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## **AAI System Analysis and Revisions**

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# **AAI System Analysis and Revisions**

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Senior Capstone Project  
Spring 2009

## AAI System Analysis and Revision Outline

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## **Abstract**

A system needs be created for handling the design, development, and manufacturing of items from multiple factories in multiple product categories that are fabricated in various Chinese factories for international companies. This system must be capable of handling product orders that to 27 different countries, with the possibility of expanding to 70 different countries. Current systems within AAI will be utilized for shipments to the United States when possible, and it is imperative that these systems are not negatively affected by the addition of 27-70 countries for delivery. Different aspects and topics of Industrial Engineering should be utilized in this system such as Information Systems, Operations Research, Work Study and Measurement, Lean Principals, and Simulation.

## **Introduction**

In an increasingly global economic environment, competitive companies are continually exploring opportunities in offshore manufacturing. While the cost-effective potential of such operations is alluring; developing, maintaining, and growing offshore operations is a difficult task that requires a highly skilled team of internationally focused sales, engineering, design, and marketing departments. In order to meet this demand, many companies have begun looking outside the confines of their operations to providers of global manufacturing. One such provider is American Accessories International, L.L.C. (AAI), headquartered in Knoxville, TN.

Currently, American Accessories uses a detailed and complicated system for the development and process of purchase orders that officially lead to the issuing of delivery schedules. These purchase orders and the resulting documentation is not only used within the company for planning purposes, but also by the customer, which in the case of this report is an

internationally distributed corporation. Revisions and changes to the schedule are made on an as-needed, but typically weekly, basis. Revisions include but are not limited to changes in production schedule, production capacity, and requested arrival date shipping method.

In order to process the purchase order, seven significant parties are involved: the AAI Shenzhen, China Office, the Chinese factory, the Customer, the AAI Shipping Department, the AAI Engineering Department, the AAI Accounting Department, and the AAI General and Administrative (G&A) Department. One particularly significant barrier between the interactions of the above parties is the time difference between the United States and China, a 12-13 hour delay. If information and instruction is not timed correctly, a potential 12-13 hour delay is possible; however, if the timing is correct, it is possible to achieve nearly 24 hour/day uptime. In essence, this time delay presents both a potential threat and a potential opportunity to the total lead time of the process.

Recent growth within the company's portfolio of customers has introduced consolidated orders from major international corporations. These orders merge smaller orders from the corporation's national branches to achieve lower production costs. Typically, these consolidations include 25 to 70 different countries throughout the world. The current processing system at AAI was not created to handle such a varied distribution network and the resulting disparity in legal requirements surrounding minor details, including but not limited to carton markings, warning labels, shipping terms, and safety standards.

This project is directed at analyzing and suggesting improvements to the current system that will allow AAI to handle consolidated orders in a more cost and time efficient manner. Currently, the intricate details are handled through increased attention from shipping,

engineering, and G&A departments. Administration at AAI is interested in not only improving current systems, but developing new systems with nontraditional approaches.

However, AAI Administration is not interested in limiting or making significant changes to many of the documents required within the system. Since the Purchase Order represents incoming business, the current system of documentation highlights the important and required data within the contract. This data includes the item ordered, quantity, terms of payment, shipping address, invoicing instructions, artwork required, notation of acceptable quality level (AQL), and all other legal contract agreements implied by the acceptance of the PO. If any of this information is mistranslated through the PO process then the order can be delayed or worse, rejected upon delivery, which results in the customer not paying AAI for the goods. Another reason this data is important is because of the complexity of invoicing and shipping to multiple countries. As AAI will be dealing with customs, banks, and occasionally buyers who do not speak English, it is extremely important that all information is transcribed perfectly the first time.

Key components that will be utilized in resolving this dilemma include the application of lean principals to solve the problem. The lean principals that will be used in the unraveling of this difficulty include value stream mapping, producing to takt time, potentially developing a continuous flow, using supermarkets when possible to control production where continuous flow does not extend upstream, attempting to send the customer schedule to only one production process (aka selecting a “pacemaker”), distributing the production of different products evenly over time at the “pacemaker” process (i/e level the production mix), and developing the ability to make “every part every day” (then every shift, then hour or pallet of pitch) in the fabrication process upstream of the pacemaker process.

Progress and research began early in January 2009 and has included a lean systems analysis of the current value stream. Initial value streams have been mapped, improved, and simulated using Rockwell Arena® simulation software. Arena will be used to establish models that accurately reflect reality.

Building the Arena schedule will include several unique components. The first component of the Arena simulation is the parallel processing of purchase orders. Once received, purchase orders are not sent from department to department, but are rather duplicated and processed simultaneously in multiple departments. A necessary subdivision within the parallel processing will be resource scheduling. Several resources are responsible for more than one task. Therefore, it will be necessary to schedule resources not only through working hours but also through multiple processes.

Additionally, the previously discussed time delay between offices will be included in the simulation. Simulation clocks will be set to 24 hours, but resources in China and resources in the United States will only operate during business hours (defined by AAI). Another component is the estimated financial cost. By tracking hours spent processing purchase orders by resource, hourly wage information will be used to calculate administrative cost per purchase order. Since AAI has several repeat purchase orders, some POs will not require all of the processing steps; therefore, the model will account for the different steps if the order is a repeat order. Finally, entities' processing times are based on fitted distributions dependent upon the type of purchase order (item make and demands). These distributions attempt to increase the models' validity and allow the simulation to closely mirror reality.

Data will be gathered by several different methods within AAI and statistical distributions fitted to the data using Arena Input Analyzer. This information has been greatly

enhanced by the fact that data studies were personally conducted in China. Beyond processing times, data has also been collected on the arrival rate of purchase orders into the system in order to establish an accurate arrival rate to be included in the model. By determining precise distributions, the model will yet again become more exact.

Additionally, research has been conducted for potential content management systems to automate a majority of the processes as well as centralize data to ensure reliable, official data is available throughout the product design, development, and manufacturing process. The team traveled to Shenzhen, China to visit facilities as well as gain an understanding of operations in the China office and the true lead times involved in the processing a formal PO. Receivables have been noted to imply a full degree of implementation and improvement. In many aspects, AAI has considered improvements to the consolidated purchase order process as a trial for a wider enterprise content management system implementation.

## **System Definition and Problem Outline**

### ***Two Division Approach***

The method for converting a purchase order into a shipping schedule is a detailed process passing through many individuals and departments. Initial evaluations of the system can be overwhelming and unproductive. Therefore, the system was divided into two components. The first component is the US official is headquartered out of the Knoxville, TN office and the majority of organizational efforts are conducted from this United States office. Also included in the US office are the approval processes and communication with the customer.



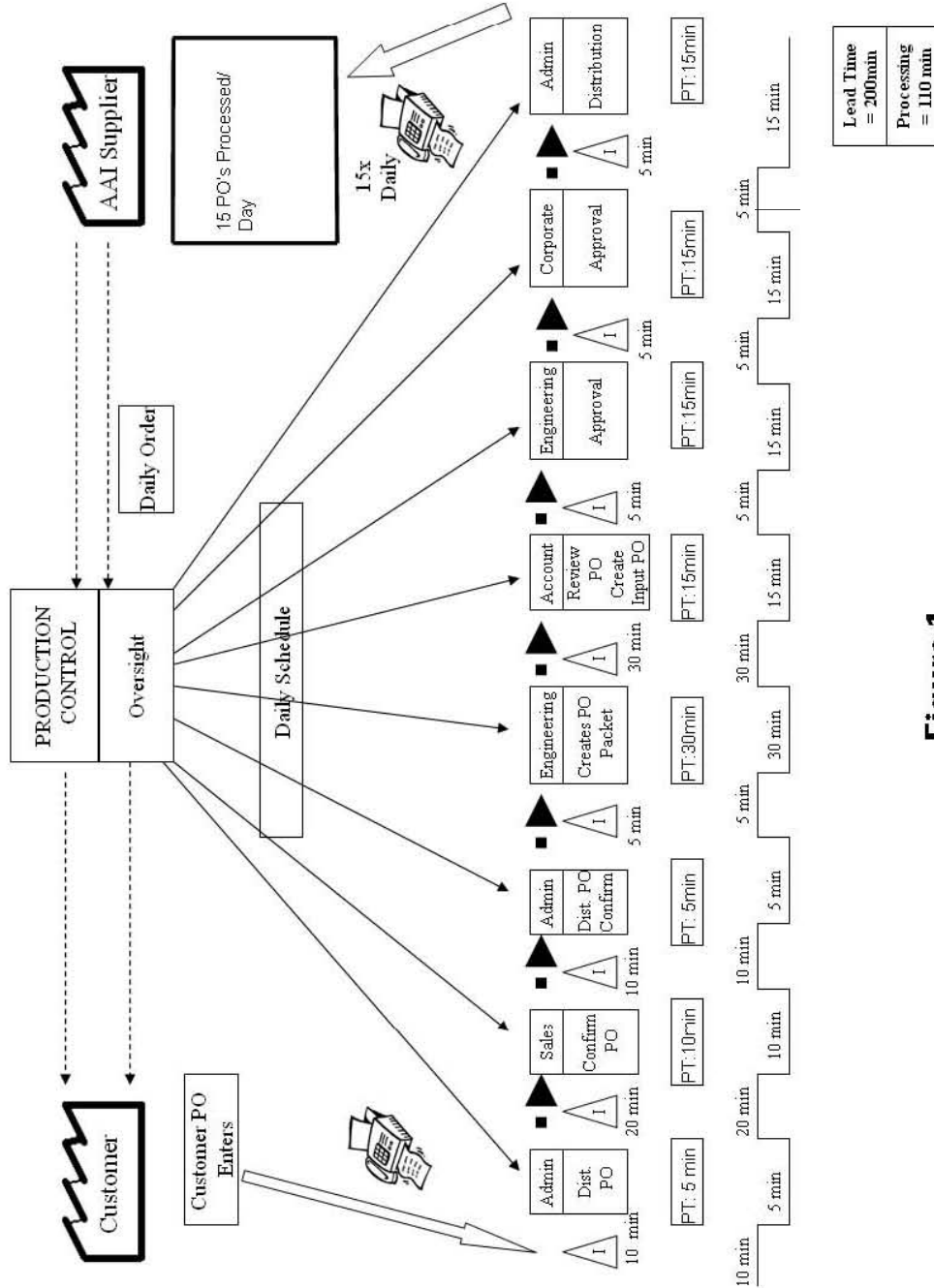
The second division is labeled “Global Involvement.” This stage of the purchase order process converts the PO Packet, generated within the US office, into a shipping schedule. However, this stage of the process does not exclude the US office. Several operations within this stage include US office departments, such as shipping. The majority of operations within the global involvement stage are manufacturing and shipping, which lead to the creation of a shipping schedule.

While the two divisions appear to be geographically based, they are in fact process based. The first division, the US office, develops the PO Packet from both internal and external information. The second stage, Global Involvement, utilizes the PO Packet as well as international resources to develop a shipping schedule that is distributed weekly to the client. Each system is defined and analyzed in detail within the following sections.

***Division One: The US Office & the PO Packet***

As mentioned in the introduction, the first and most important part of addressing a system with efficiency problems is to determine a way to visually map that system. Lean System Principals suggest the use of value stream mapping to provide a defined visual understanding. Applying value stream ideals to AAI’s PO development process is a difficult task requiring estimation of the initial state. It is not cost efficient to conduct an extended time study on each task within the network due to the global distribution of the tasks. Instead, abbreviated time studies were conducted and compared to estimated minimum, maximum, and mean processing times noted from tenured AAI employee interviews. While the estimations may involve a perception bias, the sheer cost for one individual to conduct an extended time study across international boundaries is unfeasible.

