment in inventory. The main trade-off for a MTO system is the increase in number of setups and variability of processing times, loss of capacity, leading to congestion and increasingly variable lead times (Rajagopalan, 2002). However, Rajagopalan (2002) notes a similar trade-off in the MTS system as some stocking parameters, such as lot size, affect the cycle and safety stocks of that item, as well as the number of setups. He finds that the MTS/MTO decision, and likewise the choice of lot size, is a function of demand rates and processing capacity available.

Gupta and Benjaafar (2000) discuss the MTS/MTO decision and find that a good alternative strategy is delayed differentiation, which delays product-specific features until their demand materializes. One of the major benefits is the reduction in lead-time because semi-finished goods require less time to complete than a pure make-to-order system. However, in contrast with make-to-stock systems, delayed differentiation typically results in lower inventory costs due to inventory risk-pooling and decreased holding costs. Delayed differentiation is particularly useful when there is high product commonality, high product variety, or medium system utilization (Gupta & Benjaafar, 2000). Cattani et al. (2002) develop a similar concept called "*Spackling*," where some common components are made-to-stock and others, typically customizable, are made to order. The facility's capacity varies to ensure customized components pre-empt standard or common jobs. Common components wait for available capacity, while inventory of common components provides a buffer against variability. This flexible-capacity approach produces preferable results as long as the cost for that resource is not too high (Cattani, Dahan, & Schmidt, 2002).

While these policies have their benefits, optimal strategies, developed by Arreola-Risa and DeCroix (1997), show that the costing unit can have a significant influence on the decision to produce an item to order, or stock. In their model, each item's MTO or MTS status depends on inventory and backorder costs, system utilization, demand, and manufacturing-time randomness. Their results show that if backorder costs are in dollars per unit, the randomness in processing times does not affect the MTO/MTS decision, although it can reduce optimal inventory levels. However, if the backorder costs are in dollars per unit per unit time, the randomness in processing times has a quantifiable effect on the MTO/MTS decision (Arreola-Risa & DeCroix, 1997).

The MTO/MTS decision however, does not imply the type of control system. Hopp and Spearman note that the push or pull distinction is independent of the MTO/MTS decision (Hopp & Spearman, 2004). While hybrid strategies are common in practice, the debate between the merits and disadvantages of push and pull systems has been widely researched. Determining whether a push or pull system is appropriate for a given situation depends upon lead-time variability and demand predictability (Karmarkar, 1991). The most widely cited advantages of pull systems are the inherent limits on WIP to within pre-specified limits, which can reduce congestion and inventory costs within the production system (Spearman & Zazanis, 1992). Push systems however, underlie most MRP software that became popular in America during the 1980's (Hopp & Spearman, 2004).

Regardless of the particular system, its parameters can influence performance. Stock levels are one such parameter. In some cases, the parameters could reflect re-order and order quantity levels, and in others, WIP levels. Hopp and Roof (1998) discuss setting such WIP levels within a ConWIP framework. By considering the necessary throughput rate for demand requirements, calculation of appropriate WIP levels follows Little's Law: WIP = Cycle Time × Throughput Rate (Hopp & Roof, 1998). Karmarkar (1987) explores the impact of lot sizes on manufacturing lead-time for a standard M/M/1 queuing model and finds that conventional Economic Order Quantities (EOQ) lot sizes, typically based on unit and setup costs, differ from the acceptable lot sizes found in his model. Persona et al. (2007) develop optimal levels of safety stock for MTO and ATO (Assembly-to-Order) systems depending on service levels (Persona, Battini, Manzini, & Pareschi, 2007). Brander and Forsberg (2006) develop methods for determining safety stock levels and minimizing production costs for a stochastic economic lot sizing problem producing multiple items on a single machine (Brander & Forsberg, 2006).

2.1. Capacity Expansion

Though observing the system with respect to inventory strategies remains the focus of this research, other types of analysis and problem solving techniques could provide further insight and deserve mention. Capacity expansion and planning has been the subject of extensive research (Davis, Dempster, Sethi, & Vermes, 1987) where models with demand derived from deterministic forecasts experience the inherent consequences of not planning for uncertainty. Davis et al. (1987) describe a straightforward model that includes two conditions that expand on previous capacity expansion methods. The first is uncertainty in demand and the second is that a capacity expansion project requires a certain cost and time to achieve the added capacity. Their dynamic programming approach creates a trade-off between cost of inventory shortages and overages. Indeed, a number of capacity expansion approaches use a subjective cost value to minimize cost or maximize profit. Ahmed et al. (2003) formulate an integer program model to review various solution heuristics. Though subjective costs still exist in this model, they suggest these types of models allow for logistical constraints difficult to implement with dynamic programming approaches (Ahmed, King, & Parija, 2003).

Other forms of capacity expansion introduce a specific condition or feature in the model to analyze capacity requirements. Most common types of these analyses in manufacturing and production environments consider scenarios such as equipment replacement and machine routings. Chand, McClurg, and Ward (2000) develop a model to find the optimal purchasing schedule meeting both capacity expansion and machine replacement requirements. This combines two widely explored problems in the literature into a single model and suggests the approach could offer some advantages as opposed to separate models for both capacity expansion and machine replacement analysis (Chand, McClurg, & Ward, 2000). Another common type of machine analysis is the flexibility within the system. Research by Chandra and Tombak (1991) shows that flexibility designed into the system, and managed correctly, can minimize production costs.

In a model similar to the one explored in this research, Van Nyen et al. (2005) find set-up costs as the dominant factor in their simulation experiments and advocate Just-in-Time strategies to achieve the required reduction in set-up. Other job routing heuristics as described by Averbakh and Berman (1999) attempt to approximate an optimal schedule while a tabu search algorithm, evaluated by the decomposition of routings and a job-shop scheduling sub-problem, can adapt to different objective functions (Brandimarte, 1993).

2.2. Forecasting

Forecasting demand is common practice among organizations and a survey of over one hundred Canadian companies in 1997 indicates most use judgemental and non-statistical forecasting methods. Although newer statistical methods of forecasting have been widely cited by academics, small and medium businesses typically reject these mathematical models in favour of basic methods such as sales force composite, jury of executive opinion, surveys or simple moving averages. Academics commonly teach that forecasts should not only be a single value but a statistical confidence interval; but only 28% of firms sampled reported using a range for forecasts. Of the 62% of firms that monitor the accuracy of their forecasts, the most common method is a visual analysis to determine its suitability (Klassen & Flores, 2000). Bunn and Wright (1991) examine judgemental versus statistical forecasting methods. They suggest a structured judgemental process can outperform statistical methods in certain, atypical cases (Bunn & Wright, 1991). Indeed not all events are completely random, and prediction of future states with advance information of future orders can enhance the accuracy of the forecast. Recently, computer communication and decision technologies in industry have enhanced the performance of the organizational decision-making hierarchy (Huber, 1990). As human error will always exist in judgemental forecasts, statistical methods are not prevalent in industry despite continuing research for a variety of applicable conditions. Freeland and McCabe (2004) develop a forecasting model using an integer, low-valued time series. Although the system they studied represents wage-loss benefit claims, their model could apply to this research in better predicting customer arrivals by using estimates of probabilities in the forecast and not a constant number of units (Freeland & McCabe, 2004).

2.3. Approach to Research

The approach used to examine the system in question avoids analyses difficult to model computationally, such as forecasting methods, due to the lack of data available, and capacity expansion analysis, due to the subjective cost-based nature of decision variables. A model of the facility, created using computer simulation, can determine the performance of various inventory scenarios without subjective measurements and speculative data. Some valid approaches outside the scope of this research deserve recognition. They include many well-documented problems in industry, such as batching policies, job release mechanisms, and inventory risk pooling, which can apply to this system.

The conventional Economic Order Quantity (EOQ) model determines the replenishment quantity that results in the minimum average cost. Though researchers have devoted many studies to extensions of the EOQ model, it assumes an infinite planning horizon and can lead to unrealistic inventory policies (Hariga, 1994). Various lot-sizing approaches suggested by Roundy (1986) include dynamic programming algorithms and stationary policies, while Tarim et al. (2003) examine integer programming models and heuristics under stochastic demands.

Job release mechanisms operate according to pre-specified strategies and play an important role in the performance of production systems. The flexibility in the job routing can improve performance, though highly flexible systems diminish the impact of the order release mechanism, as suggested in a simulation study by Newman and Maffel (1999). Ragatz and Mabert (1988), examine common queuing and dispatching rules, such as First-come-first-serve (FCFS,) Shortest Processing Time (SPT,) and Earliest Due Date (EDD.) They show that while some sequencing policies outperform others, management could reject such in favour of a less complex strategy (Ragatz & Mabert, 1988). Hendry and Kingsman (1991) devise a strategy for small make-to-order operations, which combines marketing and production functions. Other work by Ben-Daya and Raouf (1994) model the lead-time as a decision variable and attempt to minimize the total cost.

To handle variability in systems, one must utilize some combination of three buffers: inventory, capacity, and lead-time (Hopp & Spearman, 2000). Comparing inventory pooling to capacity pooling, the benefit of pooling inventory decreases with increased utilization whereas a using capacity to buffer variability appears to increase the relative benefit (Benjaafar, Cooper, & Kim, 2005). Other models for risk pooling of inventory include Weng (1999) who observes effects of risk pooling under uncertain demand and product modularity, and Tagaras and Cohen (1992) who find a heuristic algorithm to compute near-optimal order-up-to levels for multi-location systems. McClelland (1988) examines a MTO company with modular subassembly product structures to observe the interaction between the Master Production Schedule (MPS) and the accuracy of lead-time promising. She finds methods that monitor capacity have a higher percentage of promises kept (McClelland, 1988).

CHAPTER 3 PROBLEM FORMULATION

This Canadian facility has three stages in its manufacturing process. The initial production area, used for fabricating metal and electrical components, consists of the twenty-two workstations in Table 1. Each product consists of hundreds of different components, each with known setup time, run time, and routing. Some components have subcomponents, which are required in order to start the first job of the parent component, as the bill of materials (BOM) has several levels. Each workstation has a capacity of one with the exception of the miscellaneous (MISC) station, which has an estimated capacity of six parallel servers.

ASSY	CUT	LATHE	PARTS	PSASSY	COILS
ATST	DM	MILL	PASH	PTST	PASL
BEND	DRILL	MISC	PLATE	PUNCH	
CABLES	FMCUBE	PAINT	PRGM	SILKSC	

Table 1 – Production Workstations

The second stage in the process, final assembly, consists of six parallel servers available for assembling components into a semi-finished product, which then requires a customer order to complete the unit. Each product requires a certain number of hours for assembly. Past data of actual times suggest the time required follows the lognormal distribution in Table 2. The final part of the manufacturing process requires a customer order to make customized adjustments and to test the quality of the semi-finished unit before delivery. Eight parallel servers test the semi-finished products and, according to past data, service time appears triangularly distributed. However, if the need for troubleshooting arises and the product requires rework, additional time incurred follows another triangular distribution, also in Table 2.

Product	Final Assembly (Log-normal)		Testing (Triangular)		
	Mean Time (hrs)	Variance	Initial Time	% Reworked	Rework Time
1	25.03	2.1	(18, 20.1, 23)	5.1 %	(3, 8.6, 12)
2	24.5	1.5	(18, 22.3, 25)	4.2	(3, 9.2, 13)
3	43.85	3.0	(22, 26.6, 33)	6.6	(4.5, 13.8, 21)
4	74.07	5.5	(32, 37.2, 45)	6.3	(5, 21.3, 30)
5	41	3.6	(28, 33.5, 38)	9.9	(3.5, 6.5, 11)
6	68	5.2	(34, 42.4, 48)	12.1	(4, 12.4, 19)

Table 2 – Final Assembly and Testing Times

The company has recorded the products sold for each order, the order quantity, and the date of each sale over the past two years. There is no identifiable seasonality or trend. However, the available data shows that customer inter-arrival times for each product appear exponentially distributed according to parameters in Table 3. The order quantity also follows a Poisson distribution. Customers typically order a single unit, as $Mode_i = \lceil \lambda_i \rceil - 1$; orders for multiple products arrive according to the rates in Table 3. The demand model is consistent with a renewal-reward process with Poisson parameters describing both the renewal and reward distributions. This type of process considers the time between events, renewals, and the order quantity, the reward, and with these two parameters, one can determine the long-term average rate of demand for a particular product.

Product	Inter-arrival Rate Poisson(orders/day)	Order Quantity Poisson(units/order)
1	0.04693	1.43
2	0.08556	1.33
3	0.08647	1.56
4	0.05010	1.31
5	0.06017	1.26
6	0.07512	1.16

Table 3 – Product Demand Information

3.1. Validity and Data Integrity

Measurements from the actual system are required to build a representative model of the system. Demand measurements originate from the sales information, while data on job times from production require actual time measurement. Depending on the production stage, the duration of a particular process could fluctuate for a number of reasons and this eliminates the possibility of a deterministic, stationary processing time. As jobs for final assembly and testing require a human operator, the model should reflect the inherent variability. Though this research uses past data to determine the distribution of job times, incorporating other conditions such as learning curves, product-specific training for operators and their individual service rates, could improve the credibility and accuracy of the model. For personal allowances, the impact on total productive time could vary depending on the availability of the worker. The particular allowances given to workers require modifications to either the number of productive hours per day or the processing time standards. For example, if there are seven productive hours out of eight work hours then the model should reflect such downtime as realistically as possible to create an appropriately 'soft' system.

The data used for this model represents the format of the actual system that we studied, modified to some extent in order to simplify the parameters. Data on particular sales and products, excluded to protect the company's competitive confidence, can only indicate the average rate of sales. The actual sales process is more complex as an intensive quoting process allows production to begin before the actual sales order arrives. Integrating real variance into a model requires information and data on the process and if unavailable, requires simplifying assumptions, such as eight productive work-hours per day with processing time standards extended to compensate for the various personal allowances of workers, or customer orders arriving at random with no quoting or forecasting process. This allows the model to simulate a similar, simplified system without any measurements from the quoting process or production availability.

A simulation model can be used to test various alternatives of production policies and manufacturing strategies. If the measurements do not reflect the parameters of the actual system, the model's response could be misleading. Demand measurements reflect the past two years and the model's response should imitate what would have happened over the past two years for each scenario. Without any patterns for statistical forecasting evident in demand, the best indication of the future is past sales history. If sufficiently accurate forecasts can predict demand, testing the predicted measurements can allow the model to determine what will happen at this measurement and specific operating procedures. Two key indicators, the lead-time to the customer from the time of order and the average level or value of the inventory on hand, measure the overall performance of the system.

3.2. Experiments and Objectives

There are two stock points available along the production line in Figure 1, semi-finished goods and component inventory. The focus of these experiments is to examine the effects on responsiveness while holding different levels of inventory at one or both of the available stock points. The two potential stock points create four (2^2) possible systems to look at, each with many possible variations depending on the parameters, and even more possibilities if different components can have different inventory policies. First, a purely MTO system would push all orders from raw materials and hold no inventory except WIP which, in a purely push system, is unbounded. Second, a purely MTS system stocks both component and semi-finished goods. The remaining two systems have only component inventory, or only semi-finished goods, with operating procedures and policies described in Chapter 4. Make-to-stock strategies require an investment in inventory for improved performance and responsiveness over make-to-order strategies.

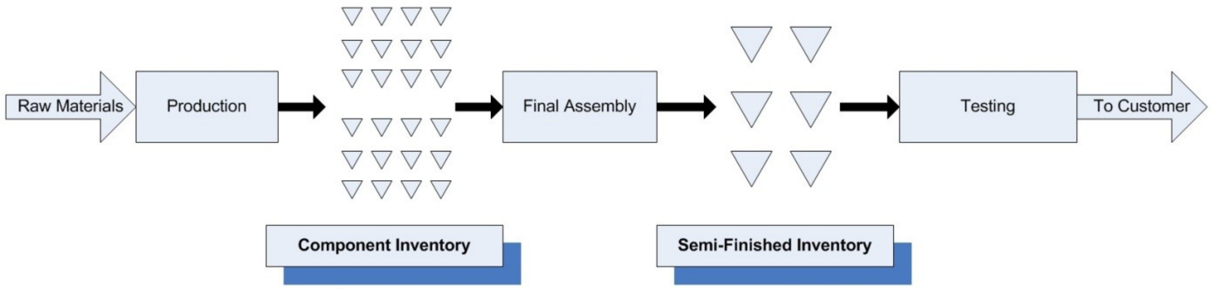

Figure 1 – System Stock Points

To model system alternatives, operating procedures that govern the flow of materials and information throughout the facility require specific and appropriate guidelines. Although the make-to-order or make-to-stock decision is independent of push, pull, or hybrid production control schemes (Hopp & Spearman, 2004), for items that are stocked it is assumed that orders for the item are triggered by inventory removal somewhere in the system, making such sections pull based. Products or components that are made-to-order push the required jobs through the system at the time of a customer order.

In addition to this top-level experiment, other quantitative experiments determine the re-order and order quantity parameters for each scenario. Sensitivity analyses determine the response to other demand rates, randomness in job processing time, capacity in final assembly and testing, and indicate the robustness of the system. The renewal-reward demand model creates additional difficulties as opposed to the typical Poisson process, as orders for multiple units cause large variations in demand. Policies that gradually remove inventory to fulfil long-term contracts aim to aggregate, or reduce, the variability perceived in demand. For example, a contract could arrive and order many units with a specified due date, and instead of a single order for 21 units, releasing three units a week for seven weeks could reduce the perceived congestion in production and allow for the processing of other customer's orders, reducing any backlog or time waiting in queue. To compensate for large contract orders, limiting the order quantity to three units per order in the simulation model effectively controls the variability perceived in demand.

3.3. System Design and Parameters

The design of experiments determines the feasibility, performance, and trade-offs for each alternative. One important test for this system is the necessity to build components before the sales order arrives, or wait for the order to make the required components. The job release policy for making components to fulfil a customer order must consider the sequence of jobs to push through the system with respect to component routings and necessary sub-components. Making component stock also requires consideration of routings and subcomponents; however, inventory levels become the job release mechanism instead of the predetermined job schedule.

One key aspect of this system is the large number of identical parts within product families. Products 1-4 and 5-6 in Figure 2 show the number of common components in each product. Of the 188 components in product 1, product 2 has 171 components in common, product 3 has 116, and product 4 has 104, and so on. Therefore, holding component stock, common to several products, could be an effective method to reduce lead-time, congestion, and the required investment in inventory.

Product / Number of Common Components Between Two Products	1	2	3	4	5	6
1	-	171	116	104	1	1
2		-	129	122	1	1
3			-	152	3	3
4				-	3	3
5					-	132
6						-
Total Number of Components in Product	188	194	214	245	163	160

Figure 2 – Number of Common Components

Under these business conditions, a simulation of various policies and inventory parameters can reveal the performance of each scenario. Comparing the performance measures between the system designs can allow us to determine how applicable certain policies are. By considering a wide range of different inventory parameters, we can observe the trade-offs between these parameters and performance indicators.

CHAPTER 4 SOLUTION METHODOLOGY

A discrete-event simulation model of the Canadian facility has been developed using SimPy, a simulation language based in Python, to examine the various alternatives. In order to effectively model and simulate the system, each part of the manufacturing process runs as a separate process in the SimPy model. Modeling the production system requires formulating the demand process, job release policies, inventory parameters (re-order point, order quantity) for stocked items, with the available bill of materials structure and component routings and job times in order to yield an accurate response that demonstrates the effects of certain factors and conditions in the real system.

The design of experiments should reveal if any factors, or interactions between factors, significantly affect the customer lead-time or average inventory levels. The main 2^2 factorial experiment design in Table 4 describes the system alternatives of interest. Within this main experiment, further experiments, conducted for a number of parameter settings, determine the effects of inventory levels and different policies. The design of experiments on inventory models have been studied by Law (2007, pp. 626-636). The different design points plotted on a response surface sample the effects due to the factors and their interactions (Sanchez, 2006).

Design Point (Model)	Production (Components)	Final Assembly (Semi-Finished Units)
1 (-, -)	MTO	MTO
2 (+, -)	MTS	MTO
3 (-, +)	MTO	MTS
4 (+, +)	MTS	MTS

Table 4 – Main Experiment Design

4.1. Demand Analysis

From the demand arrival process, as process described in Table 3, the long-run average demand rate, $F(\lambda) = \Sigma_i F(\lambda_i) = 0.404$ *orders/day*, in (0.1) for a given product is the expected order quantity, q_i, divided by the expected inter-arrival time, λ_i (Ross, 2007). The overall demand rates for products in Table 5 indicate the average number of products ordered per day. Though this rate can reflect product demand with a single parameter, it is important to remember that the customer ordering process consists of two facets, the inter-arrival time and order quantity. For this exercise, an assumption that this results in a Poisson process further simplifies the demand model for components.

$$F(\lambda_i) = \frac{q_i}{\lambda_i} \qquad \textbf{(0.1)}$$

Though the total demand rate with assumed Poisson distributions for each product can estimate demand, it is not a suitable model for simulating the customer ordering process. Instead, it forms the basic guideline for component inventory parameters. This allows the component inventory levels to vary according to their demand, C_j. The sum of the total demand rate for each product, multiplied by the quantity of a component in the given product, $Q_{j,i}$, creates a compound Poisson process estimating the component's demand (Ross, 2007) in (0.2). This allows estimates of inventory parameters to reflect the demand for each component with a limited number of parameters to set.

$$C_j = \sum_{i=1}^{Num\ Products} Q_{j,i} \times F(\lambda_i) \qquad \textbf{(0.2)}$$

To model the ordering process, the product inter-arrival rates follow independent Poisson processes, D_i, in Table 3, the sum of which yields a compound Poisson process in (0.3) describing the overall inter-arrival rate for customer orders. The customer arrival rate is the sum of the product arrival rates (Ross, 2007). For the past two years of data available, the average arrival rate, $E(D_t)$, is 0.40435 orders per day, about one order every two and an half days, or 20 work hours.

$$D_t = \sum_{i=1}^{\text{Num Products}} D_i \qquad \textbf{(0.3)}$$

For this overall compound demand process, the probability that an order from a particular sub-process of product demand, in (0.4), identifies the proportion of orders for each product in Table 5. Using the proportion of sales and superimposed arrival process, simulating an appropriate model of customer demand follows the process in Figure 3.

$$P(Event\ arrived\ from\ process\ i) = \frac{\lambda_i}{\sum_i \lambda_i} \qquad \textbf{(0.4)}$$

Product	Proportion of Sales	Average Demand (units/day)
1	0.1160	0.0671

2	0.2115	0.1137
3	0.2138	0.1348
4	0.1239	0.0656
5	0.1488	0.0758
6	0.1857	0.0871

Table 5 – Total Demand and Proportion of Sales by Product

Order inter-arrival times generated according to the customer arrival process, while a random Uniform (0, 1) variable determines the particular product ordered with respect to its proportion of sales. Random Poisson variables determine the order quantity of the product according to the historical information. A number of modifications could generalize this arrival process to incorporate different distributions, though it closely represents the characteristics of the actual process.

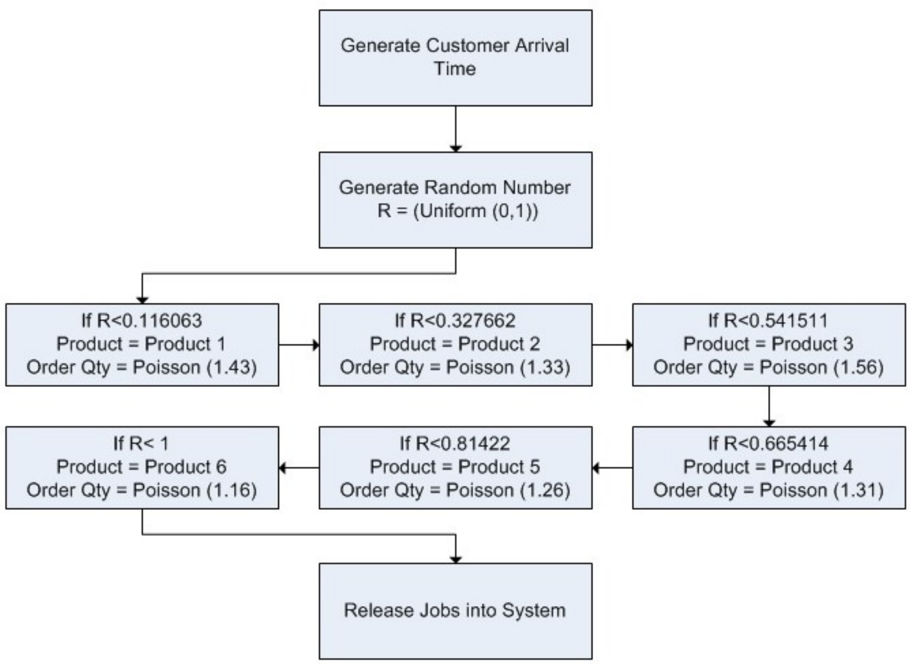

Figure 3 – Simulation of Ordering Process

4.2. Make-to-Order Environment

Modeling a pure make-to-order system implies that each job can be attached to a particular customer order as illustrated in Figure 4 with no inventory held except for raw materials and work in progress. This model is simple, with no stock parameters involved. However, the sequencing of jobs could affect system performance. The optimal solution to minimize the makespan of a job-shop scheduling problem is NP-complete and unsolvable in polynomial time for more than a few machines (Garey, Johnson, & Sethi, 1976). Due to the large number of machines (22) and jobs (thousands), an optimal solution is unattainable; however, finding a relatively 'good' makespan from a sample of randomly generated schedules ensures limits on makespan have some measure of organization. Though extensive literature on heuristics for job shop scheduling problems exists, none replicates the exact conditions required for an accurate analysis of this system. Typical priority schemes, like First-Come-First-Serve (FCFS,) are not effective, as each order would release hundreds of jobs simultaneously.

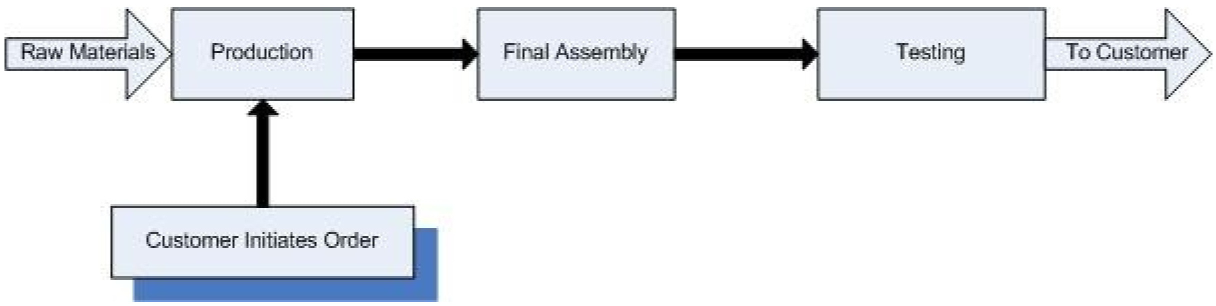

Figure 4 – Make-to-Order System

While it could be beneficial to find a new sequence every time new jobs enter the system, it could be too complex to generate a decent random schedule within a practical time. Instead of generating schedules for every set of circumstances, a job sequence is associated with a particular product and whenever ordered, triggers the predetermined job release. While repeatedly finding different random schedules could be impractical, it could be possible to arrange or pre-process jobs in a particular logical pattern to reduce waste or resource traffic. Indeed, many other extensively researched techniques practiced in industry focus on reducing cycle time, work in process, project makespan, and squandered setup time.

For all the components in a particular product, examining a series of randomly generated schedules for all the required jobs yields a set of job sequences for the product. The schedule resulting in the smallest makespan forms the job release sequence for components, triggered by a customer order for a particular product. Each component in a product has an associated quantity, setup time and unit run time, for all workstations in the component's routing, as well as any subcomponent quantities.

With the job sequence for a particular product determined, the make-to-order production process initiates the given sequence to build a unit when necessary. The total component quantity for all products in Appendix A shows the number of components required for a single finished unit. Two constraints for the random schedule ensure feasibility; first, the subcomponents of any component finish processing before the parent component begins processing, and second, the workstation routing for each component requires the first operation to finish before the second begins, and so on.

4.2.1. Generating Feasible Random Job Schedules

To ensure these constraints are satisfied and component jobs follow the correct order, an index determines the sequence of jobs while considering a random element. Over a number of randomly generated schedules, selecting the schedule with the minimum makespan determines the feasible and a relatively 'good' job schedule associated with a particular product.

Data for each component incorporates a routing and any subcomponents as depicted in Table 6. The job processing times in Appendix B, and BOM in Appendix C, reveal the complexity in the system. To ensure job schedules incorporate a random variable and any constraints, the sum of the operation number and a Uniform random variable creates an index. Components of predecessors (children or subcomponents,) add the integer part of the child's index to its successor (or parent component) as demonstrated in Table 7. This operation is repeated one less than the number of levels in the BOM to ensure all predecessors begin before their parent component at each level in the BOM. Should a particular component have more than one sub-component, the maximum index number is used. This index, sorted from smallest to largest, results in a feasible random job schedule for a particular product.

Components	WorkStation	Operation	Setup Time (hrs)	Run Time (hrs)	Predecessors
176-1129-01	CUT	1	0.1	0.001	
176-1129-01	LATHE	2	0.75	0.05	
176-1129-01	MISC	3	0	0.0054	
176-1129-01	PLATE	4	0.02	0.02	
183-6058	COILS	1	0.33	0.018107	
183-6059	COILS	1	0.37	0.24525	183-6058
203-6016	MISC	1	0.32	0.051	203-6016-FP
203-6016	DM	2	0.075	0.006	203-6016-FP
203-6016	BEND	3	0.285	0.007	203-6016-FP
203-6016	PLATE	4	0.02	0.02	203-6016-FP
203-6016-FP	PRGM	1	0.074	0	
203-6016-FP	PUNCH	2	0	0.004	

Table 6 – Sample of Components and Operations for Products

Components	Operation	Precedence	Random No.	Index (to Sort)
176-1129-01	1		0.71248	1.71248
176-1129-01	2		0.884967	2.884967
176-1129-01	3		0.742932	3.742932
176-1129-01	4		0.441959	4.441959
183-6058	1		0.859888	1.859888
183-6059	1	1	0.731092	2.731092
203-6016-FP	1		0.652837	1.652837
203-6016-FP	2		0.032103	2.032103
203-6016	1	2	0.61581	3.61581
203-6016	2	2	0.188578	4.188578
203-6016	3	2	0.186834	5.186834
203-6016	4	2	0.038159	6.038159

Table 7 – Sample Calculation of Index to Sort by

Generating a sample of random schedules, comparing results, selecting the sequence resulting in the best solution, in this case the one with the shortest makespan, creates the job release policy for components in a make-to-order environment. The minimum, maximum, and mean makespan for a particular product's random job sequences in Figure 5 shows any changes in makespan diminish after about thirty randomly generated schedules. The distribution of the random schedule's makespan for each product in Figure 6 appears approximately Normal. This could imply how many random schedules are necessary to find a solution under a specified time, given an initial sample. The resulting makespan for each product in Table 8 is rather large as the schedules assume component routings are completely random. This assumption is not correct.

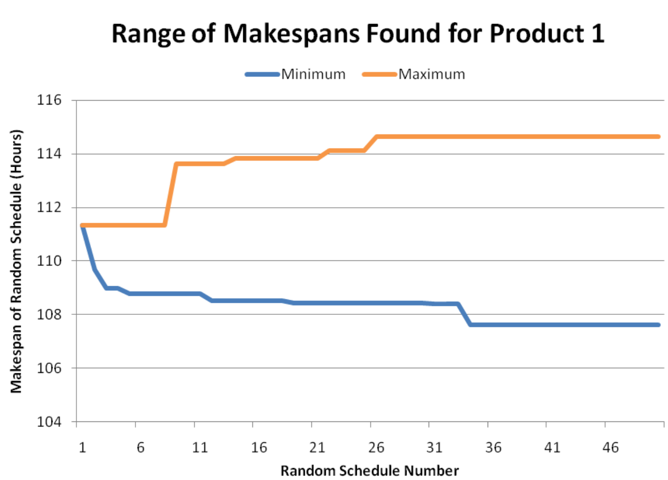

Figure 5 – Makespan Results for the Number of Iterations of Random Component Sequences

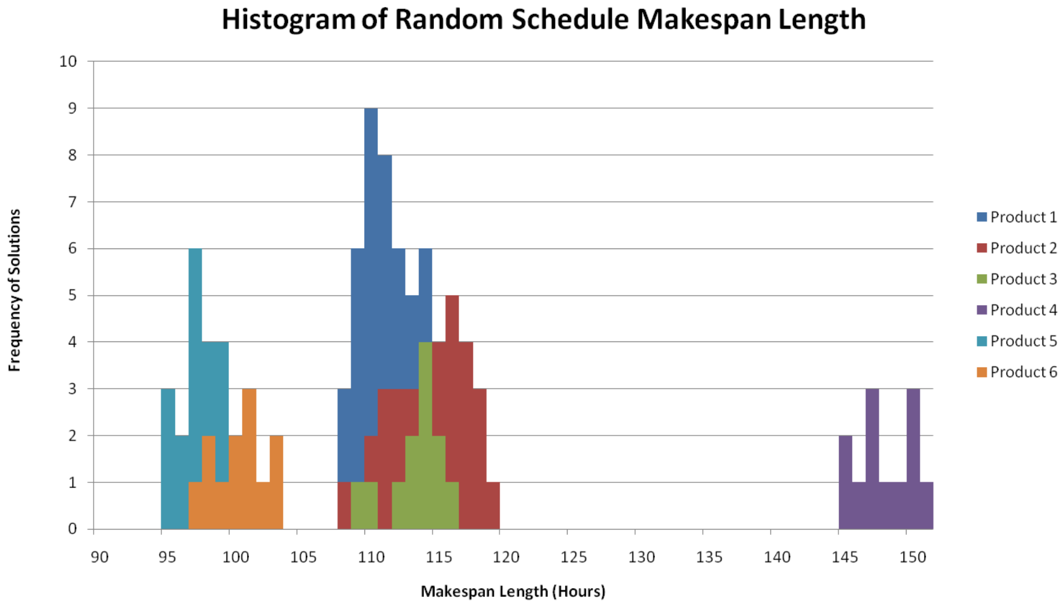

Figure 6 – Histogram of Makespan's for Random Job Sequences

Product	1	2	3	4	5	6
Minimum Makespan (hrs)	*107.02*	*107.88*	*108.98*	*144.77*	*94.68*	*96.45*

Table 8 – Makespan Results for Products

Although this method of testing randomly generated schedules could succeed for problems where production routings are truly random, data from Appendix C reveals only 56 unique routings for all components. Since this pattern exists, and component routings are not entirely random, scheduling components with similar routings consecutively could increase the flow of jobs as a more compact schedule logically results in a shorter makespan illustrated in Figure 7.

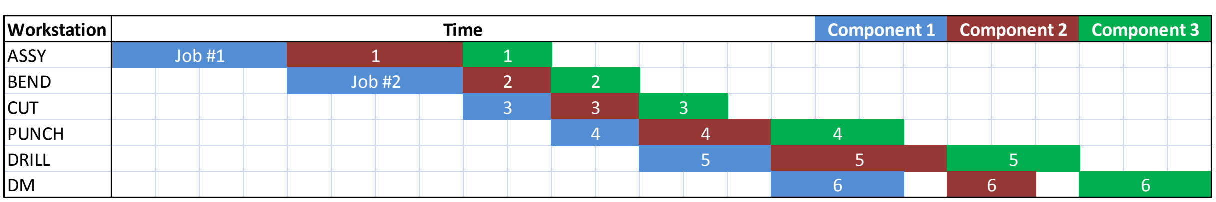

Figure 7 – Blocking Routings Results in a Compacted Gantt chart (Coloured by Component)

To schedule components in order of routing, the same approach of randomizing the job sequence is applied; however, by introducing two random elements in Table 9, components with common routings are constrained to process their associated jobs consecutively. The first randomization lies within the jobs with common routings, while the second random element identifies the order of the routing within the schedule. Assigning a random Uniform (1, 1000) variable to each unique routing ensures jobs with a common routing have the same random route number. Another random Uniform (0, 1) variable added to the route number creates an index in Table 9, modified to incorporate subcomponent precedence as in Table 7, then sorted, yields a feasible random job schedule according to component routing.

Component	Route	Route #	Random # for Job	Random # for Route	Total (Sort)
183-6058	1 COILS	5	0.946355537	958	958.9464
183-6059	1 COILS	5	0.647631795	958	958.6476
206-1004	1 CABLES	13	0.801532211	492	492.8015
206-1150	1 PARTS	2	0.870488477	710	710.8705
206-6520	1 PARTS	2	0.854064452	710	710.8541
206-6522	1 PARTS	2	0.225604993	710	710.2256
206-6132	1 CUT 2 LATHE 3 PLATE	26	0.362535667	701	701.3625
206-6134	1 CUT 2 LATHE 3 PLATE	26	0.639978629	701	701.64
206-6528	1 CUT 2 LATHE 3 PLATE	26	0.008670966	701	701.0087
206-8086	1 PSASSY 2 PAINT 3 MISC	31	0.989765525	573	573.9898
206-8282	1 PSASSY 2 PAINT 3 MISC	31	0.931234754	573	573.9312
206-8482	1 PSASSY 2 PAINT 3 MISC	31	0.308744429	573	573.3087
207-6174-01	1 CUT 2 MILL 3 MISC 4 PLATE	35	0.495535672	863	863.4955
207-6176-02	1 CUT 2 MILL 3 MISC 4 PLATE	35	0.689792168	863	863.6898
206-1030-03	1 PRGM 2 PUNCH 3 MISC 4 DM	39	0.126619372	374	374.1266
...	...	...	...	...	...

Table 9 – Example of random scheduling data with common routings

The resulting makespan in Table 10 for each product using this method of job sequencing, reveal a dramatic reduction. This is due to the compacted nature of resulting schedule, as sequencing components by common routings processes the jobs in a logical, flowing order. The set of job schedules for each product, in Appendix D, provides the sequence of jobs triggered in component make-to-order environments. Though no other patterns are evident in the data provided, generally more patterns in the job structure can provide insight and enable strategic advantages in performance. In addition, the more random job sequences examined for a product improves the probability of finding a better result.

Product	1	2	3	4	5	6
Minimum Makespan (hrs)	30.72	32.80	31.45	41.70	36.61	37.16

Table 10 – Makespan Results while Blocking Components with Common Routings

4.3. Make Components to Stock

Holding stock of components could dramatically reduce the time needed to fulfil orders relative to a pure make-to-order system. The question of how much stock to keep falls on the allowable lead-time and inventory investment. Experiments quantify the trade-off, if any, between the two performance indicators and other responses. With the demand profile for components in Section 4.1, two parameters form the values for component re-order points and order quantities. This approximation, depicted in Figure 8, uses the probability, *p*, and timeframe, *t*, to set the inventory parameters for all components. Although this cannot simulate the component removal, as it removes components one at a time and not in multiples of the quantity per product, it can apply to their stocking parameters. Equation (0.2) defines the individual component rates and results in the expected number of units per day, as illustrated in Table 11.

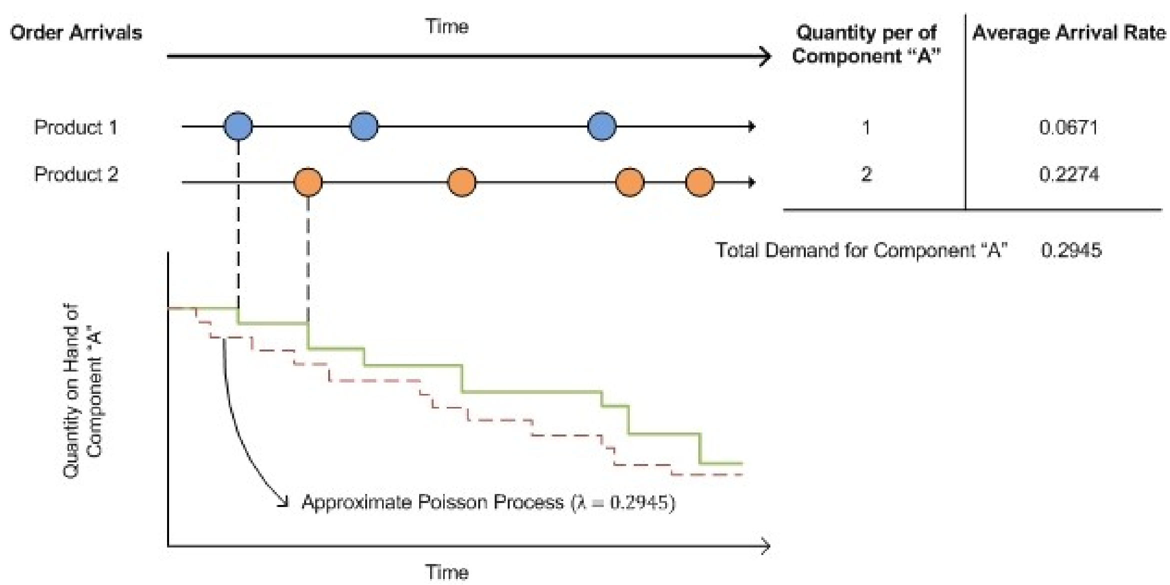

Figure 8 – Component Demand Model

Product	1	2	3	4	5	6	
Demand Rates	0.06711	0.113795	0.134893	0.065631	0.075814	0.087139	Units/Day
Component	Product Quantity					Component Demand:	
176-1129-01	2	2	4	6			1.295168
176-6141-01					1	1	0.845279
184-6129-01					2	2	1.690558
198-8357-01	2	4	8	16			2.71864
200-5514-20	1	1	1				0.315798
200-5514-40				1			0.065631

202-8037					1	1	0.845279
…	…	…	…	…	…	…	…

Table 11 – Demand of Individual Components

This model for components allows four parameters to describe an appropriate amount of stock based on their demand, as both the re-order and order quantity parameters consider the probability of demand within a given timeframe. These parameters determine how the simulation model triggers orders for more components. When the quantity on hand of a particular component reaches the re-order level, r, the simulation releases all necessary jobs for Q units of the component. However, this component demand model can only represent top-level components in order to formulate re-order and order quantity parameters. Since the stocking parameters of a particular component define the demand of its subcomponents, using the total quantity of subcomponents in final products as an indicator of demand could lead to frequent shortages. Instead, multiplying the subcomponent quantity and the order quantity of the parent component defines the lot size associated with a particular subcomponent. For example, if component "A" has two subcomponents, "B" and "B" has three subcomponents, "C," then B relies on the order quantity of A to determine the appropriate amount of stock to fulfill a request for A. If the order quantity of A is five, then B should have a lot size of $2 \times 5 = 10$ units, and C should have a lot size of $3 \times 10 = 30$, provided the subcomponent order quantity is a single lot, as exemplified in Table 12.

Component	Total Quantity	Sub-Component	Quantity Per	Lot Size (L)
A	1	B	2	Order Quantity = 5
B	2	C	3	10
C	6	-	-	30

Table 12 – Example of Subcomponent Batching

The re-order and order parameters for subcomponents, specified by the number of lots, now incorporate the demand of their parent component. In the case of multiple parents for a single subcomponent, selecting the greatest possible lot size ensures availability for the replenishment of any parent. With component re-order and order levels of subcomponents being multiples of a lot size, the system protects against subcomponent stock-outs by design. Indeed many other situational factors can affect the choice of lot size. The physical circumstances could demand small adjustments to the lot size, for example, if a unit of raw material creates exactly six items and the lot size is five, adjusting the lot size to six could both reduce waste and be more convenient. The system in Figure 9 illustrates the policies for holding component inventory.

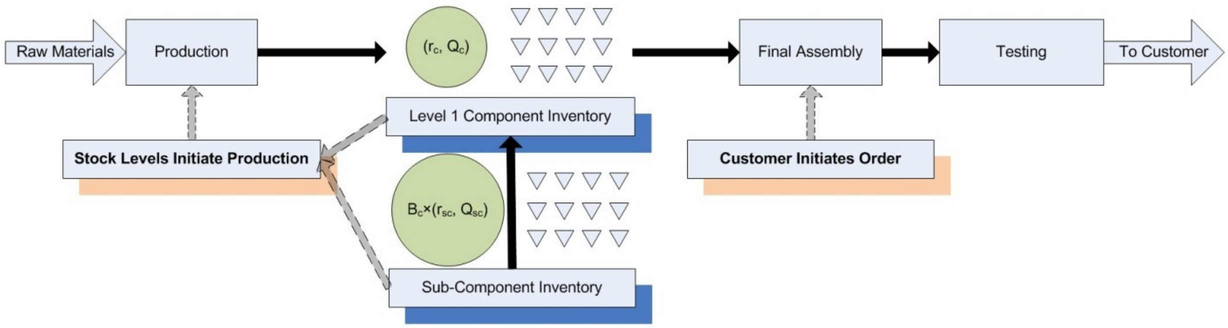

Figure 9 – Inventory Handling in Component Stock

Each inventory parameter influences the performance of the system differently. The re-order point protects against demand variability because additional inventory on hand is capable of sustaining greater shocks, while the order quantity reflects the number of setups in component production. The average number of setups required for each component at each workstation, in (0.5), is the long-term demand divided by the item's order quantity. In contrast, a make-to-order environment requires a setup for each job of every customer order.

$$Number\ of\ Setups = \frac{Demand}{Order\ Quantity} \qquad \textbf{(0.5)}$$

The design of experiments in Table 13 identifies the change in response due to a particular factor or interaction between factors. The factors are the inventory re-order point and the order quantity for both top-level components and subcomponents. The inventory parameter for top-level components, used directly to build semi-finished units, is the number of units demanded within a timeframe *t*. The inventory parameter for subcomponents, used to build other components, is the number of lots. This 2^4 factorial experiment considers a high and low level of each factor, as testing every possible combination of inventory would consume vast computational resources. A few varied experiments should provide enough insight to approximate the effects of factors and trade-off in the model's response.

Separating the inventory factors by component level in the experiment design in Table 13, shows the settings for component re-order and order quantities in the initial factorial experiment. The values for high and low levels of top-level stock are estimated as *0.95* of probable demand within a value of $t = 22$ days (one month) for the low level and $t = 44$ days for the high level. Subcomponent parameters include the re-order point and order quantity in terms of number of lots. However since their demand is dependent on the withdrawal of other components, the lot size determines the value of the parameter, and not *p* of demand within *t*. The low inventory setting for subcomponents is two lots and the high setting is set at five.

Design Point Low Level = - High Level = +	**Top-Level**		**Subcomponents**	
	Re-Order Point (TR)	Order Quantity (TOQ)	Re-Order Point (SR)	Order Quantity (SOQ)
1 (-, -, -, -)	t = 22 days	t = 22 days	B_C = 2 lots	B_C= 2 lots
2 (-, -, -, +)	t = 22	t = 22	B_C = 2	B_C = 5
3 (-, -, +, -)	t = 22	t = 22	B_C = 5	B_C = 2
4 (-, -, +, +)	t = 22	t = 22	B_C = 5	B_C = 5
5 (-, +, -, -)	t = 22	t = 44	B_C = 2	B_C = 2
6 (-, +, -, +)	t = 22	t = 44	B_C = 2	B_C = 5
7 (-, +, +, -)	t = 22	t = 44	B_C = 5	B_C = 2
8 (-, +, +, +)	t = 22	t = 44	B_C = 5	B_C = 5
9 (+, -, -, -)	t = 44	t = 22	B_C = 2	B_C = 2
10 (+, -, -, +)	t = 44	t = 22	B_C = 2	B_C = 5
11 (+, -, +, -)	t = 44	t = 22	B_C = 5	B_C = 2
12 (+, -, +, +)	t = 44	t = 22	B_C = 5	B_C = 5
13 (+, +, -, -)	t = 44	t = 44	B_C = 2	B_C = 2
14 (+, +, -, +)	t = 44	t = 44	B_C = 2	B_C = 5
15 (+, +, +, -)	t = 44	t = 44	B_C = 5	B_C = 2
16 (+, +, +, +)	t = 44	t = 44	B_C = 5	B_C = 5

Table 13 – Design Experiment for Component Inventory

Further analysis of the sensitivity of a single factor, while holding the others unchanged, can provide additional details on its effect. Significant interactions between factors should exist in the response of component inventory on hand, as the top-level order-quantities influence the lot size of subcomponents.

4.4. Make Semi-Finished Goods to Stock

Holding semi-finished inventory could result in even lower customer lead-times relative to component inventory, as semi-finished units only require testing and not assembly. The job schedules in Appendix D release jobs for the necessary components when required for semi-finished stock replenishment. The order quantity of the semi-finished stock determines the number of components per setup. The balance between reducing the number of setups and increasing the unit run time of jobs must be appropriate for such a policy to operate in steady state. There is no guarantee that a feasible system is possible as it is highly dependent on both the job structure and system capacity, as ordering one at a time results in the same setup requirements as the make-to-order model. The diagram in Figure 10 illustrates the system and job release policies while holding only semi-finished inventory on hand.

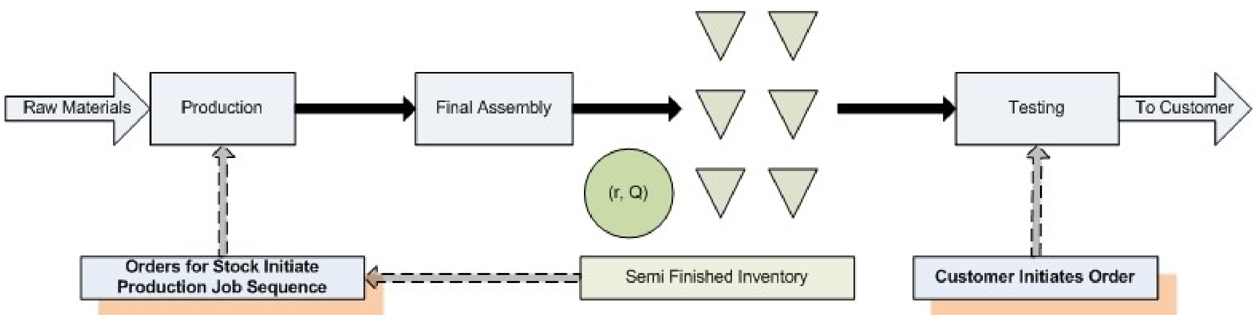

Figure 10 – Holding Semi-Finished Stock

The initial design experiment tests the effects of semi-finished re-order and order quantity parameters. The initial 2^2 factorial experiment in Table 14 implements common inventory parameters across all products. The low level is set at two semi-finished units and the high level is set at five for each product. Adjusting stock parameters to reflect demand could reduce stock-outs and inventory overages. From the results of this initial experiment, other sensitivity experiments show how other settings can affect the stability and performance in this production environment.

Design Point	**Re-Order Level** (Semi-Finished Units)	**Order Quantity** (Semi-Finished Units)
1 (-, -)	r = 2	Q = 2
2 (-, +)	r = 2	Q = 5
3 (+, -)	r = 5	Q = 2
4 (+, +)	r = 5	Q = 5

Table 14 – Design Experiment for Semi-Finished Inventory Levels

4.5. Make to Stock

Utilizing both stock points along the production line will result in the best customer service but also the most stock held of any alternative considered. Semi-finished stock provides a quick response to customers while component inventory reduces the number of setups and congestion in the production process. Due to the number of component commonalities within products, it could be beneficial to keep components in stock, in order to initiate final assembly when required. The testing process, where custom final adjustments require a customer order, can begin as soon as the order arrives, provided sufficient stock of semi-finished units as shown in Figure 11.

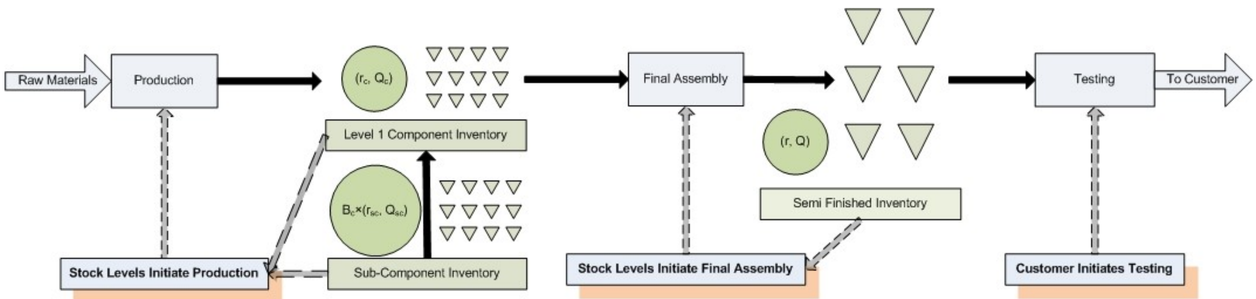

Figure 11 – Make to Stock System

The parameters for component demand must suit the system. Stock levels should reflect the demand experienced by components. In Section 4.3, the re-order and order quantity parameters for top-level components represent the demand from customer orders. Since component demand is a function of the order quantity for semi-finished stock, much like top-level components and subcomponents, parameters for top-level components also incorporate a lot size. Holding semi-finished stock now acts like the top level in the BOM. The top-level components still consider the demand within a timeframe but include a lot size in order to satisfy any request for semi-finished stock.

Top-level component parameters, defined as the maximum of a lot size and the proportion p of demand within timeframe t, ensure that components common in multiple products consider the combined demand, and not just enough to replenish a single product. Subcomponent parameters still experience demand from the order quantity of parent components and remain defined as a multiple of the lot size. Semi-finished inventory factors, such as re-order level and order quantity, with component and subcomponent parameters of lot size and demand, yields a large 2^7 factorial experiment with 128 design points. To reduce the number of design points, the four factors describing component inventory are replaced with a single factor considering the component demand within a particular timeframe. The lot sizes for components are set at a single lot. The demand timeframe used for top-level re-order and order quantities is set equal, further eliminating another factor. This also reflects the lot sizes of subcomponents as determined from the order quantity of its parent. Reducing the number of factors describing inventory parameters creates the 2^3 factorial experiment detailed in Table 15. In this initial experiment, the low level for both component re-order and order quantity parameters is set at 95% of demand within 22 days, and 44 days for the high level. Semi-finished inventory levels consider the same parameters for all products.

The low level for the re-order point of semi-finished units is three and the high level is five. The low level for the order quantity is set at one unit and the high level at three.

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Design Point	Component Demand Timeframe	Semi-finished Re-Order Point	Semi-Finished Order Quantity
1 (-, -, -)	t = 22 days, p = 0.95	r = 3 Units	Q = 1 Unit
2 (-, -, +)	t = 22	r = 3	Q = 3
3 (-, +, -)	t = 22	r = 5	Q = 1
4 (-, +, +)	t = 22	r = 5	Q = 3
5 (+, -, -)	t = 44	r = 3	Q = 1
6 (+, -, +)	t = 44	r = 3	Q = 3
7 (+, +, -)	t = 44	r = 5	Q = 1
8 (+, +, +)	t = 44	r = 5	Q = 3

Table 15 – Initial Experiment Design for Make to Stock System

In the case of common components among products, the greatest quantity of the component used in the replenishment of semi-finished goods determines the lot size. In practice, adjusting lot sizes could protect against inventory stock-outs and overages. The parameter that describes the component stock inventory in these experiments is responsible for buffering variation in demand and controls the number of setups in production. The larger the order quantity, the fewer setups required.

Further experiments on the make-to-stock model test various other factors that could provide insight into the system's nature. Inventory parameters in the initial experiment consider the same stock levels across each semi-finished product. Since the volume of orders is low and distributed evenly among products, the effect of common inventory parameters as opposed to demand-based parameters might not be significant; though incorporating such inventory parameters could better suit a particular product. For example, a unit with low demand would have an appropriately low re-order level, whereas products with longer production lead-times or higher demand should have re-order levels that reflect such conditions.

4.6. Additional Experiments

Experiments to determine appropriate stock levels provide a sample of different models to compare the effect of other parameters and measurements. These experiments, in the form of sensitivity analyses, determine the robustness of the models and any trade-off between operating procedures. A sample of the design points tested in the stocking experiments provide an adequate base to perform the sensitivity analyses, which typically have only a single factor. These experiments allow one to interpret the effects of elements such as job randomness, capacity, and demand.

4.6.1. Sensitivity of Job Randomness and Production Interference

To simulate variation in processing time, several values of the coefficient of variation, C_V in (0.6), establish a standard deviation for job process times. A random number generated according to the average, μ, and standard deviation, σ, subject to non-negativity, determines the processing time for each job.

$$C_v = \frac{\sigma}{\mu} \tag{0.6}$$

Interference or 'noise' introduced in the production system's processes simulates the effect of other uncommon activities or events. Possible representations include rare products with negligible or unknown demand, machine breakdowns, expediting jobs, re-work, or experimental components used in the research and development of future products or upgrades.

4.6.2. Sensitivity to Demand

Even though demand in this environment is uncontrollable, it is changeable in the simulation model. Sensitivity analyses on the variables that control customer ordering reveal the implications and limits of changes in demand. Comparing the performance with different demand rates can provide a critical rate where the parameters for the particular scenario prove unstable. This could influence the managerial decisions when implementing such a system. To simulate the effect of alternative demand rates, varying the customer inter-arrival rate effectively models changes in demand as customers arrive more or less frequently. If a critical demand rate exists, it is due to one of two possible causes. First, if the current measurement of demand results in an unstable system, the critical value represents the maximum, stable, demand rate. Second, the system is stable for measured demand rate, and the critical value determines the highest possible demand the system can experience while maintaining stability.

4.6.3. Final Assembly and Testing Capacity

Another factor of interest is the capacity in final assembly and testing areas. An initial sensitivity analysis compares the response of modifying capacity at each stage separately. From the simulation results, the minimum capacity required for a particular service level represents the number of parallel servers required for each process. The analyses of these capacities consider each process independently, though many interesting conditions could enhance the accuracy of the model.

To build a more realistic model, one could develop a cross-training model where servers can only assemble or test certain products. If it is possible to add or reduce labour for a particular process, a model considering non-stationary capacity can provide the necessary resources when required, using idle servers elsewhere to reduce the workload in highly active processes. By modeling the skill and experience of the servers individually, instead of assuming identical rates of performance, one can enhance the model to incorporate a more accurate representation of the real processes. Although this model does not incorporate these conditions, they can serve to increase the credibility of the model. With the appropriate assumptions, the model can reflect a more human, or “soft,” (Checkland, 2000) system.

CHAPTER 5 SIMULATION MODELING

Each system described in Table 5 requires a well-defined process to construct a suitable model. The simulation processes mathematically represent the conditions of the real system. Each process corresponds to a series of events resulting from a particular aspect of the system. These discrete events, scheduled chronologically, form the demand for stock and compete for system resources. From the response of output variables, a few key metrics, such as the proportion of orders delayed due to stock-outs or the variation in customer lead-time, reveal the performance of each scenario.

The model developed includes processes for demand and ordering, production, final assembly, and testing. Depending on the particular system, the manufacturing processes follow their assumed operating procedures for job release and material flow. Though these systems differ in operation, a valid comparison is possible by collecting a series of variables representing some performance level independent of the particular system. Such data, like the time from the order arrival to when the particular order finishes testing, determines the lead-time, while the sum of time-averaged inventory-on-hand indicates the level of inventory held in the system.

Depending on the operating procedures, the chart in Figure 12 shows how the simulation models each aspect of the system. With the ordering process described in Figure 3, recording the output from each replication yields a possible instance of performance for a particular set of inventory parameters. Performance measures include both the average amount of inventory-on-hand and the lead-time to customer.

Production Triggers by Model	Make-to-Order	Make Components	Make Semi-Finished Goods	Make-to-Stock
Component Job Release	Customer Order	QOH	Stock Replenishment	QOH
Assembling Semi-Finished Units	Component Availability	Customer Order	QOH	QOH
Testing Semi-Finished Units	Semi-Finished Availability	Semi-Finished Availability	Customer Order	Customer Order

Figure 12 – Simulation Job Release Chart

The value of inventory, represented in (0.1) by the sum of the time-averaged number of components on hand, does not incorporate the unit cost of raw materials. Literature commonly references a holding cost associated with a particular item depending on its cost, weight, volume, or turnover. This holding cost typically considers a subjective cost measure for an item's properties in order to minimize the total cost of the production system, with respect to some economic and physical constraints. Incorporating the inventory investment required for a scenario would necessitate the cost of each component to be included in the overall value of inventory as in (0.2). With a small sample of information on the cost of components, it is possible for one to construct an estimate of the inventory cost based on an exponential distribution. There are typically many low-cost parts and only a few expensive components.

$$Inventory\ Amount = \frac{\sum_{i=0}^{Components} \int_0^t (Quantity\ i\ on\ Hand)\, dt}{t} \quad \textbf{(0.1)}$$

$$Inventory\ Cost = \frac{\sum_{i=0}^{Components} (Cost\ of\ i\ \times \int_0^t (Quantity\ i\ on\ Hand)\, dt)}{t} \quad \textbf{(0.2)}$$

The order arrival process spawns all other processes, which simulate the build of a product. With each arrival, an instance of the particular production process arises to fill the order. The simulation runs these processes independently, and they compete for various resources and inventory in order to create an event list, which forms the basis for measuring various performance metrics. Depending on the operating procedures, the model adds jobs and removes inventory to simulate the production system. For example, while holding component stock, the arrival process adds the order to final assembly and initiates a check for stock replenishment. The final assembly process removes necessary components, subject to availability, to construct a semi-finished unit, and then initiates testing.

The main entities in this model are customer orders. Their arrival spawns other entities in the form of jobs for resources to complete, given a certain processing time for the event. Once a job or event is complete, the entity enters a queue for the next job until the customer order is satisfied. If more orders arrive while others are in progress, the separate instances of the same process chronologically schedule events. This ensures that customer orders are not waiting for a process to end in order for another to begin, processing the different customer orders in parallel. The simulation processes that interfere with production operate outside the main simulation, though they compete for the same resources. This creates a random set of conditions such as machine failures or miscellaneous jobs. The operating procedures for each model, detailed below, describe how the simulation operates in a particular environment.

5.1. Make to Order

The make-to-order simulation waits for an order to arrive to begin the production of components. Once complete, assembling the components forms a semi-finished unit, which is then tested and shipped to the customer, as described in Section 4.2. The sequences in which the components are loaded into the production system, described in Section 4.2.1, ensure feasibility in the bill of materials structure and job routings. The ordering process in Figure 3 triggers the job release for components.

The simulation ordering process releases the pre-determined sequence of jobs into the production system once an order arrives and begins processing. After all component quantities for the particular order are available, the process in final assembly begins by removing all the required components from the system. Once final assembly produces a semi-finished product, testing removes the semi-finished unit, makes custom adjustments, and ensures product quality. The entire simulation process described in Figure 13 illustrates the real world processes that a make-to-order system would experience.

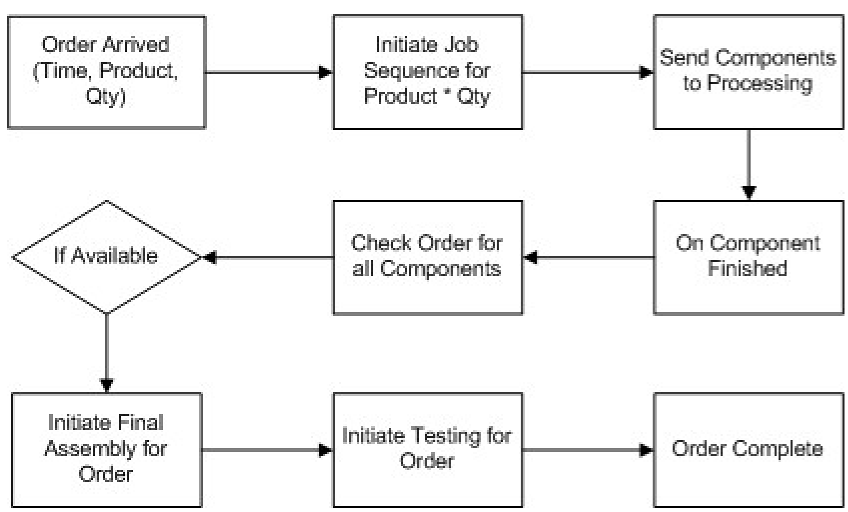


Figure 13 – Make to Order Simulation Process

5.2. Make Components to Stock

Making components to stock requires a separate process to monitor the stock levels of each component and initiate orders for replenishment. As this replaces the need to initiate jobs based on order arrivals, the order enters a queue for final assembly. If the stock on hand of any component is less than sufficient to assemble the ordered product, the order remains in the queue until all the required components become available. The order removes components from stock to begin final assembly and the simulation process in Figure 14 describes the system model according to these policies.

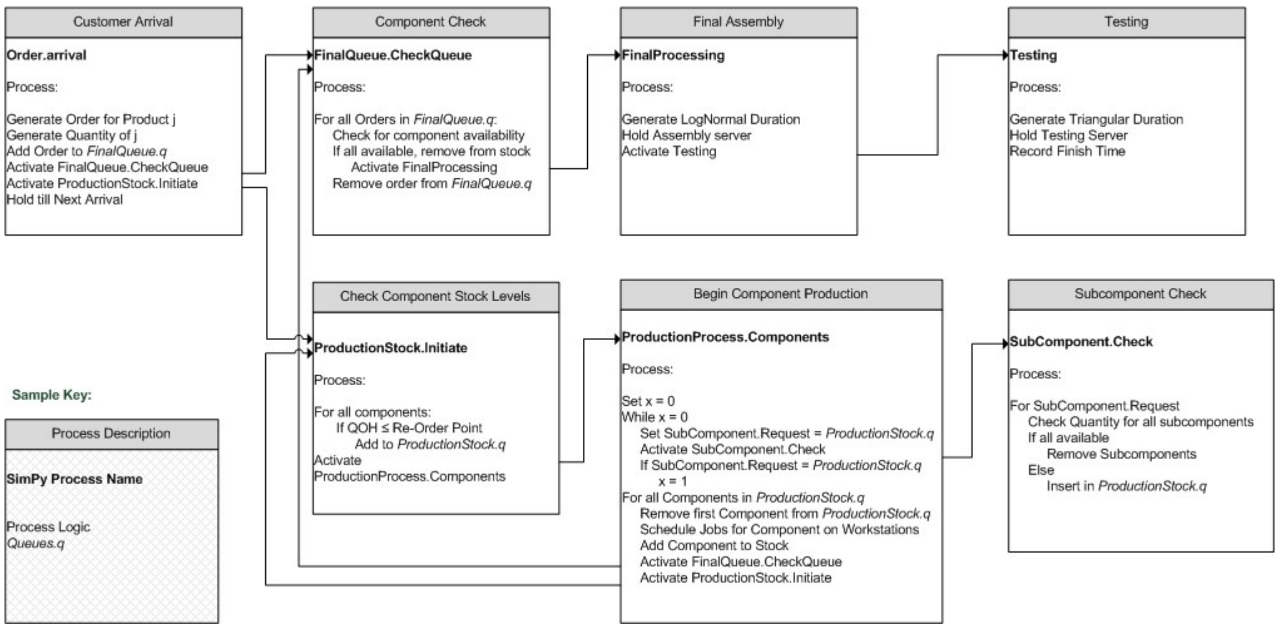


Figure 14 – Make Components to Stock Simulation Process

Although the sequence of jobs is not pre-determined as in the pure make-to-order system, further research and experimentation in the scheduling and loading of jobs, such as releasing component jobs by routing, can improve the operating policies in this system. Since this model holds inventory, it has the ability to pool variance of product demand on component inventory much like a delayed differentiation approach. Due to the abundance of common components among product families, in Figure 2, the effects of variance pooling can provide an effective measure against component inventory excesses and stock-outs in this system.

There are also practical considerations and constraints for the re-order and order quantities of components as described in Section 4.3. The lot size of subcomponents could depend on many other physical parameters of the component or job process; however, this model only considers lot size as a function of the parent component's order quantity. Should the subcomponent have more than one parent, selecting the greatest possible lot size ensures all requests can be satisfied with a single lot. Other limits on inventory parameters, found experimentally, translate to certain requirements in the real system. For example, consider the order quantity levels for components and its inverse relationship to the number of setups in the system. Should setup time exceed the available production capacity, the set of inventory parameters creates unstable queues and are infeasible. System instability is a result of excessive traffic intensity in the system's resource queues. If any machine queue is unstable, violating (0.3), the system is unstable as no steady state exists, and production queues, along with customer lead-time, continuously inflate.

$$\frac{Arrival\ Rate}{Service\ Rate} \leq \text{Number of Parallel Servers} \tag{0.3}$$

Though the arrival rate for components, $1/t_a$, estimated in Table 11, is constant, the service rate depends on the particular job and order quantity at each workstation. The service time for a component depends on the setup time, t_s, run time, t_r, and order quantity, Q, for each job. Since the arrival of jobs is somewhat random, the total expected productive time in a workstation should be less than the time available for the particular resource as shown in (0.4).

$$Total\ Run\ Time + Total\ Setup\ Time \ \leq Available\ Capacity$$
$$\sum_{C} t_r(c)D(c) + \sum_{C} \frac{D(c)}{Q(c)} t_s(c) \leq Available\ Capacity \tag{0.4}$$

Though this can determine the viability of a given order quantity, different production times and multiple machines make it difficult to find the smallest ordering value for each component. Assuming only one component and machine, the total production time for a batch of Q components, $t_s + Q \times t_r$, results in the service time, $\mu(Q)$, as a function of Q as shown in (0.5). Since the arrival rate must be less than the service rate, (0.6) determines the minimum order quantity for a stable queue. As this simplified case considers only a single component and workstation, the actual order quantity parameter still follows the definition described in Section 4.3, determining the minimum Q experimentally.

$$\mu(Q) = \frac{Quantity}{Time\ to\ Produce} = \frac{Q}{t_s + Q \times t_r} \tag{0.5}$$

$$Arrival\ Rate \leq Service\ Rate$$
$$\frac{1}{t_a} \leq \mu(Q)$$
$$\frac{1}{t_a} \leq \frac{Q}{t_s + Q \times t_r}$$
$$Q \ \geq \frac{t_s}{t_a - \ t_r} \tag{0.6}$$

This minimum bound on Q can provide a rough estimate of the component batch size required for stability. Further analysis of each component, its material requirements and physical properties, could find a more convenient batch size to work with. Ordering costs, unit costs, supplier lead-times, and turnover rates could alter the decision to find a more acceptable batch size that suits the particular component.

5.3. Make Semi-Finished Goods to Stock

The parameters for modeling this scenario include only the re-order and order quantity levels for the six products. The job schedules determined in Section 4.2.1 trigger the production of components for semi-finished stock replenishment when the quantity on hand of particular product reaches the re-order point. In this way, the order quantity of final stock determines the number of setups required in the production area in the absence of component stocking parameters. The model of this system in Figure 15 details the simulation processes that describe operating procedures for this scenario.

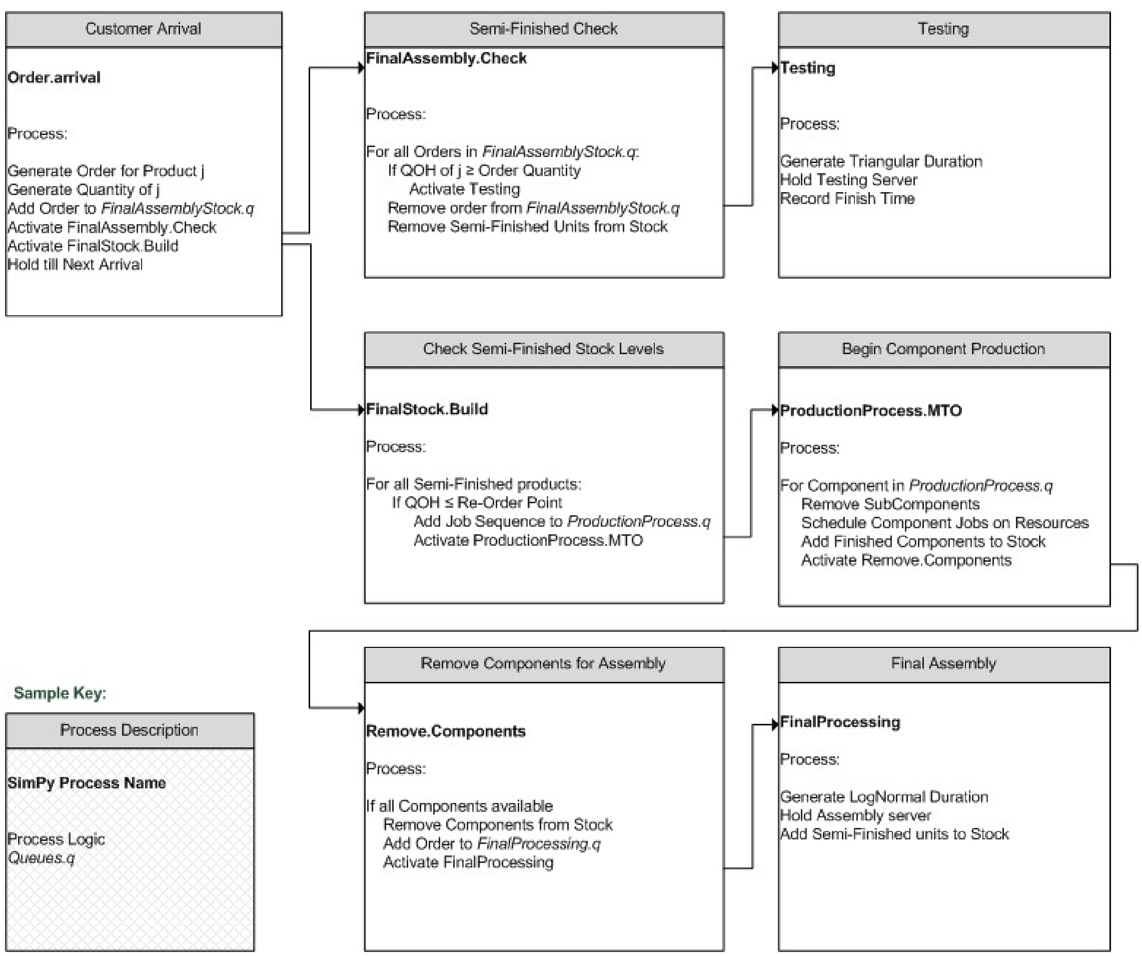


Figure 15 – Semi-Finished Stock Simulation Process

Jobs for components follow the sequence in Appendix D, and like the pure make-to-order model, there is no guarantee of a stable outcome. If setup time exceeds allowable limits, congestion overwhelms the system and this particular scenario is infeasible for the set of parameters. There exists a feasible opportunity should the number of setups be reduced to an acceptable point. Due to the complicated nature of this system, with several machines and constraints on component routings and subcomponents, the opportunity for this to become a feasible system relies on relatively small unit-run times compared to setup time, so larger order quantities do not outweigh the benefits of combining job setups. As described in the previous section, if the setup time exceeds allowable limits, increasing the order quantity can reduce the number of setups. With low order quantities, some other means of capacity expansion or forecasting could provide a stable system. Accurately predicting demand can alter the production process according to a schedule with aggregate demand to reduce setups among components. Machine component analysis and grouping, essentially a form of capacity expansion, could also yield an effective method of increasing the throughput of this system.

5.4. Make to Stock

Holding semi-finished and component stock can increase the responsiveness to customers while directly controlling the number of setups in production. Though lot sizes for all components are associated with the order quantity of semi-finished goods, incorporating component demand rates into the inventory parameters ensure common components have a reasonable amount of stock on hand. The simulation for this scenario considers two separate processes that monitor inventory levels for both stock points. When a product's stock reaches the re-order level, the system triggers an order for more. Final assembly removes components and replenishes the semi-finished stock while another process monitoring component stock releases the necessary jobs into production to replenish components. Customer orders form a queue in testing that checks the availability of semi-finished stock and initiates testing as portrayed in Figure 16.

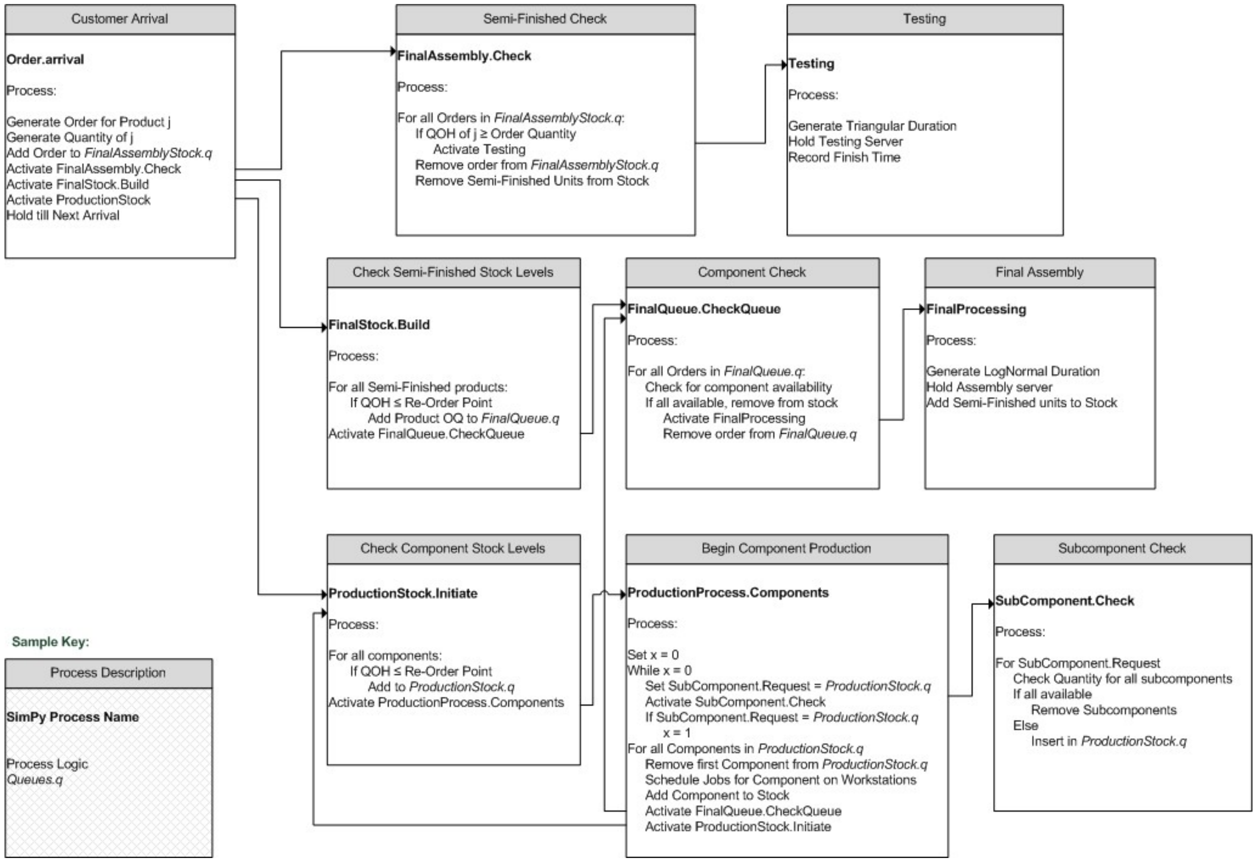


Figure 16 – Make to Stock Simulation Process

5.5. Simulation Parameters

For most experiments, the run length of the simulation is five thousand hours, about four years at forty work hours a week. Since no known initial conditions exist, the simulation starts with random stock levels between the re-order point and order quantity. This allows the simulation to begin operating with a realistic amount of inventory, though including a small warm-up time of one hundred hours lets orders initiate the first few job releases. The output data during this simulation warm-up is not included in the overall statistics as it could affect the measurement of steady state responses.

The simulation model considers one day as eight hours of available machine time, five days a week, fifty-two weeks a year. Assuming continuous production from the end of one day to the beginning of the next, the rate of demand requires units of work-hours for consistency. There exist many cases where the time unit should change depending on working conditions, personal allowances, and other historical factors, as there might only be seven hours of productive machine time during an eight-hour work shift.

5.6. Simulation Operation

The settings for the simulation parameters, besides model run time and warm-up time, include the stock points for each component and semi-finished product. A Microsoft Excel spreadsheet calculates the inventory parameters for each stocked item and exports the information to a text file. The simulation model in Python v2.7, with SimPy v2.1.0, reads the inventory parameters from the text files and runs a single replication of the simulation as shown in Figure 17. The simulation response of various performance measures, exported to text files, and read in Excel, calculates the resulting performance indicators over a number of replications, in order to form statistical bounds on the actual response.

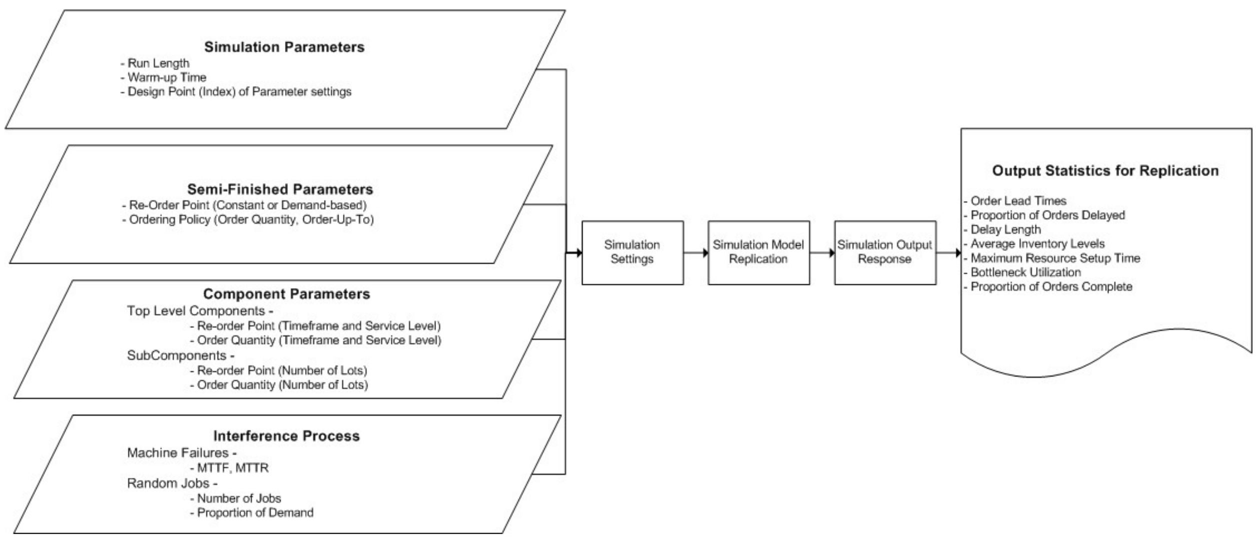


Figure 17 – Simulation Process

5.6.1. Input

Several input settings for inventory levels determine the operating procedures and amount of stock on hand. The subcomponent's re-order point and order quantity, in terms of lot size, can hold any positive integer value. Top-level component parameters depend on the semi-finished order quantity if it exists, and if so, considers the same lot size approach as subcomponents. Without semi-finished products in stock, the top-level component parameters depend on two values, a given service level, $p = 0.95$, and timeframe, t. To calculate the parameter values, an Excel add-in developed by Roger Myerson at the University of Chicago (Myerson, 2005), *SimTools,* calculates inverse statistical functions. The semi-finished inventory levels require setting constant parameters among all products or incorporating the expected demand for the product within a given timeframe. Other semi-finished parameters, such as order-up-to levels, can provide additional options to examine. Appendix F shows an example of setting parameters for the make-to-stock simulation model.

5.6.2. Analysis

The simulation reads the given inventory parameters and runs a single replication for the specified run length. Once the replication is complete, logging the output data forms the basis for statistical analysis. After a number of replications for different scenarios, two Excel files plot the output information. This allows one to identify the significant changes in response for both factorial experiments and sensitivity analyses. Factorial experiments examine a number of factors with only two settings, a low and high value for each factor. The design of a particular experiment, copied to the Excel file for analysis, can use up to four possible factors. The selected response from the available output data results in the significant factors and any interactions between them as shown in Figure 18.

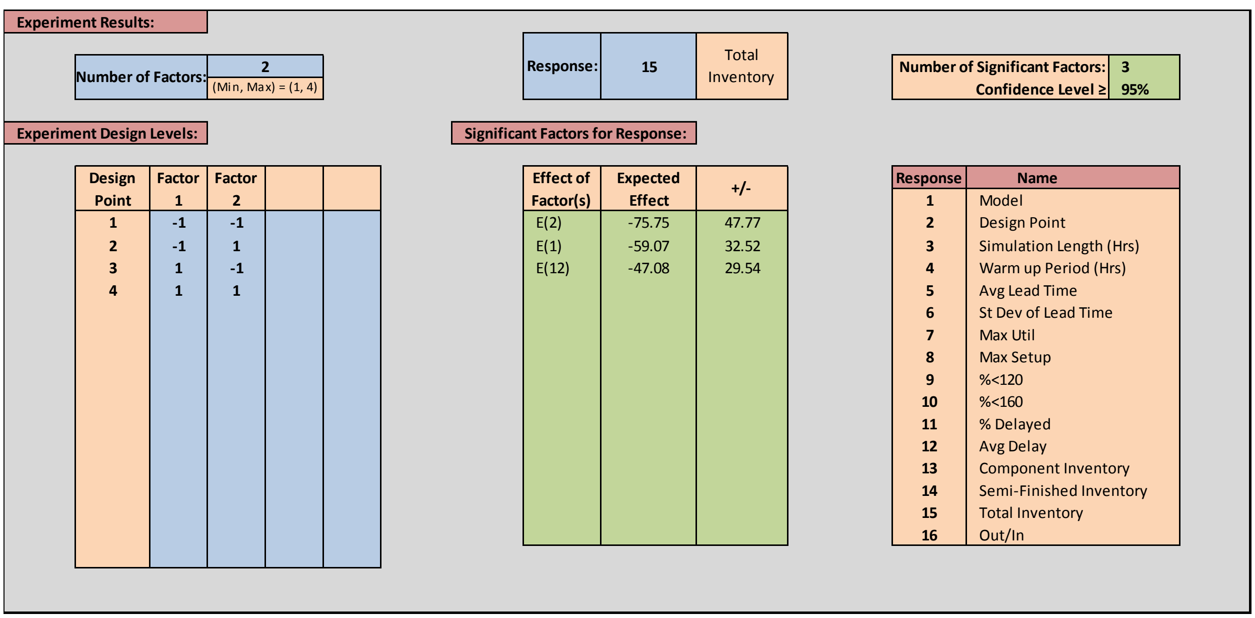


Figure 18 – Factorial Experiment Example

The sensitivity analyses only consider a single parameter, but for a range of values. For a selected response, the output information shows how the response changes with respect to the value of the parameter. Two graphs plot the raw output information as well as a confidence interval for each setting, as shown in Figure 19.

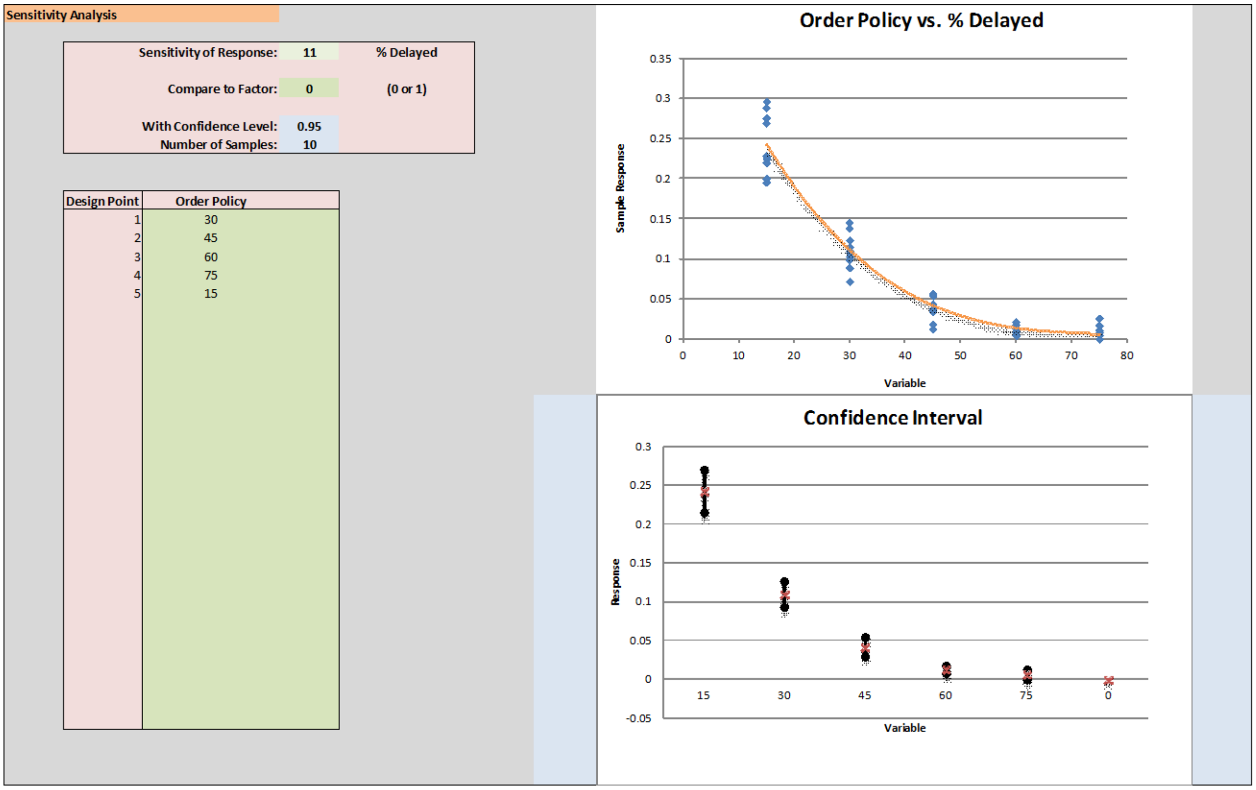


Figure 19 – Sensitivity Analysis Example

5.6.3. Simulation Verification

Simulation models can only represent the actual system to a certain degree. The extent of the model's accuracy and level of detail depends on both the measurement data and the developer's understanding of how the system operates. Certain aspects of the real system, too complex to model, rely on assumptions and simplification to allow the simulation to approximate such conditions. There are two main methods in the literature that attempt to analyze and produce a credible simulation: model *verification*, which involves ensuring the code and processes in the simulation model follows the intended procedures; and model *validation*, which compares the simulation response to the actual system's measurements. These two methods give the model credibility and persuade managers to accept the model as a correct representation of the actual system (Law, 2007).