The current process for the AAI PO handling system can be shown as follows:



**Figure 1**

As is apparent in Figure 1, the current PO process is fairly complex. The system can be described in more detail as follows:

- 1) **AAI Receives a PO from the Customer** – As mentioned, the Customer PO contains information such as the item ordered, quantity, terms of payment, shipping address, invoicing instructions, artwork required, notation of acceptable quality level (AQL), and all other legal contract agreements implied by the acceptance of the PO. All of this information should be noted by multiple departments and much of it must be transcribed and prepared for the China Office.
  
- 2) **AAI Administration Distributes the Received PO** – Whether the PO is received via fax or email, the company administrator will make copies of the purchase order and distribute to the necessary departments, which include Accounting, Shipping, Engineering, and Corporate so that each department is aware of the new order and can prepare accordingly.
  
- 3) **Sales Confirmation** – The salesman responsible for the order is accountable for confirming with the buyer all details outlined on the PO. As it is not unusual for purchasing agents to make typographical and/or general errors in regards to the PO. This step is significant and important to the overall PO process.
  
- 4) **AAI Administration Distributes the Sales Confirm** – After the PO is confirmed by the salesman the PO and PO Confirm are redistributed to all parties involved with its creation. At this point in the process either no errors are present and AAI can proceed or corrections are made to any errors that may have been present. The sales confirm documentation is understood to be final and accurate.

- 5) **Engineering Creates PO Packet** – The PO Packet consists of Cost Cards, China Purchase Order, Sales Confirmation, PO Specifications, and any other information passed on with the PO, such as AQL requirements. It is the Engineer’s responsibility to assemble this packet as he/she is responsible for the development with the given factory. The first page of the PO Packet is the China Purchase Order (Appendix 1-A). It consist of first cost or factory pricing, required ship dates, payment terms, shipping destination, method of shipment, etc. After this document is re-typed and filed by the Accounting Department, it will become one of two pages that will be sent to the China factory. The second page of the PO Packet is the PO Confirmation (Appendix 1-B). As mentioned above, this is filled out by the salesman involved. The third page of the PO Packet is the Customer PO (Appendix 1-C); the fourth page of the PO Packet is the PO Specification Document (Appendix 1-D). The PO Specification document is the other page that will be sent to the factory and includes all the necessary specifications including size, pack out, labels required, colors required, etc. The fifth, and final page, is the Cost Card (Appendix 1-E). This is used to account for all costs incurred by AAI through the development process as well as any testing, freight, or other costs that might occur in the order to arrange for the receipt of the goods at destination. All costs should be covered by the final payment amount seen on the Customer PO. The Cost Card must be authorized by the Corporate Administrators.
- 6) **Accounting Department Review and Creation of Final PO** – The next step in the PO process involves the creation of the input PO, which is used in the AAI Accounting

system *Peachtree Accounting Software*. This final PO is printed on carbon paper to allow one copy to be kept in house and another to be sent to the factory.

- 7) **Engineering Department Review** – Once the Accounting Department inputs the PO and creates a carbon copy, the Engineering Department must review and sign off to ensure that all the information required is present and that there are no quantitative pricing errors.
- 8) **Corporate Approval** – When the final PO Packet is complete, Corporate Administrators must approve the margin of sale and terms, before signing off on the Cost Card, and allowing the document to proceed.
- 9) **Administrative Distribution** – Once final approval is received, copies of the PO Packet are made and the necessary documents are filed and sent to the China factory to begin the production process.

### ***Division Two: Global Involvement & Shipping Schedule Development***

In order to develop the weekly shipping schedule from the PO Packet, five significant parties are involved: the AAI China office, the Chinese Factory, the Customer, the AAI Shipping Department, and the AAI Engineering Department. In general, each department's responsibilities are listed below:

- 1) **China Engineer Confirmation** – When the PO is received by the China Engineer, they must record and verify all information to their files and translate all necessary documents.

- 2) **Third Party Factory** – Once the PO is received by the factory, they must make sure they can comply with all delivery terms and production requirements before confirming back to the China Engineer.
  
- 3) **China Engineer Completion** – When the factory has confirmed receipt of the PO and that they are in agreement with all terms, a schedule for production and estimated ready-to-ship date will be compiled.
  
- 4) **Shipping Department** – During steps 1-3, the Shipping Department works with all third party freight forwarders, both foreign and domestic, to attain a more defined freight quote. This process determines which group will be utilized for the shipment. Once confirmation is received from the China Office and the third party factory, the Shipping Department will develop an AAI Shipping Schedule to note all important dates for the customer's reference. At this time all information regarding carton markings and required shipment documentation are compiled for the order.
  
- 5) **Administration Shipping Schedule Delivery** – Once the schedule is completed (Example noted in Appendix 1-F); Administration will forward the schedule to all customers via fax or email.

As noted, a significant barrier between the interactions of the above parties is the time difference between the United States and China, a 12-13 hour delay. Particular attention to the timing of information flow is essential for system efficiency.

### **Process Mapping: PERT Diagrams & Critical Paths**

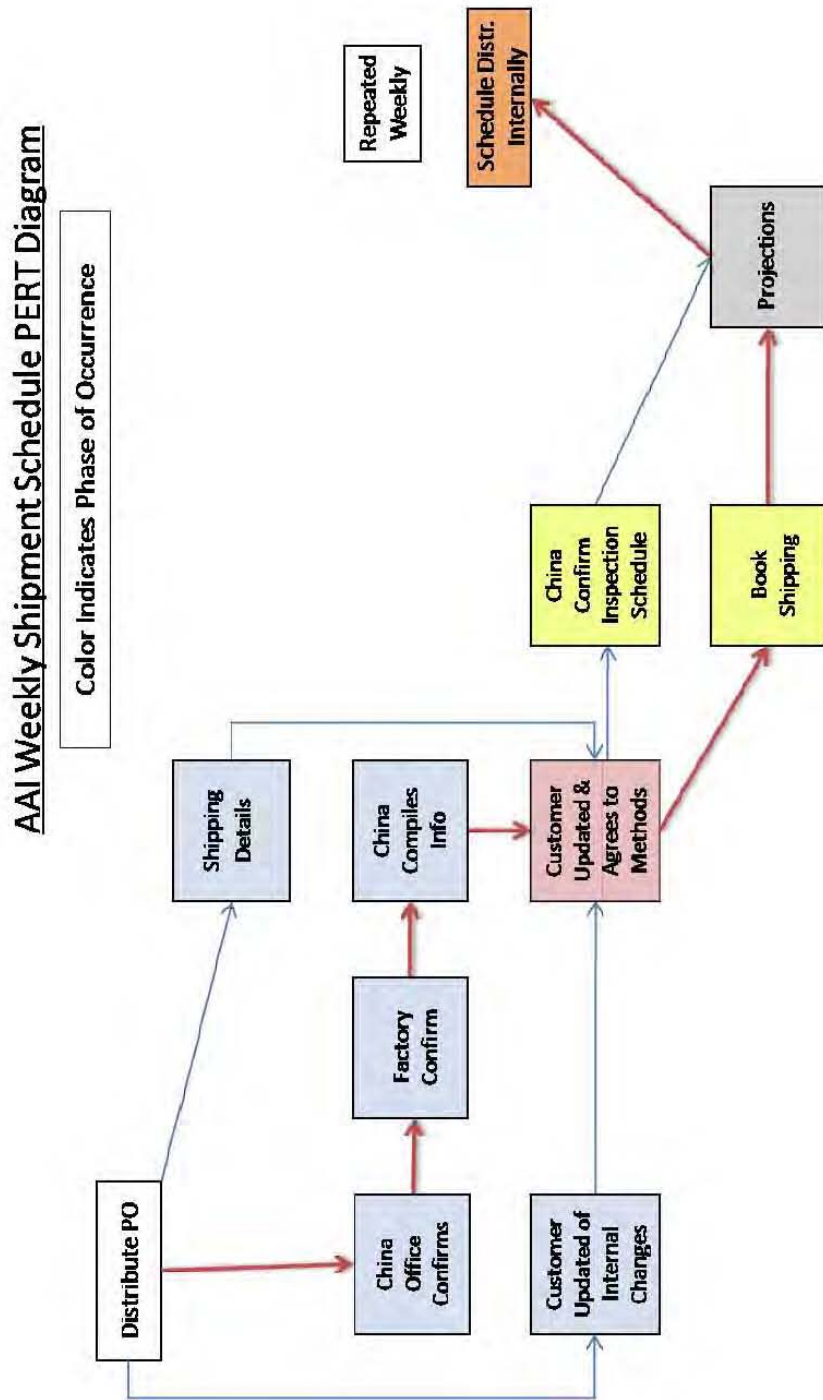
Because the global phase of the Purchase Order Process is more complex than the US Office involvement, the central value stream is not readily apparent. In order to improve the process, a focus on the limiting value stream currently determining the completion time per unit is required. In doing this, one should note that improving a value stream that is not the slowest does not improve the completion time. Just as the bottleneck in a production process is the first process improved, the bottleneck operation, or group of tasks within the process, is the first operation to be improved.

Identifying a bottleneck process is not an easy task; however, several methods exist to help map and identify limiting operations in a process. One of the most common methods is PERT, or Program Evaluation and Review Technique. PERT maps the entire network of tasks and then identifies the critical path, which is the longest path through the entire network, or the previously referred to bottleneck operation.

A PERT chart for AAI's schedule development process can be found in Figure 2 on the following page. The critical path of the system has been highlighted in red. A unique feature of AAI's system is the central point, when the customer is updated with the manufacturing and shipping arrangements. This practice is purely a facet of excellent customer relation; the client has already developed a purchase order in which manufacturing and shipping details have been agreed upon. Both party's legal obligations are clearly defined, but AAI continually strives to include the customer and reassure them of the reliability of their overseas operations.

Another important element is the presence of two operational streams: manufacturing and shipping. One stream involves working with the China Office and Chinese Factories to confirm

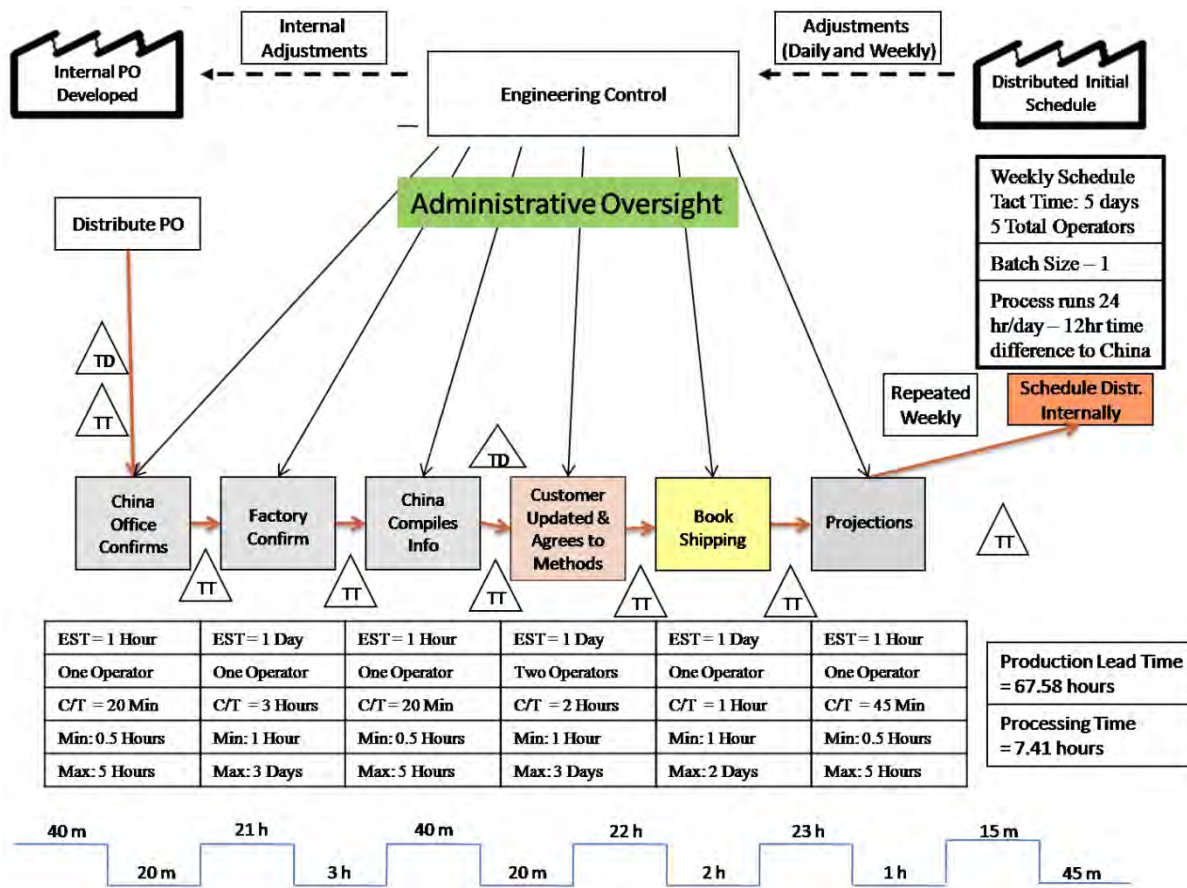
capabilities, pricing, and inspection schedules, while the other stream involves researching and booking shipping methods that meet the required arrival date. Interestingly, the critical path is split between these two processes, first progressing through the manufacturing processes and then through the shipping processes.



**Figure 2**



Using the defined critical path it is possible to develop an initial value stream map, seen below in Figure 3. Each process of the critical path is defined in more detail and placed consecutively in the value stream. The color codification demonstrates the progress first through the manufacturing process in China and second through the shipping process, which is connected by a customer update. A total lead time of 75 hours is calculated, of which less than 10% is processing time. However, the total lead time, 3.125 days, is within the required tact time of 5 days. While this demonstrates the procedure is capable, the fact that 90% of the process's lead time is not processing time suggests significant room for improvement.



**Figure 3**

While it is possible to define a critical path through this network, the unique nature of the critical path passing through two separate operational streams suggests that improvements need

to be made to both operational streams. Essentially, the system must be considered holistically in order for true improvements to be made. Using the PERT chart's critical path, an initial value stream map has already been created. However, to analyze the process holistically, a second initial value stream map has also been created. This initial value stream map, Figure 4 below, is a value stream including the entire process, not just the critical path.

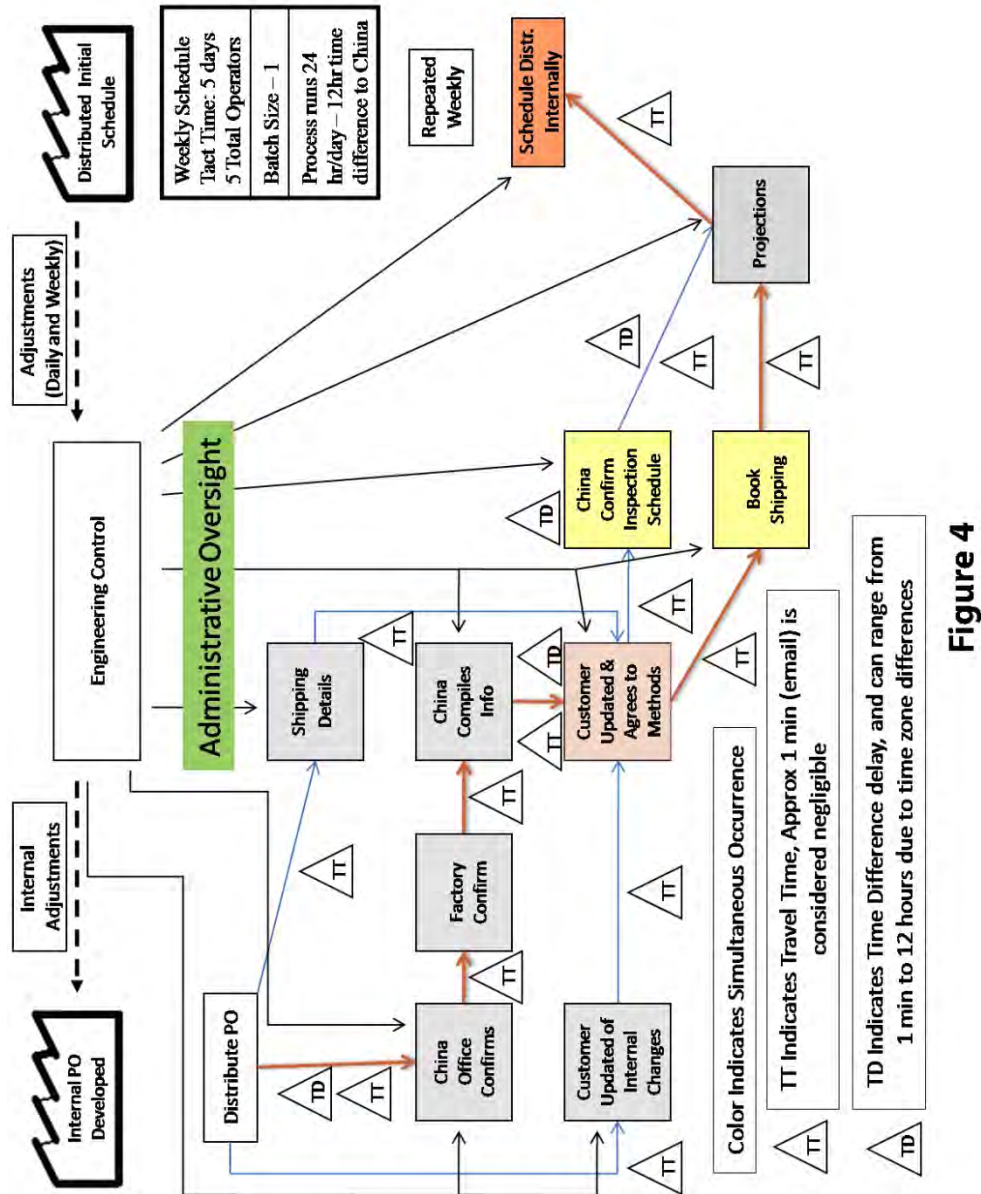
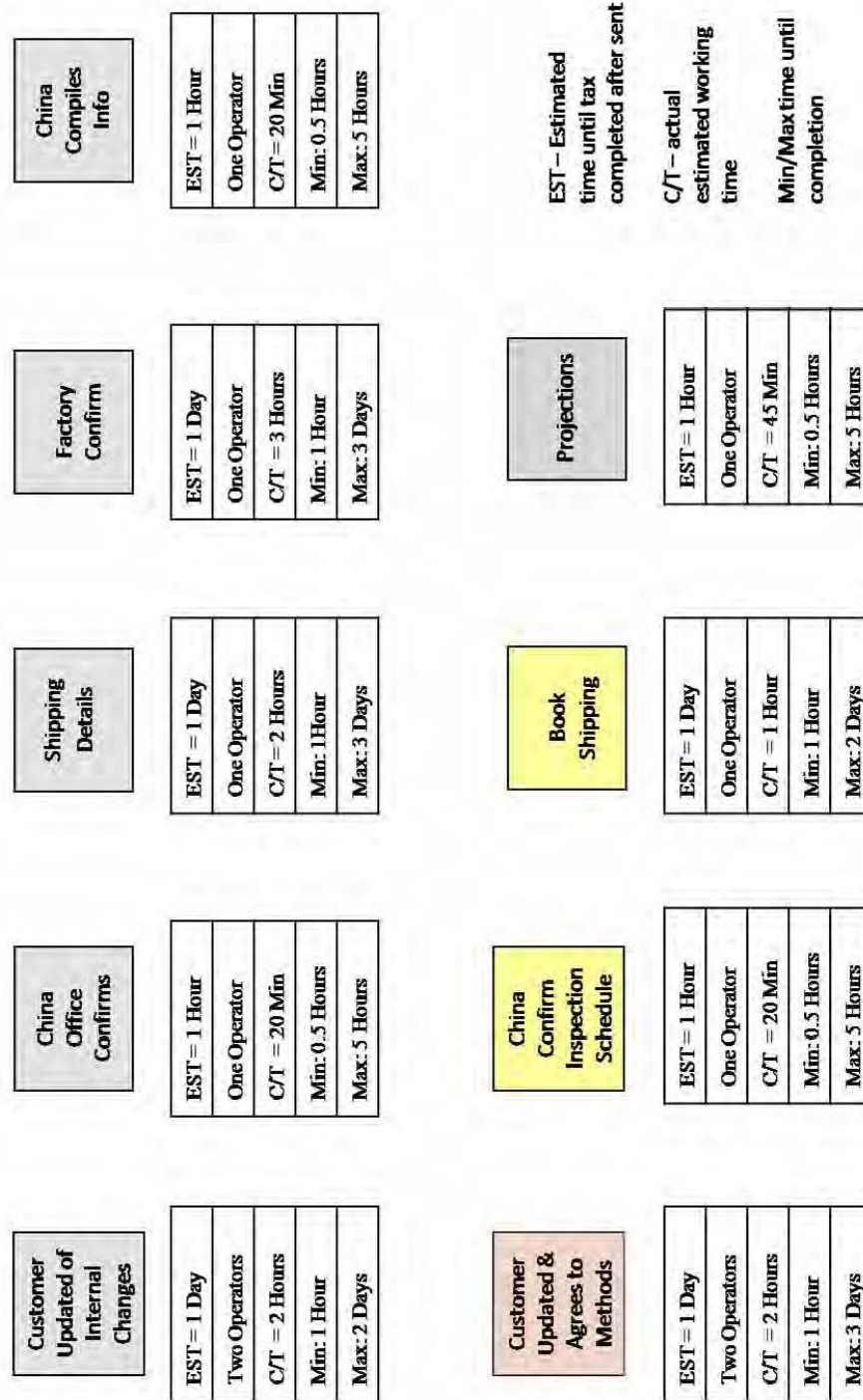


Figure 4

The resulting map is a large and complicated value stream demonstrating the significant amount of required administrative oversight. The process descriptions and lead time analysis can be found in Figure 4.1 seen below.



**Figure 4.1**

Total lead time is calculated along the critical path. The lead time and processing times for non-critical operations are shown as well (Note: Total lead time for both value stream maps is the same due to the fact that it is defined by the critical path).