Methods and analyses for simulation validation and verification remain controversial, as there is no single approach considered correct. How to prove the simulation reflects what is actually happening in the system most often appears as a form of subjective analysis, though several studies suggest standards that are more quantifiable and scientific. Model validation, verification, and accreditation, used increasingly in military modeling and simulation (Pace, 2004) can provide guidelines to building a credible model.

Validation of this simulation requires access to and parameters from the existing system. If any company applies a simulation model without the required validation, the consequences could be disastrous. Since access to the current system is not possible, only verification steps can enhance the model's credibility. Law (2007, pp. 248-250) identifies eight techniques useful for simulation verification. Though some techniques simply suggest the use of simulation packages or proper debugging, several can apply to this simulation to improve the credibility of this model as much as possible. Listing the assumptions used in the simulation allows a reviewer to comment on the approximations used in the model, a reasonable output without any unexpected surprises can strengthen the model's integrity, and looking at the state of the simulation via an animation or event list can ensure the model follows the intended coding processes.

To verify this model, each process associated with a particular action such as the removal or addition of inventory, and displayed when the process is active, shows the flow of inventory throughout the simulation run. By observing the event log, the logic of the model appears to function as intended and the reasonable output in each scenario further suggests the model's code operates as designed. Figure 20 shows a short timeframe of possible events for the simulation model.

```
Component  206-8469                      Held in : BEND   Until  53.504859998
Component  206-8064                      Held in : PLATE  Until  53.710859998
Component  206-8066                      Held in : BEND   Until  53.942859998
Component  206-8469                      Held in : PLATE  Until  53.970859998
Component  206-8469                      Added to inventory at  53.970859998 QOH:  22
Component  206-8066                      Held in : PLATE  Until  54.050859998
Component  206-8066                      Held in : ASSY   Until  54.250859998
Component  206-8066                      Added to inventory at  54.250859998 QOH:  5
Component  206-8064                      Held in : PAINT  Until  54.376859998
Component  206-8065                      Held in : BEND   Until  54.615206153
Component  206-8064                      Held in : ASSY   Until  54.678859998
Component  206-8064                      Added to inventory at  54.678859998 QOH:  5
Component  206-8090                      Held in : BEND   Until  54.715206153
Component  206-8065                      Held in : PLATE  Until  54.749552308
Component  206-8090                      Held in : PLATE  Until  54.866552308
Order 4  for Product:  1 Order qty:  2  Arrived at:  54.9337118888
Final Product Removed from Stock at: 54.9337118888 Type, Qty: 1 2
Testing Initialized for (Order, Type, Qty): ( 4 1 2 ) QOH:  3 at:  54.9337118888
Final Product Removed from Stock at: 54.9337118888 Type, Qty: 1 2
Testing Initialized for (Order, Type, Qty): ( 4 1 2 ) QOH:  2 at:  54.9337118888
Component  200-5514-20                   2 removed at  54.9337118888 QOH:  6
Component  206-3024                      2 removed at  54.9337118888 QOH:  5
Component  206-4060                      16 removed at  54.9337118888 QOH:  66
Component  206-8009                      2 removed at  54.9337118888 QOH:  2
Component  206-8027                      2 removed at  54.9337118888 QOH:  4
Component  206-8027-01                   2 removed at  54.9337118888 QOH:  4
Component  206-8040                      4 removed at  54.9337118888 QOH:  1
Component  206-8041                      2 removed at  54.9337118888 QOH:  1
Component  206-8043                      2 removed at  54.9337118888 QOH:  3
Component  206-8049                      2 removed at  54.9337118888 QOH:  2
Component  206-8052                      2 removed at  54.9337118888 QOH:  2
Component  206-8055                      2 removed at  54.9337118888 QOH:  2
Component  206-8056                      2 removed at  54.9337118888 QOH:  3
Component  206-8057                      2 removed at  54.9337118888 QOH:  2
Component  206-8059                      2 removed at  54.9337118888 QOH:  4
Component  206-8063                      4 removed at  54.9337118888 QOH:  2
```

Figure 20 – Event List Example

The assumptions made to code this model range from mathematical approximations to zero-transfer time between workstations. Indeed, any empirical assumptions require analysis of the actual system and expert opinions on their validity. Many assumptions crucial for modeling feasibility restrict the ability to model forecasts and other types of processes that require human thought and decision-making processes. There are circumstances where judgemental policies outperform mathematical and computer-coded policies (Bunn & Wright, 1991), and since the existing system operates in a make-to-order environment with a forecast, this could be one such case, as the completely make-to-order simulation model appears infeasible.

One of the greatest difficulties encountered for verification was the data received from the organization. The bill of materials, job routings, processing times, and information on demand, as provided, show a number of logical errors. Although these errors could be necessary for the MRP software to operate as intended, the logic in the simulation model needs to address such inconsistencies. Processing times provided by the organization show excessive time allocated to a few jobs, some larger than three weeks and reducing these times allows the simulation to effectively compare alternatives. Since information of the actual process is not available, altering the data provides the simulation with an understandable set of parameters. Changing these measurements is possible and straightforward if the data is available in the future.

CHAPTER 6 SIMULATION RESULTS

Selecting a few key performance indicators, each of which represents a particular measure of efficiency, allows for a comparison of the most attractive and effective strategies from the simulation. Results from the initial experiments described in Chapter 4 indicate other potential experiments, which further examine the system's robustness under various inventory parameters. For a select few stocking policies, the sensitivity due to other system parameters described in Section 4.6 can indicate their impact on performance. A number of simulation replications for each design point provide statistical evidence of the particular factor's effect. The number of replications depends on the desired confidence level and variability in response.

Factorial experiments measure the effect of *m* factors in an experiment. Each design point in the experiment, simulated with *n* replications, create *n* independent samples of each response. Comparing the difference in response of a factor's low and high value, *L* and *H*, respectively, in (0.1), for each of the *n* replications yield *n* instances of a factor's effect, *E*. This represents the difference in response by moving from the low to high level for a particular factor. For less than thirty samples, a confidence interval on the factor's effect using the Student T-distribution determines its significance. If the interval does not contain zero, then the effect is statistically significant, otherwise, the factor does not have a perceivable influence on the particular response. Comparing the difference in the response due to the change in effect with respect to another factor measures the effects of interacting factors (Law, 2007).

$$E_j = \frac{\sum_{\mathrm{i}} \left(H_{ij} - L_{ij}\right)}{2^{m-1}} \qquad j = 1, .., \mathrm{n} \qquad i = 1, .., 2^{m-1} \tag{0.1}$$

In addition to statistically significant effects, the response magnitude could also bear some practical relevance. Sensitivity analysis examines the trade-off between the model's response and the value of the particular factor to determine the relationship and trend of its effects on performance. Conducting this analysis for more than one factor requires setting every combination of factors, a time consuming process as each additional factor increases the number of replications at an exponential rate.

Several responses measured from the simulation indicate the performance and feasibility of the particular system and its parameters. Although customer lead-time and inventory levels describe the overall performance, other metrics taken into account such as the proportion of orders delayed due to insufficient stock, the maximum setup time and utilization experienced by a resource, and the proportion of orders satisfied, reveal clues for production lead-time, congestion, and stability in within the system, respectively. Analyzing the response determines the effectiveness of stocking strategies and the operating procedures of each inventory scenario in Table 4. Further experiments based on initial results show detailed information of certain parameters and the conditions required for implementing such policies. Appendix E contains descriptions of the electronic files used in the simulation and analysis.

6.1. Make-to-Order Response

Since there are no stocking parameters to set in this system, the experiment is straightforward. It turns out that given the demand profile and job sequencing, this system is not stable. Data from the simulation reveals excessive utilization among some resources. The lead-time for orders, in Figure 21, increases continually. The response from ten replications Table 16, shows only about half the orders that enter the system depart, inventory and setup times are highly variable, indicating a steady state does not exist. Ordering a single unit at a time shows a large amount setup in at least one resource for the five thousand hours of simulation run time. This is important because this model directly relates to the current system, albeit without a forecast, and too much time spent on machine setups clogs the system resources, creating the escalating queues.

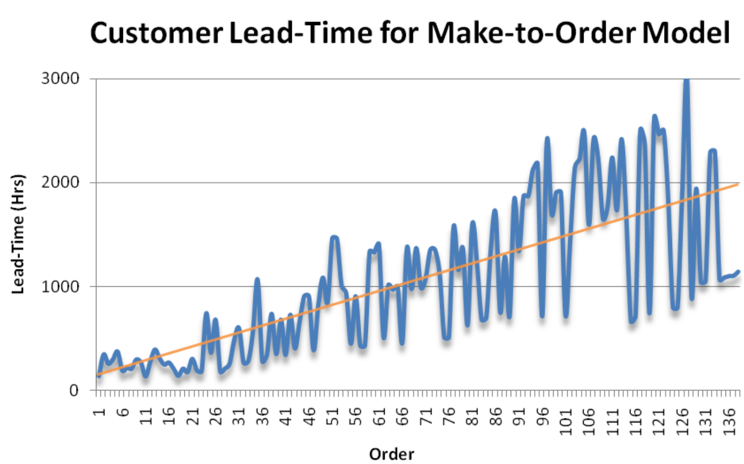


Figure 21 – Lead-Time for Customer Orders increases with Simulation time

Run	Average Inventory	Proportion Complete	Max Setup (Hrs)	Max Utilization
1	17189	0.446	4899.64	0.995
2	8195	0.555	4555.79	0.999
3	13233	0.459	4822.65	0.999

4	11413	0.458	5044.47	0.999
5	10788	0.551	4231.47	0.999
6	16948	0.451	6299.97	0.999
7	8778	0.545	5677.91	0.999
8	13866	0.487	5715.99	0.970
9	17093	0.460	6093.49	0.999
10	19194	0.382	6588.35	0.999

Table 16 – Results of Make to Order Simulation show unstable performance

6.1.1. Sensitivity to Demand

Considering this response, the make-to-order system is infeasible as it is unable to satisfy current demand requirements due to excessive setup time. Reducing the setup time by decreasing the demand rate can determine a critical value of demand where this scenario does reach a feasible, steady state. To reduce demand, the inter-arrival time between customer orders increases, simulating less frequent customer arrival with the aim of achieving stability. Though this reduces the number of orders, the simulation run time gradually increases to compensate for the reduction in inter-arrival time.

Ten samples from each demand rate in Figure 22 allow for a reasonable approximation of the critical demand value. The proportion of completed orders describes the feasibility of the model, and an average inter-arrival time of approximately five days, shows a stable system fulfilling the vast majority of demand. The small proportion of incomplete orders represents the orders currently active in the system.

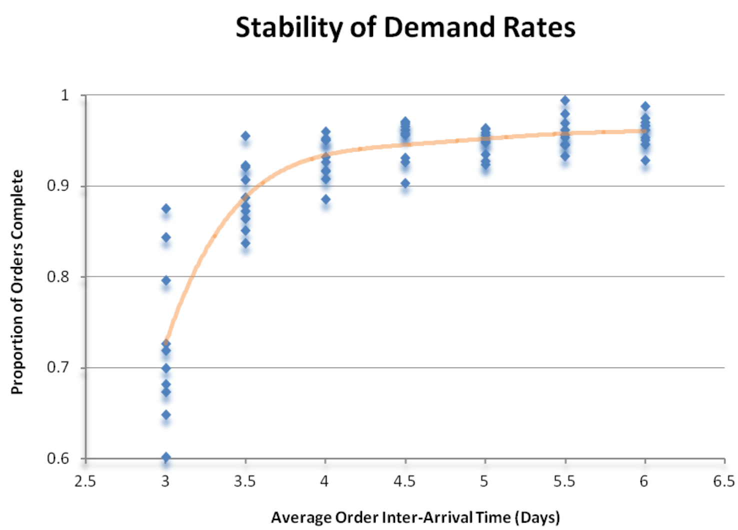


Figure 22 – Replication Data for Varying Demand

Indeed, measures from other responses verify the system's stability. The effect of demand on the average lead-time and maximum utilization in Figure 23 show significant ($\alpha = 0.05$) reductions in mean and variation.

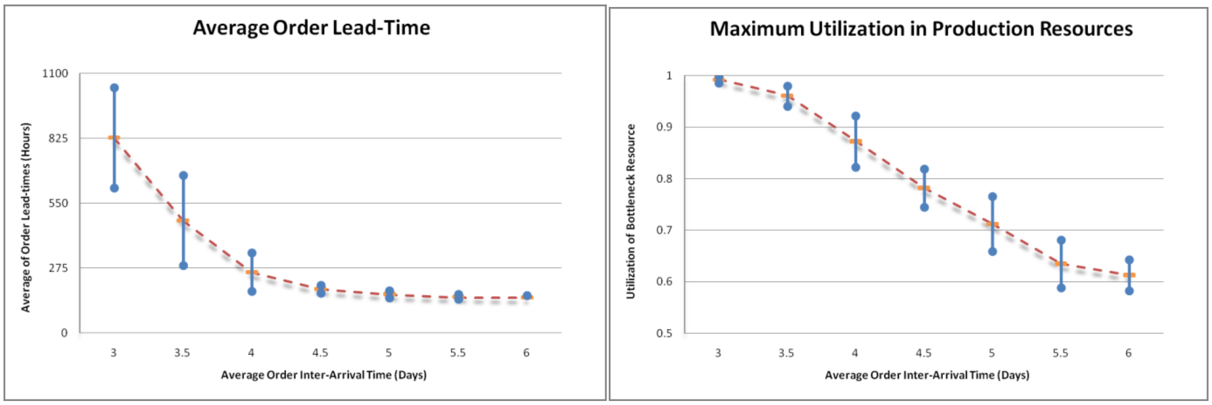


Figure 23 – Confidence Interval for Responses Compared to Demand Inter-Arrival Time

The demand rate is not a decision variable, and accurately comparing this against other models requires consistent demand measurements, which do not correctly represent the physical parameters. Though this is a currently infeasible scenario, if such reduced demand conditions arise, the steady state response with parameters in Table 17 could be of practical interest.

Order Inter-Arrival Time = 5 days	Lead Time (Hrs)	Std. Deviation of Lead Time	Average WIP Count
Average	176.25	75.888	560.50
Std. Deviation	24.58	23.90	144.2

Table 17 – System Response for Demand Rate of 5 Days per Order

6.1.2. Comparisons to Little's Law

Other enhancements to cycle time could also yield a stable system. Given a rough estimate of each product's throughput rate from (0.2), it could be possible to estimate the discrepancy in demand. The cycle time for each product varies according to the section of the system in Figure 24. Each part of the system requires the maximum possible throughput to exceed demand in order to operate in steady state.

$$Maximum\ Throughput\ Rate = \frac{Work\ in\ Process}{Minimum\ Cycle\ Time} \qquad \textbf{(0.2)}$$

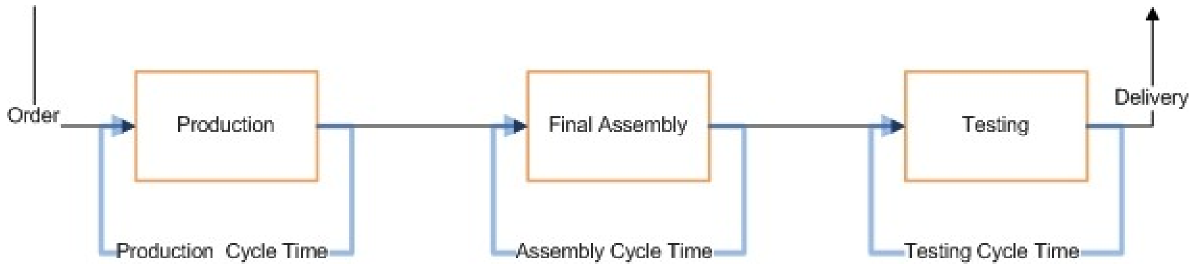


Figure 24 – Workstation Cycle Time and Capacity Limit Product Throughput

Minimum cycle time for production operations in Table 10 bounds the maximum possible throughput by considering the makespan of the pre-determined job schedule as the shortest possible time to make components for the order. Order quantities greater than one, and any jobs currently in the system, can only increase the time required to produce the components. Work in process is one semi-finished unit as these cycle times are per unit, and according to Little's law, the resulting throughput rates in Table 18 shows demand exceeds the rate of production. The maximum possible throughput for each product represents dedicating all resources to only building the particular product. Considering demand for all products, the sum of the sales rates in Table 5, *0.554*, or about one unit every two days, exceeds the average theoretical throughput of all products, *0.2307*, in Table 18.

Product	**Minimum Cycle Time** (hours)	**Maximum Possible Throughput** (units per hour)	**Maximum Theoretical Throughput Rate** (units per day)	**Average Demand Rate** (units per day)
1	30.719	0.03255	0.26042	0.0671
2	32.804	0.03048	0.24387	0.1137
3	31.446	0.03180	0.18244	0.1348
4	41.698	0.02398	0.10800	0.0656
5	36.614	0.02731	0.19512	0.0758
6	37.156	0.02691	0.11764	0.0871
	Average Theoretical Throughput:		**0.2307**	**Demand: 0.5441**

Table 18 – Product Cycle Time and Maximum Throughput for MTO Policy

While processing times for final assembly and testing can also limit throughput, these processes have multiple parallel servers that increase the maximum possible throughput proportionally. In this case, the maximum throughput for each server, determined by the inverse of median processing time, multiplied by the capacity, or number of servers, yield the maximum possible throughput of the process. Table 19 displays each product's maximum throughput rate in final assembly and testing, which appear to satisfy demand requirements and are not a limiting factor with respect to the overall system throughput.

Product	Median Processing Time (Hrs)		Theoretical Throughput (Units per Day)		Demand (Units per Day)
	Final Assembly	Testing	Final Assembly	Testing	
1	24.98	20.71	1.9209	3.0893	0.0671
2	24.46	22.23	1.9616	2.8777	0.1137
3	43.81	27.94	1.0954	2.2904	0.1348
4	74.03	39.09	0.6483	1.6370	0.0656
5	40.95	33.93	1.1719	1.8864	0.0758
6	67.96	43.11	0.7062	1.4844	0.0871
Average Possible Throughput:			**1.251**	**2.211**	**Sum: 0.5441**

Table 19 – Possible Throughput for Final Assembly and Testing

Feasibility is possible when the average throughput of all products is greater than the total demand. This yields two possible bounds on cycle time and demand that, reduced proportionally, can determine some approximate requirements for feasibility. Figure 25 depicts the effects of proportional reductions in demand and cycle time, as compared to the maximum throughput and total demand, respectively. This shows the theoretical impact of these factors on feasibility while avoiding simulation experiments. To satisfy customer orders, a fifty-five percent reduction in cycle time or demand, could stabilize the make-to-order system.

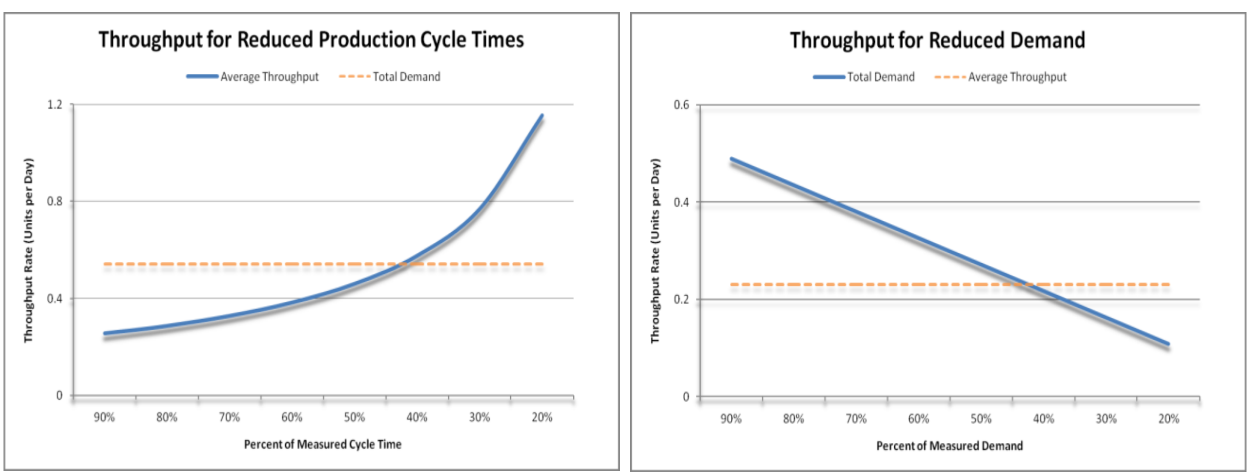


Figure 25 – Reduction of Cycle time or Demand for Feasibility

The make-to-order simulation experiment shows a stable system by reducing the customer arrival rate by about fifty percent, from every 2.47 days to every five days. The same is true for Little's law, indicating the calculated limits on cycle time and demand can provide a rough estimate of the requirements for a stable make-to-order system.

6.2. Make-Components-to-Stock Experiment Response

Twenty samples for each design point of the experiment described in Section 4.3 yielded twenty independent response values of each factor's effect. Confidence intervals in Table 20 from the sample show that the stocking factors have a clear effect on the average inventory level. Indeed all possible interactions exist, as factors are dependent on one another. For example, the subcomponent lot size is dependent on the top-level component order quantity. Factor one of the experiment in Table 13 corresponds to *TR*, the re-order point for top-level components. The second, *TOQ*, represents the order quantity of top-level components. The third, *SR*, and fourth, *SOQ*, factors describe the re-order and order quantity of subcomponent in terms of the number of lots.

Effect of Factor(s)	Description of Factor(s) relating to Component Inventory	Expected Effect (Inventory Count)	+/- Confidence Interval (α=0.05)
E(3)	Subcomponent Re-Order Point (SR)	17898.56	332.63
E(2)	Top-Level Order Quantity (TOQ)	16686.71	191.01
E(4)	Subcomponent Order Quantity (SOQ)	14674.03	107.3
E(1)	Top-Level Re-Order Point (TR)	8469.11	179.73
E(23)	Interaction – TOQ, SR	6837.61	88.08
E(14)	Interaction – TR, SOQ	2214.12	213.74
E(234)	Interaction – TOQ, SR, SOQ	1909.4	164.84
E(134)	Interaction – TR, SR, SOQ	1683.66	159.75
E(1234)	Interaction – TR, TOQ, SR, SOQ	1648.86	145.36
E(24)	Interaction – TOQ, SOQ	1136.24	208.96
E(123)	Interaction – TR, TOQ, SR	1114.34	266.05
E(13)	Interaction – TR, SR	1096.56	90.45
E(124)	Negative Interaction – TR, TOQ, SOQ	-812.8	140.14
E(12)	Interaction – TR, TOQ	580.29	180.27
E(34)	Negative Interaction – SR, SOQ	-377.13	195.43

Table 20 – Average Inventory Response for Stock Factors

Other responses, such as the average order lead-time, show that not all factors have a significant effect on all responses. As in Figure 26, the re-order level has a minor impact on customer lead-time and variability. However, the lead-time does not necessarily correlate directly with the re-order level, as increasing the component stock level can only reduce the probability of stock-out and not processing time in final assembly or testing.

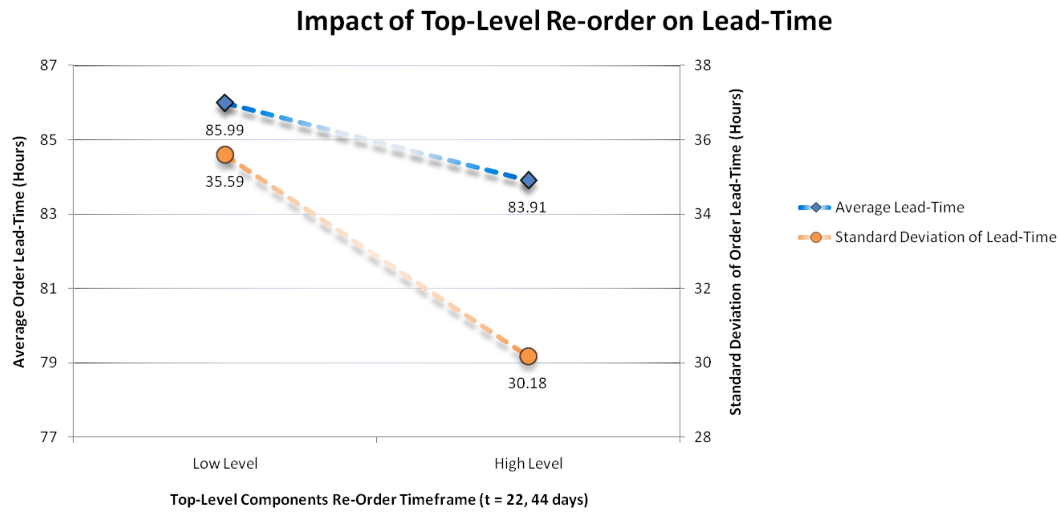


Figure 26 – Effect of Top-Level Component Re-Order Parameters on Order Lead-Time

The response of the frequency and duration of delays due to insufficient stock in Figure 27 reveal only the top-level component re-order factor has a significant effect. The reduction seen in lead-time is a result of buffering demand with top-level components to reduce delays. The practical problem in industry is to find the minimum inventory value that result in satisfactory service levels. Sensitivity analysis can determine the trade-offs for a single factor. However, determining interactions between inventory parameters requires a rather large experiment.

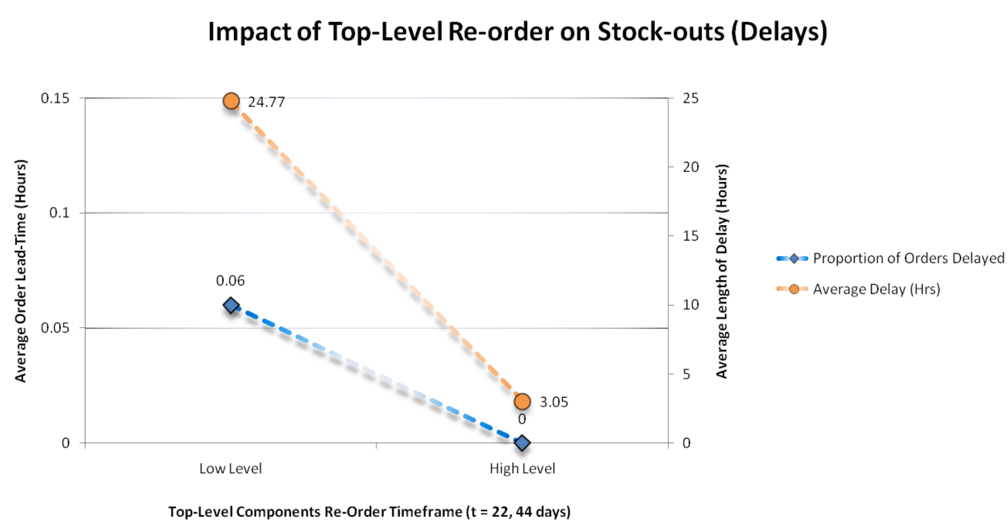


Figure 27 – Effect of Top Level Re-Order Quantity on Component Stock-Outs and Delay Time

Sensitivity analysis for each factor shows the magnitude in any changes to response. Holding all other factors constant allows one to estimate a minimum value of inventory for the given parameter. Sufficient top-level component inventory minimizes the interference of stock-outs due to top-level components in order to detect the any stock-outs related to subcomponents. The effect of increasing subcomponent re-order levels from zero to three, and order quantity from one to five lots, shows no significant impact on lead-time, however the amount component inventory on hand increases in Figure 28. This indicates only a single lot of subcomponent inventory is required for acceptable service. Therefore, all further experiments hold a single lot of subcomponents unless specified otherwise.

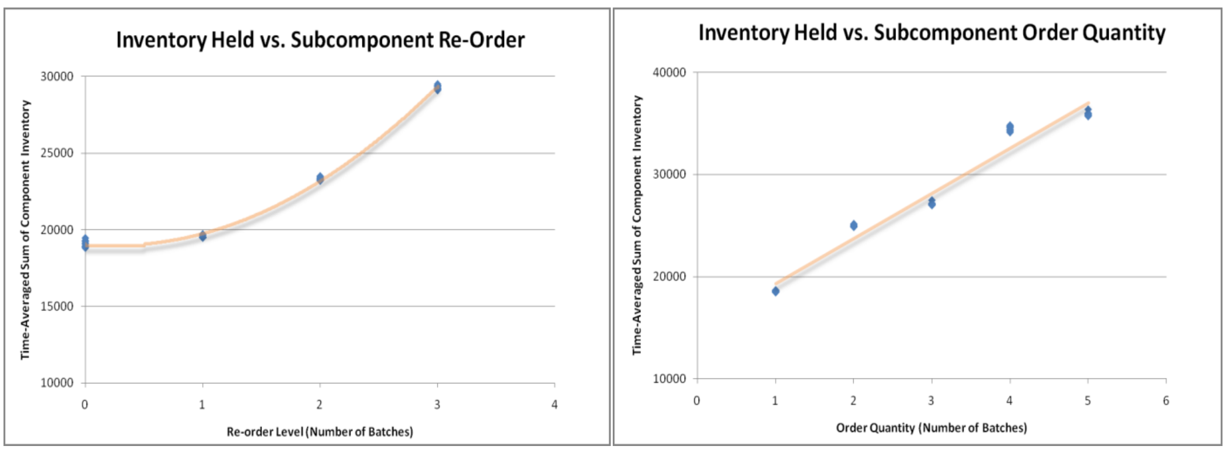


Figure 28 – Subcomponent Parameters Impact the Level of Inventory

With subcomponent re-order and order parameters at zero and one lot, respectively, the top-level component stock requires a timeframe, *t,* and probability, *p*. The value of the inventory parameters approximate the number of components required to satisfy $p \times 100$ percent of demand within *t* days. Values of *t* range from one week (5 days) to two months (50 days) with $p = 0.95$. With re-order parameters for top-level components held constant at 95 percent of demand within 44 days, the order quantity for top-level components in Figure 29 shows the proportion of orders complete does not reach an acceptable level while $t \leq 15$ days. This model is infeasible at these particular stock points as the frequency of setups required exceeds the production time available resulting in a large proportion of orders incomplete.

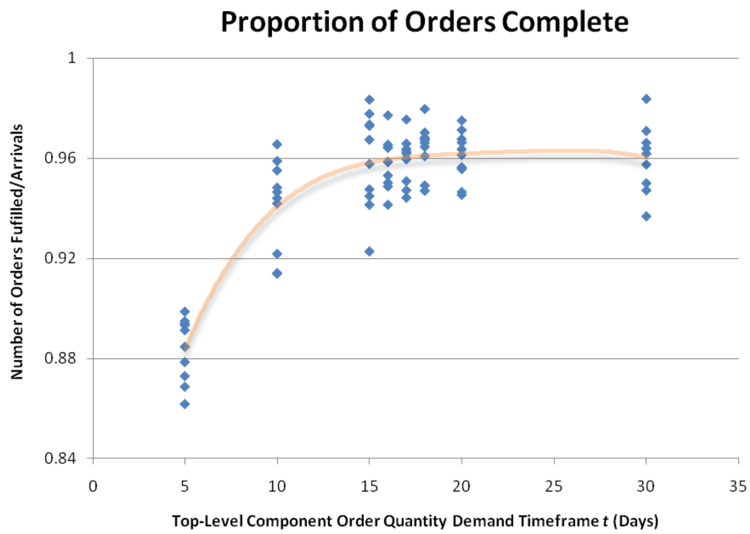


Figure 29 – Top-Level Component Order Quantity requires *t > 15* days for Stability

Holding the order quantity parameter for top-level components constant at $t = 17$ and $p = 0.95$, service is satisfactory and the system is stable. Sensitivity of the top-level re-order parameter in Figure 30 suggests a stable system with $t \geq 18$ days and $p = 0.95$, though does not necessarily indicate acceptable performance.

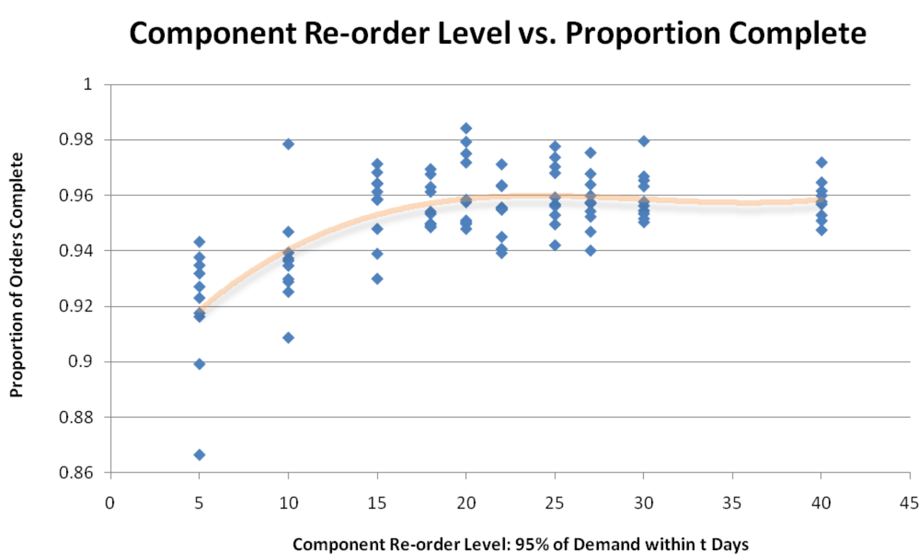


Figure 30 – Proportion of Orders Complete for Component Re-Order Level *t*

For $t \geq 25$ days, the system appears to provide a satisfactory, stable response, with a minimal amount of inventory. Lead-time for customer orders in Figure 31 show no significant change in responsiveness for values of $t > 25$ days. The amount of setup time and stock-outs can also reflect the level of performance and available slack in production.

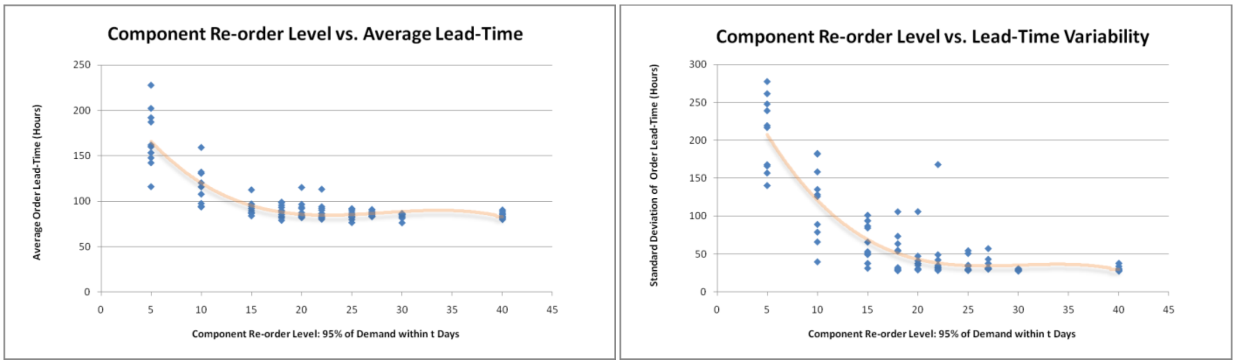


Figure 31 – Order Lead-Time for Component Re-Order Parameter *t*

6.2.1. Production Lead-Time Estimation

Analytical approaches to estimating production lead-time, the time required to fulfil requests for stock, might not suffice due to the intricate production processes and variability in jobs. However, it is possible to derive an upper bound on the lead-time in production by observing the proportion of orders delayed and re-order parameters for top-level components. Should the proportion of delays, or component stock-outs, be less than $1 - p$, then the minimum corresponding timeframe, t^*, can provide an upper bound on production lead-time. If the re-order level considers timeframe t^* and p, and the proportion of orders delayed, q, equals $1 - p$, then the choice of p likely determines the frequency of stock-outs and not t^*.

If t^- is less than t^*, the proportion of orders delayed increases, $q \geq 1 - p$, as demand variability accounts for $1 - p$ of delays, any additional delays result due to insufficient stock and time required for the replenishment of components exceeds the demand buffer set at t^-. If t^+ is greater than t^*, excessive inventory is held and the proportion of orders delayed decreases, $q \leq 1 - p$, as stock-outs occur less frequently than planned. Should q approximate the proportion of orders delayed, then $t \approx t^*$, as delays only result due to the design of inventory parameters. This implies that top-level component re-order parameters fulfil $p \times 100$ percent of demand – and replenish stock – within t^* days. Though component cycle times vary according to routing, processing time, and a number of other factors, the lead-time for stock fulfilment, bounded by t^*, estimates the production lead-time for this set of inventory parameters at $t^* \approx 27$ days in Figure 32.

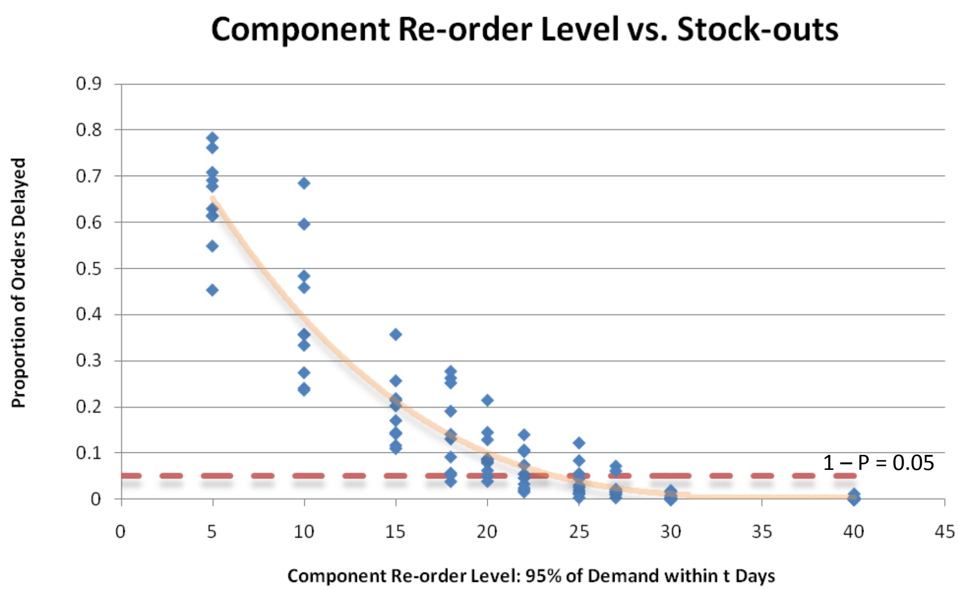


Figure 32 – Proportion of Delays for Top-Level Component Re-order Timeframe *t*

This feasible model has potential for implementation. To compare the response and robustness of this scenario, two samples of inventory parameters indicate the effect of other factors or policies. These two alternatives consider two values of the re-order point for top-level components. The first scenario represents a normally stocked case, with the re-order point for top-level components set at $t = 27$, and an over-stocked case with $t = 40$ days. The top-level order quantity, held at 95% of demand within 17 days, determines the lot sizes for subcomponents, holding only a single lot in stock. Table 21 shows the response of ten samples for these two scenarios ($\alpha = 0.05$) for various performance indicators.

MTS (Components) Scenario	Re-Order Level Timeframe *t* Days (p = 0.95)	Average Number of Components	Average Order Lead-Time (Hrs)	Standard Deviation of Lead-Time	Proportion of Delays (Stock-outs)
1 – Normal	27	9414 +/- 80.4	86.02 +/- 2.24	35.41 +/- 6.6	0.026 +/- 0.017
2 – Over-Stocked	40	11108 +/- 83.6	84.02 +/- 2.65	30.74 +/- 2.5	0.003 +/- 0.003

Table 21 – Make-Components-To-Stock Alternative Scenarios

The use of common components among products benefits the performance of this model greatly when compared to the make-to-order scenario. Using an order quantity reduces the required setup time, as incurring a setup for every order congests production to an unstable point in the make-to-order model. Making components to stock results in a lead-time distribution with almost all orders satisfied within 160 work-hours, or four weeks, as shown in Figure 33. This lead-time comes from the final assembly and testing processes, initiated after receiving a firm customer order.

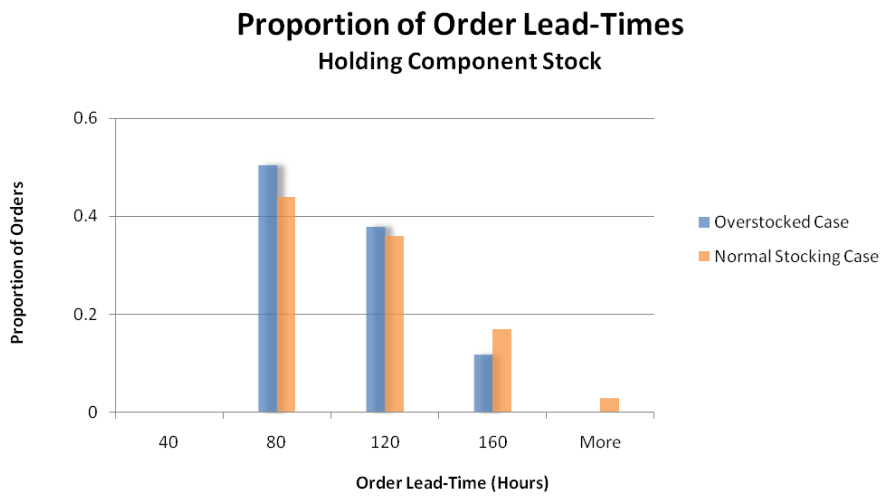


Figure 33 – Making Components to Stock Typically Results in Order Lead-Times under a Month

6.3. Make Semi-Finished Goods to Stock Experiment Response

Since inventory held in this scenario only relates to semi-finished units and not components, some previous performance metrics do not apply. For example, the proportion of orders delayed, or stock-outs, consider any inventory shortage as a delay. However, component stock-outs wait for production to replenish stock while semi-finished units rely on final assembly. This requires a change in the measurement of delays, as the time for semi-finished stock relies on the finish time of final assembly rather than production. As the proportion of orders complete can indicate stability, additional measures ensure feasibility by examining time-averaged quantity on hand of each semi-finished product, which reveals the difference in demand and production ability. If a product has a time-averaged quantity-on-hand approximating the re-order quantity, it suggests a stable and responsive policy. Whereas if the quantity on hand is frequently much lower than the re-order point, or close to zero, this indicates frequent stock-outs of the product as its demand exceeds the rate of replenishment.

The initial experiment considers identical re-order and order quantities across all products. Additional experiments observe the effect of other types of inventory parameters. Stock points for products based on demand, and not a constant value, could reduce inventory and better suit the demand for a product much like the component inventory parameters. Experiments that use demand-based parameters reflect the expected demand within a given number of days; other experiments with units not in days are simply the number of semi-finished products. Testing the use of a semi-finished order quantity against order-up-to parameters identify any changes in response. To compare semi-finished and component inventory, the number of components in each product, multiplied by the time-averaged number on-hand, determines the number of components held in semi-finished stock. This allows the sum of component and semi-finished inventory performance measures to show the total inventory held with a consistent unit dimension, the number of components. The total number of components allows one to compare alternatives across different models using the same measurement for inventory value.

6.3.1. Constant Stock Parameters

The results of the initial experiment (described in Table 14,) shows the order quantity for semi-finished units in Figure 34 significantly affects the proportion of orders completed. This suggests low order quantities result in an unstable system, as frequent setups congest production and begin to exceed the available time for at least one resource. The re-order level in Figure 35 shows significant responses in inventory on hand and the proportion of delays. However, as higher order quantities also show reductions in utilization, setup, and lead-time, a sensitivity analysis observes the response to various values of order quantity with constant re-order levels.