Two significant benefits are presented by the full process initial value stream map. The first is the revealing of four potential 12 hour delays arising from information transfer between China and the United States. By requiring a customer update halfway through the process, two potential international time delays are introduced, which could lead to an additional 24 hours on the total lead time. On the critical path value stream map, two of these delays are not shown because the critical path is through the shipping department, not the manufacturing operations. If both of these delays materialize, the critical path will in fact shift from the shipping department to the manufacturing operations.

The second presented benefit is a measure of the degree to which the critical path is longer than the other paths. Within the first phase of the process, the critical path is only 7.6% longer than the other paths. Including variation, the effective difference between these paths is negligible. Therefore, including potential time difference delays as well as the relative difference between the critical path and other operational paths, it becomes evident that an initial value stream map must include all of the processes, not just the critical path process.

## **Simulation of Current System**

### ***Benefits of Simulation***

It is possible to build a simulation based upon a predetermined critical path of the process. Simulation provides several unique benefits not realized in a value stream map. While

simulation is not required to progress to future state development and potential solutions, it will provide important insights into the process.

The largest benefit provided by simulation is the analysis of random variation. Variation affects systems differently depending on their construction. While it can generally be stated that pull systems are more susceptible to random variation than push systems, the precise results cannot be determined. When defining objective future states, the exact effect of variation on the current state can potentially alter perceptions of bottleneck processes and the utilization of resources.

Another benefit provided by simulation is an understanding of resource interaction. Any complicated process involves the utilization of multiple resources, whether employees, office equipment, or machinery. In order to understand how the multiple responsibilities weigh on individual resources' effect on the overall system, simulations must be completed.

Considering the potential benefits provided by simulation, a simulation of the current process has been created. Several obstacles and assumptions were encountered during the construction of the simulation. While these obstacles limit the outcomes of the model, the results were still beneficial. Included in this section are future actions AAI employees may take if a more accurate simulation is desired.

### ***Data Collection***

When simulating any system, the first step is to determine what data is needed and where it can be found. As AAI communicates primarily by email or fax, all International POs on record will have a time stamp. Therefore, determining the date and time a PO enters the system

becomes a relatively straightforward process of collecting and recording the time stamps. A more difficult task is, determining individual department times.

Since the international purchase order process is complicated and the time frame for the project was small, task time data was gathered in one of two ways. Option A was to gather data by analyzing time stamps on emails, as stated previously. This method worked well in China, as it could be noted when the email was sent from one department and when it was forwarded again to the next. However, since POs are printed and physically moved between processes in the US office, another method of data collection was required. Option B was to determine task times by interviewing several individuals within the department who have worked with the company for more than five years. These individuals were able to provide average process times as well as maximum and minimum process times. In order to estimate the validity of these projections, simple time studies for five POs were conducted on each individual process. Using these verified averages, Arena Input Analyzer was utilized to generate the raw data using triangular distributions for each US process on each PO (Appendix 2A & 2-B).

Once the raw data was collected, arena Input Analyzer was utilized to fit the raw data to a distribution. The input analyzer fits the data to each of its catalogued distributions and then selects the distribution with the lowest standard error. Appendix 3 provides the fitted distributions as well as Chi Square and Kolmogorov-Smirnov fit tests. The Kolmogorov-Smirnov fit tests are not as thorough as the Chi Square test; therefore, only the results of the Chi Square tests were used to determine the goodness of fit.

A passing threshold for goodness of fit was established at 0.05 (this value is commonly accepted within industry as acceptable). Using this threshold, only the fitted distributions for the China Compilation and Factory Response were acceptable. The vast majority of the fitted

distributions displayed high P-Values within the Chi Square test as well as large square errors.

Therefore, it is safe to conclude that the fitted distributions do not accurately represent the processes from which the raw material was gathered.

Given the poor fit of the distributions it is logical to run the model simulation under scheduled arrival rates and processing times. This would recreate the past 52 days within the simulation. However, there are several complications arising from scheduled process times. If the process times as well as the arrival times are strictly based on schedules from the past three months, replications will continually provide the same results. Additionally, the gathered data is seasonal and does not represent an entire bid cycle. As purchase orders are generated unevenly throughout the bid cycle, data should be collected for the entire bid cycle rather than three months (bid cycles usually run between 6 months and 1 year).

With the given time restrictions it was not feasible to collect further data to ensure fitted distribution validity. As a response, two model simulations were run. The first run (Appendix 4) employed the generated distributions regardless of their poor fit. The second run (Appendix 5) modeled each processing time using a triangular distribution that employed the mean, max, and min estimated by experienced employees within AAI. This second model provides a comparison for the fitted distribution model. By comparing these two models with the actual results shown by the gathered data over the past three months, it is possible to estimate the overall implication of the poor distributions.

The final distribution to be considered is the arrival rate. This rate, as with the task times, must be fitted into a distribution and also be identified as a stationary or non-stationary process. The stationary process allows the arrival rate to be forecasted as a distribution that estimates future arrivals. Appendix 6-A provides a histogram of the arrival distributions as well as the

arrival moments. The histogram depicts the majority of total daily arrival rates centering on 1 or 0; however, the standard deviation is fairly large. As such, the process shouldn't be labeled as stationary because of the resulting histogram.

Appendix 6-B provides more detailed analysis concerning whether the arrival rate is stationary or non-stationary. A simple Exponential Smoother Model was applied to the arrival rates. The results of this model reveal that the process is stable and can be forecasted. Further analysis could match the arrival rates with improved forecasting models; however, more data would need to be collected from Alibi cycles create "seasons" for POs in which the number of incoming POs peak. This trend is not seen in the collected data considering the short span of collection time (3 months). Due to these "seasons," an accurate forecasting model would likely involve the application of a seasonal decomposition.

For the purpose of the project, the arrival rates, once determined to be stationary, were fitted to a distribution. As with the process distributions, the fit was poor and a high P Value was produced by the Chi Square test. Among many complications, the small number of data points (52) as well as the small size of the numbers complicated the fit and the Chi Square test.

As with the process schedules, the poor fit of the distribution suggests arrivals should be scheduled. A similar solution was applied in which two model simulations were run. The first run included scheduled arrivals while the second run included forecasted arrivals. Unfortunately, several programming errors within Arena version 10.0 do not allow Arena to process the multiple schedules within the model. A demo version of Arena 12.0 was provided but it was unable to process the schedule. Several troubleshooting methods were applied including reducing the inter-arrival period to hours and the creation of an infinite schedule that yields 0 POs after the



simulation period; however, no solution was found. Therefore, all model results utilized the fitted distribution.

Finally, the required number of repetitions for statistical validity was calculated. Due to the large standard error in the fitted distributions and the equally large coefficient of variation, the result was a large number of required repetitions (Appendix 7). A calculation for the required number of repetitions was performed for each fitted distribution; the largest required number was in excess of 115,000 repetitions. These numbers are not feasible and again suggest that better data needs to be collected. In order to progress with the simulation, 35 replications were used. This number is a generally accepted rule of thumb for statistical validity; however, as noted, the actual number of required repetitions with the fitted distributions is much higher.

### *Assumptions*

Several assumptions were made prior to building the model logic. The first of these assumptions pertains to employee overtime. This model assumes that employees strictly obey the clock and do not work any overtime. In reality, employees often work overtime; however, this overtime does not significantly affect the cost as most are exempt salary employees.

In terms of arena schedules, employee schedules were placed on preempt, in which case entities are left in progress while the resource is not available. While other decision rules such as wait and ignore were considered, they were ultimately rejected due to the fact that employees exercise a level of judgment prior to working overtime. If the job takes only a few minutes, the employee will work overtime; however, if the job requires several hours and is not high priority, the employee will leave the work until the following morning. Therefore, the other standard decision rules provided by arena were discarded as possibilities.

The second major assumption concerns errors on the purchase orders. It is unlikely that zero errors leave the purchase order process; however, this number is so small it was deemed insignificant. The rate of occurrence is so rare that statistics on the number of POs with errors leaving the system were not available. Thus, it is assumed that all errors will be caught at the latest by the China office.

Another more significant assumption was made in determining employee availability during office hours. Most of the employees simulated have responsibilities other than purchase orders. In the model, it is assumed that an employee is idle if they are not working on a purchase order. In reality, each employee is conducting one of many other responsibilities when they are not processing a purchase order. Statistics and data on the percentage of time spent by employees on other responsibilities were not readily available and thus could not be reliably programmed into the model simulation. Instead, it is assumed that each employee is available to work on the purchase order as soon as it arrives at their desk. While this is an assumption, purchase orders are normally given the highest priority by each employee as they represent incoming business.

### ***Model Logic & Flow***

Due to the complexity of the purchase order process as well as the global environment, activities throughout the process are divided into departments. In order to make a clear model of the process, corresponding departments were defined with appropriate resources. Transfer stations were used to route the purchase order through the departments (often routing the purchase order through one department several times).

Before the model logic within each department is defined it is important to understand several overarching structures that apply to all departments. The first of these structures are the

office operating hours. The global positioning of different departments require that two resource availability schedules be created, one for the US office hours and one for the China office hours. The resources within each department are then scheduled to the availability defined by their respective office hours. The simulation is set from the perspective of the Knoxville office, so the China office availability is from 8:30 PM to 12:00AM and 1:00 AM to 6:30 AM (an hour is given for lunch).

These opposite resource availabilities create a lag between both offices when neither office is working. As a result, purchase orders incur significant wait time due to international working schedules. This delay time is of particular interest to AAI, so holding modules were incorporated between the Knoxville and China offices to calculate the average time each purchase order spends waiting due to international delay.

Another overarching structure concerns errors within the purchase order itself. While errors are not common, they are part of the system and should be included in the model logic. In reality errors occur as the purchase orders progress through the system. However, it is not necessary to assign errors multiple times throughout the logic. Instead, an error attribute is assigned to a small number of purchase orders as they are created. Throughout the model, these errors are “caught” by a decide module based on the frequency at which errors are caught in each department. If the error is caught, it is rerouted to the department where the error occurred and it is resolved. Errors are given high priority in the respective department and incur a reduced processing time due to the fact that the resolution of errors does not usually require a complete rework within the department.

This error creation can be seen in the first model “department” – PO Creation. This is the only model department that does not have a corresponding department at AAI (purchase orders

are sent directly to the company via email, fax, or postal mail).Figure 5 displays this department. As can be seen, after purchase orders are created both the WIP variable and the start count is increased by one. At this point, two decide modules determine if the PO will have an error and if the error will be an accounting error or an engineering error (the only two possible errors).After the error attributions are assigned, the purchase order is sent via a station/route transfer to the engineering department.