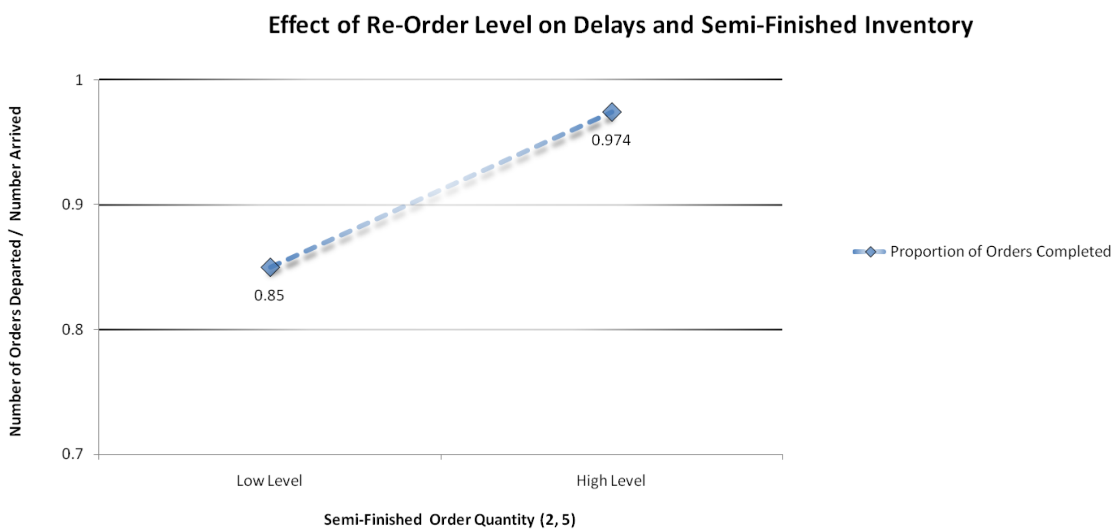


Figure 34 – The Order Quantity for Semi-Finished Stock Impacts the Stability of the System

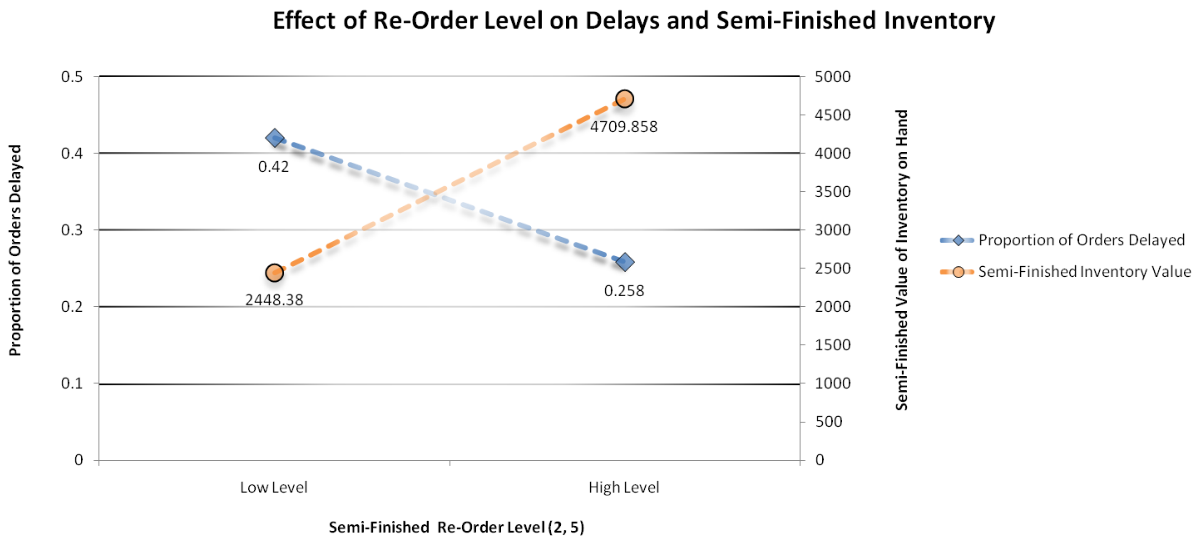


Figure 35 – Re-Order Level of Semi-Finished Stock impacts Delays

With re-order points held at five semi-finished units, the order quantity, varied from one to five, in Figure 36 shows the proportion of orders does not reach a satisfactory level in some cases. The minimum number of semi-finished average on hand a product indicates order quantities less than three result in frequent stock-outs.

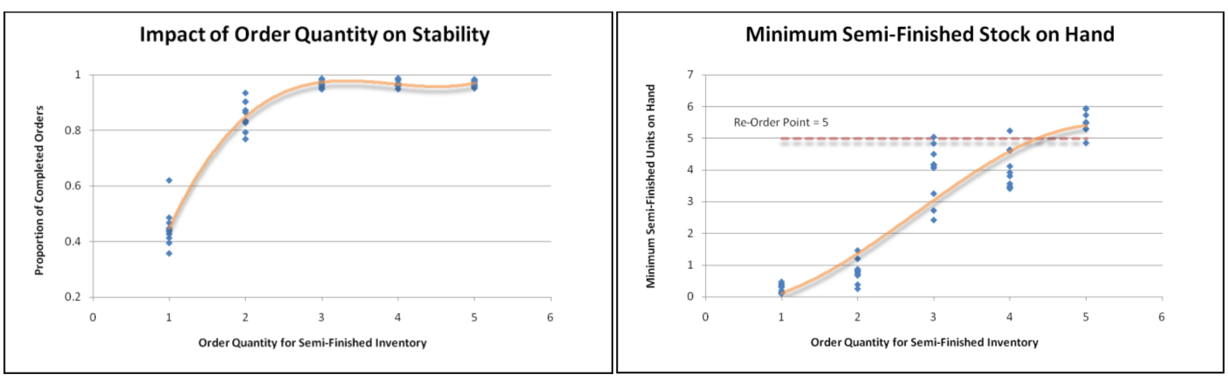


Figure 36 – Minimum Order Quantity of Three Required for Stability

An order quantity of three shows satisfactory performance in the system. To investigate the causes behind this performance, the maximum utilization and setup time experienced by a resource in Figure 37 indicates overwhelming setup time for the bottleneck resource (usually "*BEND,"*) with low order quantities.

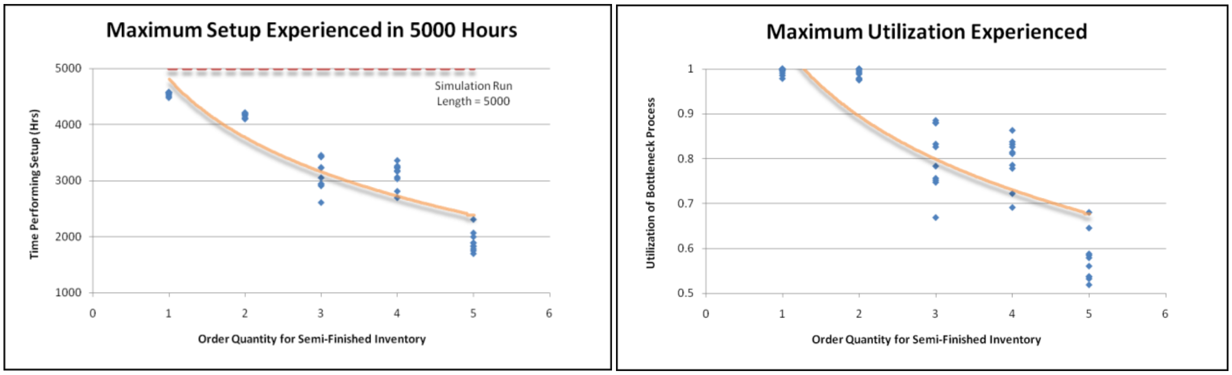


Figure 37 – Low Order Quantities Increase the Required Setup Time and Bottleneck Utilization

Though the order quantity appears to stabilize the lead-time and variation in Figure 38, it requires an investment in semi-finished stock on hand, in Figure 39, of about five thousand components. Larger order quantities show improved performance at the expense of higher levels of semi-finished stock on hand.

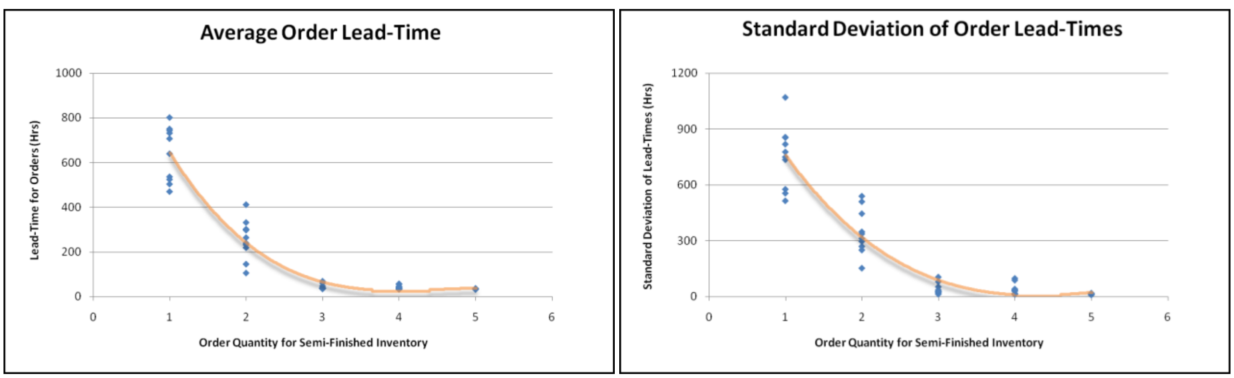


Figure 38 – Order Lead-time and Variation Compared to Semi-Finished Order Quantity

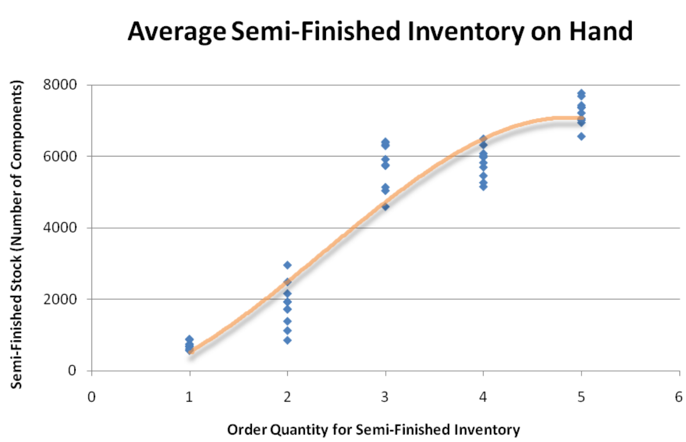


Figure 39 – Order Quantity Increases the Average Semi-Finished Stock on Hand

Sensitivity on the semi-finished re-order parameter, with a constant order quantity of three, as it appears required for stable response, indicate its effect on performance measures. Constant re-order values range from two to seven units and the responses for setup or utilization remain unchanged. Although the re-order point does not influence the stability of this scenario, an observable difference in the performance of the system appears in the proportion of orders delayed. Figure 40 shows how the frequency of stock-outs relates to the re-order level of semi-finished stock. The resulting change in inventory held in Figure 41 shows the approximate trade-off with the average lead-time of customer orders.

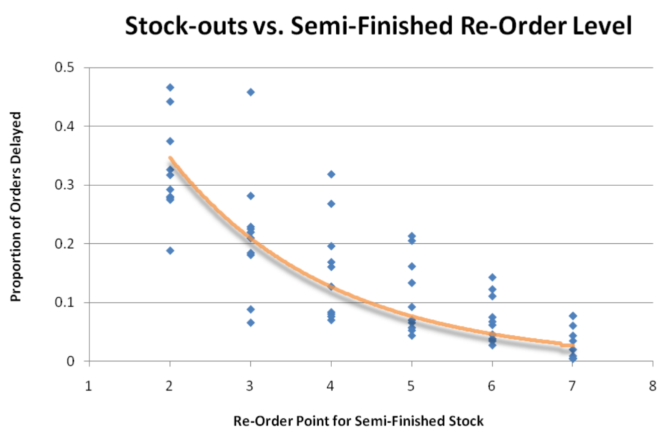


Figure 40 – Re-Order Level relates inversely to Stock-outs and Customer Delays

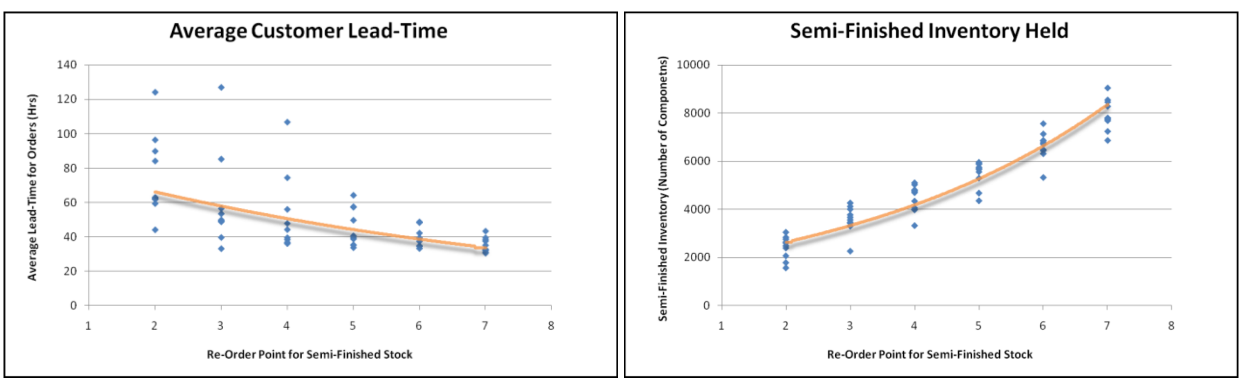


Figure 41 – Trade-off between Semi-Finished Inventory Held and Lead-Time

These relationships provide an understanding of constant semi-finished inventory parameters. Although feasible and responsive parameters exist, slight adjustments could improve some of the performance measures. Two more sensitivity experiments consider non-stationary inventory parameters based on the demand of a product and the effect of order-up-to levels, as opposed to a constant order quantity.

6.3.2. Demand-Based Stock Parameters

With demand-based parameters for semi-finished stock, the rates for product sales in Table 5 provide the expected number of units ordered within a particular timeframe, *t*. Comparing the difference in performance against constant ordering parameters across all products, in Section 6.3.1, involve setting inventory levels based on the various values of *t* in Table 22. To compare demand-based parameters, the order quantity remains constant at five units for re-order analysis, and a constant re-order point of five units for the analysis of semi-finished order quantity.

Product	Expected Number of Units in Demand Within Timeframe (*t* =)			
	30 Days	45 Days	60 Days	75 Days
1	2	3	4	5
2	3	5	7	8
3	4	6	8	10
4	2	3	4	5
5	2	3	4	6
6	2	4	5	6

Table 22 – Expected Number of Units Ordered within *t* days

For demand-based order quantities, the setup and utilization of the bottleneck resource in Figure 42 show the same trend in Figure 37 for constant order quantities. The response of average semi-finished inventory on hand, in Figure 43, shows how the order quantity reflects the number of components on hand. However, it appears in Figure 44 that the same level of performance, lead-time, requires similar amounts of inventory on hand when compared to a constant order quantity parameter.

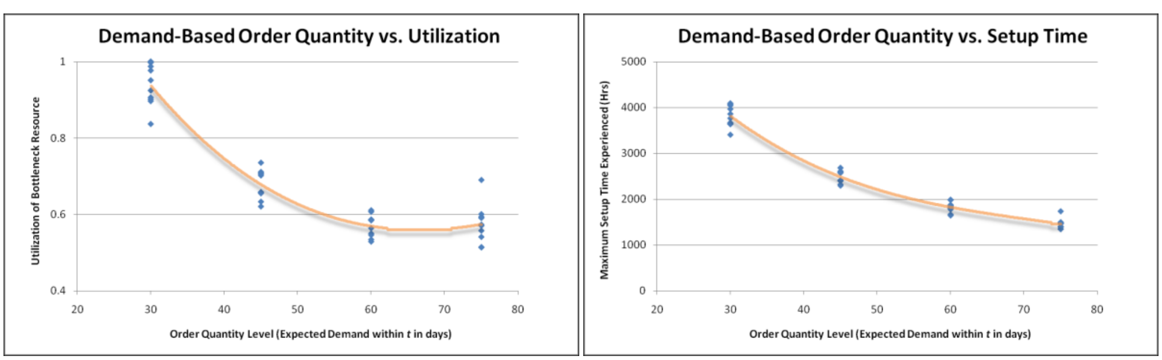


Figure 42 – Effect of Demand-Based Order Quantities on Bottleneck Resource Traffic

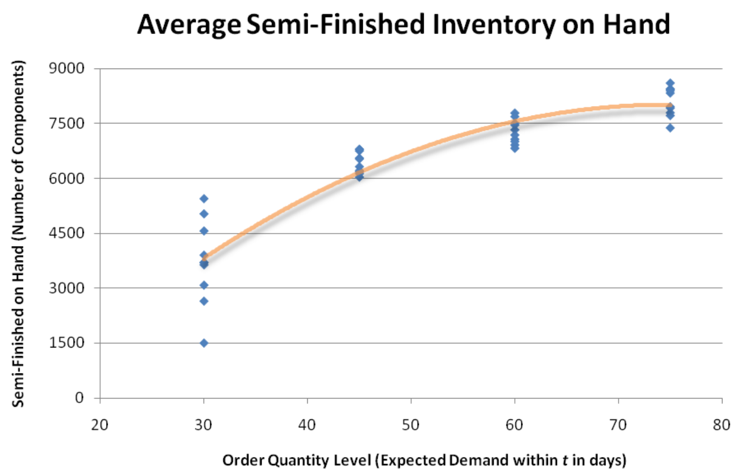


Figure 43 – Amount of Semi-Finished Inventory on hand for Demand-Based Order Quantities

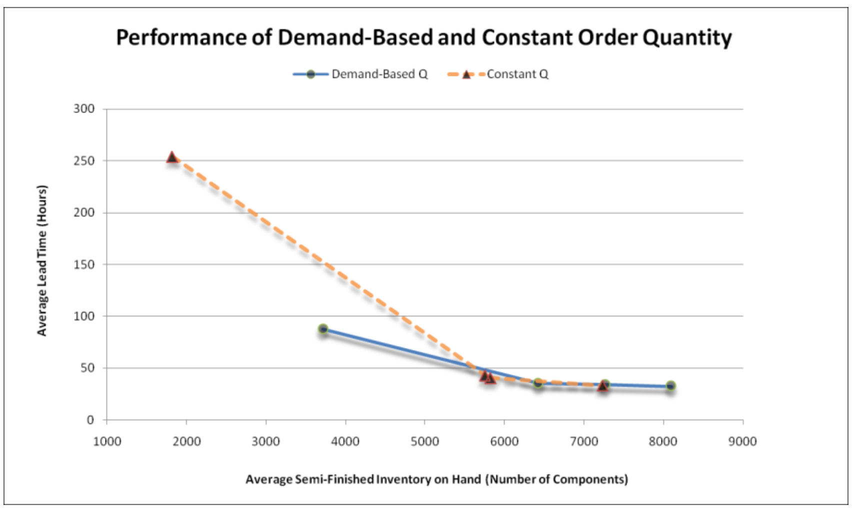


Figure 44 – Constant and demand-based order quantities show similar performance

The demand-based re-order point uses the product's expected demand within a given timeframe while holding order quantities constant at three units. Comparing the proportion of orders delayed and the level of semi-finished inventory in Figure 45, shows the two polices do not differ greatly however, using demand-based re-order levels could reduce the frequency of stock-outs. Since the demand does not differ greatly from product to product, using demand-based parameters does not drastically improve the response; however, the more variable the demand distribution among products, the more appropriate demand-based parameters become as they can better fit a non-uniform distribution.

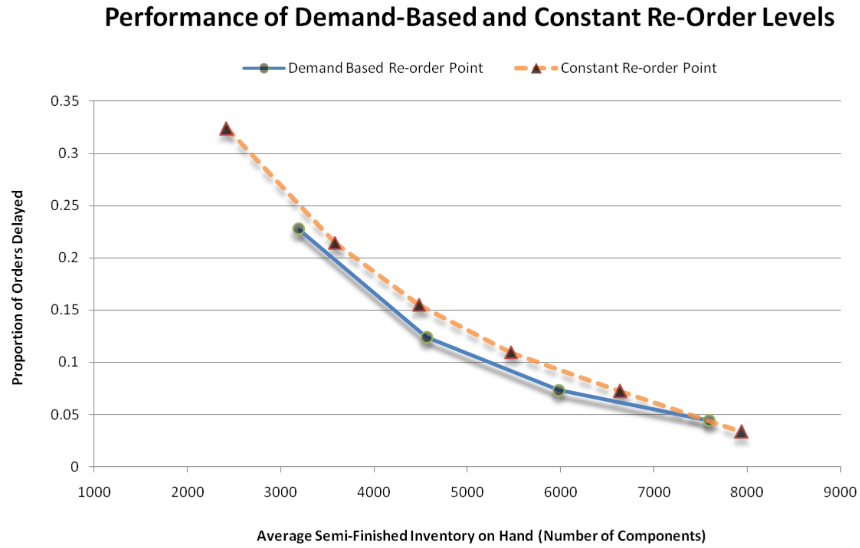


Figure 45 – Comparison of Demand-Based and Constant Re-Order Parameters

6.3.3. Order-Up-To Stock Parameters

To observe the effects of order-up-to semi-finished stock parameters, instead of pre-determined order quantities, both constant and demand-based order-up-to experiments consider a constant re-order level of seven among all products. Order-up-to levels, measured with respect to the re-order point, can reduce the setup necessary as it reflects the current level of stock. Figure 46 illustrates how order-up-to parameters affect the setup in production resources. Though more effective than constant order quantities, as it can order more than one at a time, the difference in order-up-to and re-order level specifies the minimum number of units built per setup and frequency of orders for stock replenishment.

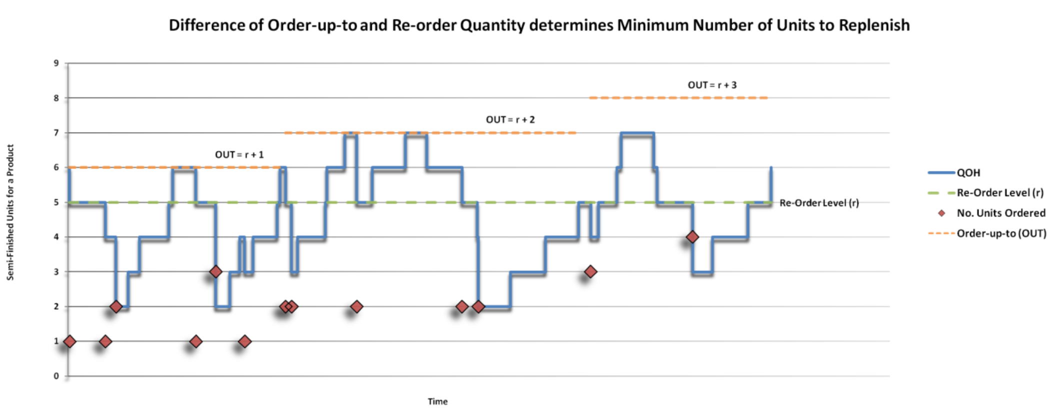


Figure 46 – Order-up-to Level controls the minimum number of units ordered

Figure 47 shows low order-up-to levels do not achieve stability, as at least one product is frequently out of stock. Larger values reduce the number of setups required per unit, and with a minimum of three units per setup, Figure 48 indicates stable and acceptable performance in terms of average lead-time and the frequency of stock-outs.

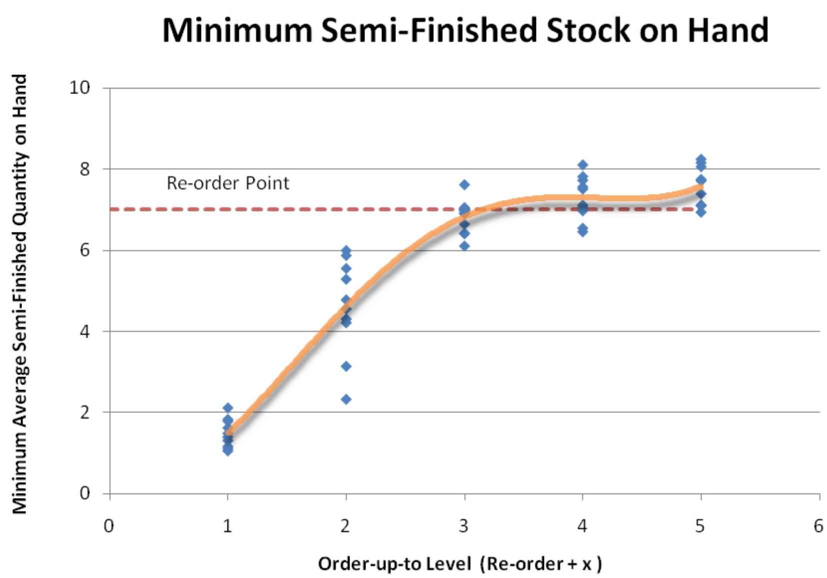


Figure 47 – Order-up-to Levels greater than three show stable performance

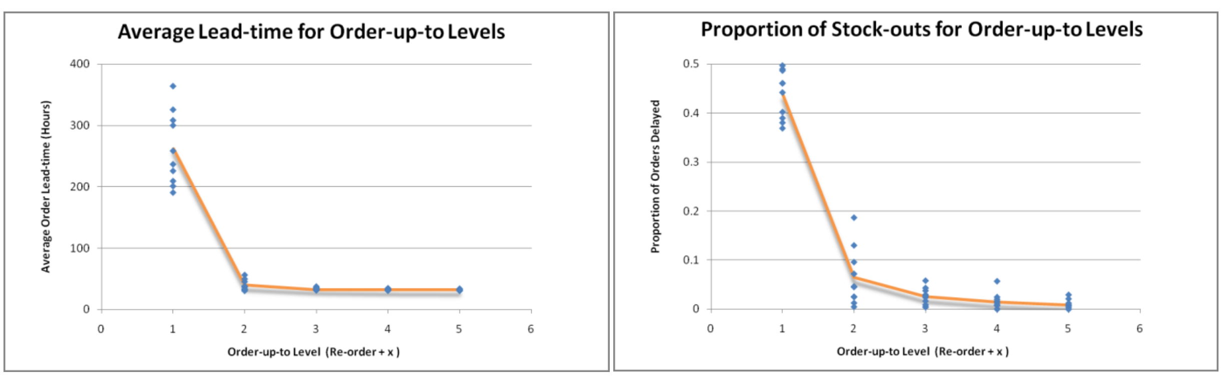


Figure 48 – Performance of Order-up-to Semi-finished Parameters

If the order-up-to quantity incorporates the demand for a product, performance remains relatively unchanged. The setup and utilization in Figure 49 show minor differences when compared to constant order-up-to parameters. The trade-off in average lead-time and semi-finished inventory on hand, depicted in Figure 50, also indicates negligible variations in the response between demand-based and constant order-up-to parameters.

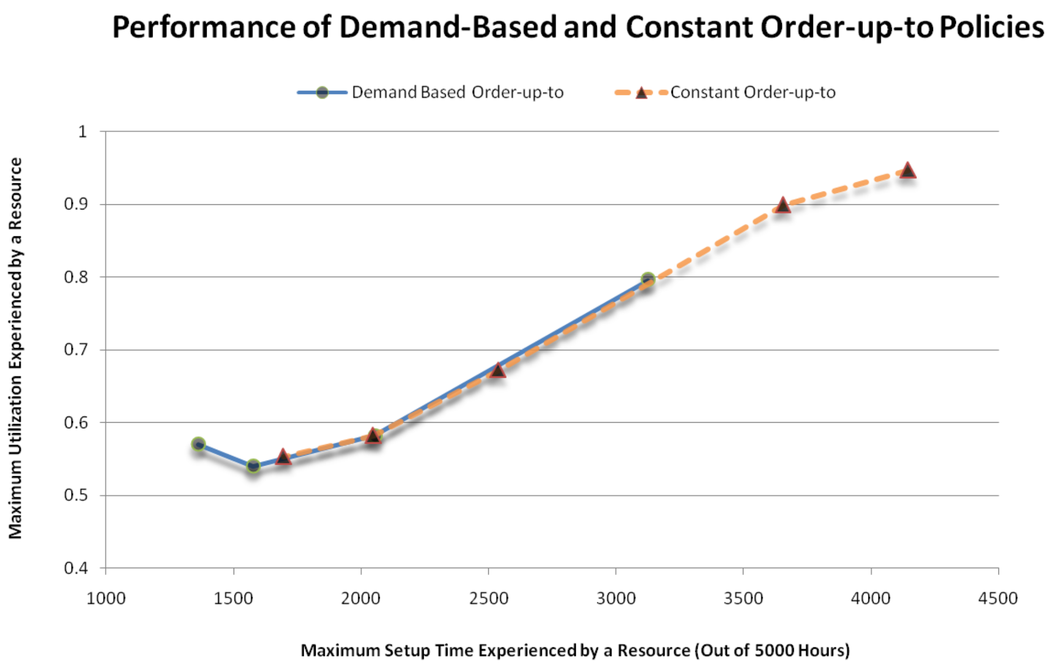


Figure 49 – Production slightly less congested using demand-based order-up-to parameters

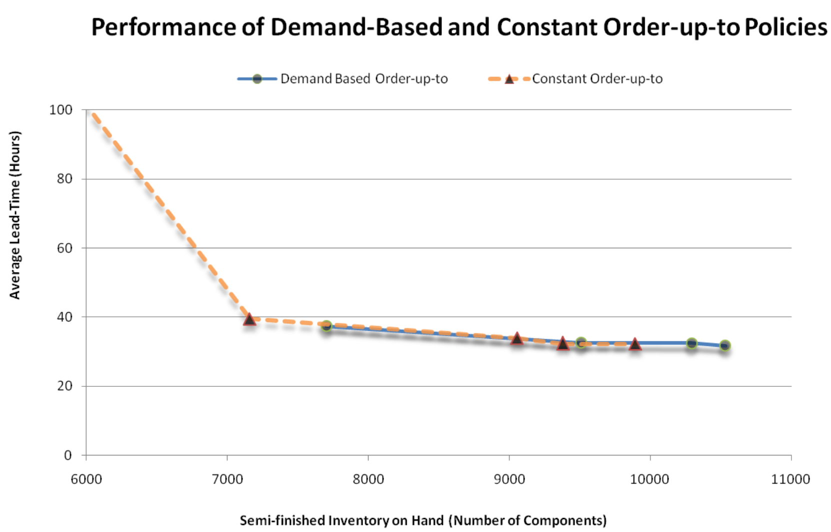


Figure 50 – Lead-Time and Semi-Finished Inventory on-Hand for Order-up-to Policies

Since neither policy, demand-based or constant stock replenishment, significantly out-performs the other, constant ordering parameters compared to re-order levels indicate the performance between various re-order policies. Comparing constant order quantities and order-up-to levels in Figure 51 indicate the impact of constant re-order levels on semi-finished inventory and stock-outs. However, demand-based re-order levels, found to reduce the frequency of stock-outs, could improve some measure of performance at the expense of increased inventory.

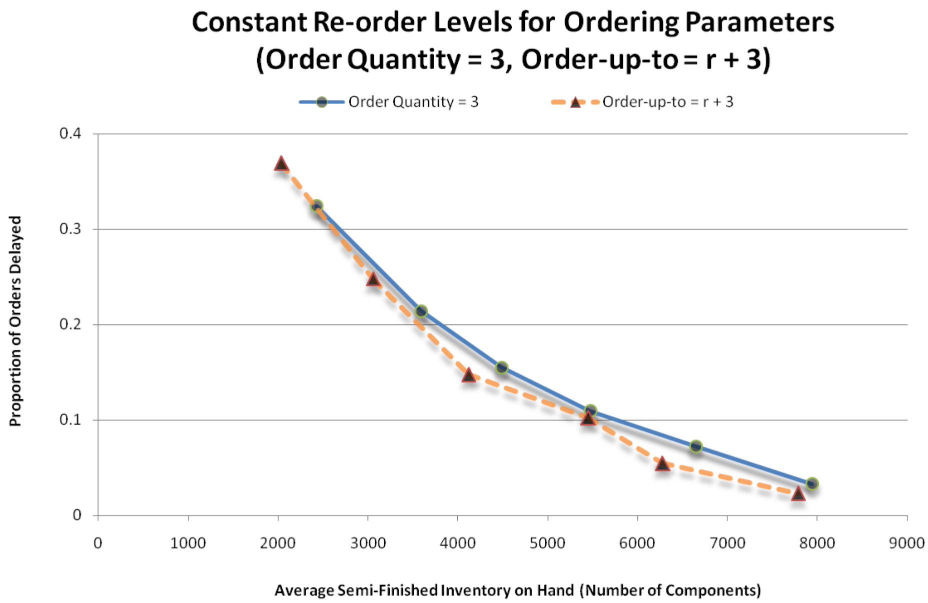


Figure 51 – Re-order levels for semi-finished stock show similar performance of ordering Policies

The impact of holding semi-finished stock, while ordering only the components required to replenish it, could improve responsiveness by holding about six thousand components worth of semi-finished inventory and a thousand components in WIP. This semi-finished inventory holds approximately five units on-hand for each product in Table 23, and a with constant re-order level of five, indicates stable and acceptable performance. Since the components in process do not directly buffer demand, their ability to pool variance through commonality cannot apply.

Product	1	2	3	4	5	6
Time-Averaged Number of Semi-Finished Units on Hand	5.213	4.599	4.159	5.417	5.402	5.384

Table 23 – Average Stock of Semi-Finished Products (Re-Order = 5, Order Quantity = 3)

This scenario can plausibly operate with some minimum inventory level and two potential sets of parameters examine their performance in further detail. The first considers constant order quantities of three for all products and the second considers constant order-up-to levels, both with re-order levels calculated as the expected demand for the product within 60 days. The measures of performance, in Table 24, yield a baseline response for analysis of robustness to sources of uncertainty in these cases and the proportion of lead-times in Figure 52 shows the responsiveness of both policies.

Case	Re-order Level	Ordering Policy	Average Lead-Time	Proportion of Delays	Stocked Inventory	WIP	Bottleneck Utilization
1	Demand in 60 Days	Order Qty = 3	43.6 hrs +/- 9.87	0.102 +/- 0.043	5495 +/- 401	1507 +/- 399	0.8177 +/- 0.0315
2	Demand in 60 Days	Order-up-to = Re-order + 3	34.02 hrs +/- 1.93	0.036 +/- 0.018	6829 +/- 332	948 +/- 195	0.7026 +/- 0.0311

Table 24 – Average response of ten replications (α = 0.05) for each stocking scenario

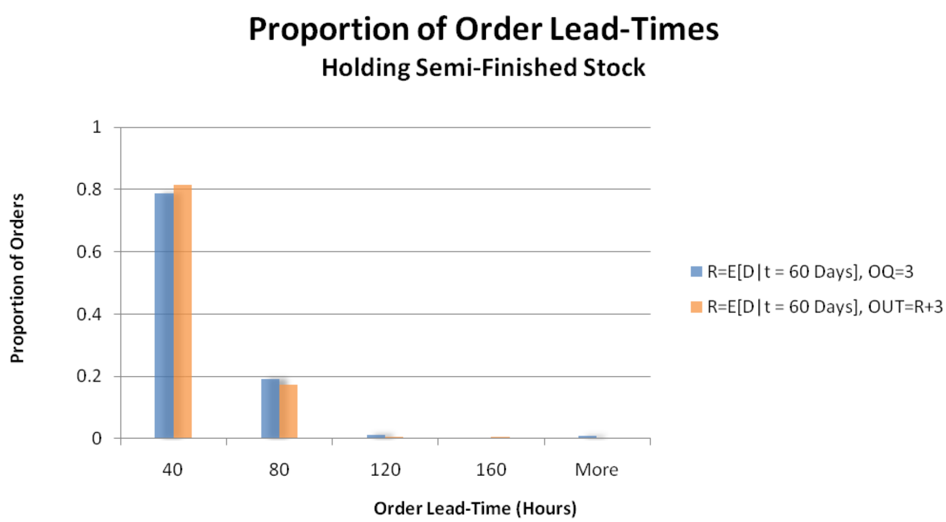


Figure 52 – Histogram of Typical Order Lead-Times

6.4. Make to Stock Experiment Response

The make-to-stock model considers inventory of both components and semi-finished units. The three-factor experiment described in Section 4.5, utilizes common re-order and order quantities for semi-finished goods. Since other inventory parameters, such as demand-based stock levels and order-up-to policies in the previous model, could influence the response, further experiments observe the effectiveness of such alternate strategies while holding component stock. Sensitivity analyses of various stock factors determine the effect of such ordering policies and any trade-offs in performance.

6.4.1. Factorial Experiment of Stock Levels

Ten replications of the experiment in Table 15 shows component levels have a significant effect on the maximum setup time and utilization in the system with respect to the number of components held in stock. The re-order level of semi-finished stock appears inversely correlated with the variability of order lead-time and the frequency of stock-outs. The order quantity of semi-finished products appears to influence the proportion of orders complete, indicating the factor has a possible limit required for stability. Logically, the number of setups is a function of the order quantity however; cycle times for component replenishment can vary due to the additional run-time incurred from each additional unit. Table 25 shows the expected change in performance measures for each factor's low and high setting.

Expected Response for Factor (Low Value, High Value)	**Component Lot Size**	**Semi-Finished Re-order Point**	**Semi-Finished Order Quantity**
Performance Measure	(22, 44 days)	(1, 3 units)	(1, 3 units)
Average Lead Time (hrs)		-0.79	-0.39
St. Dev. Of Lead time		-1.87	-0.88
Proportion Delayed		-0.03	-0.01
Setup Time (hrs)	-240.44	-35.44	-122.95
Component Inventory	3027.02		
Semi-Finished Inventory		1164.5	650.9

Table 25 – Significant Changes in Response due to Stock Levels

6.4.2. Sensitivity of Stock Parameters

Further analysis of each factor, while holding the others constant, observes its effect on performance indicators. Component lot size and the re-order point, tested while holding sufficient levels of semi-finished stock, reveal how component stock influences the response. Using the minimum component inventory resulting in acceptable performance, the re-order level of semi-finished stock considers two alternative stocking policies. First, constant re-order levels across all products, and second, the expected demand within a given timeframe for a particular product's re-order level. The semi-finished ordering policy also studies two cases, order quantities and order-up-to parameters, to compare the performance and response of various values for each policy.

Component parameters ensure a minimum of one batch satisfies almost any request for semi-finished stock replenishment; however, to incorporate the demand of components common to multiple products, the parameters also consider the demand within a specified timeframe. Figure 53 compares the maximum setup time and utilization to various lot sizes of components, considered as 95 percent of their demand within *t* days. The traffic in production is acceptable at low levels of component lot size, although further reductions in congestion can improve flexibility. As such, it is logical to hold the minimum lot size with *t* = *5* days as larger lots do not appear to affect performance and only increase the required investment in inventory in Figure 54.

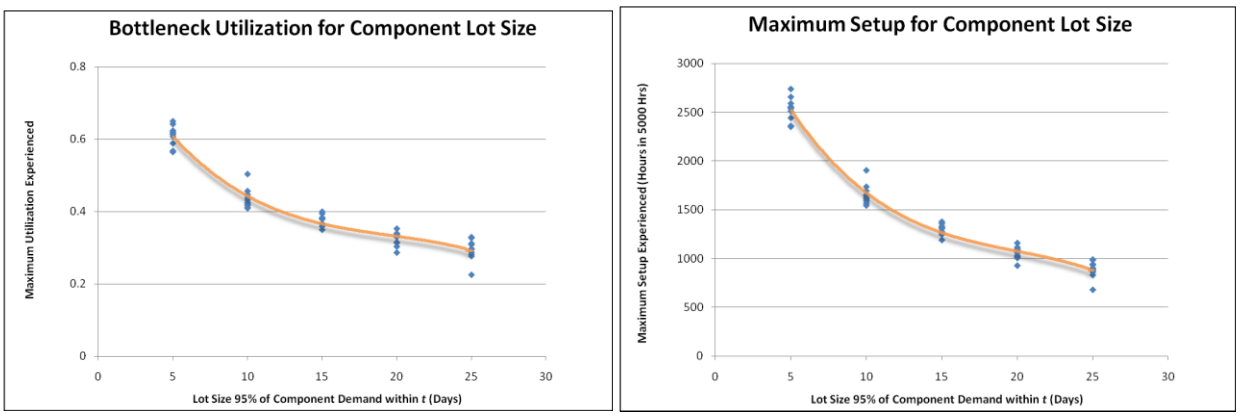


Figure 53 – Varying Lot Size with Semi-Finished re-order level of 5, and order quantity 1

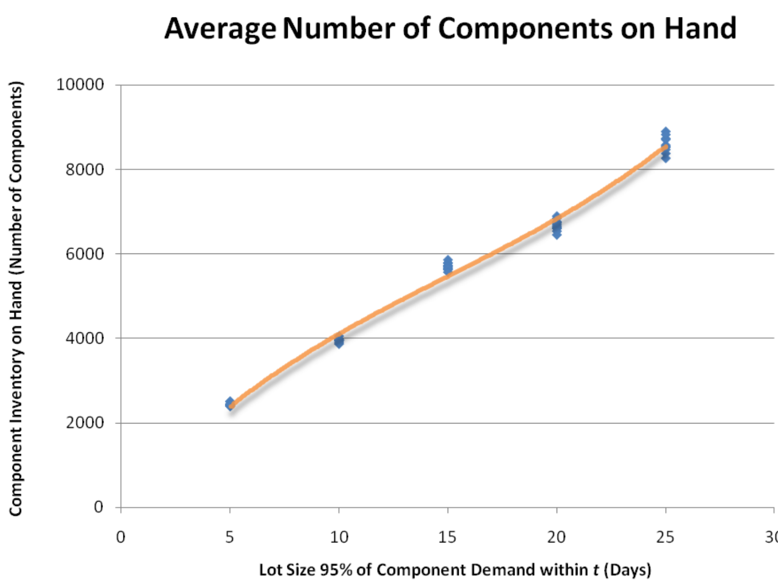


Figure 54 – Lot Size Compared to Average Number of Components on hand

While lot size does not appear to affect responsiveness measures, increasing the re-order level in multiples could reduce frequency and length of stock-outs. While holding the lot size constant, larger re-order levels in Figure 55 do not appear to change responsiveness measures and only increase the amount of component inventory on hand.

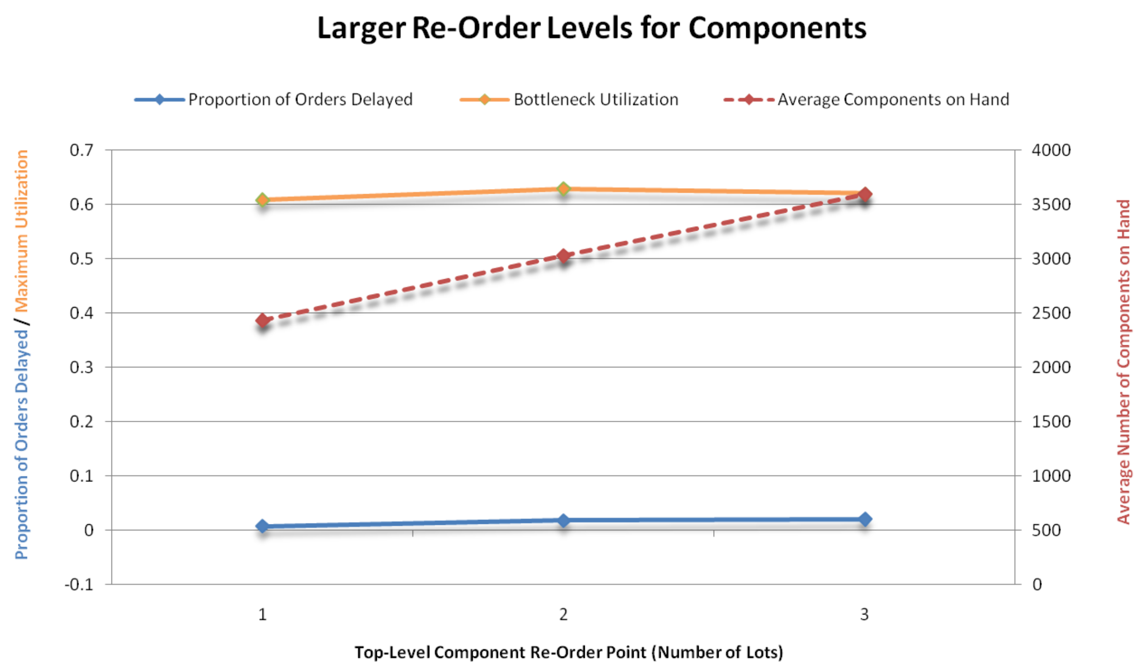


Figure 55 – Component Re-order level shows little affect on performance

While the re-order level of components does not improve responsiveness for this set of inventory parameters, it could prove useful under some other circumstances. For one batch of components held, the re-order level for semi-finished units considers two cases, demand-based and constant parameters among the products. Figure 56 shows low re-order levels for semi-finished inventory indicate demand-based parameters perform better than constant levels. However, at larger re-order levels, demand-based parameters hold more stock than constant parameters for no further reduction of stock-outs. Depending on the acceptable frequency of stock-outs, the stocking decision could change, though additional cases consider constant semi-finished re-order levels of five units.