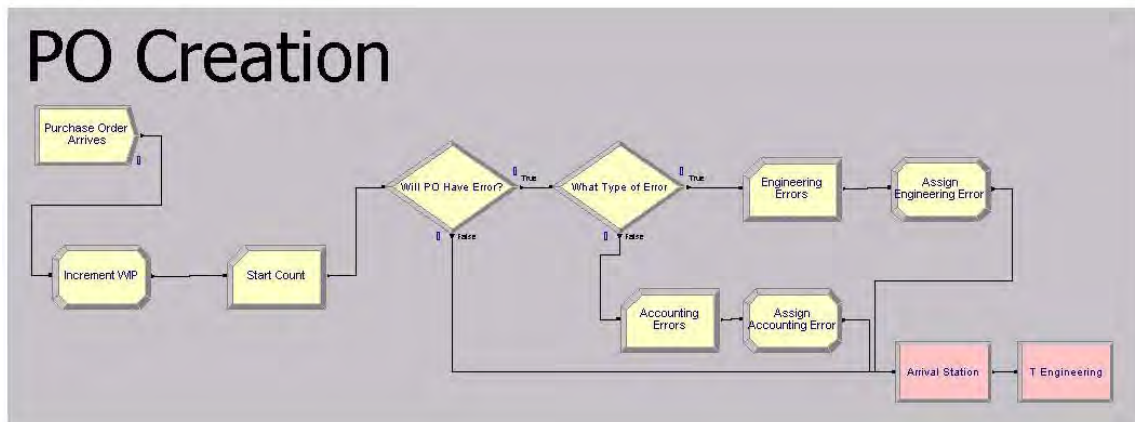
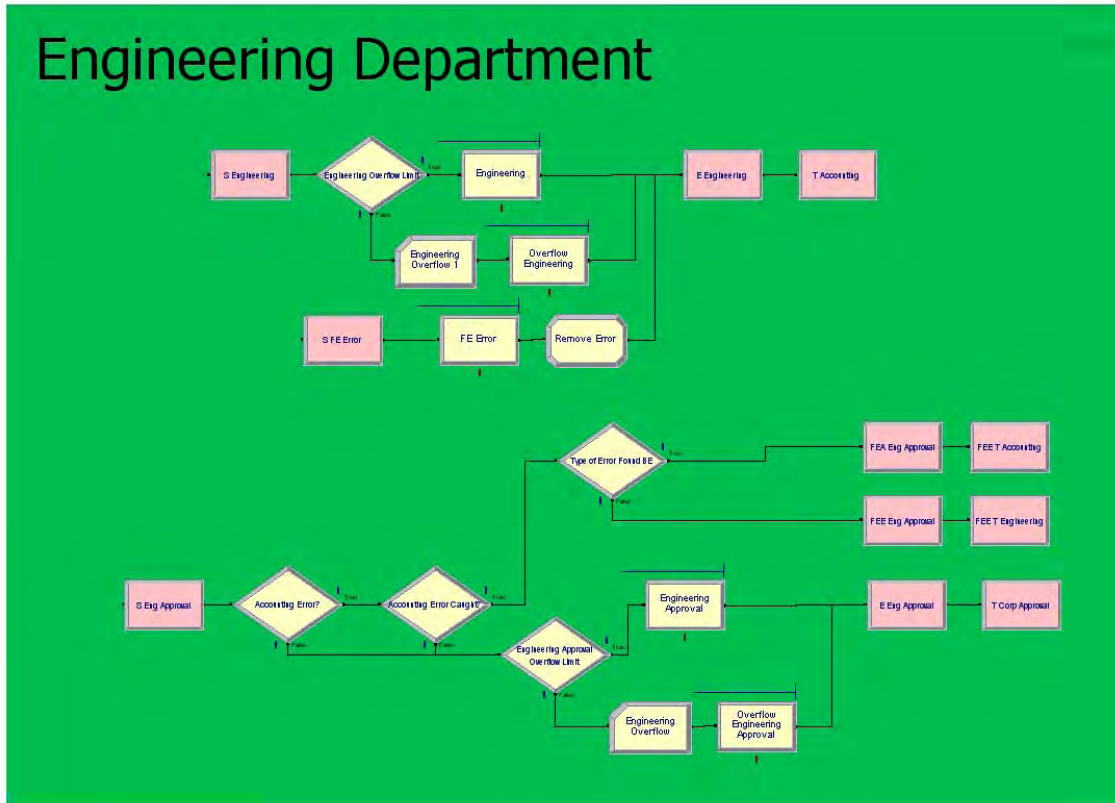


Figure 5



**Figure 6**

The engineering department, seen above in Figure 6 shows two different operations. The first operation, located in the top of the box, is the first route the PO takes through the engineering department. This route is the period in which Engineering generates the required documentation and prepares the required calculations needed within accounting. It should be noted that there are two inbound stations on the left. The top station is the route for new purchase orders that have not been processed, while the bottom station is the route for purchase orders in which an error has been found and the purchase order has been rerouted to the engineering department. Once the error is corrected in the process module, an assign module is used to remove the error attribute. The second process, in the bottom portion of the box, involves the same engineer but at later stages in the purchase order process. In this stage, the engineer checks

the PO for errors, and if errors are found, reroutes them to either the first engineering activity or the accounting department.

After the first process in the engineering department, POs are sent to the accounting department, found in Figure 7. In this department all necessary accounting and booking operations occur. As with the first process in the engineering department, the accounting process involves two inbound stations, one for errors and one for new POs. The first two decide modules determine if the error is caught by sorting out POs with errors and then “catching” the errors based on predetermined chance. Additionally, the accounting error includes an “overflow” section in which an additional accountant helps the PO accountant if the volume is too high. This help is limited because the additional accountant has other responsibilities. Therefore, purchase orders are only sent to the additional accountant if the queue for the PO accountant is above 3.

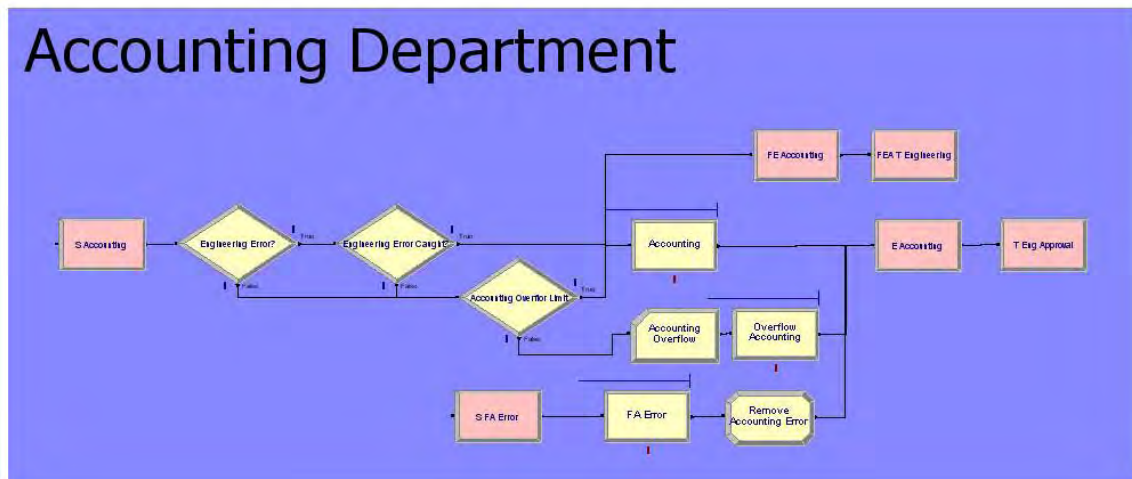


Figure 7

Once the accounting phase of the process is complete, the purchase order reroutes to engineering for approval, which was previously discussed. After engineering approval, the purchase order progresses to the corporate level for approval. Then the PO is sent to administration for distribution. The corporate department model logic is seen below in Figure 8 and is similar to Accounting and Engineering. If the error is caught, the PO is sent to the department in which the error occurred.

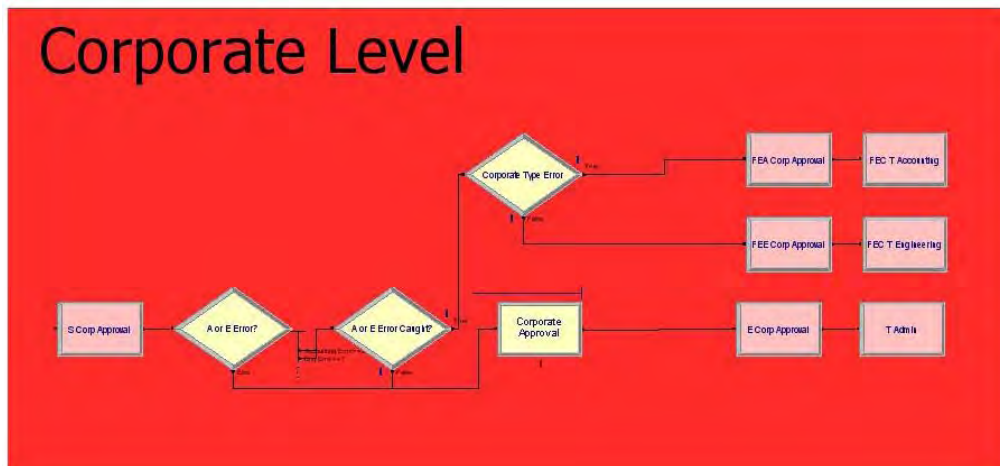


Figure 8

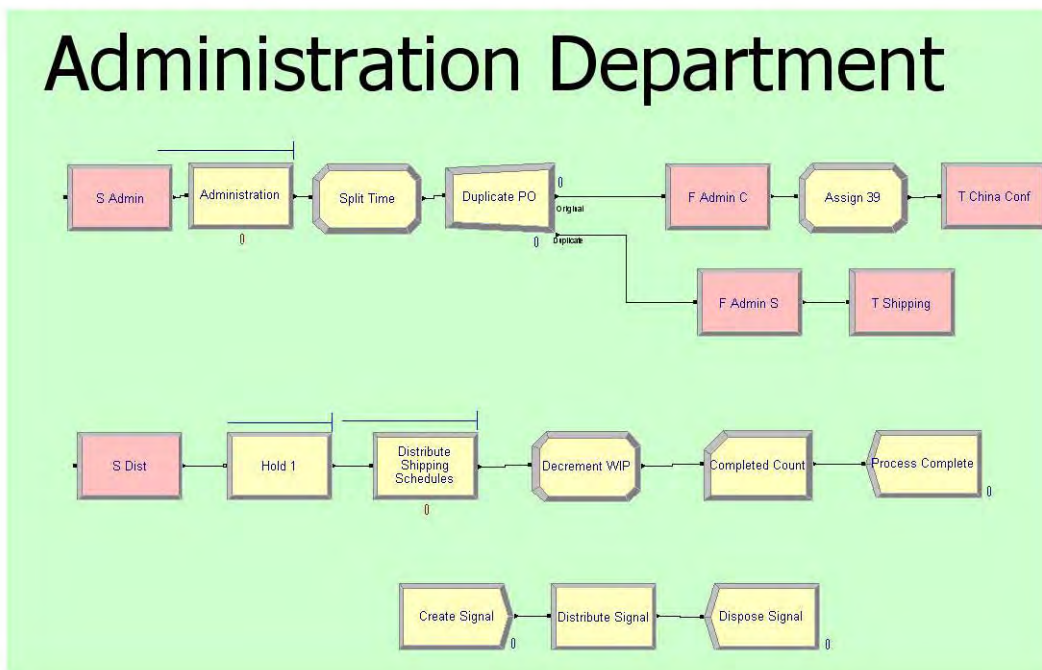


Figure 9

Once the purchase order has progressed through corporate approval it is sent to the administration department for distribution to the China office as well as the shipping department, as seen above in Figure 9. Both of these activities occur in parallel, so the PO entity is split into duplicates. One duplicate is sent to shipping while the other is sent to China. An assign module is used to define the duplication time, which will later be used to batch the duplicates together for final distribution.