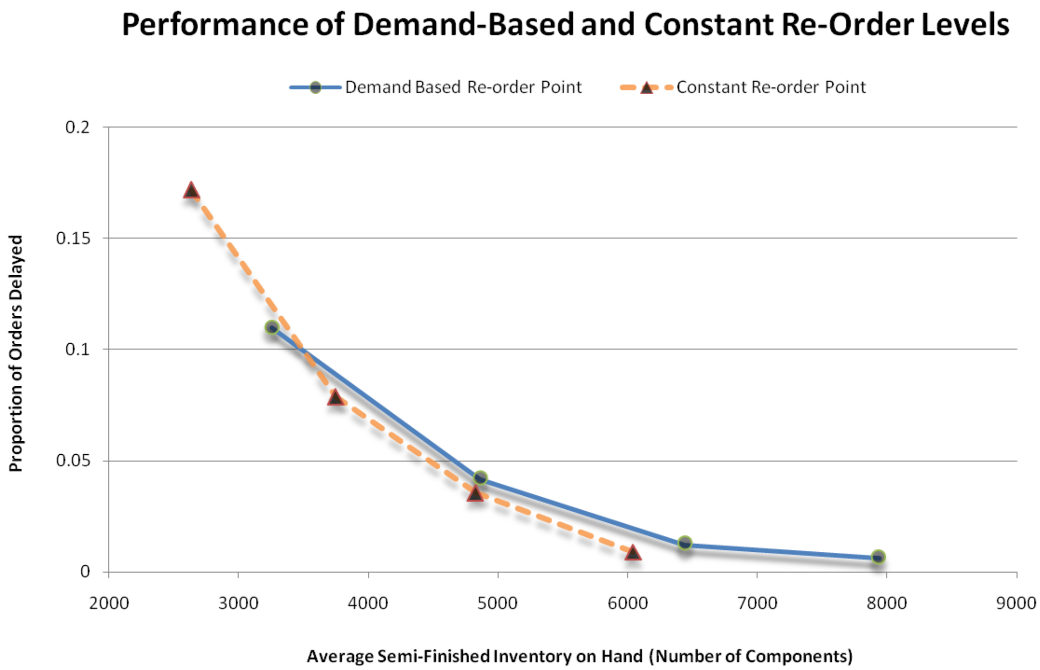


Figure 56 – Comparison of Re-order parameters on stock-outs and inventory on hand

With inventory parameters for components and semi-finished re-order levels held constant, stationary order quantities compared to order-up-to levels require some modification as order-up-to policies in Figure 57 show unstable performance. Since component lot sizes depend on the order quantity of semi-finished stock, order-up-to levels often require additional component to replenish stock. To compensate for this error in lot sizing, re-order levels for components were increased to two lots. This shows stable performance in Figure 58 when compared to constant order quantities, though the order-up-to policy appears to hold more component stock.

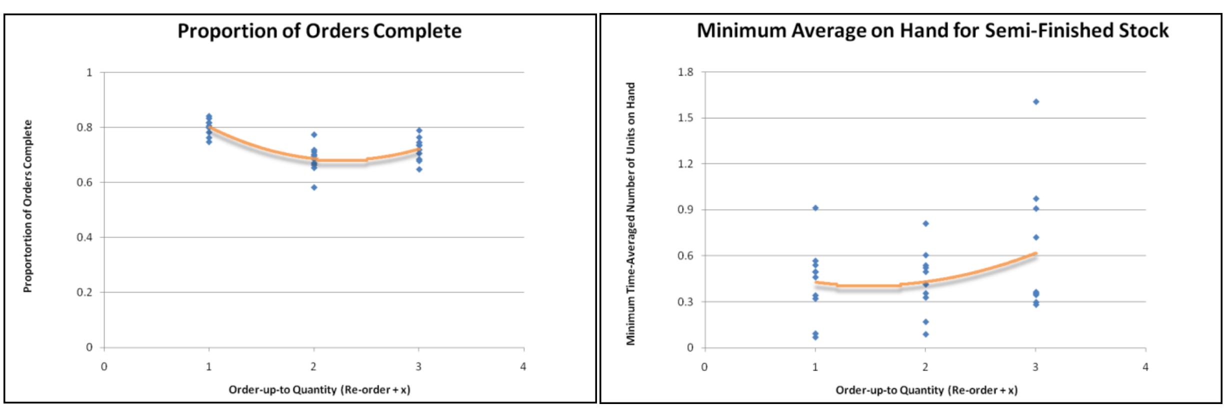


Figure 57 – Order-up-to Policies for Semi-finished Units show instability

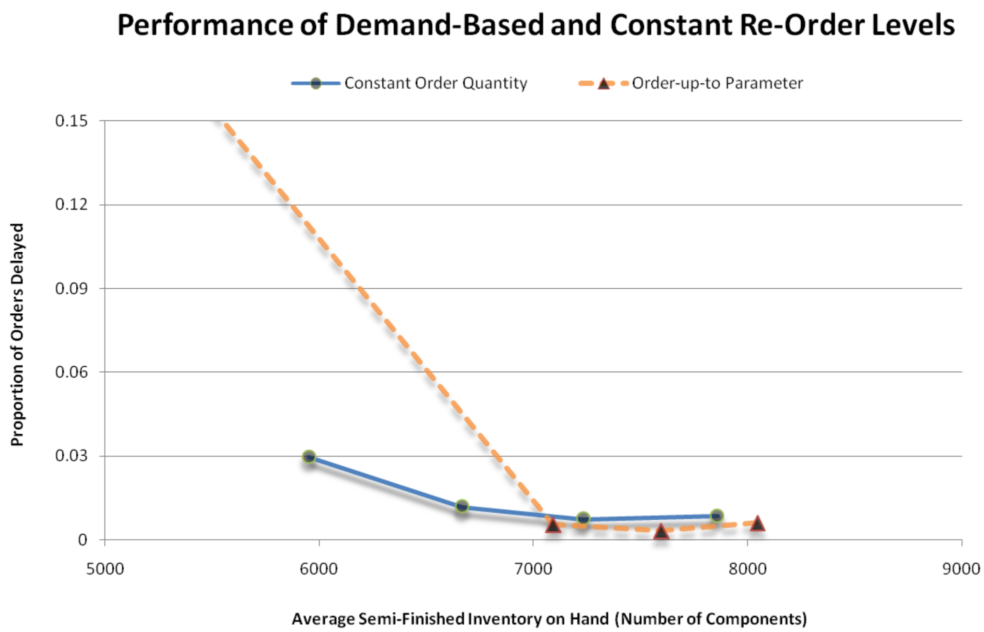


Figure 58 – Comparison of Order-up-to and constant Order Quantity Policies show little difference

With low values of order quantity, constant parameters appear to perform better though larger quantities do not show any significant difference in responsiveness. Though this policy shows some improvements over making semi-finished units while not holding any component inventory, few differences appear while holding component stock. Two sets of parameters examine further cases of this stocking scenario. As the order quantity increases without respect to the re-order point, the time for stock replenishment could result in poor performance, so the first case holds low amounts of semi-finished stock with constant re-order levels and order quantities of three and one respectively. The second case considers increased inventory with re-order levels of five, and order quantity two, for each product. The average response of ten replications in Table 26 creates a baseline performance measure for further experiments, while the histogram in Figure 59 shows the distribution of customer lead-times.

Case	Re-Order Point	Order Quantity	Average Lead-Time	St. Dev. Of Lead-Time	Proportion of Delays	Component Stock	Semi-Finished Stock
1	3	1	34.77	18.58	0.0886	2403.4	3709.8
2	5	2	31.12	9.59	0.0071	3488.7	6661.5

Table 26 – Two possible inventory levels for the Make-to-Stock Scenario

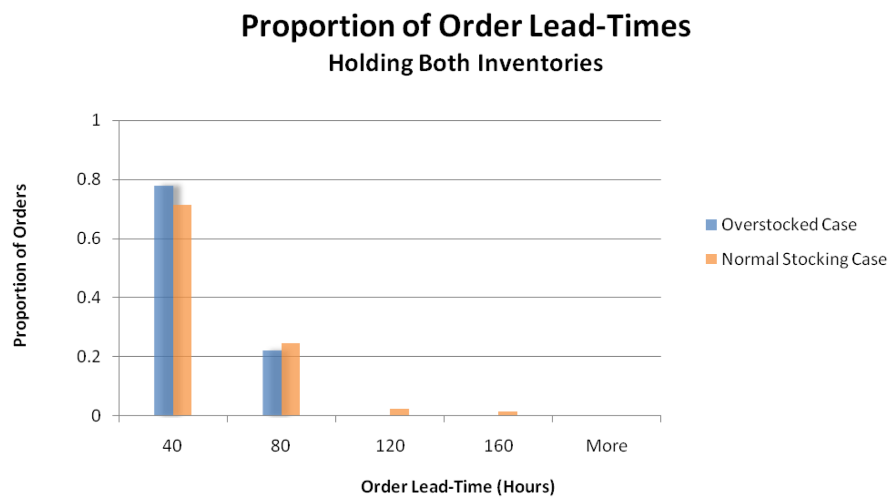


Figure 59 – Proportion of Order Lead-times while holding both component and semi-finished stock

6.5. Comparison of System Reponses

Throughout these experiments of stocking policies, six sets of inventory parameters from three of the four scenarios in Table 4 show the effects and robustness while introducing a source of randomness. The objective of these further analyses is to represent real world variability in the simulation model to explore the limiting factors and capacity of the system. The average response from ten replications of each parameter setting allow for reasonable level of confidence to detect any significant changes.

Experiments for capacity in final assembly and testing are straightforward as it is possible to specify the capacity for a resource. The randomness of job duration requires a parameter to represent the level of variation as described in (0.6), subject to a non-negative minimum processing time. Production interference represents possible conditions in the real system absent in the model. Additional parameters allow the system to model a likely set of interference. The maximum level of demand the system can sustain shows how each model responds to business expansion.

6.5.1. Feasible Alternatives

The six sets of parameters selected for further study in Table 27 determines how each alternative responds to changes in capacity for final assembly and testing processes, randomness in job durations, and interference from other practical circumstances. This subset of possible stocking configurations can identify how the operating procedures and inventory level affects the system's response. However, it includes only three of the four possible inventory scenarios in Table 4, as the bare minimum inventory choice in Section 6.1, the completely make-to-order model, shows unstable performance and requires a reduction in cycle time or demand for sustainable throughput and steady state.

Model	Average Lead-Time (Hrs)	Proportion of Orders Delayed	Component Inventory	Semi-Finished Inventory
Component Stock (Low)	86.02	0.026	9414	
Component Stock (High)	84.02	0.003	11108	
Semi-Finished Stock (Low)	43.6	0.102		5495
Semi-Finished Stock (High)	34.02	0.036		6829
Both Stocked (Low)	34.77	0.0886	2403	3709
Both Stocked (High)	31.12	0.0071	3488	6661

Table 27 – Six sets of Inventory Parameters for Further Analysis

6.5.2. Capacity in Final Assembly

The current parameters indicate six parallel servers exist for assembling semi-finished units from components. Reducing the number of servers in Figure 60 shows poor responsiveness for only three servers, though the deterioration in service surfaces earlier while holding component stock and not semi-finished products.

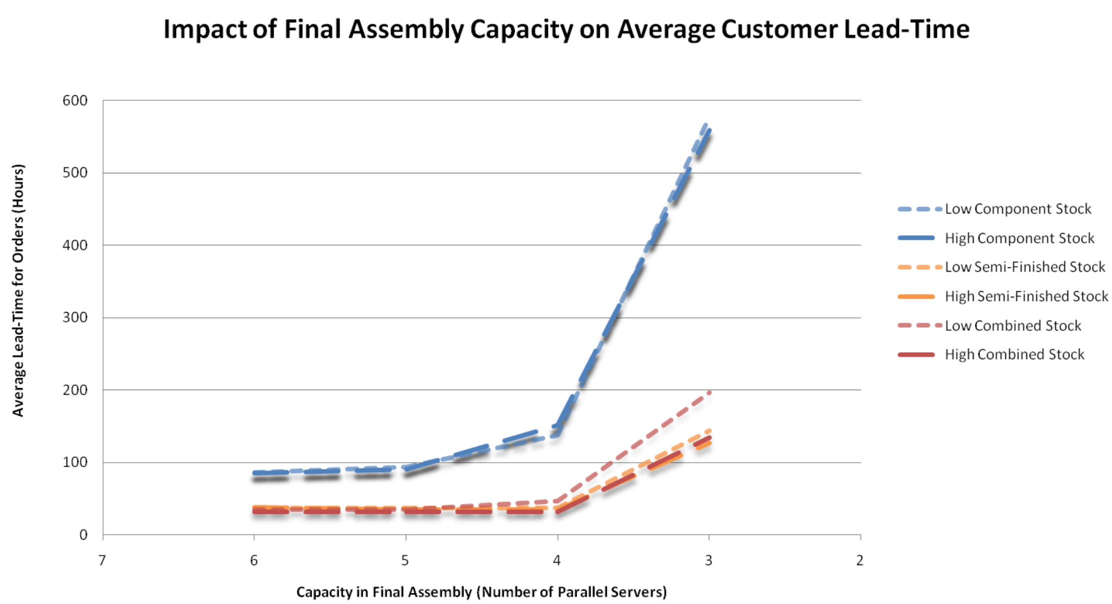


Figure 60 – Average Lead-time for Customer Orders with Reduced Capacity in Final Assembly

Indeed decreasing the capacity of final assembly one or two servers does not significantly change performance in terms of average lead-time. The standard deviation of lead-time in Figure 61 confirms this as variability in lead-time remains unchanged when considering a final assembly capacity of five for component stock, and four while holding semi-finished units. Some performance indicators, such as the proportion of orders delayed; do not apply since the definition changes according to the placement of stock points. With only small reductions in the final assembly processing capacity, changes appear negligible though more than three servers seem required for stable implementation of any inventory policy. To determine if reducing the number of servers is economically beneficial, the cost per unit time of the server should exceed the monetary benefit of the theoretical service level.

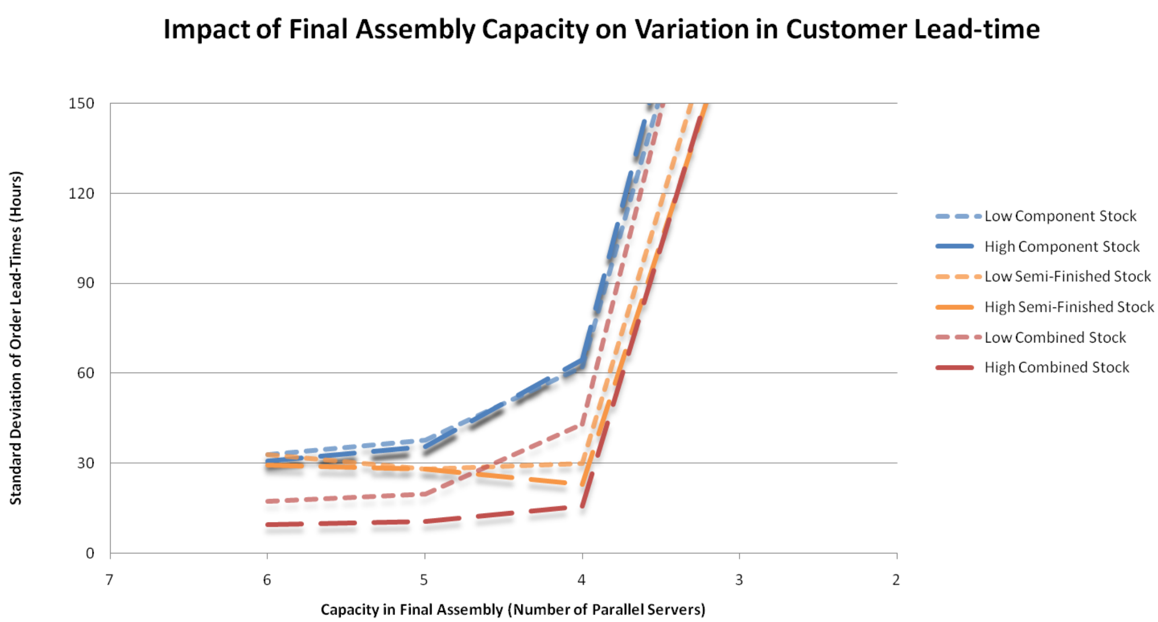


Figure 61 – Variability in Order Lead-times corresponding to capacity in Final Assembly

The performance depends on many variables and the response from the model can indicate an overall service level, though considering only the final assembly process requires assigning subjective costs to some measure of performance. For example, to assess the final assembly process, consider an M/M/s first-in-first-out queue to approximate the M/G/6 queue in the simulation. This approximation assumes an inter-arrival rate as the expected time between customer arrivals of 20 hours, and an exponential service distribution with mean 46 hours, the average processing time for all products. As the number of servers decrease in Table 28, the resource's utilization and queue length increase and with two servers, traffic intensity exceeds allowable limits. The simulation model appears to require more than three servers whereas the rough approximation to analytical queuing equations signifies more than two servers can achieve steady state. Though subjective and approximate, the queue's parameters could indicate an 'optimal cost,' or the minimum number of servers required for satisfactory performance.

Number of Servers (Final Assembly Capacity)	Traffic Intensity (λ/sμ)	Probability (Queue Length > 0)	Average Queue Length
6	0.388	0.035	0.022
5	0.466	0.103	0.089
4	0.582	0.266	0.371
3	0.777	0.611	2.130
2	1.165		

Table 28 – Approximate M/M/s Queuing Model Shows Analytical Performance Measures

6.5.3. Capacity in Testing

Considering six servers in final assembly, reducing capacity in the testing process examines its influence on performance and critical requirements. For small reductions in testing capacity, each model does not indicate any altered performance with more than five servers, though larger reductions show worsening performance and steady state requires at least three servers. Figure 62 shows how gradual changes in order lead-time response eventually reach a tipping point where the system becomes unstable.

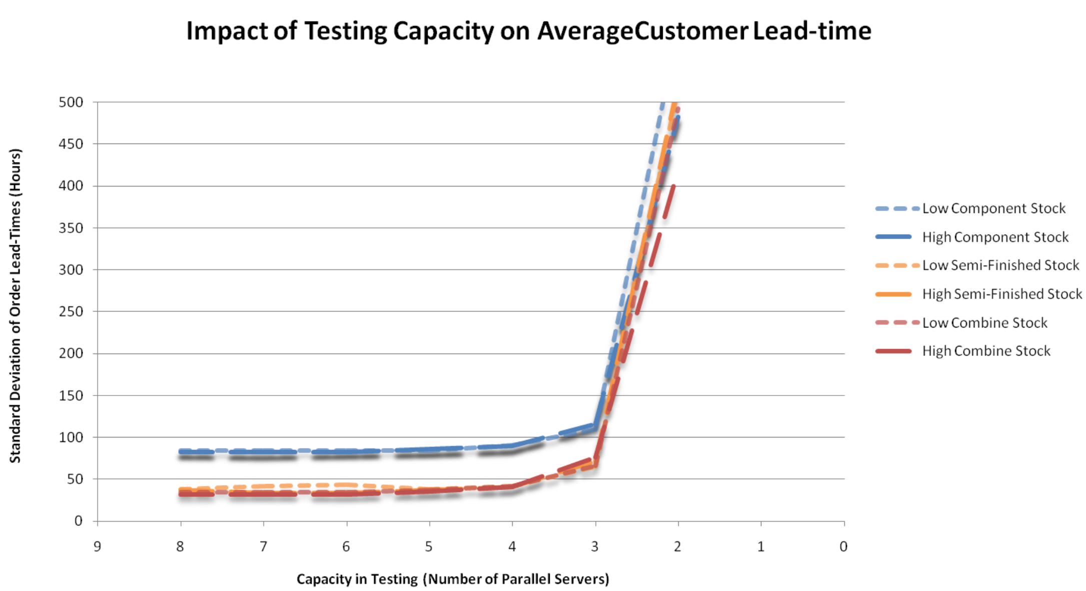


Figure 62 – Number of Servers in Testing compared to Average Lead-time

It is conceivable that the eight parallel servers in the testing process exceed the necessary capacity for no significant improvement in performance. The standard deviation of order lead-times in Figure 63 indicates the number of servers required before a noticeable change in responsiveness. For each stocking scenario, the minimum capacity shows four servers required for satisfactory performance.

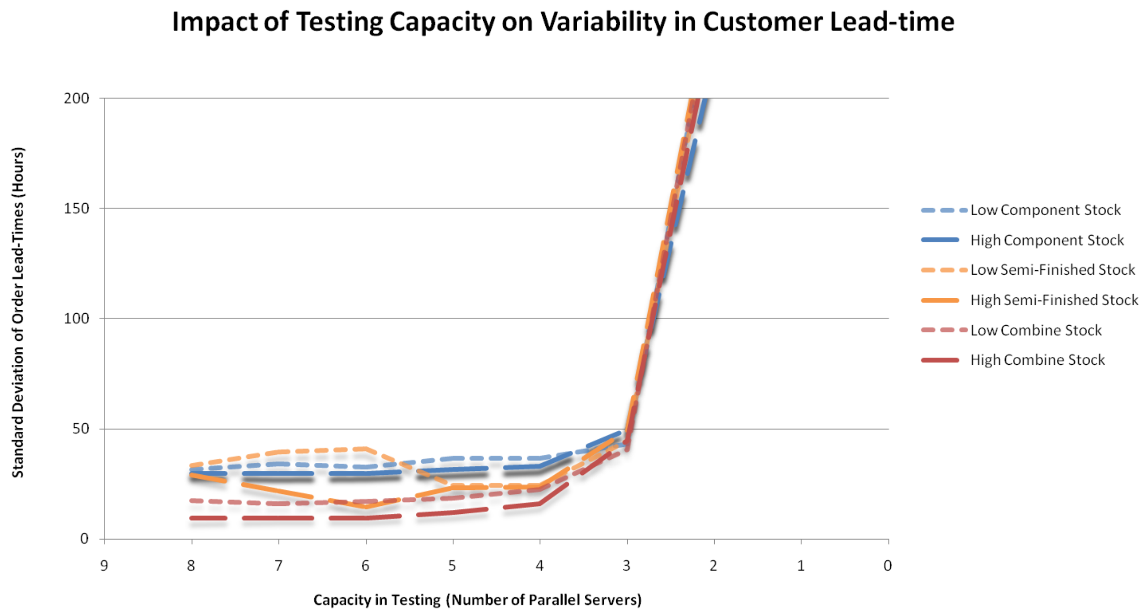


Figure 63 – Variation in Customer Lead-time considering the Number of Servers in Testing

6.5.4. Randomness in Job Processing Times

One of the most common sources of variability arises from non-stationary job durations, typically due to complex tasks requiring a human operator. A common measurement of this job variability known as the co-efficient of variation, C_V, considers the ratio of standard deviation and mean processing time for jobs in (0.6). Introducing randomness by changing the co-efficient of variation, subject to a minimum processing time of half the mean to ensure non-negativity, shows a robust system for small variations in job durations. However, as the measure of randomness grows, the model in Figure 64 indicates that increased component stock provides an excellent buffer against this variability. An additional make-to-stock model, holding increase levels of components stock, shows how robust the completely stocked model can be.

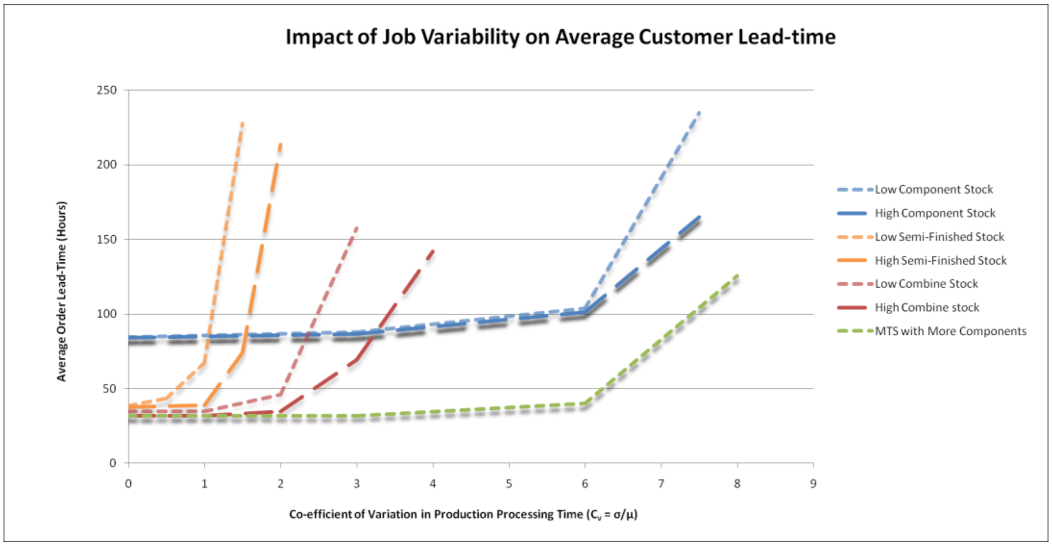


Figure 64 – Component Stock Buffers Variability for Job Processing Times

Although the variations in processing time eventually change the average customer lead-time, the randomness alone does not cause the delay in customer orders. The maximum utilization experienced by a resource show the delay in customer orders results from excessive congestion in production. Indeed the level of randomness appears directly correlated to the bottleneck's utilization and as congestion increases in Figure 65, the system queues become unstable and order lead-times explode. As utilization exceeds about 0.95 for a particular resource, any stocking policy cannot satisfy customer orders in a stable and sustainable manner.

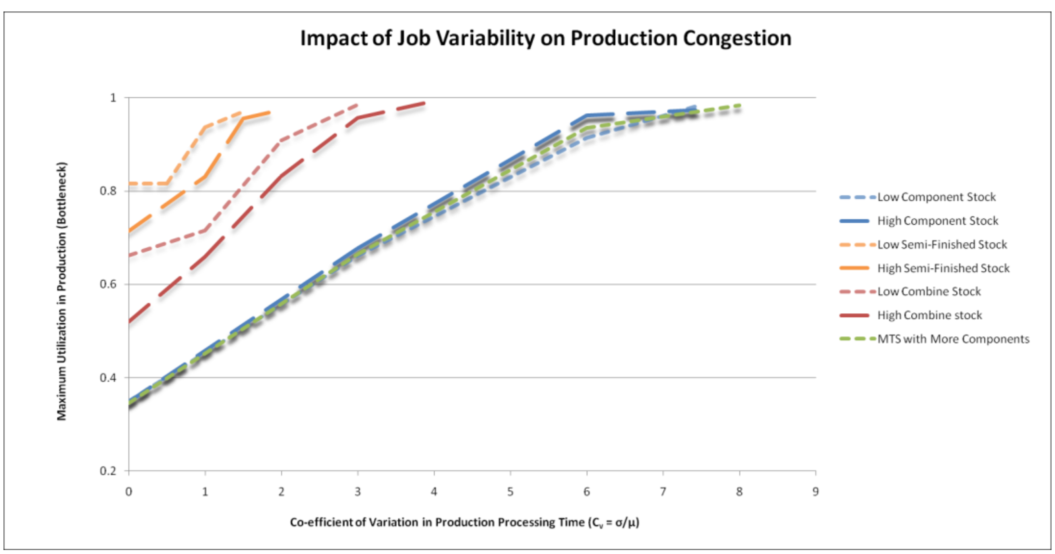


Figure 65 – Job variability increases the bottleneck's utilization

6.5.5. Production Interference

The randomness in job duration might not be the only source of variation in the production area. Other forms of variation model possible conditions that could affect the system's performance. Three experiments observe the robustness and impact of introducing such hypothetical measures of variability. The first experiment considers the frequency of machine breakdowns in production with an average repair time of one day. Second, the length of breakdown increases from one day to several for a particular rate of machine failure. The third examines the effect of introducing additional jobs to production queues to represent the production of specialized orders or for research and development purposes.

To interrupt production or introduce additional jobs, another process in the simulation creates the effects by either pre-empting the existing queue or adding a series of random jobs to the individual machine queues. The parameters for pre-empting the queue consider time between failures, and for repairs, exponential, independent, and identically distributed. Adding jobs to a resource's queue requires the frequency as a proportion of demand and the number of jobs to insert into production. For this case, job length set at a half hour shows the affect of additional jobs at a rate proportional to demand and a combination of low and high values for each parameter examine the effect on performance.

With mean time to repair (MTTR) machines of one day, increasing the frequency of failures in Figure 66 do not appear to affect the response even with a mean time before failure (MTBF) of less than one week. An average failure rate of once every 100 hours, repair rates in Figure 67 show failures lasting more than one week can significantly affect the performance of customer lead-time, though increasing stock on hand could mitigate the reduction in responsiveness.

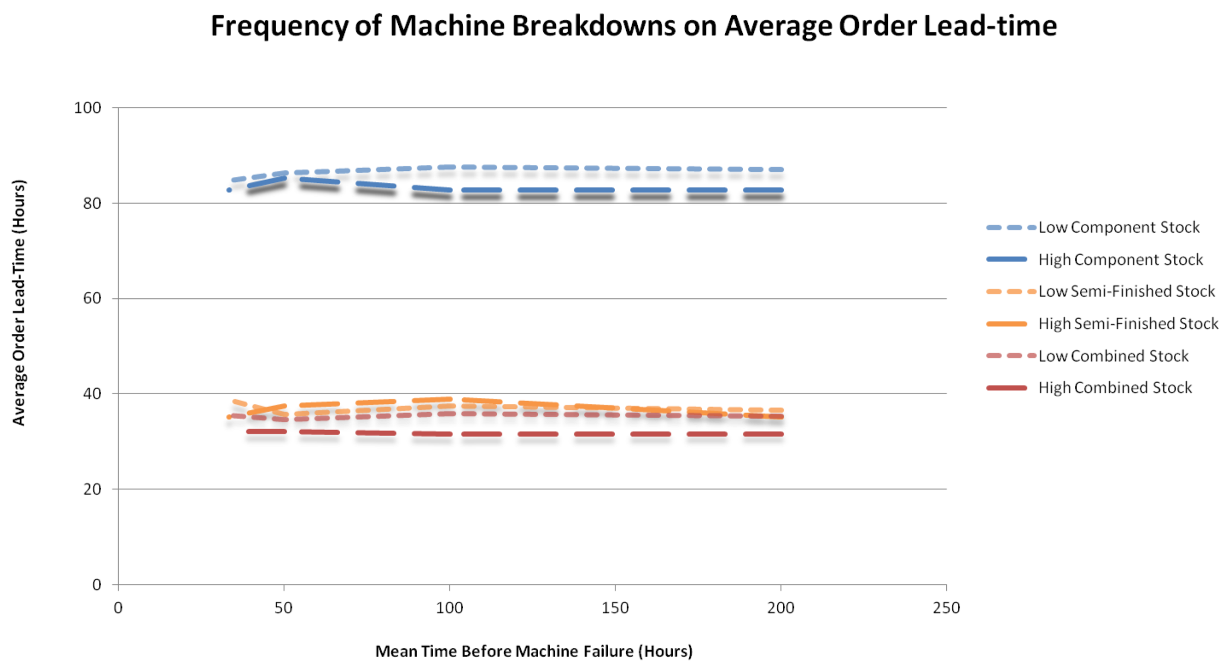


Figure 66 – Frequency of Machine Breakdowns does not change performance with MTTR = 8 hours

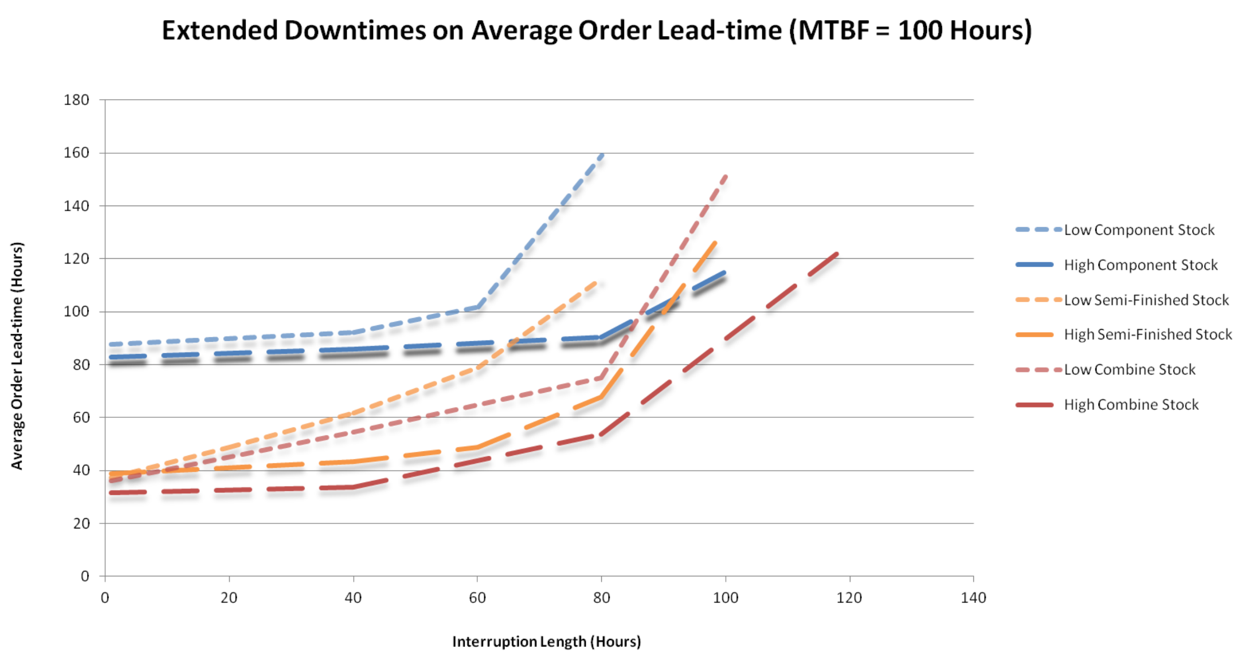
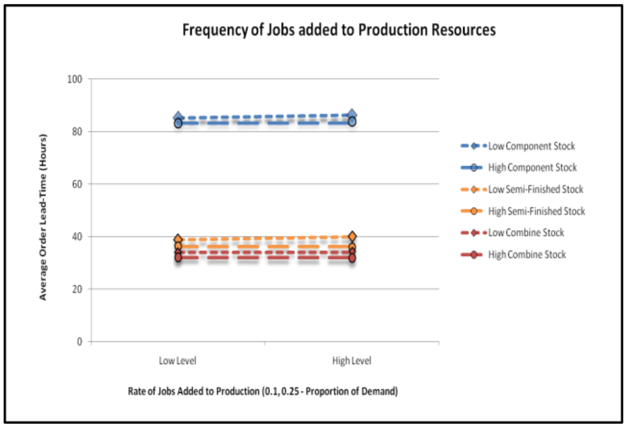


Figure 67 – Performance deteriorates with MTTR greater than two weeks

Since data on machine failures is absent, the hypothetical parameters can only indicate robustness and are not representative of the actual failures. Adding jobs in production can represent a number of conditions and rather than test every possibility, a low and high value from an appropriate range reveal any change in response. The two parameters that describe the interference, the frequency and number of random jobs, each have a low and high value. For the frequency of additional jobs, the low value set at ten percent and a high value of twenty five percent of demand, while the magnitude of the interference considers one thousand jobs at the low level and five thousand at the high level. Figure 68 shows no statistical difference in responsiveness for both the frequency and amount of jobs added randomly to production.



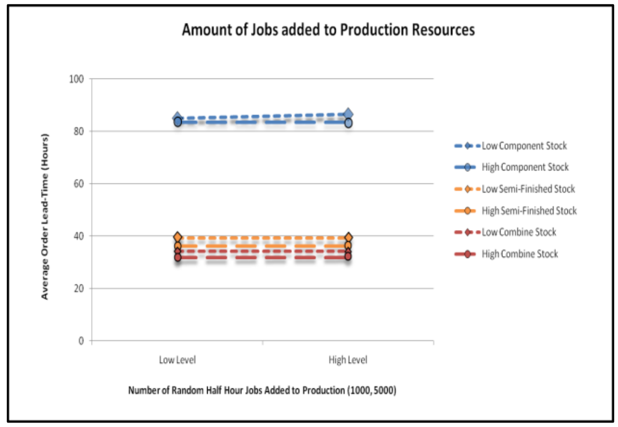


Figure 68 – Number of Jobs added to Production Resources shows no change in responsiveness

The range of parameters for jobs added to production queues considers a maximum level of interference of five thousand half-hour jobs approximately once every four orders. Holding stock appears to buffer variability from excessive jobs, however it is not readily quantifiable, as the completely make-to-order model is not tested and would likely have the worst performance under increased job loadings.

6.5.6. Limiting Demand

Though parameters for stock points incorporate demand measurements, the sensitivity and robustness of the experienced demand indicates some stocking polices protect against excess demand better than others do. If the demand measurements actually change, it would be sensible to adjust the stocking parameters accordingly. Figure 69 shows component stock protects against excess demand better than semi-finished stock however holding both inventories can sustain the largest increase in demand.

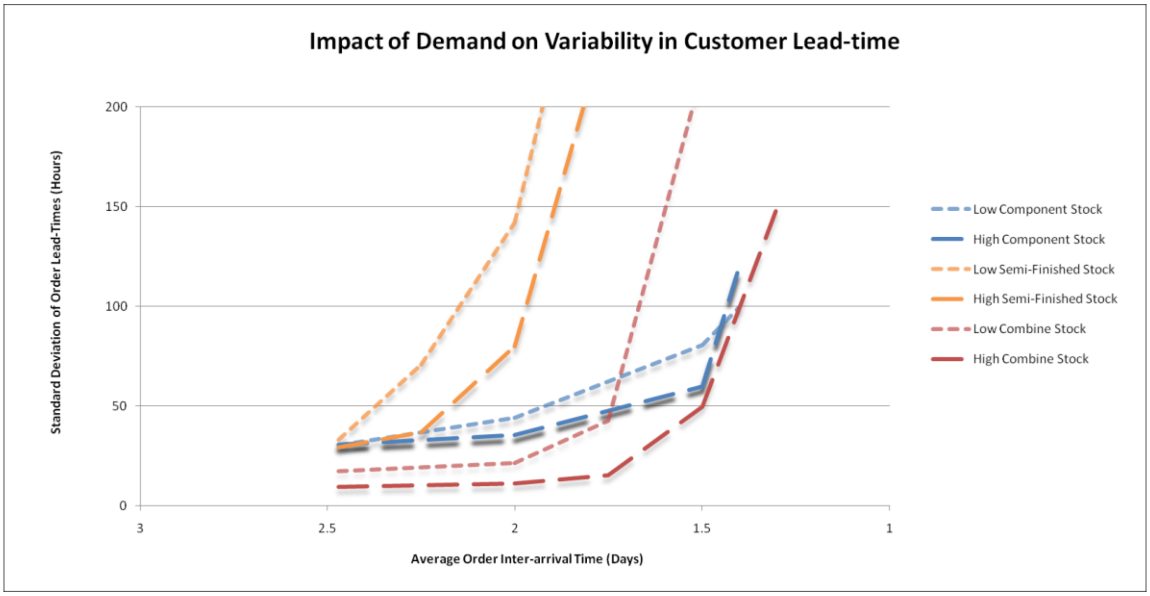


Figure 69 – Effect of increased demand on order lead-time variability

CHAPTER 7 CONCLUSION

Through these simulation experiments, the inventory parameters and operating procedures show that some stock is necessary, as the completely make-to-order model does not achieve a steady state. This implies large amounts of setup are congesting the production resources to a point where they cannot satisfy demand. The verification of this model includes debugging and tracing the active processes in the simulation. Several conclusions can allow key decision-makers to observe the connection between the impact of various parameters on the simulation response and the expected effect on the real system.

7.1. Inventory Parameters and Constraints

Although it is possible for a job schedule to improve the makespan of product-job sequences in the pure make-to-order model, the required 55% reduction in cycle time does not appear likely without some process re-design or effective forecasting method. As interference from random jobs in Section 6.5.5 show a negligible impact on performance for inventory policies, it could greatly affect the untested make-to-order scenario.

Holding component stock was shown to significantly improve customer lead-time if we impose a minimum order quantity. The order quantity can reduce the setup time in production resources, which in turn, reduces the congestion and queuing stability. A stable system requires batching components in some form. The re-order level for components influences the proportion of orders delayed, though it does not alter the stability of the system's queues. Holding semi-finished stock alone shows similar traits, though implementing order-up-to inventory parameters show some improved performance levels as the number of setups decreases slightly. Holding both inventories indicate semi-finished order-up-to parameters are not as effective, as the component stocking parameters, which control the number of setups, rely on constant order quantities to ensure their availability for replenishment. As order-up-to parameters create variability in the ordering quantity, the amount of subcomponents required can vary and therefore their stock levels would require some statistically based parameters.

Holding component inventory shows an average lead-time of about two weeks, however with semi-finished units on hand, the average lead-time falls to one week. Since this analysis considers the inventory on hand as the time-averaged number of components, holding five thousand components of semi-finished inventory could provide a week advantage in lead-time as opposed to holding five thousand individual components. However, semi-finished units require added labour costs, though incurring these costs is mandatory, and do not have the same flexibility as component stock, which can apply to multiple products. Depending on the customer's expectations of lead-time and the company's allowable investment in inventory, the decision on where to place stock and the associated inventory parameters can perform suitably under a variety of conditions.

7.2. System Parameters

Introducing possible sources of variability examine the robustness of the model. Capacity in the final assembly process should exceed three servers or four if holding only component stock. The analysis of testing capacity shows room for reductions as only four parallel servers appears required as opposed to the current practice of eight. Several sources of variability include job time randomness, which shows significant impact on semi-finished stock scenarios however holding component inventory can absorb the variability until the utilization for a resource reaches unacceptable levels. Other types of production interference such as machine downtimes begin to affect performance if repair times exceed a week.

The maximum demand any scenario can handle shows the make-to-order model can only satisfy half the existing demand whereas inventory allows the system to buffer demand variability as shown in Figure 69. However, if such demand materializes one can simply change the stocking levels to compensate for the increase in demand though a make-to-order system requires increases in capacity, forecasting, outsourcing, or some other method to absorb the added demand.

7.3. Implementation Challenges

To implement such policies inside an MRP framework, the job release mechanism needs alterations to provide work orders to the shop floor at the correct time and not when an order arrives. Many conditions could arise which create problems for the system, such as extremely large orders that could alter the demand for an entire year. One of the main advantages of this production system is the commonality between components to buffer variability in product variety.

The simulation model is only a representation of the actual system, which is much more complex and requires considering a number of aspects not included in this study. The raw materials for components, assumed always available, realistically depend on supplier lead-times and the available space for inventory. For any of the considered inventory approaches, one of the main issues will be where the items are actually going to go and if there is enough warehouse space. Typically, holding costs associated with the value or size of the material part estimate how expensive they are to stock; however, the actual cost incurred can depend on the location, cost of building new facilities, renovate existing facilities, and physical parameters of the inventory itself.

Before the results of the simulation can provide useful decision-making information, validating the model, to ensure that it represents the current system accurately, should take place for every aspect in the production process. With expert knowledge, validation increases the likelihood that the model's code is an appropriate translation of the real system, and can correct any overlooked details or assumptions. With a valid and credible model, adjusting the parameters can provide insight into how the real system reacts under similar conditions. Reducing inventory costs to an optimal level requires a valid model, as such; this simulation study is more of a proof of concept for alternate operating procedures, rather than the best possible solution. The essential concept illustrated in this research is the considerable reductions in customer lead-time and variability with the proper placement of inventory.

To implement different operating procedures requires support from all levels of management and a transition phase to reach the target stock levels. The production facilities should prepare for inventory and material handling systems while building a stock of components, and then semi-finished inventory if applicable. Integrating the production operating procedures into the existing MRP system is possible, though designing in-house software could better suit the specific needs and environment of the organization.

7.4. Further Study

With additional information from the organization, the model can incorporate further developments to include accurate details of personal factors and allowances. Further experiments through simulation modeling with other types of inventory parameters or operating procedures could improve the managerial understanding of the system, its limits and performance. For example, modeling component inventory with order-up-to parameters could provide insight into the effectiveness of such strategies with different levels of subcomponents.

Other types of analysis could apply to the system in question. The methods for overall analysis as described in Chapter 2 provide broad areas for additional research. Should information on capacity planning or forecasting become available, the system could benefit from such research. However, job scheduling and heuristics for production components could improve the responsiveness and reduce congestion for added flexibility. Other types of analysis could involve lead-time promising, where the expected time to fulfil an order can depend on the type of product ordered and the state of the production system.

These additional analyses require the organization to provide information about their environment and the goals they would like to achieve. Although using intuition as a manufacturing strategy can be effective with small production operations, growing organizations should not only consider product design, engineering, sales and marketing, but also the production control system.