The second process, in the middle of the box, is the final distribution of schedules to the customer. Shipping schedules are sent to customers once a week, therefore completed purchase orders (which have become shipping schedules in the shipping department) are held in the model until every 7<sup>th</sup> day. The process at the bottom of the box is the control logic for the hold module. This logic creates a signal every seven days that is sent to the hold module in the previously discussed process. Once the signal is sent, it is disposed. The count in the PO Creation Department is necessary because of this signal. The final arena report displays the total number of completed entities, regardless of entity type. Therefore, a user defined count displays the number of purchase orders received as well and the number of purchase orders completed, which is recorded immediately before disposal in the administration department.

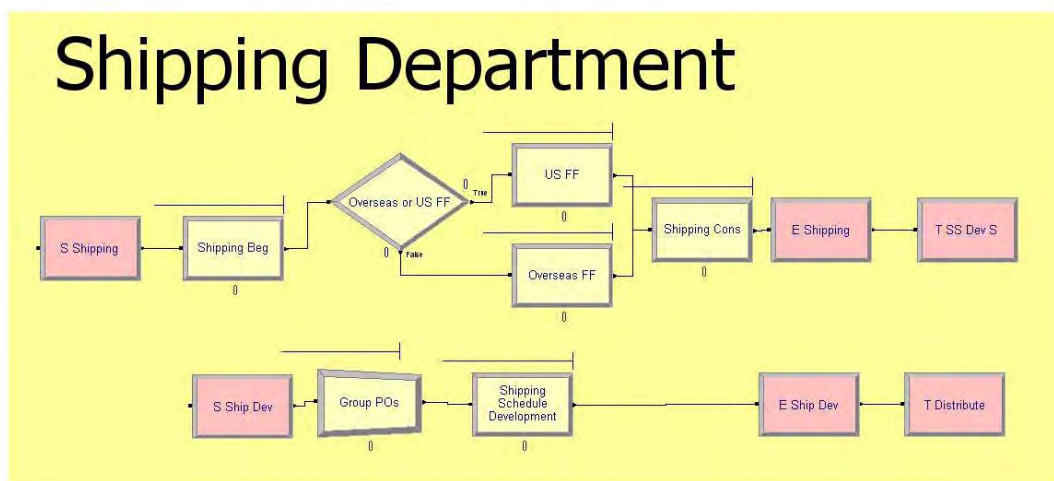
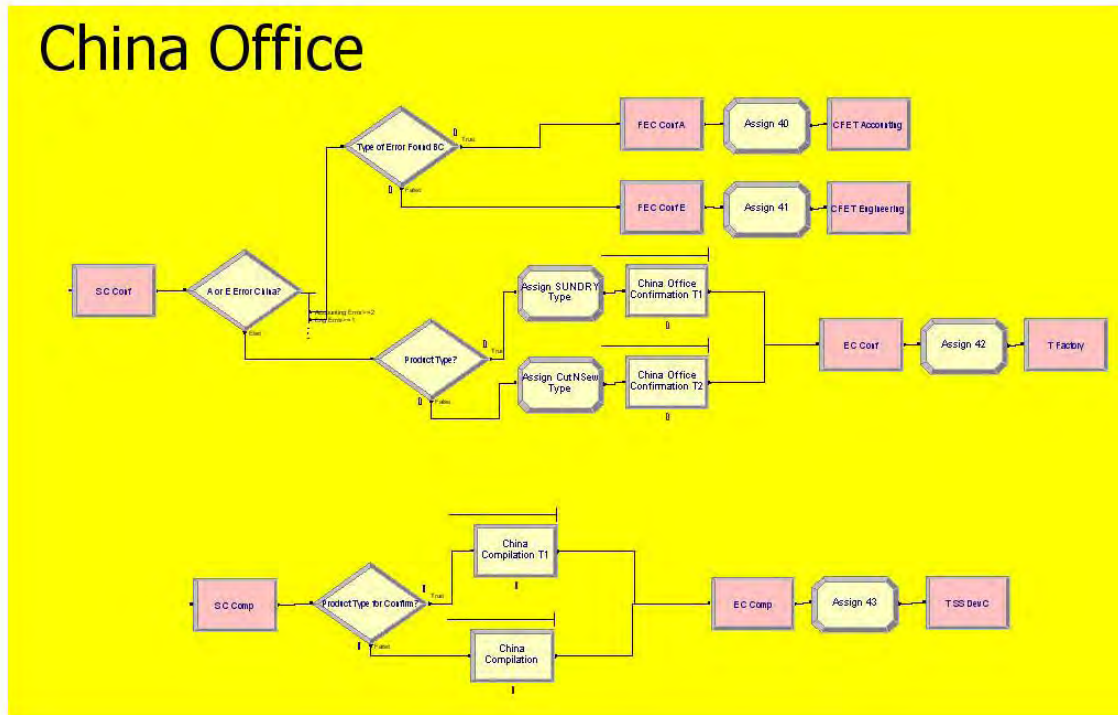


Figure 10



The final department in the US office is the shipping department, as seen in Figure 10. It is within this department that purchase orders are converted to shipping schedules for distribution to clients. The first process at the top of the box is the booking of freight. The shipping process consists of a three part process. The first phase occurs in the US office where the shipping department determines which freight forwarder will be used. At this point the information is sent to the freight forwarder who books the freight and returns with a schedule and cost. Finally, the shipping department combines this information and enters it into the systems at AAI.

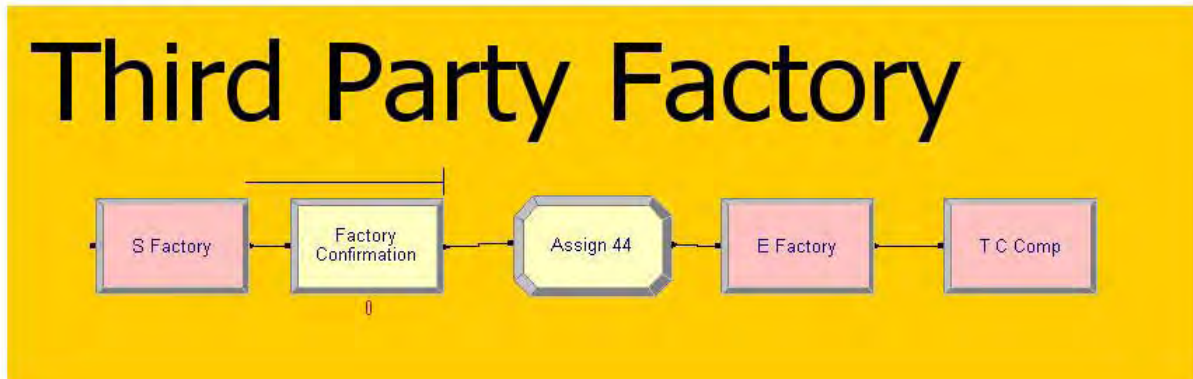
These three phases can distinctly be seen in the model logic with the exception of the freight forwarders who are divided into two processes. This division is necessary because half of the freight forwarders used by AAI are located in China where the goods are manufactured, while half are located in the US. Thus, a portion of the purchase orders are sent to US freight forwarders while the remaining portion is sent to the Chinese freight forwarders. The process times for each freight forwarder are the same, but the operating hours are not. The Chinese freight forwarders are on the same office hour schedule as the China office. Therefore, longer delays are incurred when Chinese freight forwarders are used.



**Figure 11**

The remaining resources are located in the China office, which is represented in Figure 11. The China Office includes two engineers that are involved twice in the purchase order process. The first activity conducted by the China office involves preparing the POs for the factory as well as checking for errors. If errors are found they are rerouted to the appropriate department in the US office. At this point all errors are caught. While some errors may in actuality make it to the factory, statistics were not available on this frequency since it is an uncommon occurrence. Therefore, the model assumes that all errors are caught before progressing to the factory. Additionally, the two engineers in the China office work specifically with only 1 category of product. Therefore, purchase orders are divided among the engineers according to their type. Rather than defining an attribute for product type, sales records were used to calculate the percentage of work in each category. This percentage was used in the decide module to send purchase orders to the appropriate engineer.

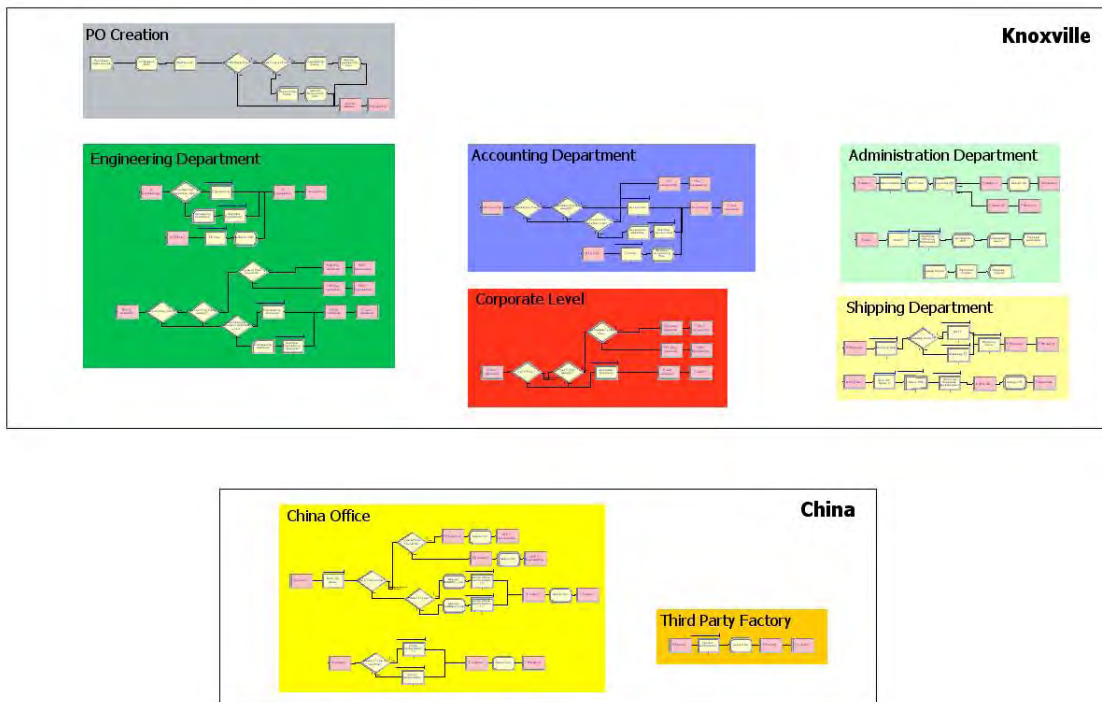
The second process conducted in the China office is the compilation of information from the factory for the US office. Again, each engineer only deals with one product category, so the feedback from the factory is distributed to each engineer based on the percentages described above. Once this process is completed, the compilation prepared by the China office is sent back to the US office.