APPENDIX A – Total Component Quantities in Products

Component	Total Quantity in Product					
	1	2	3	4	5	6
176-1129-01			4	6		
183-6058					1	1
183-6059					1	1
184-6129-01					2	2
198-8357-01	2	4	8	16		
200-5503-16					1	1
200-5514-20	1	1	1			
200-5514-40				1		
200-5515-12					1	1
202-8037					1	1
203-6016					1	
203-6016-FP					1	
203-6098					2	2
206-1004	2	4	8	16		
206-1010-01	2	4	8	16		
206-1012-01	2	4	8	16		
206-1014	2	4	8	16		
206-1016	2	4	8	16		
206-1018	2	4	8	16		
206-1020-02	2	4	8	16		
206-1022	2	4	8	16		
206-1024	2	4	8	16		
206-1026	2	4	8	16		
206-1028-01	2	4	8	16		
206-1030	2	4	8	16		
206-1030-01	2	4	8	16		
206-1030-02	2	4	8	16		
206-1030-03	4	8	16	32		
206-1030-04	4	8	16	32		
206-1032	2	4	8	16		
206-1034	2	4	8	16		
206-1034-01	2	4	8	16		
206-1036	2	4	8	16		
206-1036-01	4	8	16	32		
206-1036-02	2	4	8	16		
206-1038	4	8	16	32		
206-1038-01	2	4	8	16		
206-1040	8	16	32	64		
206-1041-02	2	4	8	16		
206-1042	2	4	8	16		
206-1044	2	4	8	16		
206-1150	2	4	8	16		
206-3024	1	1	1	1		
206-4060	8	12	20	37		
206-8009	1	1				
206-8012	1	1	1			
206-8016	1	1				
206-8016-01	1	1				
206-8018	1	1				
206-8018-01	1	1				
206-8022	1	1				
206-8022-01	1	1				
206-8024	6	6				
206-8026	1	1				
206-8027	1	1				
206-8027-01	1	1				
206-8028	2	2				
206-8030	1	1				

Component	Total Quantity in Product					
	1	2	3	4	5	6
206-8032	1	1				
206-8036	1	1	1			
206-8040	2	2				
206-8041	1					
206-8042	1	1				
206-8043	1	1				
206-8044	1	1				
206-8045	1	1				
206-8046	1	1				
206-8047	1	1				
206-8049	1					
206-8049-02		1				
206-8050	1	1				
206-8051	2	2				
206-8052	1	1				
206-8055	1					
206-8056	1	1				
206-8057	1	1				
206-8058	1	1				
206-8059	1	1				
206-8063	2	2				
206-8064	1	1				
206-8065	1	1				
206-8066	1	1				
206-8066-01	1	1				
206-8070	1	1				
206-8072	1	1				
206-8074	1	1				
206-8075	1	1				
206-8079	1	1				
206-8086	2	2				
206-8087	2	2				
206-8088	2	2				
206-8089	1	1	1			
206-8090	1	1				
206-8092	1	1				
206-8093	1	1				
206-8094	1	1				
206-8094-01	1	1	1			
206-8096	1	1				
206-8097	1	1				
206-8098	1	1				
206-8099	1	1	1			
206-8209-01			1			
206-8216-02			1			
206-8216-03			1			
206-8222			1			
206-8222-01			1			
206-8230			1			
206-8232-01			1			
206-8234	1	1	1			
206-8236	1	1	1			
206-8242-01			1			
206-8244-01			1			
206-8245			1			
206-8247			1			
206-8250			2			
206-8251			1			

Component	Total Quantity in Product					
	1	2	3	4	5	6
206-8252			1			
206-8254-01			1			
206-8257			1			
206-8258			2			
206-8263			2			
206-8263-01			1			
206-8264-01			1			
206-8265-01			1			
206-8270			1			
206-8272			1			
206-8274			1			
206-8275			1			
206-8276			1			
206-8276-01			1			
206-8276-02			1			
206-8277			1			
206-8278			1			
206-8281			1			
206-8281-01	1	1	2			
206-8282			2			
206-8283			2			
206-8284			1			
206-8287			1			
206-8290			1			
206-8292			1			
206-8296			1			
206-8296-01				1		
206-8409			1	1		
206-8410	1	1		1		
206-8410-01			1	1		
206-8412	1	1	1	1		
206-8412-01	1	1		1		
206-8414				1		
206-8414-01			3	3		
206-8415-01	2	2				
206-8415-03	1	1				
206-8415-04	1	1		1		
206-8416				1		
206-8416-01			1	1		
206-8418				1		
206-8418-01			1			
206-8418-03				1		
206-8420				1		
206-8420-01				1		
206-8422				1		
206-8422-01			5	10		
206-8424				1		
206-8425			1	2		
206-8426			4	8		
206-8428				1		
206-8430				1		
206-8430-01				2		
206-8432				1		
206-8434				1		
206-8434-01				2		
206-8436			25	50		
206-8438	18	18	4	8		
206-8440				1		

Component	Total Quantity in Product					
	1	2	3	4	5	6
206-8440-01				1		
206-8442			1	1		
206-8443				1		
206-8443-01				1		
206-8444				1		
206-8445			1	2		
206-8446				1		
206-8447				1		
206-8448			4	6		
206-8449	2	2		1		
206-8450				2		
206-8451				1		
206-8452				1		
206-8452-01			2	2		
206-8453				1		
206-8453-01	2	2		1		
206-8454			1	2		
206-8455	1	1	8	16		
206-8456	4	4		1		
206-8457				1		
206-8458			4	4		
206-8460	4	4	2	2		
206-8461			2	2		
206-8462	2	2		2		
206-8463				1		
206-8464				1		
206-8464-01				1		
206-8465				1		
206-8465-01			1	1		
206-8466				2		
206-8466-01				1		
206-8467			1	1		
206-8468	1	1	4	4		
206-8469	4	4		1		
206-8470				1		
206-8472			1	1		
206-8473	1	1		1		
206-8474				1		
206-8475				1		
206-8476				1		
206-8476-01				1		
206-8476-02				1		
206-8477				1		
206-8478				4		
206-8480				1		
206-8481				2		
206-8482				2		
206-8482-01				2		
206-8483				2		
206-8483-01				2		
206-8484				2		
206-8484-01				2		
206-8486				1		
206-8486-01				1		
206-8486-02				2		
206-8487			2	2		
206-8488	2	2		1		
206-8489				2		

Component	Total Quantity in Product					
	1	2	3	4	5	6
206-8490				1		
206-8492				1		
206-8492-01			2	4		
206-8493	2	2	1	1		
206-8493-01			1	2		
206-8493-02	2	2	2	1		
206-8496				2		
206-8496-01				2		
207-1022				1	40	20
207-1024				1	40	20
207-1024-01					40	20
207-1026					40	20
207-6112					1	1
207-6112-01					1	2
207-6114					1	1
207-6114-01						1
207-6115						1
207-6116					1	1
207-6117					1	1
207-6117-01					1	1
207-6118					1	
207-6118-01						1
207-6119					1	1
207-6122					1	1
207-6122-01					1	1
207-6124					1	1
207-6130-03					1	1
207-6130-04					1	1
207-6130-05					1	1
207-6132					1	1
207-6133					2	2
207-6133-01					1	1
207-6134					2	2
207-6134-01					1	1
207-6135					1	1
207-6135-01					1	1
207-6136					1	1
207-6136-01					1	1
207-6136-02					1	1
207-6138					1	1
207-6140					1	1
207-6140-01					1	1
207-6140-02					1	1
207-6142-01					1	1
207-6144					1	1
207-6146					1	1
207-6148					1	
207-6148-01						1
207-6158					1	1
207-6172					1	1
207-6174					1	1
207-6174-01					1	1
207-6176-02					1	1
207-6176-03					1	1
207-6180					1	1
207-6182					1	1
207-7126					1	
207-7126-01					1	

Component	Total Quantity in Product					
	1	2	3	4	5	6
207-7126-02						1
207-7126-03						1
207-7128					1	1
207-7128-01					1	1
207-7130					2	2
207-7130-01					2	2
207-7130-02					1	1
207-7132					4	4
207-7132-01					1	1
207-7132-02					1	1
207-7135					2	2
207-8110					40	20
207-8112					1	
207-8112-01						1
207-8120					1	
207-8120-01						1
207-8128					1	
207-8128-01					1	
207-8128-02						1
207-8128-03						1
207-8130					3	1
207-8136					1	
207-8136-01						1
207-8138					1	
207-8138-01					4	
207-8138-02						1
207-8138-03						4
207-8140					1	
207-8140-01						1
207-8144					2	1
207-8146					1	
207-8148-01					1	1
207-8149					1	
207-8149-01					1	
207-8149-02						1
207-8149-03						1
207-8154					1	1
207-8156					1	1
207-8158					20	10
207-8158-01					4	2
207-8160					3	1
207-8162					4	2
207-8164					1	1
207-8172					2	2
207-8172-FP					2	2
207-8174					1	1
207-8182					1	1
207-8186					1	1
207-8186-01					1	1
207-8188					1	1
207-8188-01					1	1
207-8190					1	1
207-8192					1	
207-8192-01						1
207-8198					4	8
207-8198-01					2	
207-8198-02					2	
207-8220					2	2

Component	Total Quantity in Product					
	1	2	3	4	5	6
207-8224					1	1
207-8230						2
207-8230-01						1
207-8232						1
207-8234						2
207-8286					2	2
207-8290			1	1		
207-8292	1	1	1	1		
207-8512-01						1
NAA56/01	2	4	8	16		
NAH57					5	
NAH57/01					5	5
NAP36/01A						20
NAP36A					40	
NAPA19					40	20
NAPC156	1	1	1	1		
NAPI100					1	1
NAPI105/01	2	4	8	16		
NAPI111	1	1	2	4		
NAPI115	1	1	1	1		
NAPI98					1	1
NAPI99					1	1

APPENDIX B – Job Routings and Times

Component	WorkStation	Operation	Setup Time	Run Time
176-1129-01	CUT	1	0.1	0.001
176-1129-01	LATHE	2	0.75	0.05
176-1129-01	MISC	3	0	0.0054
176-1129-01	PLATE	4	0.02	0.02
183-6058	COILS	1	0.33	0.018107
183-6059	COILS	1	0.37	0.24525
184-6129-01	CUT	1	0.2	0.015
184-6129-01	LATHE	2	0.25	0.13
184-6129-01	PLATE	3	0.02	0.02
198-8357-01	PRGM	1	0.074	0
198-8357-01	PUNCH	2	0	0.004
198-8357-01	MISC	3	0.05	0.005915
198-8357-01	PLATE	4	0	0.006
198-8357-01	DM	5	0.075	0.006
200-5503-16	CUT	1	0.094	0.0416
200-5503-16	MISC	2	0.32	0.051
200-5503-16	PLATE	3	0.02	0.02
200-5514-20	CUT	1	0.15	0.02
200-5514-20	MISC	2	0.11	0.0067
200-5514-20	PLATE	3	0.02	0.02
200-5514-40	CUT	1	0.15	0.02
200-5514-40	MISC	2	0.11	0.0067
200-5514-40	PLATE	3	0.02	0.005
200-5515-12	MISC	1	0.32	0.051
200-5515-12	PLATE	2	0.02	0.02
200-5515-12	CUT	3	0.094	0.0416
202-8037	CUT	1	0.095	0.015
202-8037	MILL	2	0	0
202-8037	DRILL	3	0.094	0.006
202-8037	MISC	4	0.32	0.051
202-8037	PLATE	5	0.02	0.02
203-6016	MISC	1	0.32	0.051
203-6016	DM	2	0.075	0.006
203-6016	BEND	3	0.285	0.007
203-6016	PLATE	4	0.02	0.02
203-6016-FP	PRGM	1	0.074	0
203-6016-FP	PUNCH	2	0	0.004
203-6098	LATHE	1	0.8	0.108
203-6098	PLATE	2	0.02	0.005
206-1004	CABLES	1	0	0.0125
206-1010-01	PRGM	1	0.074	0
206-1010-01	PUNCH	2	0	0.006
206-1010-01	MISC	3	0.124	0.003184
206-1010-01	DM	4	0.075	0.006
206-1010-01	PLATE	5	0	0.006
206-1012-01	PRGM	1	0.074	0
206-1012-01	PUNCH	2	0	0.006
206-1012-01	MISC	3	0.124	0.004684
206-1012-01	DM	4	0.075	0.006
206-1012-01	PLATE	5	0.02	0.004949
206-1012-01	ASSY	6	0.07	0.003301
206-1014	PRGM	1	0.074	0
206-1014	PUNCH	2	0	0.006375
206-1014	MISC	3	0.124	0.004006
206-1014	DM	4	0.075	0.006
206-1014	PLATE	5	0	0.005
206-1016	PRGM	1	0.074	0
206-1016	PUNCH	2	0	0.006375
206-1016	MISC	3	0.124	0.004006
206-1016	DM	4	0.075	0.006
206-1016	PLATE	5	0	0.005
206-1018	PRGM	1	0.074	0
206-1018	PUNCH	2	0	0.006
206-1018	MISC	3	0.124	0.004184
206-1018	DM	4	0.075	0.006
206-1018	PLATE	5	0	0.006
206-1018	ASSY	6	0.07	0.004167
206-1020-02	PRGM	1	0.074	0
206-1020-02	PUNCH	2	0	0.006
206-1020-02	MISC	3	0.124	0.004684
206-1020-02	DM	4	0.075	0.006
206-1020-02	PLATE	5	0	0.006
206-1020-02	ASSY	6	0.07	0.006214
206-1022	PRGM	1	0.074	0
206-1022	PUNCH	2	0	0.006
206-1022	MISC	3	0.124	0.004184
206-1022	DM	4	0.075	0.006
206-1022	PLATE	5	0	0.006
206-1022	ASSY	6	0.07	0.003214
206-1024	PRGM	1	0.074	0
206-1024	PUNCH	2	0	0.0035
206-1024	MISC	3	0.124	0.004006
206-1024	DM	4	0.075	0.006
206-1024	BEND	5	0.085	0.003355
206-1024	PLATE	6	0	0.006
206-1024	ASSY	7	0.07	0.004667
206-1026	PRGM	1	0.074	0
206-1026	PUNCH	2	0	0.0045
206-1026	MISC	3	0.124	0.006006
206-1026	DM	4	0.075	0.006
206-1026	PLATE	5	0	0.005
206-1028-01	PRGM	1	0.074	0
206-1028-01	PUNCH	2	0	0.0065
206-1028-01	MISC	3	0.124	0.006006
206-1028-01	DM	4	0.075	0.006
206-1028-01	BEND	5	0.085	0.003533
206-1028-01	PLATE	6	0	0.003625
206-1028-01	ASSY	7	0.07	0.004281
206-1030	PRGM	1	0.074	0
206-1030	PUNCH	2	0	0.006
206-1030	MISC	3	0.124	0.003684
206-1030	DM	4	0.075	0.006
206-1030	PLATE	5	0	0.006
206-1030-01	PRGM	1	0.074	0
206-1030-01	PUNCH	2	0	0.0035
206-1030-01	MISC	3	0.124	0.006184
206-1030-01	DM	4	0.075	0.006
206-1030-01	PLATE	5	0	0.006
206-1030-02	PRGM	1	0.074	0
206-1030-02	PUNCH	2	0	0.0035
206-1030-02	MISC	3	0.124	0.004006
206-1030-02	DM	4	0.075	0.006
206-1030-02	PLATE	5	0	0.006
206-1030-03	PRGM	1	0.074	0
206-1030-03	PUNCH	2	0	0.002
206-1030-03	MISC	3	0.124	0.002842
206-1030-03	DM	4	0.075	0.002936
206-1030-03	PLATE	5	0	0.003
206-1030-04	PRGM	1	0.074	0
206-1030-04	PUNCH	2	0	0.0025
206-1030-04	MISC	3	0.124	0.002315
206-1030-04	DM	4	0.075	0.002936
206-1030-04	PLATE	5	0	0.001875
206-1032	PRGM	1	0.074	0
206-1032	PUNCH	2	0	0.006
206-1032	MISC	3	0.124	0.006006
206-1032	DM	4	0.075	0.006
206-1032	PLATE	5	0	0.006
206-1034	PRGM	1	0.074	0
206-1034	PUNCH	2	0	0.0035
206-1034	MISC	3	0.124	0.003434
206-1034	DM	4	0.075	0.006
206-1034	BEND	5	0.08	0.003296
206-1034	PLATE	6	0	0.005
206-1034-01	PRGM	1	0.074	0
206-1034-01	PUNCH	2	0	0.0035
206-1034-01	MISC	3	0.124	0.003789
206-1034-01	DM	4	0.075	0.006
206-1034-01	BEND	5	0.08	0.005796
206-1034-01	PLATE	6	0	0.006
206-1036	PRGM	1	0.074	0
206-1036	PUNCH	2	0	0.004
206-1036	MISC	3	0.124	0.004684
206-1036	DM	4	0.075	0.006
206-1036	PLATE	5	0	0.00375
206-1036-01	PRGM	1	0.074	0
206-1036-01	PUNCH	2	0	0.002
206-1036-01	MISC	3	0.124	0.00294
206-1036-01	DM	4	0.075	0.002936
206-1036-01	PLATE	5	0	0.001875
206-1036-02	PRGM	1	0.074	0
206-1036-02	PUNCH	2	0	0.004
206-1036-02	MISC	3	0.124	0.003434
206-1036-02	DM	4	0.075	0.006
206-1036-02	PLATE	5	0	0.00375
206-1038	PRGM	1	0.074	0
206-1038	PUNCH	2	0	0.002
206-1038	MISC	3	0.124	0.001565
206-1038	DM	4	0.075	0.002936
206-1038	PLATE	5	0	0.001875
206-1038-01	PRGM	1	0.074	0
206-1038-01	PUNCH	2	0	0.004
206-1038-01	MISC	3	0.124	0.003434
206-1038-01	DM	4	0.075	0.006
206-1038-01	PLATE	5	0	0.006
206-1040	PRGM	1	0.074	0
206-1040	PUNCH	2	0	0.001
206-1040	MISC	3	0.124	0.000839
206-1040	DM	4	0.075	0.001452
206-1040	PLATE	5	0	0.0015
206-1041-02	PRGM	1	0.074	0
206-1041-02	PUNCH	2	0	0.005
206-1041-02	MISC	3	0.124	0.004631
206-1041-02	DM	4	0.075	0.006
206-1041-02	BEND	5	0.085	0.003355
206-1041-02	PLATE	6	0	0.006
206-1042	PRGM	1	0.074	0

Component	WorkStation	Operation	Setup Time	Run Time
206-1042	PUNCH	2	0	0.006
206-1042	MISC	3	0.32	0.005184
206-1042	DM	4	0.075	0.006
206-1042	PLATE	5	0	0.006
206-1042	ASSY	6	0.07	0.005821
206-1044	PRGM	1	0.074	0
206-1044	PUNCH	2	0	0.004
206-1044	MISC	3	0.124	0.005684
206-1044	DM	4	0.075	0.006
206-1044	BEND	5	0.085	0.003355
206-1044	PLATE	6	0	0.006
206-1044	ASSY	7	0.07	0.004881
206-1150	PARTS	1	1	0
206-3024	PRGM	1	0.074	0
206-3024	PUNCH	2	0	0.02
206-3024	MISC	3	0.124	0.007
206-3024	DM	4	0.075	0.002
206-3024	PLATE	5	0.02	0.004
206-4060	PARTS	1	1	0
206-4060	ATST	2	0	0.0125
206-8009	PARTS	1	0	0
206-8009	PASH	2	0	0.1875
206-8012	PRGM	1	0.074	0
206-8012	PUNCH	2	0	0.034
206-8012	MISC	3	0.124	0.051
206-8012	DM	4	0.075	0.006
206-8012	BEND	5	0.57	0.015864
206-8012	PLATE	6	0.02	0.041197
206-8012	PAINT	7	0.288	0.030455
206-8012	ASSY	8	0.17	0.039
206-8016	PRGM	1	0.074	0
206-8016	PUNCH	2	0	0.03375
206-8016	MISC	3	0.32	0.03
206-8016	DM	4	0.075	0.006
206-8016	BEND	5	0.475	0.035
206-8016	PLATE	6	0.02	0.053197
206-8016	ASSY	7	0.17	0.02
206-8016-01	PRGM	1	0.074	0
206-8016-01	PUNCH	2	0	0.0435
206-8016-01	MISC	3	0.32	0.03
206-8016-01	DM	4	0.075	0.006
206-8016-01	BEND	5	0.475	0.027803
206-8016-01	PLATE	6	0.02	0.053197
206-8016-01	ASSY	7	0.17	0.045136
206-8018	PRGM	1	0.074	0
206-8018	PUNCH	2	0	0.05175
206-8018	MISC	3	0.32	0.020652
206-8018	DM	4	0.075	0.006
206-8018	BEND	5	0.38	0.031742
206-8018	PLATE	6	0.02	0.032095
206-8018	ASSY	7	0.17	0.038924
206-8018-01	PRGM	1	0.074	0
206-8018-01	PUNCH	2	0	0.05175
206-8018-01	MISC	3	0.32	0.020652
206-8018-01	DM	4	0.075	0.006
206-8018-01	BEND	5	0.38	0.029242
206-8018-01	PLATE	6	0.02	0.032095
206-8018-01	ASSY	7	0.17	0.037636
206-8022	PRGM	1	0.074	0
206-8022	PUNCH	2	0	0.014
206-8022	MISC	3	0.32	0.020652
206-8022	DM	4	0.075	0.006
206-8022	BEND	5	0.38	0.021
206-8022	PLATE	6	0.02	0.02
206-8022	PAINT	7	0.288	0.024205
206-8022	ASSY	8	0.17	0.01
206-8022-01	PRGM	1	0.074	0
206-8022-01	PUNCH	2	0	0.014
206-8022-01	MISC	3	0.32	0.01
206-8022-01	DM	4	0.075	0.006

Component	WorkStation	Operation	Setup Time	Run Time
206-8022-01	BEND	5	0.333	0.014
206-8022-01	PLATE	6	0.02	0.02
206-8022-01	ASSY	7	0.17	0.01
206-8024	PRGM	1	0.074	0
206-8024	PUNCH	2	0	0.009
206-8024	MISC	3	0.32	0.003788
206-8024	DM	4	0.075	0.006
206-8024	BEND	5	0.428	0.005379
206-8024	PLATE	6	0.02	0.009949
206-8024	ASSY	7	0.17	0.004571
206-8026	PRGM	1	0.074	0
206-8026	PUNCH	2	0	0.03
206-8026	MISC	3	0.32	0.036
206-8026	DM	4	0.075	0.006
206-8026	BEND	5	0.428	0.028515
206-8026	PLATE	6	0.02	0.034
206-8026	ASSY	7	0.17	0.039617
206-8027	PRGM	1	0.074	0
206-8027	PUNCH	2	0	0.009
206-8027	MISC	3	0.32	0.018
206-8027	DM	4	0.075	0.006
206-8027	PLATE	5	0.02	0.02
206-8027-01	PRGM	1	0.074	0
206-8027-01	PUNCH	2	0	0.009
206-8027-01	MISC	3	0.32	0.02
206-8027-01	DM	4	0.075	0.006
206-8027-01	PLATE	5	0.02	0.02
206-8028	PRGM	1	0.074	0
206-8028	PUNCH	2	0	0.009
206-8028	MISC	3	0.32	0.01
206-8028	DM	4	0.075	0.006
206-8028	BEND	5	0.285	0.014
206-8028	PLATE	6	0.02	0.02
206-8030	PRGM	1	0.074	0
206-8030	PUNCH	2	0	0.039
206-8030	MISC	3	0.32	0.03
206-8030	DM	4	0.075	0.006
206-8030	BEND	5	0.285	0.024
206-8030	PLATE	6	0.02	0.045
206-8032	PRGM	1	0.074	0
206-8032	PUNCH	2	0	0.024
206-8032	MISC	3	0.32	0.015
206-8032	DM	4	0.075	0.006
206-8032	BEND	5	0.428	0.018515
206-8032	PLATE	6	0.02	0.026
206-8032	ASSY	7	0.17	0.01
206-8036	PRGM	1	0.074	0
206-8036	PUNCH	2	0	0.016
206-8036	MISC	3	0.124	0.008
206-8036	PLATE	4	0.02	0.02
206-8040	PRGM	1	0.074	0
206-8040	PUNCH	2	0	0.019
206-8040	MISC	3	0.32	0.03
206-8040	DM	4	0.075	0.006
206-8040	BEND	5	0.38	0.04
206-8040	PLATE	6	0.02	0.02
206-8040	ASSY	7	0.17	0.005
206-8041	PRGM	1	0.074	0
206-8041	PUNCH	2	0	0.006
206-8041	MISC	3	0.32	0.024
206-8041	DM	4	0.075	0.006
206-8041	PLATE	5	0.02	0.02
206-8042	PRGM	1	0.074	0
206-8042	PUNCH	2	0	0.051
206-8042	MISC	3	0.32	0.024
206-8042	DM	4	0.075	0.006
206-8042	BEND	5	0.333	0.025
206-8042	PLATE	6	0.02	0.06
206-8042	ASSY	7	0.17	0.029
206-8043	PRGM	1	0.074	0

Component	WorkStation	Operation	Setup Time	Run Time
206-8043	PUNCH	2	0	0.028
206-8043	MISC	3	0.32	0.018
206-8043	DM	4	0.075	0.006
206-8043	BEND	5	0.428	0.08
206-8043	PLATE	6	0.02	0.031
206-8043	ASSY	7	0.17	0.015
206-8044	PRGM	1	0.074	0
206-8044	PUNCH	2	0	0.054
206-8044	MISC	3	0.32	0.02
206-8044	DM	4	0.075	0.006
206-8044	BEND	5	0.285	0.024
206-8044	PLATE	6	0.02	0.032197
206-8044	ASSY	7	0.17	0.034
206-8045	PRGM	1	0.074	0
206-8045	PUNCH	2	0	0.015
206-8045	MISC	3	0.32	0.018
206-8045	DM	4	0.075	0.006
206-8045	BEND	5	0.38	0.019242
206-8045	PLATE	6	0.02	0.02
206-8046	PRGM	1	0.074	0
206-8046	PUNCH	2	0	0.021
206-8046	MISC	3	0.32	0.024
206-8046	DM	4	0.075	0.006
206-8046	BEND	5	0.285	0.007
206-8046	PLATE	6	0.02	0.022
206-8047	PRGM	1	0.074	0
206-8047	PUNCH	2	0	0.023
206-8047	MISC	3	0.32	0.020652
206-8047	DM	4	0.075	0.006
206-8047	BEND	5	0.428	0.018515
206-8047	PLATE	6	0.02	0.024
206-8047	ASSY	7	0.17	0.024
206-8049	PRGM	1	0.074	0
206-8049	PUNCH	2	0	0.034
206-8049	MISC	3	0.32	0.051
206-8049	DM	4	0.075	0.006
206-8049	BEND	5	0.333	0.014
206-8049	PLATE	6	0.02	0.039
206-8049-02	PRGM	1	0.074	0
206-8049-02	PUNCH	2	0	0.019
206-8049-02	MISC	3	0.32	0.01
206-8049-02	DM	4	0.075	0.006
206-8049-02	BEND	5	0.333	0.035
206-8049-02	PLATE	6	0.02	0.02
206-8050	PRGM	1	0.074	0
206-8050	PUNCH	2	0	0.023
206-8050	MISC	3	0.32	0.020652
206-8050	DM	4	0.075	0.006
206-8050	BEND	5	0.428	0.043515
206-8050	PLATE	6	0.02	0.025
206-8050	ASSY	7	0.17	0.044
206-8051	PRGM	1	0.074	0
206-8051	PUNCH	2	0	0.007
206-8051	MISC	3	0.32	0.024
206-8051	DM	4	0.075	0.006
206-8051	BEND	5	0.285	0.012841
206-8051	PLATE	6	0.02	0.02
206-8052	PRGM	1	0.074	0
206-8052	PUNCH	2	0	0.043
206-8052	MISC	3	0.32	0.024
206-8052	DM	4	0.075	0.006
206-8052	BEND	5	0.475	0.075
206-8052	PLATE	6	0.02	0.053
206-8052	ASSY	7	0.17	0.088
206-8055	PRGM	1	0.074	0
206-8055	PUNCH	2	0	0.011
206-8055	MISC	3	0.32	0.051
206-8055	DM	4	0.075	0.006
206-8055	PLATE	5	0.02	0.02
206-8056	PRGM	1	0.074	0

Component	WorkStation	Operation	Setup Time	Run Time
206-8056	PUNCH	2	0	0.007
206-8056	MISC	3	0.32	0.024
206-8056	DM	4	0.075	0.006
206-8056	BEND	5	0.285	0.042
206-8056	PLATE	6	0.02	0.02
206-8056	ASSY	7	0.17	0.02
206-8056	DRILL	8	0.094	0.002
206-8057	PRGM	1	0.074	0
206-8057	PUNCH	2	0	0.007
206-8057	MISC	3	0.32	0.015
206-8057	DM	4	0.075	0.006
206-8057	BEND	5	0.333	0.042
206-8057	PLATE	6	0.02	0.02
206-8057	ASSY	7	0.17	0.01
206-8058	PRGM	1	0.074	0
206-8058	PUNCH	2	0	0.054
206-8058	MISC	3	0.32	0.024
206-8058	DM	4	0.075	0.006
206-8058	BEND	5	0.285	0.022
206-8058	PLATE	6	0.02	0.032197
206-8058	ASSY	7	0.17	0.036424
206-8059	PRGM	1	0.074	0
206-8059	PUNCH	2	0	0.004
206-8059	MISC	3	0.32	0.015
206-8059	DM	4	0.075	0.006
206-8059	PLATE	5	0.02	0.02
206-8063	PRGM	1	0.074	0
206-8063	PUNCH	2	0	0.005
206-8063	MISC	3	0.32	0.015
206-8063	DM	4	0.075	0.006
206-8063	PLATE	5	0.02	0.02
206-8063	ASSY	6	0.17	0.01
206-8064	PRGM	1	0.074	0
206-8064	PUNCH	2	0	0.148
206-8064	MISC	3	0.32	0.1
206-8064	DM	4	0.075	0.006
206-8064	BEND	5	0.523	0.12
206-8064	PLATE	6	0.02	0.185
206-8064	PAINT	7	0.288	0.126
206-8064	ASSY	8	0.17	0.044
206-8065	PRGM	1	0.074	0
206-8065	PUNCH	2	0	0.031
206-8065	MISC	3	0.32	0.021346
206-8065	DM	4	0.075	0.006
206-8065	BEND	5	0.618	0.018115
206-8065	PLATE	6	0.02	0.038115
206-8065	ASSY	7	0.17	0.02
206-8066	PRGM	1	0.074	0
206-8066	PUNCH	2	0	0.009
206-8066	MISC	3	0.32	0.012
206-8066	DM	4	0.075	0.006
206-8066	BEND	5	0.333	0.035
206-8066	PLATE	6	0.02	0.02
206-8066	ASSY	7	0.17	0.01
206-8066-01	PRGM	1	0.074	0
206-8066-01	PUNCH	2	0	0.019
206-8066-01	MISC	3	0.32	0.021397
206-8066-01	DM	4	0.075	0.006
206-8066-01	BEND	5	0.333	0.04
206-8066-01	PLATE	6	0.02	0.02
206-8066-01	ASSY	7	0.17	0.039321
206-8070	PRGM	1	0.074	0
206-8070	PUNCH	2	0	0.009
206-8070	MISC	3	0.32	0.03
206-8070	DM	4	0.075	0.006
206-8070	BEND	5	0.523	0.042
206-8070	PLATE	6	0.02	0.02
206-8070	ASSY	7	0.17	0.02
206-8072	PRGM	1	0.074	0
206-8072	PUNCH	2	0	0.036
206-8072	MISC	3	0.32	0.016
206-8072	DM	4	0.075	0.006
206-8072	BEND	5	0.428	0.021515
206-8072	PLATE	6	0.02	0.041
206-8072	ASSY	7	0.17	0.039
206-8074	PRGM	1	0.074	0
206-8074	PUNCH	2	0	0.031
206-8074	MISC	3	0.32	0.018
206-8074	DM	4	0.075	0.006
206-8074	PLATE	5	0.02	0.036
206-8075	PRGM	1	0.074	0
206-8075	PUNCH	2	0	0.005
206-8075	MISC	3	0.32	0.02
206-8075	DM	4	0.075	0.006
206-8075	BEND	5	0.285	0.024
206-8075	PLATE	6	0.02	0.02
206-8079	PRGM	1	0.074	0
206-8079	PUNCH	2	0	0.007
206-8079	MISC	3	0.32	0.02
206-8079	DM	4	0.075	0.006
206-8079	PLATE	5	0.02	0.02
206-8079	PSASSY	6	0	0.02
206-8086	PSASSY	1	0	0.175
206-8086	PAINT	2	0.275	0.08
206-8086	MISC	3	0	0.033
206-8087	PRGM	1	0.074	0
206-8087	PUNCH	2	0	0.016
206-8087	MISC	3	0.32	0.013864
206-8087	DM	4	0.075	0.006
206-8087	BEND	5	0.333	0.017477
206-8087	PLATE	6	0.02	0.02
206-8087	PSASSY	7	0	0.02
206-8088	PRGM	1	0.074	0
206-8088	PUNCH	2	0	0.013
206-8088	MISC	3	0.32	0.023076
206-8088	DM	4	0.075	0.006
206-8088	BEND	5	0.333	0.014
206-8088	PLATE	6	0.02	0.02
206-8089	PRGM	1	0.074	0
206-8089	PUNCH	2	0	0.006
206-8089	MISC	3	0.124	0.018
206-8089	DM	4	0.075	0.006
206-8089	BEND	5	0.475	0.035
206-8089	PLATE	6	0.02	0.02
206-8089	ASSY	7	0.17	0.02
206-8090	PRGM	1	0.018	0
206-8090	PUNCH	2	0	0.056
206-8090	MISC	3	0	0.033
206-8090	DM	4	0.037	0.006
206-8090	BEND	5	0.073	0.009
206-8090	PLATE	6	0	0.039
206-8090	PAINT	7	0.275	0.147
206-8090	PSASSY	8	0	0.14
206-8092	PRGM	1	0.074	0
206-8092	PUNCH	2	0	0.053
206-8092	MISC	3	0.32	0.024
206-8092	DM	4	0.075	0.006
206-8092	PLATE	5	0.02	0.064
206-8092	PAINT	6	0.288	0.141
206-8092	ASSY	7	0.17	0.039
206-8093	PRGM	1	0.074	0
206-8093	PUNCH	2	0	0.009
206-8093	MISC	3	0.32	0.024
206-8093	DM	4	0.075	0.006
206-8093	BEND	5	0.333	0.014
206-8093	PLATE	6	0.02	0.02
206-8093	PAINT	7	0.288	0.023705
206-8094	PRGM	1	0.074	0
206-8094	PUNCH	2	0	0.012
206-8094	MISC	3	0.32	0.01
206-8094	DM	4	0.075	0.006
206-8094	PLATE	5	0.02	0.02
206-8094	SILKSC	6	0.933	0.005
206-8094-01	PRGM	1	0.018	0
206-8094-01	PUNCH	2	0	0.007
206-8094-01	MISC	3	0	0.033
206-8094-01	DM	4	0.037	0.006
206-8094-01	PLATE	5	0	0.039
206-8094-01	SILKSC	6	0.22	0.005
206-8096	PRGM	1	0.074	0
206-8096	PUNCH	2	0	0.008
206-8096	MISC	3	0.124	0.02
206-8096	DM	4	0.075	0.006
206-8096	BEND	5	0.38	0.045
206-8096	PLATE	6	0.02	0.02
206-8097	PRGM	1	0.074	0
206-8097	PUNCH	2	0	0.013
206-8097	MISC	3	0.32	0.011
206-8097	DM	4	0.075	0.006
206-8097	PLATE	5	0.02	0.02
206-8097	ASSY	6	0.17	0.026
206-8098	PRGM	1	0.074	0
206-8098	PUNCH	2	0	0.032
206-8098	MISC	3	0.32	0.024
206-8098	DM	4	0.075	0.006
206-8098	BEND	5	0.618	0.085
206-8098	PLATE	6	0.02	0.036
206-8098	ASSY	7	0.17	0.039
206-8099	PRGM	1	0.074	0
206-8099	PUNCH	2	0	0.01
206-8099	MISC	3	0.32	0.024
206-8099	DM	4	0.075	0.006
206-8099	BEND	5	0.333	0.032
206-8099	PLATE	6	0.02	0.02
206-8099	ASSY	7	0.17	0.029
206-8209-01	PARTS	1	0	0
206-8209-01	PASH	2	0	0.25
206-8216-02	PRGM	1	0.074	0
206-8216-02	PUNCH	2	0	0.035
206-8216-02	MISC	3	0.124	0.051
206-8216-02	DM	4	0.075	0.006
206-8216-02	BEND	5	0.475	0.020125
206-8216-02	PLATE	6	0.02	0.039
206-8216-02	ASSY	7	0.17	0.02
206-8216-03	PRGM	1	0.074	0
206-8216-03	PUNCH	2	0	0.035
206-8216-03	MISC	3	0.124	0.051
206-8216-03	DM	4	0.075	0.03
206-8216-03	BEND	5	0.475	0.023125
206-8216-03	PLATE	6	0.02	0.039
206-8216-03	ASSY	7	0.17	0.04225
206-8222	PRGM	1	0.074	0
206-8222	PUNCH	2	0	0.02
206-8222	MISC	3	0.124	0.051
206-8222	DM	4	0.075	0.006
206-8222	BEND	5	0.38	0.035
206-8222	PLATE	6	0.02	0.05
206-8222	PAINT	7	0.288	0.036
206-8222	ASSY	8	0.17	0.02
206-8222-01	PRGM	1	0.074	0
206-8222-01	PUNCH	2	0	0.02
206-8222-01	MISC	3	0.122	0.051
206-8222-01	DM	4	0.075	0.006
206-8222-01	BEND	5	0.333	0.04
206-8222-01	PLATE	6	0.02	0.021
206-8222-01	ASSY	7	0.17	0.03
206-8230	PRGM	1	0.074	0
206-8230	PUNCH	2	0	0.041
206-8230	MISC	3	0.124	0.035
206-8230	DM	4	0.075	0.006
206-8230	BEND	5	0.285	0.005
206-8230	PLATE	6	0.02	0.048
206-8232-01	PRGM	1	0.074	0
206-8232-01	PUNCH	2	0	0.024
206-8232-01	MISC	3	0.124	0.03
206-8232-01	DM	4	0.075	0.006
206-8232-01	BEND	5	0.428	0.022867
206-8232-01	PLATE	6	0.02	0.026
206-8232-01	ASSY	7	0.17	0.01
206-8234	PRGM	1	0.074	0
206-8234	PUNCH	2	0	0.008
206-8234	MISC	3	0.124	0.024
206-8234	DM	4	0.075	0.006
206-8234	BEND	5	0.285	0.022
206-8234	PLATE	6	0.02	0.02
206-8236	PRGM	1	0.074	0
206-8236	PUNCH	2	0	0.006
206-8236	MISC	3	0.124	0.02
206-8236	DM	4	0.075	0.006
206-8236	BEND	5	0.333	0.03
206-8236	PLATE	6	0.02	0.02
206-8236	ASSY	7	0.17	0.01
206-8242-01	PRGM	1	0.074	0
206-8242-01	PUNCH	2	0	0.041
206-8242-01	MISC	3	0.32	0.051
206-8242-01	DM	4	0.075	0.006
206-8242-01	BEND	5	0.333	0.014
206-8242-01	PLATE	6	0.02	0.049667
206-8242-01	ASSY	7	0.17	0.059
206-8244-01	PRGM	1	0.074	0

Component	WorkStation	Operation	Setup Time	Run Time
206-8244-01	PUNCH	2	0	0.044
206-8244-01	MISC	3	0.32	0.051
206-8244-01	DM	4	0.075	0.006
206-8244-01	BEND	5	0.285	0.007
206-8244-01	PLATE	6	0.02	0.053667
206-8244-01	ASSY	7	0.17	0.049
206-8245	PRGM	1	0.074	0
206-8245	PUNCH	2	0	0.012
206-8245	MISC	3	0.124	0.022
206-8245	DM	4	0.075	0.006
206-8245	BEND	5	0.38	0.04
206-8245	PLATE	6	0.02	0.01
206-8247	PRGM	1	0.074	0
206-8247	PUNCH	2	0	0.033
206-8247	MISC	3	0.124	0.051
206-8247	DM	4	0.075	0.006
206-8247	BEND	5	0.333	0.03
206-8247	PLATE	6	0.02	0.037
206-8250	PRGM	1	0.074	0
206-8250	PUNCH	2	0	0.004
206-8250	MISC	3	0.124	0.051
206-8250	DM	4	0.075	0.006
206-8250	BEND	5	0.38	0.03
206-8250	PLATE	6	0.02	0.02
206-8250	ASSY	7	0.17	0.029167
206-8251	PRGM	1	0.074	0
206-8251	PUNCH	2	0	0.018
206-8251	MISC	3	0.124	0.012
206-8251	DM	4	0.075	0.006
206-8251	BEND	5	0.285	0.012625
206-8251	PLATE	6	0.02	0.02
206-8252	PRGM	1	0.074	0
206-8252	PUNCH	2	0	0.06
206-8252	MISC	3	0.32	0.051
206-8252	DM	4	0.075	0.006
206-8252	BEND	5	0.428	0.028
206-8252	PLATE	6	0.02	0.073
206-8252	ASSY	7	0.17	0.098
206-8254-01	PRGM	1	0.074	0
206-8254-01	PUNCH	2	0	0.015
206-8254-01	MISC	3	0.32	0.051
206-8254-01	DM	4	0.075	0.006
206-8254-01	BEND	5	0.333	0.014
206-8254-01	PLATE	6	0.02	0.02
206-8257	PRGM	1	0.074	0
206-8257	PUNCH	2	0	0.014
206-8257	MISC	3	0.124	0.014
206-8257	DM	4	0.075	0.006
206-8257	BEND	5	0.38	0.08
206-8257	PLATE	6	0.02	0.02
206-8257	ASSY	7	0.17	0.024
206-8258	PRGM	1	0.074	0
206-8258	PUNCH	2	0	0.044
206-8258	MISC	3	0.124	0.04
206-8258	DM	4	0.075	0.02
206-8258	BEND	5	0.285	0.04
206-8258	PLATE	6	0.02	0.053667
206-8258	ASSY	7	0.17	0.033792
206-8263	PRGM	1	0.074	0
206-8263	PUNCH	2	0	0.009
206-8263	MISC	3	0.124	0.03
206-8263	DM	4	0.075	0.006
206-8263	BEND	5	0.428	0.06
206-8263	PLATE	6	0.02	0.012
206-8263-01	PRGM	1	0.074	0
206-8263-01	PUNCH	2	0	0.006
206-8263-01	MISC	3	0.124	0.04
206-8263-01	DM	4	0.075	0.006
206-8263-01	BEND	5	0.285	0.02
206-8263-01	PLATE	6	0.02	0.012
206-8264-01	PRGM	1	0.074	0
206-8264-01	PUNCH	2	0	0.229
206-8264-01	MISC	3	0.124	0.1
206-8264-01	DM	4	0.075	0.006
206-8264-01	BEND	5	0.428	0.18
206-8264-01	PLATE	6	0.02	0.289
206-8264-01	PAINT	7	0.288	0.22
206-8264-01	PSASSY	8	0	0.25
206-8265-01	PRGM	1	0.074	0
206-8265-01	PUNCH	2	0	0.02825

Component	WorkStation	Operation	Setup Time	Run Time
206-8265-01	MISC	3	0.124	0.028865
206-8265-01	DM	4	0.075	0.006
206-8265-01	BEND	5	0.618	0.028115
206-8265-01	PLATE	6	0.02	0.035176
206-8265-01	ASSY	7	0.17	0.021731
206-8270	PRGM	1	0.074	0
206-8270	PUNCH	2	0	0.011
206-8270	MISC	3	0.124	0.02
206-8270	DM	4	0.075	0.006
206-8270	BEND	5	0.428	0.042867
206-8270	PLATE	6	0.02	0.02
206-8270	ASSY	7	0.17	0.06
206-8272	PRGM	1	0.074	0
206-8272	PUNCH	2	0	0.036
206-8272	MISC	3	0.124	0.03
206-8272	DM	4	0.075	0.015
206-8272	BEND	5	0.333	0.03
206-8272	PLATE	6	0.02	0.043167
206-8272	ASSY	7	0.17	0.036167
206-8274	PRGM	1	0.074	0
206-8274	PUNCH	2	0	0.056
206-8274	MISC	3	0.124	0.051
206-8274	DM	4	0.075	0.02
206-8274	BEND	5	0.523	0.033783
206-8274	PLATE	6	0.02	0.033167
206-8274	ASSY	7	0.17	0.059
206-8275	PRGM	1	0.074	0
206-8275	PUNCH	2	0	0.005
206-8275	MISC	3	0.124	0.051
206-8275	DRILL	4	0.094	0.005
206-8275	DM	5	0.075	0.006
206-8275	BEND	6	0.285	0.007
206-8275	PLATE	7	0.02	0.01
206-8275	ASSY	8	0.17	0.024
206-8276	PRGM	1	0.074	0
206-8276	PUNCH	2	0	0.05
206-8276	MISC	3	0.32	0.051
206-8276	DM	4	0.075	0.006
206-8276	PLATE	5	0.02	0.06
206-8276	ASSY	6	0.17	0.039
206-8276-01	PRGM	1	0.074	0
206-8276-01	PUNCH	2	0	0.013
206-8276-01	MISC	3	0.32	0.051
206-8276-01	DM	4	0.075	0.006
206-8276-01	PLATE	5	0.02	0.02
206-8276-01	ASSY	6	0.17	0.039
206-8276-02	PRGM	1	0.074	0
206-8276-02	PUNCH	2	0	0.023
206-8276-02	MISC	3	0.32	0.051
206-8276-02	DM	4	0.075	0.006
206-8276-02	PLATE	5	0.02	0.025
206-8277	PRGM	1	0.074	0
206-8277	PUNCH	2	0	0.006
206-8277	MISC	3	0.124	0.018
206-8277	DM	4	0.075	0.006
206-8277	PLATE	5	0.02	0.02
206-8278	PRGM	1	0.074	0
206-8278	PUNCH	2	0	0.038
206-8278	MISC	3	0.124	0.051
206-8278	DM	4	0.075	0.01
206-8278	BEND	5	0.428	0.028
206-8278	PLATE	6	0.02	0.044
206-8278	ASSY	7	0.17	0.042
206-8281	PRGM	1	0.074	0
206-8281	PUNCH	2	0	0.02
206-8281	MISC	3	0.124	0.04
206-8281	DM	4	0.075	0.006
206-8281	BEND	5	0.428	0.06
206-8281	PLATE	6	0.02	0.02
206-8281-01	PRGM	1	0.074	0
206-8281-01	PUNCH	2	0	0.007
206-8281-01	MISC	3	0.32	0.01
206-8281-01	DM	4	0.075	0.006
206-8281-01	BEND	5	0.428	0.04
206-8281-01	PLATE	6	0.02	0.02
206-8282	PSASSY	1	0	0.25
206-8282	PAINT	2	0.275	0.125
206-8282	MISC	3	0	0.033
206-8283	PRGM	1	0.074	0
206-8283	PUNCH	2	0	0.024

Component	WorkStation	Operation	Setup Time	Run Time
206-8283	MISC	3	0.124	0.024352
206-8283	DM	4	0.075	0.006
206-8283	BEND	5	0.333	0.015375
206-8283	PLATE	6	0.02	0.026
206-8283	ASSY	7	0.17	0.02
206-8284	PRGM	1	0.074	0
206-8284	PUNCH	2	0	0.018
206-8284	MISC	3	0.124	0.024352
206-8284	DM	4	0.075	0.006
206-8284	BEND	5	0.333	0.013917
206-8284	PLATE	6	0.02	0.02
206-8287	PRGM	1	0.074	0
206-8287	PUNCH	2	0	0.009
206-8287	MISC	3	0.124	0.015
206-8287	DM	4	0.075	0.006
206-8287	PLATE	5	0.02	0.01
206-8287	PSASSY	6	0	0.02
206-8290	PRGM	1	0.074	0
206-8290	PUNCH	2	0	0.055
206-8290	MISC	3	0.124	0.051
206-8290	DM	4	0.075	0.02
206-8290	BEND	5	0.285	0.05
206-8290	PLATE	6	0.02	0.163
206-8290	PAINT	7	0.288	0.176
206-8290	ASSY	8	0.17	0.19
206-8292	PRGM	1	0.074	0
206-8292	PUNCH	2	0	0.086
206-8292	MISC	3	0.32	0.051
206-8292	DM	4	0.075	0.006
206-8292	PLATE	5	0.02	0.08
206-8292	PAINT	6	0.288	0.156
206-8292	ASSY	7	0.17	0.3
206-8296	PRGM	1	0.074	0
206-8296	PUNCH	2	0	0.02
206-8296	MISC	3	0.124	0.024
206-8296	DM	4	0.075	0.006
206-8296	PLATE	5	0.02	0.02
206-8296	SILKSC	6	0.933	0.06
206-8296-01	PRGM	1	0.074	0
206-8296-01	PUNCH	2	0	0.02
206-8296-01	MISC	3	0.124	0.04
206-8296-01	DM	4	0.075	0.006
206-8296-01	PLATE	5	0.02	0.02
206-8296-01	SILKSC	6	0.933	0.06
206-8409	PARTS	1	0	0
206-8409	PASH	2	0	0.5
206-8410	PRGM	1	0.074	0
206-8410	PUNCH	2	0	0.031
206-8410	MISC	3	0.124	0.051
206-8410	DM	4	0.075	0.006
206-8410	BEND	5	0.57	0.015864
206-8410	PLATE	6	0.02	0.036697
206-8410	PAINT	7	0.288	0.029705
206-8410	PSASSY	8	0	0.017
206-8410-01	PRGM	1	0.074	0
206-8410-01	PUNCH	2	0	0.062
206-8410-01	MISC	3	0.124	0.051
206-8410-01	DM	4	0.075	0.006
206-8410-01	BEND	5	0.57	0.049
206-8410-01	PLATE	6	0.02	0.074
206-8410-01	PAINT	7	0.288	0.0645
206-8410-01	PSASSY	8	0	0.017
206-8412	PRGM	1	0.074	0
206-8412	PUNCH	2	0	0.031
206-8412	MISC	3	0.124	0.051
206-8412	DM	4	0.075	0.006
206-8412	BEND	5	0.57	0.015864
206-8412	PLATE	6	0.02	0.036697
206-8412	PAINT	7	0.288	0.029705
206-8412-01	PRGM	1	0.074	0
206-8412-01	PUNCH	2	0	0.031
206-8412-01	MISC	3	0.124	0.051
206-8412-01	DM	4	0.075	0.006
206-8412-01	BEND	5	0.57	0.015864
206-8412-01	PLATE	6	0.02	0.036697
206-8412-01	PAINT	7	0.288	0.029705
206-8414	PRGM	1	0.074	0
206-8414	PUNCH	2	0	0.042
206-8414	MISC	3	0.32	0.051
206-8414	DM	4	0.075	0.006

Component	WorkStation	Operation	Setup Time	Run Time
206-8414	BEND	5	0.475	0.035
206-8414	PLATE	6	0.02	0.049
206-8414-01	PRGM	1	0.074	0
206-8414-01	PUNCH	2	0	0.042
206-8414-01	MISC	3	0.32	0.051
206-8414-01	DM	4	0.075	0.006
206-8414-01	BEND	5	0.523	0.042
206-8414-01	PLATE	6	0.02	0.05
206-8414-01	PAINT	7	0.288	0.136
206-8414-01	ASSY	8	0.17	0.078
206-8415	PRGM	1	0.074	0
206-8415	PUNCH	2	0	0.005
206-8415	MISC	3	0.124	0.022
206-8415	DM	4	0.075	0.006
206-8415	PLATE	5	0.02	0.012
206-8415-01	PRGM	1	0.074	0
206-8415-01	PUNCH	2	0	0.005
206-8415-01	MISC	3	0.124	0.022
206-8415-01	DM	4	0.075	0.006
206-8415-01	PLATE	5	0.02	0.012
206-8415-03	PRGM	1	0.074	0
206-8415-03	PUNCH	2	0	0.005
206-8415-03	MISC	3	0.124	0.022
206-8415-03	DM	4	0.075	0.006
206-8415-03	PLATE	5	0.02	0.012
206-8415-04	PRGM	1	0.074	0
206-8415-04	PUNCH	2	0	0.005
206-8415-04	MISC	3	0.32	0.022
206-8415-04	DM	4	0.075	0.006
206-8415-04	PLATE	5	0.02	0.012
206-8416	PRGM	1	0.074	0
206-8416	PUNCH	2	0	0.05725
206-8416	MISC	3	0.32	0.051
206-8416	DM	4	0.075	0.006
206-8416	BEND	5	0.57	0.049
206-8416	PLATE	6	0.02	0.071417
206-8416	ASSY	7	0.17	0.039
206-8416-01	PRGM	1	0.074	0
206-8416-01	PUNCH	2	0	0.111
206-8416-01	MISC	3	0.32	0.051
206-8416-01	DM	4	0.075	0.006
206-8416-01	BEND	5	0.475	0.035
206-8416-01	PLATE	6	0.02	0.069417
206-8416-01	ASSY	7	0.17	0.098278
206-8418	PRGM	1	0.074	0
206-8418	PUNCH	2	0	0.05325
206-8418	MISC	3	0.32	0.051
206-8418	DRILL	4	0.094	0.015
206-8418	DM	5	0.075	0.006
206-8418	BEND	6	0.38	0.021
206-8418	PLATE	7	0.02	0.033042
206-8418	ASSY	8	0.17	0.039
206-8418-01	PRGM	1	0.074	0
206-8418-01	PUNCH	2	0	0.1065
206-8418-01	MISC	3	0.32	0.051
206-8418-01	DRILL	4	0.094	0.015
206-8418-01	DM	5	0.075	0.006
206-8418-01	BEND	6	0.38	0.021
206-8418-01	PLATE	7	0.02	0.066417
206-8418-01	ASSY	8	0.17	0.039
206-8418-03	PRGM	1	0.074	0
206-8418-03	PUNCH	2	0	0.0575
206-8418-03	MISC	3	0.124	0.040433
206-8418-03	DM	4	0.075	0.04
206-8418-03	BEND	5	0.38	0.021
206-8418-03	PLATE	6	0.02	0.033042
206-8418-03	ASSY	7	0.17	0.032167
206-8420	PRGM	1	0.074	0
206-8420	PUNCH	2	0	0.048
206-8420	MISC	3	0.32	0.051
206-8420	DM	4	0.075	0.006
206-8420	BEND	5	0.475	0.035
206-8420	PLATE	6	0.02	0.056
206-8420-01	PRGM	1	0.074	0
206-8420-01	PUNCH	2	0	0.048
206-8420-01	MISC	3	0.32	0.051
206-8420-01	DM	4	0.075	0.006
206-8420-01	BEND	5	0.475	0.035
206-8420-01	PLATE	6	0.02	0.056
206-8420-01	ASSY	7	0.17	0.029

Component	WorkStation	Operation	Setup Time	Run Time
206-8422	PRGM	1	0.074	0
206-8422	PUNCH	2	0	0.036
206-8422	MISC	3	0.32	0.051
206-8422	DM	4	0.075	0.006
206-8422	BEND	5	0.38	0.021
206-8422	PLATE	6	0.02	0.041
206-8422	PAINT	7	0.288	0.0585
206-8422	ASSY	8	0.17	0.02
206-8422-01	PRGM	1	0.074	0
206-8422-01	PUNCH	2	0	0.036
206-8422-01	MISC	3	0.32	0.051
206-8422-01	DM	4	0.075	0.006
206-8422-01	BEND	5	0.333	0.014
206-8422-01	PLATE	6	0.02	0.041
206-8422-01	ASSY	7	0.17	0.02
206-8424	PRGM	1	0.074	0
206-8424	PUNCH	2	0	0.008
206-8424	MISC	3	0.124	0.00813
206-8424	DM	4	0.075	0.006
206-8424	BEND	5	0.428	0.00786
206-8424	PLATE	6	0.02	0.0089
206-8424	ASSY	7	0.17	0.009433
206-8425	PRGM	1	0.074	0
206-8425	PUNCH	2	0	0.01
206-8425	MISC	3	0.32	0.051
206-8425	DM	4	0.075	0.006
206-8425	PLATE	5	0.02	0.02
206-8426	PRGM	1	0.074	0
206-8426	PUNCH	2	0	0.047
206-8426	MISC	3	0.124	0.051
206-8426	DM	4	0.075	0.006
206-8426	BEND	5	0.428	0.0243
206-8426	PLATE	6	0.02	0.04
206-8426	ASSY	7	0.17	0.029563
206-8428	PRGM	1	0.074	0
206-8428	PUNCH	2	0	0.008
206-8428	MISC	3	0.124	0.009483
206-8428	DM	4	0.075	0.006
206-8428	BEND	5	0.285	0.006313
206-8428	PLATE	6	0.02	0.012
206-8430	PRGM	1	0.074	0
206-8430	PUNCH	2	0	0.072
206-8430	MISC	3	0.32	0.051
206-8430	DM	4	0.075	0.006
206-8430	BEND	5	0.428	0.028
206-8430	PLATE	6	0.02	0.087
206-8430	ASSY	7	0.17	0.01
206-8430-01	PRGM	1	0.074	0
206-8430-01	PUNCH	2	0	0.072
206-8430-01	MISC	3	0.32	0.051
206-8430-01	DM	4	0.075	0.006
206-8430-01	BEND	5	0.428	0.028
206-8430-01	PLATE	6	0.02	0.087
206-8430-01	ASSY	7	0.17	0.01
206-8432	PRGM	1	0.074	0
206-8432	PUNCH	2	0	0.043
206-8432	MISC	3	0.32	0.021056
206-8432	DM	4	0.075	0.006
206-8432	BEND	5	0.428	0.028
206-8432	PLATE	6	0.02	0.051
206-8434	PRGM	1	0.074	0
206-8434	PUNCH	2	0	0.068
206-8434	MISC	3	0.32	0.051
206-8434	DM	4	0.075	0.006
206-8434	BEND	5	0.38	0.021
206-8434	PLATE	6	0.02	0.083
206-8434	ASSY	7	0.17	0.029
206-8434-01	PRGM	1	0.074	0
206-8434-01	PUNCH	2	0	0.068
206-8434-01	MISC	3	0.32	0.051
206-8434-01	DM	4	0.075	0.006
206-8434-01	BEND	5	0.38	0.021
206-8434-01	PLATE	6	0.02	0.083
206-8434-01	ASSY	7	0.17	0.029
206-8436	PRGM	1	0.074	0
206-8436	PUNCH	2	0	0.01
206-8436	MISC	3	0.16	0.025
206-8436	PLATE	4	0.02	0.02
206-8438	PRGM	1	0.074	0
206-8438	PUNCH	2	0	0.0025

Component	WorkStation	Operation	Setup Time	Run Time
206-8438	MISC	3	0.16	0.001798
206-8438	PLATE	4	0.02	0.002471
206-8440	PRGM	1	0.074	0
206-8440	PUNCH	2	0	0.017
206-8440	MISC	3	0.124	0.051
206-8440	DM	4	0.075	0.006
206-8440	BEND	5	0.38	0.021
206-8440	PLATE	6	0.02	0.02
206-8440	ASSY	7	0.17	0.005
206-8440-01	PRGM	1	0.074	0
206-8440-01	PUNCH	2	0	0.012
206-8440-01	MISC	3	0.32	0.051
206-8440-01	DM	4	0.075	0.006
206-8440-01	BEND	5	0.333	0.014
206-8440-01	PLATE	6	0.02	0.02
206-8440-01	ASSY	7	0.17	0.005
206-8442	PRGM	1	0.074	0
206-8442	PUNCH	2	0	0.072
206-8442	MISC	3	0.32	0.051
206-8442	DM	4	0.075	0.006
206-8442	BEND	5	0.333	0.014
206-8442	PLATE	6	0.02	0.089444
206-8442	ASSY	7	0.17	0.078
206-8443	PRGM	1	0.074	0
206-8443	PUNCH	2	0	0.04
206-8443	MISC	3	0.124	0.031
206-8443	DM	4	0.075	0.006
206-8443	BEND	5	0.428	0.028
206-8443	PLATE	6	0.02	0.047
206-8443	ASSY	7	0.17	0.015
206-8443-01	PRGM	1	0.074	0
206-8443-01	PUNCH	2	0	0.04
206-8443-01	MISC	3	0.32	0.051
206-8443-01	DM	4	0.075	0.006
206-8443-01	BEND	5	0.428	0.028
206-8443-01	PLATE	6	0.02	0.047
206-8443-01	ASSY	7	0.17	0.015
206-8444	PRGM	1	0.074	0
206-8444	PUNCH	2	0	0.0775
206-8444	MISC	3	0.32	0.051
206-8444	DM	4	0.075	0.006
206-8444	BEND	5	0.285	0.007
206-8444	PLATE	6	0.02	0.096444
206-8444	ASSY	7	0.17	0.098
206-8445	PRGM	1	0.074	0
206-8445	PUNCH	2	0	0.01
206-8445	MISC	3	0.32	0.051
206-8445	DM	4	0.075	0.006
206-8445	BEND	5	0.38	0.021
206-8445	PLATE	6	0.02	0.02
206-8446	PRGM	1	0.074	0
206-8446	PUNCH	2	0	0.034
206-8446	MISC	3	0.124	0.051
206-8446	DM	4	0.075	0.006
206-8446	BEND	5	0.333	0.049
206-8446	PLATE	6	0.02	0.041167
206-8447	PRGM	1	0.074	0
206-8447	PUNCH	2	0	0.058
206-8447	MISC	3	0.32	0.051
206-8447	DM	4	0.075	0.006
206-8447	BEND	5	0.333	0.014
206-8447	PLATE	6	0.02	0.069
206-8448	PRGM	1	0.074	0
206-8448	PUNCH	2	0	0.062
206-8448	MISC	3	0.32	0.051
206-8448	DM	4	0.075	0.006
206-8448	BEND	5	0.333	0.014
206-8448	PLATE	6	0.02	0.074
206-8448	ASSY	7	0.17	0.034
206-8449	PRGM	1	0.074	0
206-8449	PUNCH	2	0	0.006
206-8449	MISC	3	0.124	0.024
206-8449	DM	4	0.075	0.006
206-8449	BEND	5	0.285	0.007
206-8449	PLATE	6	0.02	0.02
206-8450	PRGM	1	0.074	0
206-8450	PUNCH	2	0	0.026
206-8450	MISC	3	0.32	0.051
206-8450	DM	4	0.075	0.006
206-8450	BEND	5	0.38	0.021

Component	WorkStation	Operation	Setup Time	Run Time
206-8450	PLATE	6	0.02	0.029
206-8450	ASSY	7	0.17	0.049278
206-8451	PRGM	1	0.074	0
206-8451	PUNCH	2	0	0.014
206-8451	MISC	3	0.32	0.021056
206-8451	DM	4	0.075	0.006
206-8451	BEND	5	0.285	0.007
206-8451	PLATE	6	0.02	0.02
206-8452	PRGM	1	0.074	0
206-8452	PUNCH	2	0	0.07
206-8452	MISC	3	0.32	0.051
206-8452	DM	4	0.075	0.006
206-8452	BEND	5	0.428	0.028
206-8452	PLATE	6	0.02	0.084
206-8452	ASSY	7	0.17	0.015
206-8452-01	PRGM	1	0.074	0
206-8452-01	PUNCH	2	0	0.07
206-8452-01	MISC	3	0.32	0.051
206-8452-01	DM	4	0.075	0.006
206-8452-01	BEND	5	0.428	0.028
206-8452-01	PLATE	6	0.02	0.084
206-8452-01	ASSY	7	0.17	0.01
206-8453	PRGM	1	0.074	0
206-8453	PUNCH	2	0	0.005
206-8453	MISC	3	0.124	0.051
206-8453	BEND	4	0.333	0.03
206-8453	PLATE	5	0.02	0.02
206-8453-01	PRGM	1	0.074	0
206-8453-01	PUNCH	2	0	0.005
206-8453-01	MISC	3	0.32	0.034
206-8453-01	BEND	4	0.333	0.014
206-8453-01	PLATE	5	0.02	0.02
206-8454	PRGM	1	0.074	0
206-8454	PUNCH	2	0	0.02
206-8454	MISC	3	0.32	0.051
206-8454	DM	4	0.075	0.006
206-8454	BEND	5	0.333	0.014
206-8454	PLATE	6	0.02	0.021
206-8455	PRGM	1	0.074	0
206-8455	PUNCH	2	0	0.004
206-8455	MISC	3	0.124	0.024
206-8455	DM	4	0.075	0.006
206-8455	PLATE	5	0.02	0.02
206-8455	ASSY	6	0.17	0.012
206-8456	PRGM	1	0.074	0
206-8456	PUNCH	2	0	0.0085
206-8456	MISC	3	0.124	0.01153
206-8456	DM	4	0.075	0.006
206-8456	BEND	5	0.38	0.009061
206-8456	PLATE	6	0.02	0.009924
206-8457	PRGM	1	0.074	0
206-8457	PUNCH	2	0	0.033
206-8457	MISC	3	0.32	0.051
206-8457	DM	4	0.075	0.006
206-8457	BEND	5	0.38	0.021
206-8457	PLATE	6	0.02	0.037
206-8457	ASSY	7	0.17	0.054
206-8458	PRGM	1	0.074	0
206-8458	PUNCH	2	0	0.0775
206-8458	MISC	3	0.32	0.051
206-8458	DM	4	0.075	0.006
206-8458	BEND	5	0.285	0.007
206-8458	PLATE	6	0.02	0.096444
206-8458	ASSY	7	0.17	0.058778
206-8460	PRGM	1	0.074	0
206-8460	PUNCH	2	0	0.008
206-8460	MISC	3	0.124	0.00703
206-8460	DM	4	0.075	0.006
206-8460	BEND	5	0.285	0.00892
206-8460	PLATE	6	0.02	0.009924
206-8461	PRGM	1	0.074	0
206-8461	PUNCH	2	0	0.009
206-8461	MISC	3	0.124	0.015
206-8461	DM	4	0.075	0.006
206-8461	BEND	5	0.285	0.024
206-8461	PLATE	6	0.02	0.02
206-8461	ASSY	7	0.17	0.02
206-8462	PRGM	1	0.074	0
206-8462	PUNCH	2	0	0.006
206-8462	MISC	3	0.124	0.01

Component	WorkStation	Operation	Setup Time	Run Time
206-8462	DM	4	0.075	0.006
206-8462	BEND	5	0.285	0.02
206-8462	PLATE	6	0.02	0.02
206-8463	PRGM	1	0.074	0
206-8463	PUNCH	2	0	0.012
206-8463	MISC	3	0.32	0.051
206-8463	DM	4	0.075	0.006
206-8463	BEND	5	0.428	0.028
206-8463	PLATE	6	0.02	0.02
206-8464	PRGM	1	0.074	0
206-8464	PUNCH	2	0	0.216
206-8464	MISC	3	0.32	0.051
206-8464	DM	4	0.075	0.006
206-8464	BEND	5	0.475	0.035
206-8464	PLATE	6	0.02	0.273
206-8464	PAINT	7	0.288	0.214
206-8464	ASSY	8	0.17	0.015
206-8464-01	PRGM	1	0.075	0
206-8464-01	PUNCH	2	0.216	0
206-8464-01	MISC	3	0.32	0.051
206-8464-01	DM	4	0.075	0.006
206-8464-01	BEND	5	0.523	0.042
206-8464-01	PLATE	6	0.02	0.273
206-8464-01	PAINT	7	0.288	0.214
206-8464-01	PSASSY	8	0	0.5
206-8465	PRGM	1	0.075	0
206-8465	PUNCH	2	0	0.104
206-8465	MISC	3	0.32	0.051
206-8465	DM	4	0.075	0.006
206-8465	BEND	5	0.618	0.056
206-8465	PLATE	6	0.02	0.064667
206-8465	PAINT	7	0.288	0.0405
206-8465	ASSY	8	0.17	0.02
206-8465-01	PRGM	1	0.074	0
206-8465-01	PUNCH	2	0	0.101
206-8465-01	MISC	3	0.32	0.051
206-8465-01	DM	4	0.075	0.006
206-8465-01	BEND	5	0.618	0.056
206-8465-01	PLATE	6	0.02	0.126333
206-8465-01	ASSY	7	0.17	0.005
206-8466	PRGM	1	0.074	0
206-8466	PUNCH	2	0	0.033
206-8466	MISC	3	0.32	0.021397
206-8466	DM	4	0.075	0.006
206-8466	BEND	5	0.428	0.024513
206-8466	PLATE	6	0.02	0.016
206-8466-01	PRGM	1	0.074	0
206-8466-01	PUNCH	2	0	0.059
206-8466-01	MISC	3	0.32	0.051
206-8466-01	DM	4	0.075	0.006
206-8466-01	BEND	5	0.428	0.028
206-8466-01	PLATE	6	0.02	0.035667
206-8467	PRGM	1	0.074	0
206-8467	PUNCH	2	0	0.026
206-8467	MISC	3	0.32	0.051
206-8467	DM	4	0.075	0.006
206-8467	BEND	5	0.285	0.007
206-8467	PLATE	6	0.02	0.029
206-8468	PRGM	1	0.074	0
206-8468	PUNCH	2	0	0.026
206-8468	MISC	3	0.124	0.024
206-8468	DM	4	0.075	0.006
206-8468	BEND	5	0.57	0.015864
206-8468	PLATE	6	0.02	0.029
206-8468	ASSY	7	0.17	0.039
206-8469	PRGM	1	0.074	0
206-8469	PUNCH	2	0	0.007
206-8469	MISC	3	0.124	0.02
206-8469	DM	4	0.075	0.006
206-8469	BEND	5	0.285	0.007
206-8469	PLATE	6	0.02	0.02
206-8470	PRGM	1	0.074	0
206-8470	PUNCH	2	0	0.015
206-8470	MISC	3	0.32	0.051
206-8470	DM	4	0.075	0.006
206-8470	BEND	5	0.428	0.028
206-8470	PLATE	6	0.02	0.02
206-8470	ASSY	7	0.17	0.059
206-8472	PRGM	1	0.074	0
206-8472	PUNCH	2	0	0.0675

Component	WorkStation	Operation	Setup Time	Run Time
206-8472	MISC	3	0.32	0.051
206-8472	DM	4	0.075	0.006
206-8472	BEND	5	0.428	0.028
206-8472	PLATE	6	0.02	0.083944
206-8472	ASSY	7	0.17	0.068778
206-8473	PRGM	1	0.074	0
206-8473	PUNCH	2	0	0.008
206-8473	MISC	3	0.124	0.014
206-8473	DM	4	0.075	0.006
206-8473	BEND	5	0.38	0.021
206-8473	PLATE	6	0.02	0.02
206-8473	ASSY	7	0.17	0.044
206-8474	PRGM	1	0.074	0
206-8474	PUNCH	2	0	0.091
206-8474	MISC	3	0.32	0.051
206-8474	DM	4	0.075	0.006
206-8474	BEND	5	0.523	0.042
206-8474	PLATE	6	0.02	0.055944
206-8474	ASSY	7	0.17	0.069
206-8475	PRGM	1	0.074	0
206-8475	PUNCH	2	0	0.006
206-8475	MISC	3	0.32	0.051
206-8475	DRILL	4	0.094	0.002
206-8475	DM	5	0.075	0.006
206-8475	BEND	6	0.285	0.007
206-8475	PLATE	7	0.02	0.02
206-8475	ASSY	8	0.17	0.015
206-8476	PRGM	1	0.074	0
206-8476	PUNCH	2	0	0.093
206-8476	MISC	3	0.32	0.051
206-8476	DM	4	0.075	0.006
206-8476	PLATE	5	0.02	0.114
206-8476-01	PRGM	1	0.074	0
206-8476-01	PUNCH	2	0	0.056
206-8476-01	MISC	3	0.32	0.051
206-8476-01	DM	4	0.075	0.006
206-8476-01	PLATE	5	0.02	0.067
206-8476-01	ASSY	6	0.17	0.02
206-8476-02	PRGM	1	0.074	0
206-8476-02	PUNCH	2	0	0.04
206-8476-02	MISC	3	0.32	0.051
206-8476-02	DM	4	0.075	0.006
206-8476-02	PLATE	5	0.02	0.046
206-8477	PRGM	1	0.074	0
206-8477	PUNCH	2	0	0.02
206-8477	MISC	3	0.32	0.051
206-8477	DM	4	0.075	0.006
206-8477	BEND	5	0.428	0.028
206-8477	PLATE	6	0.02	0.02
206-8477	ASSY	7	0.17	0.02
206-8478	PRGM	1	0.074	0
206-8478	PUNCH	2	0	0.037
206-8478	MISC	3	0.32	0.051
206-8478	DM	4	0.075	0.006
206-8478	BEND	5	0.523	0.042
206-8478	PLATE	6	0.02	0.042
206-8478	ASSY	7	0.17	0.069
206-8480	PRGM	1	0.074	0
206-8480	PUNCH	2	0	0.004
206-8480	MISC	3	0.32	0.051
206-8480	DM	4	0.075	0.006
206-8480	PLATE	5	0.02	0.02
206-8481	PRGM	1	0.074	0
206-8481	PUNCH	2	0	0.019
206-8481	MISC	3	0.32	0.051
206-8481	DM	4	0.075	0.006
206-8481	BEND	5	0.428	0.028
206-8481	PLATE	6	0.02	0.02
206-8482	PSASSY	1	0	0.25
206-8482	PAINT	2	0.275	0.125
206-8482	MISC	3	0	0.033
206-8482-01	PSASSY	1	0	0.25
206-8482-01	PAINT	2	0.275	0.125
206-8482-01	MISC	3	0	0.033
206-8483	PRGM	1	0.074	0
206-8483	PUNCH	2	0	0.023
206-8483	MISC	3	0.32	0.051
206-8483	DM	4	0.075	0.006
206-8483	BEND	5	0.333	0.014
206-8483	PLATE	6	0.02	0.025

Component	WorkStation	Operation	Setup Time	Run Time
206-8483	PAINT	7	0.288	0.0248
206-8483	ASSY	8	0.17	0.02
206-8483-01	PRGM	1	0.074	0
206-8483-01	PUNCH	2	0	0.022
206-8483-01	MISC	3	0.32	0.020652
206-8483-01	DM	4	0.075	0.006
206-8483-01	BEND	5	0.333	0.014
206-8483-01	PLATE	6	0.02	0.024
206-8483-01	PAINT	7	0.288	0.025205
206-8483-01	ASSY	8	0.17	0.02
206-8484	PRGM	1	0.074	0
206-8484	PUNCH	2	0	0.021
206-8484	MISC	3	0.32	0.051
206-8484	DM	4	0.075	0.006
206-8484	BEND	5	0.333	0.014
206-8484	PLATE	6	0.02	0.022
206-8484	PAINT	7	0.288	0.02455
206-8484-01	PRGM	1	0.074	0
206-8484-01	PUNCH	2	0	0.02
206-8484-01	MISC	3	0.32	0.020652
206-8484-01	DM	4	0.075	0.006
206-8484-01	BEND	5	0.333	0.014
206-8484-01	PLATE	6	0.02	0.021
206-8484-01	PAINT	7	0.288	0.024955
206-8486	PRGM	1	0.074	0
206-8486	PUNCH	2	0	0.004
206-8486	MISC	3	0.32	0.051
206-8486	DM	4	0.075	0.006
206-8486	PLATE	5	0.02	0.02
206-8486-01	PRGM	1	0.074	0
206-8486-01	PUNCH	2	0	0.004
206-8486-01	MISC	3	0.32	0.051
206-8486-01	DM	4	0.075	0.006
206-8486-01	PLATE	5	0.02	0.02
206-8486-02	PRGM	1	0.074	0
206-8486-02	PUNCH	2	0	0.004
206-8486-02	MISC	3	0.32	0.051
206-8486-02	DM	4	0.075	0.006
206-8486-02	PLATE	5	0.02	0.02
206-8487	PRGM	1	0.074	0
206-8487	PUNCH	2	0	0.009
206-8487	MISC	3	0.32	0.051
206-8487	DM	4	0.075	0.006
206-8487	PLATE	5	0.02	0.02
206-8487	PSASSY	6	0	0.02
206-8488	PRGM	1	0.074	0
206-8488	PUNCH	2	0	0.093
206-8488	MISC	3	0.124	0.056353
206-8488	DM	4	0.075	0.03
206-8488	BEND	5	0.428	0.037412
206-8488	PLATE	6	0.02	0.116412
206-8488	PAINT	7	0.288	0.092029
206-8489	PRGM	1	0.074	0
206-8489	PUNCH	2	0	0.006
206-8489	MISC	3	0.32	0.051
206-8489	DM	4	0.075	0.006
206-8489	BEND	5	0.428	0.028
206-8489	PLATE	6	0.02	0.02
206-8490	PRGM	1	0.074	0
206-8490	PUNCH	2	0	0.119
206-8490	MISC	3	0.32	0.051
206-8490	DM	4	0.075	0.006
206-8490	BEND	5	0.285	0.007
206-8490	PLATE	6	0.02	0.149
206-8490	PAINT	7	0.288	0.171
206-8490	ASSY	8	0.17	0.059
206-8492	PRGM	1	0.074	0
206-8492	PUNCH	2	0	0.078
206-8492	MISC	3	0.32	0.02
206-8492	DM	4	0.075	0.006
206-8492	PLATE	5	0.02	0.096
206-8492	PAINT	6	0.288	0.152
206-8492	ASSY	7	0.17	0.078
206-8492-01	PRGM	1	0.074	0
206-8492-01	PUNCH	2	0	0.078
206-8492-01	MISC	3	0.32	0.051
206-8492-01	DM	4	0.075	0.006
206-8492-01	PLATE	5	0.02	0.096
206-8492-01	PAINT	6	0.288	0.152
206-8492-01	PSASSY	7	0	0.14

Component	WorkStation	Operation	Setup Time	Run Time
206-8493	PRGM	1	0.074	0
206-8493	PUNCH	2	0	0.018
206-8493	MISC	3	0.124	0.022
206-8493	DM	4	0.075	0.006
206-8493	BEND	5	0.428	0.010758
206-8493	PLATE	6	0.02	0.02
206-8493	PAINT	7	0.288	0.017818
206-8493-01	PRGM	1	0.074	0
206-8493-01	PUNCH	2	0	0.012
206-8493-01	MISC	3	0.32	0.026
206-8493-01	DM	4	0.075	0.006
206-8493-01	BEND	5	0.333	0.03
206-8493-01	PLATE	6	0.02	0.02
206-8493-01	PAINT	7	0.288	0.03
206-8493-02	PRGM	1	0.074	0
206-8493-02	PUNCH	2	0	0.011
206-8493-02	MISC	3	0.124	0.022
206-8493-02	DM	4	0.075	0.006
206-8493-02	BEND	5	0.428	0.010758
206-8493-02	PLATE	6	0.02	0.02
206-8493-02	PAINT	7	0.288	0.017818
206-8496	PRGM	1	0.074	0
206-8496	PUNCH	2	0	0.015
206-8496	MISC	3	0.32	0.051
206-8496	DM	4	0.075	0.006
206-8496	PLATE	5	0.02	0.02
206-8496	SILKSC	6	0.933	0.005
206-8496-01	PRGM	1	0.074	0
206-8496-01	PUNCH	2	0	0.017
206-8496-01	MISC	3	0.32	0.051
206-8496-01	DM	4	0.075	0.006
206-8496-01	PLATE	5	0.02	0.02
206-8496-01	SILKSC	6	0.933	0.005
207-1022	PRGM	1	0.074	0
207-1022	PUNCH	2	0	0.0065
207-1022	MISC	3	0.32	0.005194
207-1022	DM	4	0.075	0.006
207-1022	BEND	5	0.285	0.007
207-1022	PLATE	6	0.02	0.004937
207-1022	ASSY	7	0.17	0.005462
207-1024	PRGM	1	0.074	0
207-1024	PUNCH	2	0	0.006
207-1024	MISC	3	0.32	0.005194
207-1024	DM	4	0.075	0.006
207-1024	BEND	5	0.285	0.007
207-1024	PLATE	6	0.02	0.004937
207-1024-01	PRGM	1	0.074	0
207-1024-01	PUNCH	2	0	0.006
207-1024-01	MISC	3	0.32	0.005194
207-1024-01	DM	4	0.075	0.006
207-1024-01	BEND	5	0.285	0.007
207-1024-01	PLATE	6	0.02	0.004937
207-1026	PRGM	1	0.074	0
207-1026	PUNCH	2	0	0.0075
207-1026	MISC	3	0.32	0.005194
207-1026	DM	4	0.075	0.006
207-1026	BEND	5	0.57	0.004021
207-1026	PLATE	6	0.02	0.004937
207-6112	PRGM	1	0.074	0
207-6112	PUNCH	2	0	0.018
207-6112	MISC	3	0.32	0.051
207-6112	DRILL	4	0.094	0.011
207-6112	DM	5	0.075	0.006
207-6112	BEND	6	0.333	0.014
207-6112	PLATE	7	0.02	0.02
207-6112	ASSY	8	0.17	0.034
207-6112-01	PRGM	1	0.074	0
207-6112-01	PUNCH	2	0	0.016
207-6112-01	MISC	3	0.32	0.051
207-6112-01	DM	4	0.075	0.006
207-6112-01	BEND	5	0.285	0.007
207-6112-01	PLATE	6	0.02	0.02
207-6114	PRGM	1	0.074	0
207-6114	PUNCH	2	0	0.028
207-6114	MISC	3	0.32	0.051
207-6114	DM	4	0.075	0.006
207-6114	BEND	5	0.285	0.007
207-6114	PLATE	6	0.02	0.031
207-6114	ASSY	7	0.17	0.01
207-6114-01	PRGM	1	0.074	0

Component	WorkStation	Operation	Setup Time	Run Time
207-6114-01	PUNCH	2	0	0.011
207-6114-01	MISC	3	0.32	0.051
207-6114-01	DM	4	0.075	0.006
207-6114-01	PLATE	5	0.02	0.02
207-6115	PRGM	1	0.074	0
207-6115	PUNCH	2	0	0.005
207-6115	MISC	3	0.32	0.051
207-6115	DM	4	0.075	0.006
207-6115	BEND	5	0.333	0.014
207-6115	PLATE	6	0.02	0.02
207-6115	ASSY	7	0.17	0.02
207-6116	MISC	1	0.32	0.051
207-6116	DM	2	0.075	0.006
207-6116	BEND	3	0.475	0.035
207-6116	PLATE	4	0.02	0.087444
207-6116	ASSY	5	0.17	0.049
207-6117	PRGM	1	0.074	0
207-6117	PUNCH	2	0	0.049
207-6117	MISC	3	0.32	0.051
207-6117	DM	4	0.075	0.006
207-6117	BEND	5	0.38	0.021
207-6117	PLATE	6	0.02	0.058
207-6117	ASSY	7	0.17	0.039
207-6117-01	PRGM	1	0.074	0
207-6117-01	PUNCH	2	0	0.044
207-6117-01	MISC	3	0.32	0.051
207-6117-01	DM	4	0.075	0.006
207-6117-01	BEND	5	0.38	0.021
207-6117-01	PLATE	6	0.02	0.051
207-6117-01	ASSY	7	0.17	0.039
207-6118	PRGM	1	0.074	0
207-6118	PUNCH	2	0	0.111
207-6118	MISC	3	0.32	0.051
207-6118	DM	4	0.075	0.006
207-6118	BEND	5	0.428	0.028
207-6118	PLATE	6	0.02	0.067944
207-6118	ASSY	7	0.17	0.039
207-6118-01	PRGM	1	0.074	0
207-6118-01	PUNCH	2	0	0.0555
207-6118-01	MISC	3	0.32	0.051
207-6118-01	DM	4	0.075	0.006
207-6118-01	BEND	5	0.428	0.028
207-6118-01	PLATE	6	0.02	0.068083
207-6118-01	ASSY	7	0.17	0.059
207-6119	PRGM	1	0.074	0
207-6119	PUNCH	2	0	0.065
207-6119	MISC	3	0.32	0.051
207-6119	DM	4	0.075	0.006
207-6119	BEND	5	0.428	0.028
207-6119	PLATE	6	0.02	0.078
207-6119	ASSY	7	0.17	0.098
207-6122	PRGM	1	0.074	0
207-6122	PUNCH	2	0	0.014
207-6122	MISC	3	0.32	0.051
207-6122	DM	4	0.075	0.006
207-6122	BEND	5	0.333	0.014
207-6122	PLATE	6	0.02	0.02
207-6122-01	PRGM	1	0.074	0
207-6122-01	PUNCH	2	0	0.014
207-6122-01	MISC	3	0.32	0.051
207-6122-01	DM	4	0.075	0.006
207-6122-01	BEND	5	0.333	0.014
207-6122-01	PLATE	6	0.02	0.02
207-6124	PRGM	1	0.074	0
207-6124	PUNCH	2	0	0.019
207-6124	MISC	3	0.32	0.051
207-6124	DM	4	0.075	0.006
207-6124	BEND	5	0.333	0.014
207-6124	PLATE	6	0.02	0.02
207-6130-03	CUT	1	0.095	0.015
207-6130-03	MISC	2	0.32	0.021056
207-6130-03	DRILL	3	0.094	0.023
207-6130-03	PLATE	4	0.02	0.02
207-6130-04	CUT	1	0.095	0.015
207-6130-04	MISC	2	0.32	0.021056
207-6130-04	DRILL	3	0.094	0.034
207-6130-04	PLATE	4	0.02	0.02
207-6130-05	CUT	1	0.095	0.015
207-6130-05	MISC	2	0.32	0.021056
207-6130-05	DRILL	3	0.094	0.034

Component	WorkStation	Operation	Setup Time	Run Time
207-6130-05	PLATE	4	0.02	0.02
207-6132	COILS	1	0.5	0.1875
207-6133	PRGM	1	0.074	0
207-6133	PUNCH	2	0	0.012
207-6133	MISC	3	0.32	0.051
207-6133	DM	4	0.075	0.006
207-6133	PLATE	5	0.02	0.02
207-6133-01	PRGM	1	0.074	0
207-6133-01	PUNCH	2	0	0.009
207-6133-01	MISC	3	0.32	0.051
207-6133-01	DM	4	0.075	0.006
207-6133-01	PLATE	5	0.02	0.02
207-6134	PRGM	1	0.074	0
207-6134	PUNCH	2	0	0.015
207-6134	MISC	3	0.32	0.009673
207-6134	DM	4	0.075	0.006
207-6134	BEND	5	0.38	0.008064
207-6134	PLATE	6	0.02	0.02
207-6134	ASSY	7	0.17	0.01
207-6134-01	PRGM	1	0.074	0
207-6134-01	PUNCH	2	0	0.013
207-6134-01	MISC	3	0.32	0.021056
207-6134-01	DM	4	0.075	0.006
207-6134-01	BEND	5	0.38	0.021
207-6134-01	PLATE	6	0.02	0.02
207-6134-01	ASSY	7	0.17	0.01
207-6135	PRGM	1	0.074	0
207-6135	PUNCH	2	0	0.005
207-6135	MISC	3	0.32	0.021056
207-6135	DM	4	0.075	0.006
207-6135	BEND	5	0.333	0.014
207-6135	PLATE	6	0.02	0.02
207-6135-01	PRGM	1	0.074	0
207-6135-01	PUNCH	2	0	0.005
207-6135-01	MISC	3	0.32	0.021056
207-6135-01	DM	4	0.075	0.006
207-6135-01	BEND	5	0.333	0.014
207-6135-01	PLATE	6	0.02	0.02
207-6136	CUT	1	0.095	0.015
207-6136	MISC	2	0.32	0.021397
207-6136	DRILL	3	0.094	0.023
207-6136	PLATE	4	0.02	0.02
207-6136-01	CUT	1	0.095	0.015
207-6136-01	MISC	2	0.32	0.021397
207-6136-01	DRILL	3	0.094	0.028
207-6136-01	PLATE	4	0.02	0.02
207-6136-02	CUT	1	0.095	0.015
207-6136-02	MISC	2	0.32	0.021397
207-6136-02	DRILL	3	0.094	0.028
207-6136-02	PLATE	4	0.02	0.02
207-6138	COILS	1	0.5	0.28125
207-6140	CUT	1	0.095	0.015
207-6140	MISC	2	0.32	0.021056
207-6140	DRILL	3	0.094	0.023
207-6140	PLATE	4	0.02	0.02
207-6140-01	CUT	1	0.095	0.015
207-6140-01	MISC	2	0.32	0.021056
207-6140-01	DRILL	3	0.094	0.028
207-6140-01	PLATE	4	0.02	0.02
207-6140-02	CUT	1	0.095	0.015
207-6140-02	MISC	2	0.32	0.021056
207-6140-02	DRILL	3	0.094	0.028
207-6140-02	PLATE	4	0.02	0.02
207-6142-01	PRGM	1	0.074	0
207-6142-01	PUNCH	2	0	0.012
207-6142-01	MISC	3	0.32	0.051
207-6142-01	DM	4	0.075	0.006
207-6142-01	BEND	5	0.333	0.014
207-6142-01	PLATE	6	0.02	0.02
207-6144	PRGM	1	0.074	0
207-6144	PUNCH	2	0	0.007
207-6144	MISC	3	0.32	0.051
207-6144	DM	4	0.075	0.006
207-6144	BEND	5	0.333	0.014
207-6144	PLATE	6	0.02	0.02
207-6146	PRGM	1	0.074	0
207-6146	PUNCH	2	0	0.013
207-6146	MISC	3	0.32	0.051
207-6146	DM	4	0.075	0.006
207-6146	BEND	5	0.523	0.042