**Figure 12**

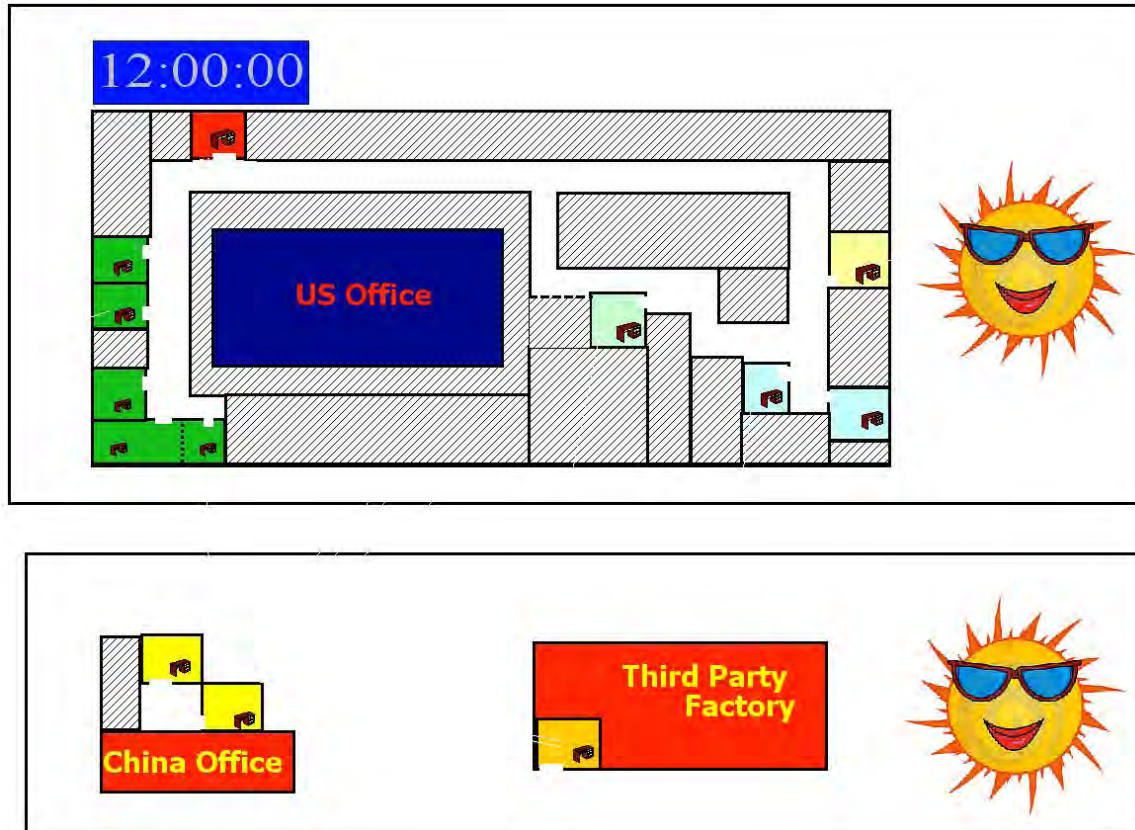
The final department in the model logic is the third party factory, seen here in Figure 12. This factory is outside of the company and the processes within each factory vary. Therefore, aggregate statistics for all factories were combined to develop the process time. Purchase orders simply queue and are processed, after which they are sent back to the China office for compilation.

A final few of the entire model logic is provided below in Figure 13. Since station and route transfers were utilized departments can be grouped and color coated. These colors are then employed in the animation to denote the grouping of resources within the US and China office. Large boxes group the departments into their respective office locations.



**Figure 13**

With the model complete, focus should be directed to the animation portion. As seen in Figure 14, the animation is relatively simplistic. Each department is coordinated with its modular counterpart by the use of colors. “Man” attributes were assigned for all walking times within the US office and for communication overseas, “Fax” attributes were assigned. To give an accurate representation of the 12 hour time change, a sun was put into place whenever the US/China office is busy or idle and a moon was put into place to note when the office is inactive.



**Figure 14**

### ***Simulation Results***

As stated in the Data Analysis section, two models with different underlying distributions for the processes. The first model employs the fitted distributions provided by Arena Input Analyzer while the second employs triangular distributions built upon estimates from senior employees at Amite two models were run as comparisons to provide a reference in determining the total effect a poor distribution could have on the end results.

Several statistics were of significant interest to AAI; in fact, the end result requested by AAI was not optimization of the current process through simulation but rather a better understanding of the process as it stands. As a result, significant effort was placed on building

and extracting the required statistics rather than optimizing the current solution. The main statistics considered important by AAI are:

- Cost per Purchase Order
- Idle vs. Busy Cost
- Departmental Cost per Purchase Order
- Total Coast of the System
- Processing Time per Department
- Average International Delay
- Average Cycle Time per Purchase Order
- Average WIP
- Volume Flow in the Busiest Departments (number of reroutes)
- Number of Errors
- Overflow Capacity Usage

These statistics were gathered in one of two methods. The first method involved the creation of user defined statistics to gather the exact statistic required. However, many of the statistics did not require unique user defined statistics as they were previously built into arena. These statistics were thus automatically generated by Arena.

Overall, the end effect of different underlying distributions proved to be significantly different. However, several statistics are not dependent on the distributions and will be discussed first. The first of these statistics was total cost. Total Cost is simply based on the scheduled office hours and the length of the simulation. Over the course of 52 days the cost of opening both the China and the US office is \$103,584.00. Another statistic independent of the underlying distributions is the number of errors in both the accounting and engineering department. Both

simulations returned an average of approximately 5 errors per department for a total average of approximately 10 errors. This amounts to approximately 10% of purchase orders incurring errors. While this number is low, the cost of rerouting purchase orders through the required departments significantly increases the volume handled by the bottleneck departments.

The remaining statistics are all dependent upon the underlying distributions. The focus of the analysis will be on the fitted distributions and collected data rather than the rough estimate provided by the estimated triangular distribution. However, both results will be given to allow for an understanding of the affect of incorrect distributions. This will hopefully remind users that further data collection is required for a more reliable simulation.

The first category of distribution dependent statistics concerns cost. Beyond total cost, the cost inquiries were related to the departmental cost per purchased order as well as the final cost per purchase order. This breakdown of costs allows AAI to communicate the final cost of the purchase order process to the sales department as well as analyze where a majority of costs are being incurred.

Appendix 4 provides detailed results for departmental costs for the fitted model while Appendix 5 provides the departmental costs for the triangular distribution model. Costs are centered first on the shipping department, followed by the China office and finally the engineering department. Both models agree on the ranking of costs but significant difference in the final numbers is present.

The second cost statistic, cost per purchase order, first requires an understanding of the idle versus busy cost statistics. As stated, the final cost of the entire system, agreed upon by both models, is in excess of 100,000.00. However, a vast majority of this cost is idle cost. Due to the previously discussed fact that the employees have many other responsibilities, it is logical that

the model should have employees idle for a majority of the time. In order to calculate cost per purchase order, the final cost cannot simply be calculated as the final total cost divided by the number of purchase orders.

Instead, the cost per purchase order must be calculated as the value-added or busy cost assigned to each entity. Again, this cost cannot simply be calculated by dividing the busy cost by the total number of completed purchase orders because there are several purchase orders in progress at the end of the simulation. Conveniently, arena keeps an entity statistic labeled cost per entity. Thus, the total cost per purchase order can be calculated by adding the component costs per entity. Arena calculates the sum of the component costs automatically and displays it in a total cost field. For the fitted distribution model the total per entity cost is \$174.14 while the triangular distribution model total per entity cost is \$161.02.

While costs affect the business's bottom line they do not always translate into good customer relations. Several statistics were gathered to measure the level of customer service provided throughout the purchase order process. These statistics include the average lead time per purchase order, the processing time per entity per department, the average time each purchase order spends waiting in-between China and US office hours, and the volume of purchase orders handled by each department.

The first of these statistics, average lead time per purchase order, was a statistic of major concern by AAI. If purchase orders can be quickly turned around and converted into shipping schedules, customers can proceed with future plans. If purchase orders incur a long lead time, the customer waits on AAI and could potentially become frustrated with the process. Within the simulation, a user defined statistic to measure lead time was calculated that summed the total time spent per entity and converted it into days. In the fitted distribution model the average lead



time was approximately 11.5 days while the triangular distribution model average lead time was approximately 8.5. This statistic particularly points out the problems that can arise from poorly fitted distributions by demonstrating such a large difference in one statistic.

The second customer service measure breaks down the average lead time and calculates the total processing time per purchase order per department. These results can be seen in detail in Appendix 4-G or 5-G. Each purchase order spends the most amount of time in the shipping department. This is especially true if the purchase order is sent to an overseas freight forwarder where it will experience another international delay. However, it is worthy to note that in reality the shipping department can often simultaneously work on multiple shipping schedules while they are waiting on booking information from the freight forwarders. Thus, the actual amount of time spent in the shipping department is likely less than that presented by the arena models.

The other departments with large processing times include the third party factory and the administration department. The administration department is expected to have a large processing time due to the frequent routing of purchase orders through the administration department as well as the weekly distribution of schedules that can potentially lead to long delays.

Beyond the processing time per department, another measure of lead time includes the volume of entities seized by each department. Due to errors, duplications, and the natural routing sequence, each department is likely to see the same purchase order more than once. This traffic can be measured by the number of units seized by each department. As seen in Appendix 4-K and 4-L or 5-K and 5-L, the departments experiencing the highest volumes are the administration, china office and engineering departments. All of these departments process each purchase order more than once and thus experience a higher volume through the department.

Unfortunately, the administration department is also one of the departments with a high component percentage of lead time.

While a majority of the lead time experienced by each purchase order can be attributed to departmental processing and waiting times, another large component is the wait time each purchase order experiences waiting for the US or China office to open. Due to the fact that the China office is 12 hours ahead of the US office, there is a significant amount of time when neither office is open. This statistic has never been analyzed by AAI and was an interesting result for management. Under both the fitted distribution and the triangular distribution each purchase order spends approximately 12 hours waiting for an overseas office to open. While this wait time is unavoidable to a degree, attention to international delay could result in a significantly reduced lead time.

The final consideration requested by AAI relates to the average work in progress. While the arrival rate of purchase orders is stationary, it is not constant. Therefore, the level of work in progress fluctuates with processing times and arrival rates. In order to calculate the average work in progress a user defined variable had to be created. This variable is incremented one whenever a purchase order enters the system and is decremented one whenever a purchase order leaves the system. The average work in progress under the fitted distribution model is 8 purchase orders and the average work in progress under the triangular distribution model is 6 purchase orders. Again, this highlights the importance of accurately fitted task time distributions.

Utilizing the user defined variable it was also possible to reconcile the number of purchase orders that enter the system with the number of purchase orders that leave the system by defining the difference between the two as the work in progress. This is not useful in an aggregate result where averages are used; however, if scheduled arrival models are used the

completed purchase orders plus the work in progress at the end of the simulation will equal the number of purchase order received. This statistic can be used as a check to ensure that the duplicating and batching as well as the error correcting process is not resulting in the accidental creation of additional purchase orders.

Overall, a large amount of statistics can be pulled from the simulation. Many of these statistics can be compared with the gathered data to judge the accuracy of the simulation assuming the gathered sample data is representative of the average process. In order to present the results of the simulation in clear and understandable implications for AAI management, the previously discussed statistics have been generated and highlighted due to the fact that they represent answers to the initial concerns presented by AAI management.

### ***Model Improvement***

Several limitations of the current simulation model have been recognized; if AAI management were interested in continuing improvement for the model for more reliable results, several steps should be undertaken. The first of these steps would undoubtedly be to improve the fitted data distributions. This would need to be accomplished by collecting more data samples. The larger the data sample the more accurate the fit test. Unfortunately, accurate fit tests often require thousands of data points. However, one advantage gained by further data collection would be the identification of seasonal trends. Potential seasonal decompositions could be applied to the data to create more reliable fitted data distributions.