Component	WorkStation	Operation	Setup Time	Run Time
207-6146	PLATE	6	0.02	0.02
207-6146	ASSY	7	0.17	0.005
207-6148	PRGM	1	0.074	0
207-6148	PUNCH	2	0	0.055
207-6148	MISC	3	0.32	0.051
207-6148	DM	4	0.075	0.006
207-6148	PLATE	5	0.02	0.066
207-6148-01	PRGM	1	0.074	0
207-6148-01	PUNCH	2	0	0.048
207-6148-01	MISC	3	0.32	0.051
207-6148-01	DM	4	0.075	0.006
207-6148-01	PLATE	5	0.02	0.057
207-6158	PRGM	1	0.074	0
207-6158	PUNCH	2	0	0.108
207-6158	MISC	3	0.32	0.051
207-6158	DM	4	0.075	0.006
207-6158	BEND	5	0.428	0.028
207-6158	PLATE	6	0.02	0.066444
207-6158	ASSY	7	0.17	0.056278
207-6172	PRGM	1	0.074	0
207-6172	PUNCH	2	0	0.015
207-6172	MISC	3	0.32	0.051
207-6172	DM	4	0.075	0.006
207-6172	BEND	5	0.333	0.014
207-6172	PLATE	6	0.02	0.02
207-6172	ASSY	7	0.17	0.01
207-6174	CUT	1	0.35	0.1
207-6174	MILL	2	0.75	0.12
207-6174	MISC	3	0.1	0.25
207-6174	PLATE	4	0.02	0.02
207-6174-01	CUT	1	0.35	0.1
207-6174-01	MILL	2	0.75	0.12
207-6174-01	MISC	3	0.1	0.25
207-6174-01	PLATE	4	0.02	0.02
207-6176-02	CUT	1	0.3	0.07
207-6176-02	MILL	2	1	0.05
207-6176-02	MISC	3	0.32	0.051
207-6176-02	PLATE	4	0.02	0.02
207-6176-03	CUT	1	0.3	0.07
207-6176-03	MILL	2	1	0.05
207-6176-03	MISC	3	0.32	0.051
207-6176-03	PLATE	4	0.02	0.02
207-6180	PRGM	1	0.074	0
207-6180	PUNCH	2	0	0.006
207-6180	MISC	3	0.32	0.051
207-6180	DM	4	0.075	0.006
207-6180	BEND	5	0.285	0.007
207-6180	PLATE	6	0.02	0.02
207-6180	ASSY	7	0.17	0.005
207-6182	COILS	1	0.5	0.153125
207-7126	PRGM	1	0.074	0
207-7126	PUNCH	2	0	0.005
207-7126	MISC	3	0.32	0.051
207-7126	DM	4	0.075	0.006
207-7126	BEND	5	0.285	0.007
207-7126	PLATE	6	0.02	0.02
207-7126-01	PRGM	1	0.074	0
207-7126-01	PUNCH	2	0	0.004
207-7126-01	MISC	3	0.32	0.051
207-7126-01	DM	4	0.075	0.006
207-7126-01	BEND	5	0.285	0.007
207-7126-01	PLATE	6	0.02	0.02
207-7126-02	PRGM	1	0.074	0
207-7126-02	PUNCH	2	0	0.004
207-7126-02	MISC	3	0.32	0.051
207-7126-02	DM	4	0.075	0.006
207-7126-02	BEND	5	0.285	0.007
207-7126-02	PLATE	6	0.02	0.02
207-7126-03	PRGM	1	0.074	0
207-7126-03	PUNCH	2	0	0.004
207-7126-03	MISC	3	0.32	0.051
207-7126-03	DM	4	0.075	0.006
207-7126-03	BEND	5	0.285	0.007
207-7126-03	PLATE	6	0.02	0.02
207-7128	PRGM	1	0.074	0
207-7128	PUNCH	2	0	0.006
207-7128	MISC	3	0.32	0.051
207-7128	DM	4	0.075	0.006
207-7128	BEND	5	0.285	0.007
207-7128	PLATE	6	0.02	0.02

Component	WorkStation	Operation	Setup Time	Run Time
207-7128-01	PRGM	1	0.074	0
207-7128-01	PUNCH	2	0	0.006
207-7128-01	MISC	3	0.32	0.051
207-7128-01	DM	4	0.075	0.006
207-7128-01	BEND	5	0.285	0.007
207-7128-01	PLATE	6	0.02	0.02
207-7130	PRGM	1	0.074	0
207-7130	PUNCH	2	0	0.009
207-7130	MISC	3	0.32	0.051
207-7130	DM	4	0.075	0.006
207-7130	BEND	5	0.428	0.028
207-7130	PLATE	6	0.02	0.02
207-7130-01	PRGM	1	0.074	0
207-7130-01	PUNCH	2	0	0.006
207-7130-01	MISC	3	0.32	0.051
207-7130-01	DM	4	0.075	0.006
207-7130-01	BEND	5	0.428	0.028
207-7130-01	PLATE	6	0.02	0.02
207-7130-02	PRGM	1	0.074	0
207-7130-02	PUNCH	2	0	0.006
207-7130-02	MISC	3	0.32	0.051
207-7130-02	DM	4	0.075	0.006
207-7130-02	BEND	5	0.428	0.028
207-7130-02	PLATE	6	0.02	0.02
207-7132	PRGM	1	0.074	0
207-7132	PUNCH	2	0	0.007
207-7132	MISC	3	0.32	0.051
207-7132	DM	4	0.075	0.006
207-7132	PLATE	5	0.02	0.02
207-7132-01	PRGM	1	0.074	0
207-7132-01	PUNCH	2	0	0.007
207-7132-01	MISC	3	0.32	0.051
207-7132-01	DM	4	0.075	0.006
207-7132-01	BEND	5	0.285	0.007
207-7132-01	PLATE	6	0.02	0.02
207-7132-02	PRGM	1	0.074	0
207-7132-02	PUNCH	2	0	0.008
207-7132-02	MISC	3	0.32	0.051
207-7132-02	DM	4	0.075	0.006
207-7132-02	BEND	5	0.285	0.007
207-7132-02	PLATE	6	0.02	0.02
207-7135	CUT	1	0.095	0.015
207-7135	MISC	2	0.32	0.051
207-7135	PLATE	3	0.02	0.02
207-8110	PRGM	1	0.074	0
207-8110	PUNCH	2	0	0.0015
207-8110	MISC	3	0.32	0.001163
207-8110	DM	4	0.075	0.001422
207-8110	BEND	5	0.333	0.001345
207-8110	PLATE	6	0.02	0.002476
207-8112	PRGM	1	0.074	0
207-8112	PUNCH	2	0	0.057
207-8112	MISC	3	0.32	0.051
207-8112	DM	4	0.075	0.006
207-8112	BEND	5	0.428	0.028
207-8112	PLATE	6	0.02	0.070444
207-8112-01	PRGM	1	0.074	0
207-8112-01	PUNCH	2	0	0.069
207-8112-01	MISC	3	0.32	0.051
207-8112-01	DM	4	0.075	0.006
207-8112-01	BEND	5	0.428	0.028
207-8112-01	PLATE	6	0.02	0.041583
207-8120	PARTS	1	0	0
207-8120	PASH	2	0	0.375
207-8120	PTST	3	0	0
207-8120-01	PARTS	1	0	0
207-8120-01	PASH	2	0	0.5
207-8120-01	PTST	3	0	0
207-8128	PRGM	1	0.074	0
207-8128	PUNCH	2	0	0.05925
207-8128	MISC	3	0.32	0.051
207-8128	DM	4	0.075	0.006
207-8128	PLATE	5	0.02	0.073917
207-8128	ASSY	6	0.17	0.098278
207-8128-01	PRGM	1	0.074	0
207-8128-01	PUNCH	2	0	0.05925
207-8128-01	MISC	3	0.32	0.051
207-8128-01	DM	4	0.075	0.006
207-8128-01	PLATE	5	0.02	0.073917
207-8128-01	ASSY	6	0.17	0.046778

Component	WorkStation	Operation	Setup Time	Run Time
207-8128-02	MISC	1	0.32	0.051
207-8128-02	DM	2	0.075	0.006
207-8128-02	PLATE	3	0.02	0.074125
207-8128-02	ASSY	4	0.17	0.046188
207-8128-03	MISC	1	0.32	0.051
207-8128-03	DM	2	0.075	0.006
207-8128-03	PLATE	3	0.02	0.074125
207-8128-03	ASSY	4	0.17	0.047958
207-8130	PRGM	1	0.074	0
207-8130	PUNCH	2	0	0.028
207-8130	MISC	3	0.32	0.022537
207-8130	DM	4	0.075	0.006
207-8130	BEND	5	0.428	0.028
207-8130	PLATE	6	0.02	0.033315
207-8130	ASSY	7	0.17	0.022139
207-8136	PRGM	1	0.074	0
207-8136	PUNCH	2	0	0.095
207-8136	MISC	3	0.32	0.051
207-8136	DM	4	0.075	0.006
207-8136	BEND	5	0.428	0.028
207-8136	PLATE	6	0.02	0.057944
207-8136	ASSY	7	0.17	0.071278
207-8136-01	MISC	1	0.32	0.051
207-8136-01	DM	2	0.075	0.006
207-8136-01	BEND	3	0.475	0.035
207-8136-01	PLATE	4	0.02	0.044375
207-8136-01	ASSY	5	0.17	0.072458
207-8138	PRGM	1	0.074	0
207-8138	PUNCH	2	0	0.022
207-8138	MISC	3	0.32	0.051
207-8138	DM	4	0.075	0.006
207-8138	BEND	5	0.618	0.056
207-8138	PLATE	6	0.02	0.023
207-8138-01	PRGM	1	0.074	0
207-8138-01	PUNCH	2	0	0.022
207-8138-01	MISC	3	0.32	0.023278
207-8138-01	DM	4	0.075	0.006
207-8138-01	BEND	5	0.618	0.007563
207-8138-01	PLATE	6	0.02	0.023
207-8138-02	PRGM	1	0.074	0
207-8138-02	PUNCH	2	0	0.023
207-8138-02	MISC	3	0.32	0.051
207-8138-02	DM	4	0.075	0.006
207-8138-02	BEND	5	0.618	0.056
207-8138-02	PLATE	6	0.02	0.025
207-8138-03	PRGM	1	0.074	0
207-8138-03	PUNCH	2	0	0.0115
207-8138-03	MISC	3	0.32	0.01025
207-8138-03	DM	4	0.075	0.006
207-8138-03	BEND	5	0.57	0.007797
207-8138-03	PLATE	6	0.02	0.012396
207-8140	PRGM	1	0.074	0
207-8140	PUNCH	2	0	0.075
207-8140	MISC	3	0.32	0.051
207-8140	DRILL	4	0.094	0.006
207-8140	DM	5	0.075	0.006
207-8140	BEND	6	0.285	0.007
207-8140	PLATE	7	0.02	0.092
207-8140	ASSY	8	0.17	0.015
207-8140-01	PRGM	1	0.074	0
207-8140-01	PUNCH	2	0	0.035
207-8140-01	MISC	3	0.32	0.051
207-8140-01	DM	4	0.075	0.006
207-8140-01	BEND	5	0.285	0.007
207-8140-01	PLATE	6	0.02	0.04
207-8140-01	DRILL	7	0.094	0.006
207-8140-01	ASSY	8	0.17	0.015
207-8144	CUT	1	0.095	0.015
207-8144	MISC	2	0.32	0.051
207-8144	PLATE	3	0.02	0.02
207-8146	PRGM	1	0.074	0
207-8146	PUNCH	2	0	0.008
207-8146	MISC	3	0.32	0.051
207-8146	DM	4	0.075	0.006
207-8146	BEND	5	0.285	0.007
207-8146	PLATE	6	0.02	0.02
207-8148-01	PRGM	1	0.074	0
207-8148-01	PUNCH	2	0	0.015
207-8148-01	MISC	3	0.32	0.051
207-8148-01	DM	4	0.075	0.006

Component	WorkStation	Operation	Setup Time	Run Time
207-8148-01	BEND	5	0.333	0.014
207-8148-01	PLATE	6	0.02	0.02
207-8149	PRGM	1	0.074	0
207-8149	PUNCH	2	0	0.014
207-8149	MISC	3	0.32	0.051
207-8149	DM	4	0.075	0.006
207-8149	BEND	5	0.333	0.014
207-8149	PLATE	6	0.02	0.02
207-8149-01	PRGM	1	0.074	0
207-8149-01	PUNCH	2	0	0.014
207-8149-01	MISC	3	0.32	0.051
207-8149-01	DM	4	0.075	0.006
207-8149-01	BEND	5	0.333	0.014
207-8149-01	PLATE	6	0.02	0.02
207-8149-02	PRGM	1	0.074	0
207-8149-02	PUNCH	2	0	0.009
207-8149-02	MISC	3	0.32	0.051
207-8149-02	DM	4	0.075	0.006
207-8149-02	BEND	5	0.333	0.014
207-8149-02	PLATE	6	0.02	0.02
207-8149-03	PRGM	1	0.074	0
207-8149-03	PUNCH	2	0	0.009
207-8149-03	MISC	3	0.32	0.051
207-8149-03	DM	4	0.075	0.006
207-8149-03	BEND	5	0.333	0.014
207-8149-03	PLATE	6	0.02	0.02
207-8154	CUT	1	0.095	0.015
207-8154	MISC	2	0.32	0.051
207-8154	DRILL	3	0.094	0.015
207-8154	PLATE	4	0.02	0.02
207-8156	PRGM	1	0.074	0
207-8156	PUNCH	2	0	0.007
207-8156	MISC	3	0.32	0.051
207-8156	DM	4	0.075	0.006
207-8156	PLATE	5	0.02	0.02
207-8158	PRGM	1	0.074	0
207-8158	PUNCH	2	0	0.00375
207-8158	MISC	3	0.32	0.002354
207-8158	DM	4	0.075	0.002896
207-8158	BEND	5	0.333	0.002806
207-8158	PLATE	6	0.02	0.004958
207-8158-01	PRGM	1	0.074	0
207-8158-01	PUNCH	2	0	0.015
207-8158-01	MISC	3	0.32	0.023278
207-8158-01	DM	4	0.075	0.006
207-8158-01	BEND	5	0.333	0.014
207-8158-01	PLATE	6	0.02	0.02
207-8160	CUT	1	0.1	0.01
207-8160	MILL	2	1	0.004444
207-8160	LATHE	3	0.75	0.098333
207-8160	PLATE	4	0.02	0.02
207-8162	PRGM	1	0.074	0
207-8162	PUNCH	2	0	0.009
207-8162	MISC	3	0.32	0.051
207-8162	DM	4	0.075	0.006
207-8162	PLATE	5	0.02	0.02
207-8164	PRGM	1	0.074	0
207-8164	PUNCH	2	0	0.04
207-8164	MISC	3	0.32	0.051
207-8164	DM	4	0.075	0.006
207-8164	PLATE	5	0.02	0.046
207-8172	MISC	1	0.32	0.051
207-8172	DM	2	0.075	0.006
207-8172	BEND	3	0.428	0.028
207-8172	PLATE	4	0.02	0.148889
207-8172	PAINT	5	0.288	0.1055
207-8172-FP	PRGM	1	0.074	0
207-8172-FP	PUNCH	2	0	0.0175
207-8174	PRGM	1	0.074	0
207-8174	PUNCH	2	0	0.005
207-8174	MISC	3	0.32	0.051
207-8174	DM	4	0.075	0.006
207-8174	BEND	5	0.333	0.014
207-8174	PLATE	6	0.02	0.02
207-8174	ASSY	7	0.17	0.02
207-8182	PRGM	1	0.074	0
207-8182	PUNCH	2	0	0.031
207-8182	MISC	3	0.32	0.051
207-8182	DM	4	0.075	0.006
207-8182	BEND	5	0.475	0.035

Component	WorkStation	Operation	Setup Time	Run Time
207-8182	PLATE	6	0.02	0.035
207-8182	ASSY	7	0.17	0.01
207-8186	PRGM	1	0.074	0
207-8186	PUNCH	2	0	0.055
207-8186	MISC	3	0.32	0.051
207-8186	DRILL	4	0.094	0.015
207-8186	DM	5	0.075	0.006
207-8186	BEND	6	0.475	0.035
207-8186	PLATE	7	0.02	0.065
207-8186	PAINT	8	0.288	0.063
207-8186-01	PRGM	1	0.074	0
207-8186-01	PUNCH	2	0	0.055
207-8186-01	MISC	3	0.32	0.051
207-8186-01	DRILL	4	0.094	0.015
207-8186-01	DM	5	0.075	0.006
207-8186-01	BEND	6	0.475	0.035
207-8186-01	PLATE	7	0.02	0.065
207-8186-01	PAINT	8	0.288	0.063
207-8188	PRGM	1	0.074	0
207-8188	PUNCH	2	0	0.055
207-8188	MISC	3	0.32	0.051
207-8188	DRILL	4	0.094	0.015
207-8188	DM	5	0.075	0.006
207-8188	BEND	6	0.475	0.035
207-8188	PLATE	7	0.02	0.065
207-8188	PAINT	8	0.288	0.063
207-8188-01	PRGM	1	0.074	0
207-8188-01	PUNCH	2	0	0.055
207-8188-01	MISC	3	0.32	0.051
207-8188-01	DRILL	4	0.094	0.015
207-8188-01	DM	5	0.075	0.006
207-8188-01	BEND	6	0.475	0.035
207-8188-01	PLATE	7	0.02	0.065
207-8188-01	PAINT	8	0.288	0.063
207-8190	MISC	1	0.32	0.051
207-8190	DM	2	0.075	0.006
207-8190	BEND	3	0.618	0.056
207-8190	PLATE	4	0.02	0.059417
207-8190	PAINT	5	0.288	0.0935
207-8190	ASSY	6	0.17	0.073778
207-8192	PRGM	1	0.074	0
207-8192	PUNCH	2	0	0.096
207-8192	MISC	3	0.32	0.051
207-8192	DM	4	0.075	0.006
207-8192	BEND	5	0.618	0.056
207-8192	PLATE	6	0.02	0.059417
207-8192	PAINT	7	0.288	0.0935
207-8192	ASSY	8	0.17	0.068778
207-8192-01	MISC	1	0.32	0.051
207-8192-01	DM	2	0.075	0.006
207-8192-01	BEND	3	0.618	0.056
207-8192-01	PLATE	4	0.02	0.063625
207-8192-01	PAINT	5	0.288	0.043
207-8192-01	ASSY	6	0.17	0.072458
207-8198	PRGM	1	0.074	0
207-8198	PUNCH	2	0	0.005
207-8198	MISC	3	0.32	0.023278
207-8198	DM	4	0.075	0.006
207-8198	BEND	5	0.285	0.007
207-8198	PLATE	6	0.02	0.02
207-8198-01	PRGM	1	0.074	0
207-8198-01	PUNCH	2	0	0.005
207-8198-01	MISC	3	0.32	0.021056
207-8198-01	DM	4	0.075	0.006
207-8198-01	BEND	5	0.285	0.007
207-8198-01	PLATE	6	0.02	0.02
207-8198-02	PRGM	1	0.074	0
207-8198-02	PUNCH	2	0	0.005
207-8198-02	MISC	3	0.32	0.021056
207-8198-02	DM	4	0.075	0.006
207-8198-02	BEND	5	0.285	0.007
207-8198-02	PLATE	6	0.02	0.02
207-8220	PRGM	1	0.074	0
207-8220	PUNCH	2	0	0.005
207-8220	MISC	3	0.32	0.021056
207-8220	DM	4	0.075	0.006
207-8220	BEND	5	0.333	0.014
207-8220	PLATE	6	0.02	0.02
207-8224	PRGM	1	0.074	0
207-8224	PUNCH	2	0	0.004

Component	WorkStation	Operation	Setup Time	Run Time
207-8224	MISC	3	0.32	0.051
207-8224	DM	4	0.075	0.006
207-8224	PLATE	5	0.02	0.02
207-8224	ASSY	6	0.17	0.01
207-8230	PRGM	1	0.074	0
207-8230	PUNCH	2	0	0.009
207-8230	MISC	3	0.32	0.022167
207-8230	DM	4	0.075	0.006
207-8230	BEND	5	0.285	0.007
207-8230	PLATE	6	0.02	0.02
207-8230-01	PRGM	1	0.074	0
207-8230-01	PUNCH	2	0	0.006
207-8230-01	MISC	3	0.32	0.051
207-8230-01	DM	4	0.075	0.006
207-8230-01	BEND	5	0.285	0.007
207-8230-01	PLATE	6	0.02	0.02
207-8232	PRGM	1	0.074	0
207-8232	PUNCH	2	0	0.01
207-8232	MISC	3	0.32	0.051
207-8232	DM	4	0.075	0.006
207-8232	BEND	5	0.333	0.014
207-8232	PLATE	6	0.02	0.02
207-8232	PAINT	7	0.288	0.122
207-8232	ASSY	8	0.17	0.02
207-8234	PRGM	1	0.074	0
207-8234	PUNCH	2	0	0.018
207-8234	MISC	3	0.32	0.051
207-8234	DM	4	0.075	0.006
207-8234	PLATE	5	0.02	0.02
207-8286	PRGM	1	0.074	0
207-8286	PUNCH	2	0	0.004
207-8286	MISC	3	0.32	0.051
207-8286	DM	4	0.075	0.006
207-8286	PLATE	5	0.02	0.02
207-8290	PRGM	1	0.074	0
207-8290	PUNCH	2	0	0.0285
207-8290	MISC	3	0.124	0.02391
207-8290	DM	4	0.075	0.006
207-8290	BEND	5	0.618	0.019365
207-8290	PLATE	6	0.02	0.033744
207-8290	ASSY	7	0.17	0.016
207-8292	PRGM	1	0.074	0
207-8292	PUNCH	2	0	0.026
207-8292	MISC	3	0.124	0.02
207-8292	DM	4	0.075	0.006
207-8292	BEND	5	0.57	0.12
207-8292	PLATE	6	0.02	0.029
207-8512-01	PARTS	1	0	0
207-8512-01	PASL	2	0	0.5
NAA56/01	FMCUBE	1	0	0.035156
NAA56/01	PTST	2	0	0.021875
NAH57	PARTS	1	0	0
NAH57	PASL	2	0	0.125
NAH57	PASH	3	0	0.125
NAH57	PTST	4	0	0
NAH57/01	PARTS	1	0	0
NAH57/01	PASL	2	0	0.0625
NAH57/01	PASH	3	0	0.0625
NAH57/01	PTST	4	0	0
NAP36/01A	PARTS	1	0	0
NAP36/01A	PASL	2	0	0.039063
NAP36/01A	PTST	3	0	0.03375
NAP36A	PARTS	1	0	0
NAP36A	PASL	2	0	0.019531
NAP36A	PTST	3	0	0.03375
NAPA19	PARTS	1	1	0
NAPC156	PARTS	1	1	0
NAPC156	ATST	2	0	0.1025
NAPI100	PARTS	1	1	0
NAPI100	PTST	2	0	0
NAPI105/01	PARTS	1	0	0
NAPI105/01	ATST	2	0	0.003906
NAPI111	PARTS	1	1	0
NAPI111	ATST	2	0	0.10125
NAPI115	PARTS	1	0	0
NAPI115	ATST	2	0	0.151
NAPI98	PARTS	1	1	0
NAPI99	PARTS	1	1	0

APPENDIX C – Bill of Materials

Parent	Child	Qtyper
183-6059	183-6058	1
203-6016	203-6016-FP	1
206-8009	206-8012	1
206-8009	206-8016	1
206-8009	206-8016-01	1
206-8009	206-8018	1
206-8009	206-8018-01	1
206-8009	206-8022	1
206-8009	206-8022-01	1
206-8009	206-8024	6
206-8009	206-8026	1
206-8009	206-8028	2
206-8009	206-8030	1
206-8009	206-8032	1
206-8009	206-8036	1
206-8009	206-8042	1
206-8009	206-8044	1
206-8009	206-8045	1
206-8009	206-8046	1
206-8009	206-8047	1
206-8009	206-8050	1
206-8009	206-8051	2
206-8009	206-8058	1
206-8009	206-8070	1
206-8009	206-8072	1
206-8009	206-8234	1
206-8009	206-8410	1
206-8009	206-8412	1
206-8009	206-8412-01	1
206-8009	206-8438	18
206-8009	206-8456	4
206-8009	206-8460	4
206-8009	206-8462	2
206-8009	206-8468	1
206-8064	206-8065	1
206-8064	206-8066	1
206-8064	206-8066-01	1
206-8086	206-8087	1
206-8086	206-8088	1
206-8090	206-8079	1
206-8090	206-8093	1
206-8090	206-8493	2
206-8092	206-8093	1
206-8092	206-8493-02	2
206-8209-01	206-8012	1
206-8209-01	206-8216-02	1
206-8209-01	206-8216-03	1
206-8209-01	206-8222	1
206-8209-01	206-8222-01	1
206-8209-01	206-8230	1

Parent	Child	Qtyper
206-8209-01	206-8232-01	1
206-8209-01	206-8234	1
206-8209-01	206-8242-01	1
206-8209-01	206-8244-01	1
206-8209-01	206-8245	1
206-8209-01	206-8247	1
206-8209-01	206-8250	1
206-8209-01	206-8251	2
206-8209-01	206-8254-01	1
206-8209-01	206-8258	1
206-8209-01	206-8270	1
206-8209-01	206-8272	1
206-8209-01	206-8274	1
206-8209-01	206-8278	1
206-8209-01	206-8410	1
206-8209-01	206-8412	1
206-8209-01	206-8412-01	1
206-8209-01	206-8418	1
206-8209-01	206-8418-03	1
206-8209-01	206-8424	5
206-8209-01	206-8426	1
206-8209-01	206-8428	4
206-8209-01	206-8438	25
206-8209-01	206-8446	1
206-8209-01	206-8456	8
206-8209-01	206-8460	4
206-8209-01	206-8461	2
206-8209-01	206-8462	2
206-8209-01	206-8468	1
206-8264-01	206-8265-01	1
206-8264-01	206-8466	1
206-8264-01	207-8290	1
206-8282	206-8283	1
206-8282	206-8284	1
206-8290	206-8287	1
206-8290	206-8493	2
206-8290	206-8493-01	1
206-8292	206-8493-01	1
206-8292	206-8493-02	2
206-8409	206-8410	1
206-8409	206-8410-01	1
206-8409	206-8412	1
206-8409	206-8412-01	1
206-8409	206-8414	1
206-8409	206-8416	1
206-8409	206-8416-01	1
206-8409	206-8418	1
206-8409	206-8418-01	1
206-8409	206-8420	1
206-8409	206-8420-01	1

Parent	Child	Qtyper
206-8409	206-8422	1
206-8409	206-8422-01	1
206-8409	206-8424	10
206-8409	206-8426	2
206-8409	206-8428	8
206-8409	206-8430	1
206-8409	206-8430-01	1
206-8409	206-8432	2
206-8409	206-8434	1
206-8409	206-8434-01	1
206-8409	206-8438	50
206-8409	206-8442	1
206-8409	206-8444	1
206-8409	206-8445	1
206-8409	206-8446	2
206-8409	206-8447	1
206-8409	206-8448	1
206-8409	206-8450	1
206-8409	206-8451	2
206-8409	206-8454	1
206-8409	206-8456	16
206-8409	206-8458	1
206-8409	206-8460	4
206-8409	206-8461	2
206-8409	206-8462	2
206-8409	206-8468	1
206-8409	206-8470	1
206-8409	206-8472	1
206-8409	206-8474	1
206-8409	206-8478	1
206-8464	206-8465	1
206-8464	206-8466	1
206-8464	207-8290	1
206-8464-01	206-8465-01	1
206-8464-01	206-8466-01	2
206-8482	206-8483	1
206-8482	206-8484	1
206-8482-01	206-8483-01	1
206-8482-01	206-8484-01	1
206-8490	206-8487	1
206-8490	206-8493	2
206-8490	206-8493-01	1
206-8492	206-8493-01	1
206-8492	206-8493-02	2
206-8492-01	206-8493-01	1
206-8492-01	206-8493-02	2
207-6132	207-6134	2
207-6132	207-6136	1
207-6132	207-6136-01	1
207-6132	207-6136-02	1

Parent	Child	Qtyper
207-6138	207-6134	2
207-6138	207-6140	1
207-6138	207-6140-01	1
207-6138	207-6140-02	1
207-6182	207-6130-03	1
207-6182	207-6130-04	1
207-6182	207-6130-05	1
207-6182	207-6134-01	1
207-6182	207-6135	1
207-6182	207-6135-01	1
207-8120	207-6116	1
207-8120	207-6118	1
207-8120	207-6158	1
207-8120	207-8110	40
207-8120	207-8112	1
207-8120	207-8128	1
207-8120	207-8128-01	1
207-8120	207-8130	3
207-8120	207-8136	1
207-8120	207-8138	1
207-8120	207-8138-01	4
207-8120	207-8149	1
207-8120	207-8149-01	1
207-8120	207-8154	1
207-8120	207-8156	1
207-8120	207-8158	20
207-8120	207-8158-01	4
207-8120	207-8182	1
207-8120	207-8186	1
207-8120	207-8186-01	1
207-8120	207-8188	1
207-8120	207-8188-01	1
207-8120	207-8190	1
207-8120	207-8192	1
207-8120	207-8198	4
207-8120	207-8198-01	2
207-8120	207-8198-02	2
207-8120	207-8220	2
207-8120	207-8286	2
207-8120-01	207-6116	1
207-8120-01	207-6118-01	1
207-8120-01	207-6158	1
207-8120-01	207-8110	20
207-8120-01	207-8112-01	1
207-8120-01	207-8128-02	1
207-8120-01	207-8128-03	1
207-8120-01	207-8130	1
207-8120-01	207-8136-01	1
207-8120-01	207-8138-02	1
207-8120-01	207-8138-03	4

Parent	Child	Qtyper
207-8120-01	207-8149-02	1
207-8120-01	207-8149-03	1
207-8120-01	207-8154	1
207-8120-01	207-8156	1
207-8120-01	207-8158	10
207-8120-01	207-8158-01	2
207-8120-01	207-8182	1
207-8120-01	207-8186	1
207-8120-01	207-8186-01	1
207-8120-01	207-8188	1
207-8120-01	207-8188-01	1
207-8120-01	207-8190	1
207-8120-01	207-8192-01	1
207-8120-01	207-8198	8
207-8120-01	207-8220	2
207-8120-01	207-8230	2
207-8120-01	207-8230-01	1
207-8120-01	207-8286	2
207-8172	207-8172-FP	1
NAA56/01	198-8357-01	1
NAA56/01	206-1004	1
NAA56/01	206-1010-01	1
NAA56/01	206-1012-01	1
NAA56/01	206-1014	1
NAA56/01	206-1016	1
NAA56/01	206-1018	1
NAA56/01	206-1020-02	1
NAA56/01	206-1022	1
NAA56/01	206-1024	1
NAA56/01	206-1026	1
NAA56/01	206-1028-01	1
NAA56/01	206-1030	1
NAA56/01	206-1030-01	1
NAA56/01	206-1030-02	1
NAA56/01	206-1030-03	2
NAA56/01	206-1030-04	2
NAA56/01	206-1032	1
NAA56/01	206-1034	1
NAA56/01	206-1034-01	1
NAA56/01	206-1036	1
NAA56/01	206-1036-01	2
NAA56/01	206-1036-02	1
NAA56/01	206-1038	2
NAA56/01	206-1038-01	1
NAA56/01	206-1040	4
NAA56/01	206-1041-02	1
NAA56/01	206-1042	1
NAA56/01	206-1044	1
NAA56/01	206-1150	1
NAA56/01	NAPI105/01	1

Parent	Child	Qtyper
NAP36/01A	207-1022	1
NAP36/01A	207-1024	1
NAP36/01A	207-1024-01	1
NAP36/01A	207-1026	1
NAP36/01A	NAPA19	1
NAP36A	207-1022	1
NAP36A	207-1024	1
NAP36A	207-1024-01	1
NAP36A	207-1026	1
NAP36A	NAPA19	1

APPENDIX D – Pre-determined MTO Job Sequences

Sequence Number	Product 1	Product 2	Product 3	Product 4	Product 5	Product 6
1	206-8079	206-8063	206-1004	206-1150	207-8128-01	NAPA19
2	206-8093	206-1012-01	206-8410	206-8493-01	207-8224	NAPI98
3	206-8488	206-1018	206-8216-02	206-8484-01	207-8128	NAPI99
4	206-8493	206-1020-02	206-8250	206-8493-02	183-6058	207-8190
5	206-8412-01	206-1042	206-8252	206-8412	207-8164	207-8192-01
6	206-8493-02	206-8097	206-8468	206-8493	207-6133	207-6112
7	206-8412	206-8455	206-1044	206-8488	207-8286	207-8136-01
8	206-8094-01	206-1022	206-8272	206-8484	207-8156	207-6116
9	206-8094	206-1004	206-8426	206-8412-01	207-7132	207-8232
10	206-8410	206-8094	206-1024	206-1020-02	207-6133-01	207-8162
11	206-8099	206-8094-01	206-8418-03	206-1042	207-8162	207-8286
12	206-8066-01	206-4060	206-8089	206-8455	207-6148	207-6114-01
13	206-8070	NAPI105/01	206-8274	206-1012-01	NAPI100	207-8234
14	206-8473	NAPI111	206-8258	206-1018	200-5503-16	207-7132
15	206-8024	NAPI115	206-8222-01	206-8476-01	207-8144	207-8156
16	206-8058	NAPC156	206-8473	206-1022	207-7135	207-6148-01
17	206-8042	206-8012	206-8278	206-8438	203-6098	207-6133-01
18	206-8016-01	206-8022	206-8216-03	206-8436	200-5515-12	207-6133
19	206-8026	206-8016	206-1028-01	NAPI115	207-8160	207-8164
20	206-8468	206-8089	207-8290	NAPI105/01	207-8146	207-8140-01
21	206-1028-01	206-8099	206-8443	NAPC156	207-7126	207-8160
22	206-8072	206-8050	206-8265-01	206-4060	207-8112	207-6176-02
23	206-1024	206-8018	206-8257	NAPI111	207-8149	207-6174
24	206-8057	206-1028-01	206-8232-01	206-8446	207-8148-01	207-6176-03
25	206-1044	206-8022-01	206-8283	206-8454	207-6135-01	207-6174-01
26	206-8043	206-8057	206-8236	206-8469	207-1026	202-8037
27	206-8050	206-8058	206-8424	206-8432	207-8149-01	NAPI100
28	206-8044	206-8072	206-8461	206-8420	207-7128-01	207-8172-FP
29	206-8089	206-8018-01	206-8270	206-8414	207-8198-02	183-6058
30	206-8018-01	206-8047	206-8440	206-8445	207-8158	207-6136
31	206-8032	206-8026	206-8244-01	207-8292	207-8138-01	207-6140
32	206-8022-01	206-8052	206-8242-01	206-8466-01	207-6142-01	207-6140-02
33	206-8018	206-8098	206-8455	206-1034	207-6124	207-6136-01
34	206-8066	206-8236	206-1022	206-1034-01	207-6122	207-6130-05
35	206-8040	206-8044	206-8276-01	206-8467	207-7132-02	207-6130-03
36	206-8065	206-8066	206-1020-02	206-1041-02	207-6144	207-6136-02
37	206-8052	206-8024	206-1042	206-8451	207-7128	207-8154
38	206-8236	206-8066-01	206-1012-01	206-8463	207-6122-01	207-6140-01
39	206-8098	206-8040	206-8276	206-8489	207-8220	207-6130-04
40	206-8016	206-8042	206-1018	206-8460	207-6135	NAH57/01
41	206-8047	206-8473	NAPC156	206-8462	207-6112-01	207-8144
42	206-1150	206-1024	NAPI115	206-8449	207-1024	207-7135
43	200-5514-20	206-8468	NAPI111	206-8428	207-7130	200-5503-16
44	206-8063	206-1044	206-4060	206-8481	207-8198	184-6129-01
45	206-1022	206-8016-01	NAPI105/01	206-8447	207-8138	207-8224
46	206-8455	206-8032	198-8357-01	206-8466	207-7126-01	203-6098
47	206-1042	206-8043	176-1129-01	206-8456	207-7130-02	207-6134-01
48	206-1020-02	206-8070	206-1041-02	206-8410	207-8110	207-6134
49	206-1018	206-8065	206-8096	206-8410-01	207-1024-01	207-8182
50	206-8097	206-8056	206-8460	206-8487	207-7132-01	207-6119
51	206-1012-01	198-8357-01	206-8449	206-8418-01	207-8158-01	207-1022
52	206-1004	206-1014	206-8428	206-8418	207-7130-01	207-8130
53	206-8056	206-8415-04	206-8245	206-8475	207-8198-01	207-6172
54	206-8074	206-1030	206-1034-01	206-1010-01	184-6129-01	207-8174
55	206-1026	206-1010-01	206-8263-01	206-8425	183-6059	207-6117-01
56	206-1036-02	206-1030-01	206-8446	206-1030-04	203-6016-FP	207-6180
57	206-8415-04	206-1030-04	207-8292	206-8480	207-8172-FP	207-6115
58	206-8055	206-1032	206-8247	206-8486-01	207-8192	207-6158
59	206-8041	206-8415-01	206-8284	206-1030	207-8186-01	207-6118-01
60	206-8059	206-8027-01	206-8462	206-8476	207-8188	207-6114
61	206-1030-02	206-1026	206-8254-01	206-1036-02	207-8188-01	207-6117
62	206-1030-04	206-1038-01	206-8263	206-1032	207-8186	207-6146
63	206-1030-03	206-8027	206-8456	206-1014	203-6016	207-8172
64	206-3024	206-8415-03	206-8251	206-1036	207-6130-05	207-8128-03
65	206-1036	206-1036-02	206-8466	206-8415-01	207-6140-02	207-8128-02
66	206-8415-03	206-8074	206-1034	206-1038	207-8154	207-8188-01
67	206-1016	206-1040	206-8230	206-1026	207-6130-04	207-8186
68	206-1014	206-1030-02	206-8234	206-1030-02	207-6136	207-8188
69	206-1030	206-1036	206-8281	206-1030-01	207-6140-01	207-8186-01
70	206-1032	206-3024	206-8469	206-1038-01	207-6130-03	183-6059

Sequence Number	Product 1	Product 2	Product 3	Product 4	Product 5	Product 6
71	206-1036-01	206-1038	206-1150	206-1036-01	207-6136-01	200-5515-12
72	206-1010-01	206-1036-01	206-8036	206-8486-02	207-6136-02	207-7130
73	206-1038-01	206-1016	206-8438	206-8476-02	207-6140	207-6122
74	206-1040	206-1030-03	206-1014	206-1040	207-6182	207-8138-02
75	206-8027-01	206-8059	206-1036	206-1016	NAPI98	207-6124
76	206-1038	206-8087	206-1030-04	206-1030-03	NAPI99	207-8158
77	206-8415-01	206-1150	206-8277	206-8486	NAPA19	207-7128-01
78	206-8027	206-8079	206-1038	206-3024	202-8037	207-8220
79	206-1030-01	206-8410	206-1036-01	206-8496-01	207-8182	207-8198
80	NAPI105/01	206-1041-02	206-1040	206-8496	207-6118	207-1026
81	NAPI111	206-8462	206-1038-01	206-8443-01	207-6119	207-8112-01
82	206-4060	206-8028	206-8415-01	206-8452-01	207-6114	207-8110
83	NAPC156	207-8292	206-1016	206-8426	207-6172	207-6122-01
84	NAPI115	206-8234	206-8276-02	206-8422-01	207-8130	207-8149-02
85	198-8357-01	206-8088	206-3024	206-8430	207-6134	207-7128
86	206-8453-01	206-8051	206-1030-01	206-8477	207-8136	207-8148-01
87	206-8092	206-8045	206-1030-02	206-1024	207-6158	207-1024
88	206-8036	206-8096	206-1036-02	206-8444	207-6117	207-7130-02
89	206-8438	206-8281-01	206-1030	206-8420-01	207-1022	207-7132-01
90	206-8087	206-8460	206-1010-01	206-8452	207-8174	207-7126-02
91	206-8090	206-8049-02	206-1026	206-8440-01	207-6134-01	207-7130-01
92	206-8022	206-8075	206-1032	206-1028-01	207-6117-01	207-8149-03
93	206-8012	206-1034-01	206-1030-03	206-8450	207-6146	207-6135
94	206-8469	206-8449	206-8296-01	206-8472	207-6180	207-8138-03
95	206-8088	206-8030	206-8296	206-8448	207-8190	207-6142-01
96	206-8028	206-8456	206-8287	206-8465-01	207-6116	207-8230-01
97	206-8046	206-8469	206-8012	206-8470	NAH57/01	207-1024-01
98	206-8051	206-1034	206-8222	206-1044	NAH57	207-7132-02
99	206-1034	206-8046	206-8282	206-8461	207-6174-01	207-8158-01
100	206-8281-01	200-5514-20	200-5514-20	206-8442	207-6174	207-6135-01
101	206-8049	206-8092	206-8264-01	206-8457	207-6176-02	207-6112-01
102	206-8030	206-8412	206-8453	206-8434-01	207-6176-03	207-8230
103	206-1034-01	206-8493	206-8493-01	207-8290	207-8172	207-6144
104	206-8449	206-8093	206-8493	206-8473	207-8140	207-7126-03
105	206-8234	206-8493-02	206-8412	206-8474	207-6112	207-8512-01
106	206-8456	206-8488	206-8493-02	206-8416-01	207-6132	207-6182
107	206-8460	206-8412-01	206-8412-01	206-8443	207-6138	207-6138
108	206-1041-02	206-8036	206-8488	206-8478	207-8120	207-6132
109	206-8462	206-8438	206-8418	206-8416	NAP36A	NAP36/01A
110	206-8045	206-8453-01	206-8275	206-8430-01		207-8120-01
111	206-8096	206-8064	206-8209-01	206-8468		
112	207-8292	NAA56/01	206-8292	206-8424		
113	206-8075	206-8009	206-8290	206-8434		
114	206-8086	206-8086	NAA56/01	206-8440		
115	206-8009	206-8090		206-8458		
116	206-8064			198-8357-01		
117	NAA56/01			206-1004		
118				200-5514-40		
119				206-8465		
120				206-8483-01		
121				206-8422		
122				206-8483		
123				206-8414-01		
124				176-1129-01		
125				206-8453		
126				206-8464-01		
127				206-8482-01		
128				206-8492		
129				206-8409		
130				206-8482		
131				206-8492-01		
132				206-8490		
133				NAA56/01		
134				206-8464		

APPENDIX E – Description of Electronic Files

The electronic files used in this analysis, found on DalSpace (dalspace.library.dal.ca), contain the simulation, experiment results, and other files used in this research. The “Read Me” text file includes instructions on how to operate the simulation and observe the results. Each folder applies to a particular aspect in the document as summarized below.

SimPy Simulation:

In the “Simulation Control.xlsm” UI Tab:
To enable a particular stock point the "Enable stock point" title should be 1, else 0.
To enable some random interference in component production set the “Enable production interference” title to one.
Parameters to set (if applicable):

- Semi-finished inventory
- Component Inventory
- Production Interference

After running the simulation, back in the “Simulation Control” Replication Data Tab the results of the simulation recorded and logged for analysis.

Experiment Responses:

The folders within "Experiment Responses" contain the results of experiments discussed in Chapter 6. Stocking experiments for each model, MTO, MCTS, MSFTS, MTS reflect the alternatives described in Sections 6.1, 6.2, 6.3, and 6.4, respectively. The remaining folders examine a particular parameter of the simulation model as discussed in Section 6.5.

Job Release Sequence for MTO:

In the folder "Job Release Sequence for MTO," there are three files:

- Job Data.accdb (Microsoft Access 2007 Database)
- Job List Sort.xlsm (Microsoft Excel 2007 Macro-Enabled Spreadsheet)
- Job Makespan.xlsm (Microsoft Excel 2007 Macro-Enabled Spreadsheet)

The results of each random product makespan is in "Job Makespan Times and Data.xlsx"
These files apply to section 4.2 of the thesis and the process consists of two parts:

1) Generate a random sequence
2) Evaluate the Makespan of that sequence

Support Programs:

Setup files, either open-source or licensed for academic use, included in this folder run the programs and add-ins necessary (with the exception of Microsoft Excel 2007.)

APPENDIX F – Setting Simulation Parameters Example

Semi-Finished Inventory Parameters (r, Q)

Enable Stock Point	1	Up-to Level:	0
	Level:	5	2
	Demand Based:	0	0
	Timeframe:	60	45

Product	Demand Rate	Re-Order point	Order Quantity
1	0.06711	5	2
2	0.113795	5	2
3	0.134893	5	2
4	0.065631	5	2
5	0.075814	5	2
6	0.087139	5	2

Export Stock Levels to Simulation

Simulation Parameters

Model:	4	*Based on Stock Points
Design Point:	1	*Optional
Simulation Length:	5000	Hours
Warm-up Time:	100	Hours
SF Order Up-to:	0	1 = Enabled
Noise:	0	1 = Enabled

Component Inventory Parameters (r, Q)

Enable Stock Point	1

Component	Re-Order	Order Qty
Top Level	Batched	Batched
Other	Batched	Batched

Either 'Demand Based' or 'Batched'

Demand Based Parameters (Top Level Components)

Not Applicable for Semi-Finished Stock	CSL	Time (Days)
Re-Order:	0.95	27
Order Qty:	0.95	17

Batching Policies (Number of Batches to Stock)

Component Parameters	Top Level	Other
Re-Order:	1	0
Order Qty:	1	1
Batch Size:	Max(Demand in (CSL, T), Max(SF Qty * Qty per))	Max(Top Level Order Qty)
(CSL, T) =	0.95	5

Component					Semi-Finished			
	Re-Order	Order Qty	Initial		Product	Re-Order	Order Qty	Initial
176-1129-01	12	12	19		**1**	5	2	6
183-6058	0	2	2		**2**	5	2	7
183-6059	2	2	4		**3**	5	2	6
184-6129-01	4	4	6		**4**	5	2	6
198-8357-01	0	32	1		**5**	5	2	7
200-5503-16	2	2	3		**6**	5	2	7
200-5514-20	4	4	6					
200-5514-40	2	2	4					
200-5515-12	2	2	4					
202-8037	2	2	3					
203-6016	2	2	4					
203-6016-FP	0	2	1					
203-6098	4	4	5					
206-1004	0	32	29					
206-1010-01	0	32	14					
...	...	...	...					

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