Beyond the data distributions, several components in the model logic could be improved. The first of these components is the shipping department. The shipping department currently processes purchase orders in series as they arrive. However, the shipping department actually has

the capability to process purchase orders in parallel. By staggering the delivery of purchase orders to freight forwarders the shipping department is able to drastically cut down the amount of time purchase orders spend in the department. In order to create accurate model logic to simulate this process, further time studies would need to be conducted.

Another department with potential improvements is the China office. The China office has more than two engineers as well as a support staff. While the support staff and other engineers do not directly involve themselves in the purchase order process, they are available to help and act as overflow capacity. As the model currently stands, these resources are not included.

Within all of the departments, distributions could be created to model the average amount of time each resource spends completing other responsibilities. While these responsibilities do not necessarily have to be defined in detail, they could be modeled as “failures” of resources where the resource is active but not available to be seized by the entity. Additionally, the current model is only concerned with international consolidation purchase orders. If the purchase orders processed by the entire engineering department were included, more accurate results could be obtained.

Finally, the cost estimates currently included in the model are rough cost estimates. While salary and pay are not commonly available in the office, AAI could review the costs estimates and adjust them as they feel necessary to create more accurate costs. To the best of current knowledge, the inputted costs are close to those actually incurred.

***Immediate Recommendations from the Simulation Model***

From the previous results several recommendations have been included. One of the first and most obvious recommendations is to implement more “mistake-proofing” to prevent errors. Errors become costly as they are rerouted through the process. Especially for engineering errors, if the error is caught in china, additional international delays are incurred as well as the required rerouting of the purchase order throughout the entire process.

Another recommendation would be to create a process by which departments, especially the China office, can fix the error and/or continue with the purchase order while the error is being fixed. While major errors will require the purchase order be rerouted to the engineering department, minor errors and typos could possibly be resolved without restarting the purchase order at the beginning of the process. Any and all efforts to reduce rerouting due to errors throughout the process will reduce the total cost as well as the lead time.

Continuing with the costs and lead times associated with the current routing of the purchase order process, efforts should be made to reduce the number of times a purchase order is routed through each department to one time. The fewer number of phases the purchase order goes through the shorter the lead time as well as the lower the chance for possible errors. This will reduce the currently high volume of purchase orders experience by the china office as well as the administration and engineering departments. Additionally, reducing the number of times a purchase order is routed through the department will open resource availability for other responsibilities such as building new business relationships. Ultimately, reducing the number of times a department must process the purchase order will increase the overall efficiency while reducing the overall cost.

While AAI has reduced the cost per purchase orders to acceptable levels, efforts should still be made to reduce the number of unnecessary purchase orders that are completed.

Occasionally, purchase orders generated by the sales department are not realized due to fluctuating business conditions. Efforts are currently being made to reduce these errors; the current simulation model reinforces the motivation for these efforts by demonstrating not only the monetary cost per purchase order but also the time costs incurred by each department.

While reducing routing costs and rerouting of purchase orders will reduce the total lead time, a significant portion of the lead time is incurred by international delays. As the company is currently structured, many of these delays are unavoidable; however, certain measures could be implemented to reduce these international delays. One possibility is to locate more engineers in China to reduce the delay time between US and Chinese departments. This effort will reduce the delay between the US and China office; however, it will also increase the delay between the US office and the US and European clients.

A second solution is to improve scheduling to ensure that purchase orders are not sent to the China office early in the US working day. Instead, work on purchase orders could be scheduled to minimize delay times. Currently most departments are aware of the international delay and work to prevent unnecessary delays. Creating a more rigid schedule would not only be difficult but it would also require additional resources. By confining departments to schedules the company would lose its flexibility, which is one of its major competitive advantages.

A final possibility would be to increase the global distribution of employees. By locating employees in closer proximity to clients and manufacturing facilities the company would become more responsive to client and supplier needs. Employees would necessarily have to be cross trained in order to prevent international delays between departments that are currently

simultaneously scheduled (such as the shipping, engineering, accounting, corporate, and administrative departments). However, if systems could be designed to allow for global distribution of employees, AAI could quickly respond to business conditions, client needs, and supplier inputs.

Before employees could be globally distributed, systems would need to be setup to allow for a centralization of purchase order data. Currently, purchase orders move between departments via printed copies, emails and faxes. Instead of the physical movement of purchase orders and revisions, information could be stored in one central location or database. This would also reduce rerouting costs by allowing multiple departments to access information simultaneously.

Overall, the general recommendation that can be gained from the simulation is that processes should be streamlined and standardized. By reducing phases in the process and standardizing the steps within each phase the process will become flexible and fast enough to allow for a global distribution of employees that will ultimately result in better response to customer needs. In turn, this increased response will lead to business growth and net positive bottom line effects.

## **Temporary and Permanent Solutions**

### ***Necessity of a Temporary Solution***

As with any business project, operations continue throughout the analysis and improvement. While future states are developed and the supporting systems built, it is often necessary to develop an immediate solution. Immediate solutions are not intended as long term

solutions or even complete solutions, but rather solutions that will allow the business processes to continue functioning until the ideal state can be achieved.

Theoretically, ideal solutions are a waste of time and resources. Lean principles continually strive to only provide permanent improvements. However, the reality of the business world conflicts with such an ambition. As such, a temporary solution was designed to improve the process flow and allow AAI to continue international consolidations.

Additionally, the current process was analyzed and an ideal permanent solution was developed. This ideal future state is not subject to cost or resource constraints. The reason the ideal solution was not subjected to constraints was to allow the design team to develop a solution that truly removes the problem. Later, realistic constraints are applied and the ideal solution is altered into a feasible and applicable current solution. However, the ideal future state should not be forgotten or discarded in current or future development.

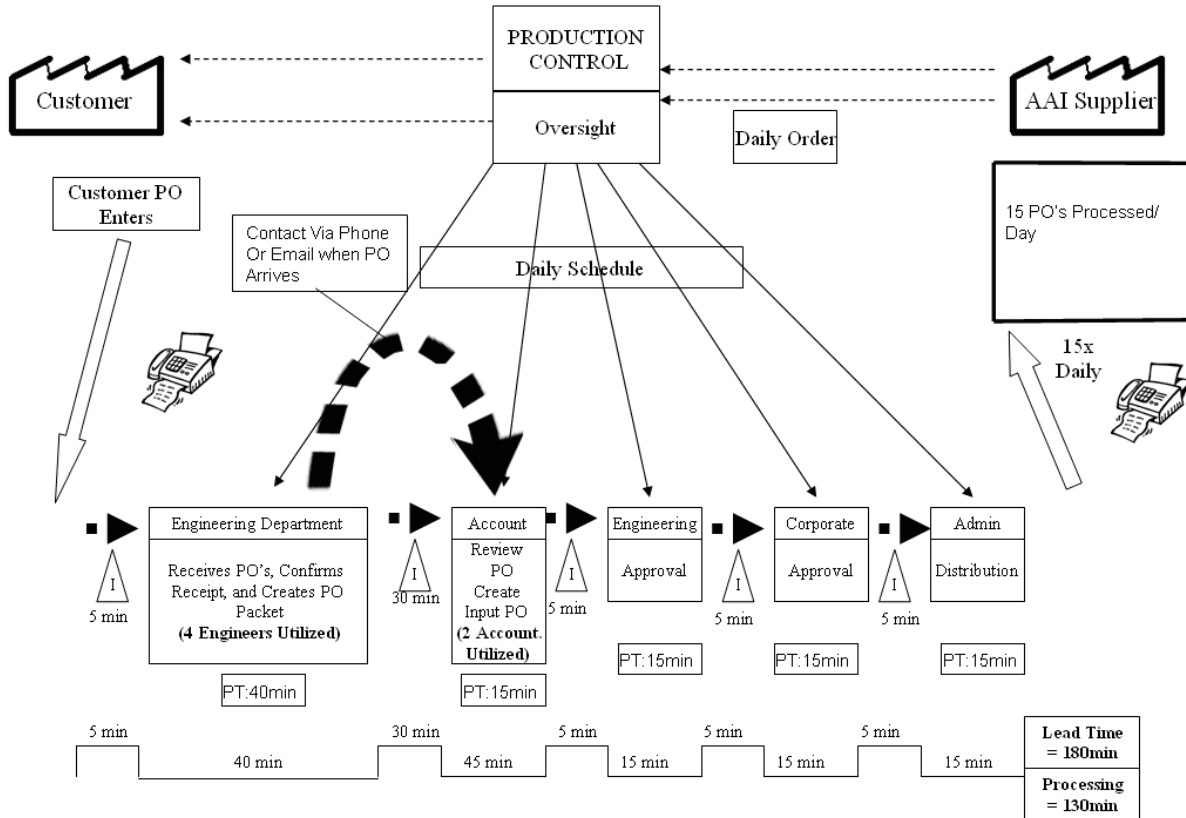
### ***Implemented Temporary Solution***

As is evident, the PO Process is fairly complex in its current form. In order to expedite the process so that it is possible to process at least 15 per day, lean principals will be implemented. With the initial value stream map complete (Figure 1), a takt time must now be defined for the total operation. Because each work day is 8 hours long and the goal is to complete 15 POs per day, the takt time can be defined as 8 hours. It is difficult to create continuous flow in this particular process as all departments have other tasks to complete that do not relate to the PO process. However, one implementation of continuous flow is the utilization of communication. When the Engineer begins the PO Packet, he/she will call the Accounting Department to advise that the PO has begun be created. This allows the Accounting Department



to open their schedule for when they expect the Engineer to complete the PO, therefore creating partial continuous flow. In this particular process, a super-market will not be utilized. As all employees are working on different tasks they must wait for the previous department to complete their task before beginning their own in regards to the PO process. Effectively, the PO process is a Pull System. When analyzing the Value Stream Map, it is apparent that the bottle neck or “Pacemaker” occurs at the Engineering Department. To ensure this department determines the schedule, all processes prior to the Engineer Receiving the PO were eliminated. The Engineer now receives the customer PO directly and is responsible for confirming it. This cuts all wait times prior to the Engineer receiving the PO. As the documentation development process is still the bottle neck, four Engineers are assigned to create the packet when POs begin to queue. This allows more POs to be completed when there is an urgent need. As a new bottle neck occasionally appears in the Accounting Process when the Engineering Department lead time is shortened, a second Accountant is also utilized in the most urgent circumstances. Finally, a fifth Engineer not assigned to the PO Packet Process is set as responsible for Engineering Approval only. This allows the other four Engineers to remain free when new POs come in.

After this analysis, a revised Value Stream Map was created as seen in Figure 15. This Value Stream Map reveals that 10% of total time was reduced by making simple adjustments to the process while still allowing all current documentation processes to take place. Also, by adding multiple Engineers in the PO Packet Process less queuing occurs when multiple Customer POs enter the system at the same time.



**Figure 15**

***Suggested Permanent Solution***

Beyond “temporary fixes,” lean principals can also be applied to suggest a more permanent fix. Thus, a potential future state was developed and proposed to AAI management. This initial solution does not represent the final solution and requires further analysis of required inputs as well as simulation of the total process to gain a better understanding of forecasted steady-state operation.

Again a goal was set to produce to the tact time, as well as understand the required tact time. The tact time is set by the customer as one shipping schedule every five days. The system

already produces above the tact time (in fact averaging twice the requirement). This does not suggest improvements are not required; instead, the current maximum work in progress of 73 purchase orders is required. This inventory is waste because it is not required to produce to the tact time or even account for variability.

The second principle considered developing continuous flow where possible; continuous flow is largely impossible in the AAI shipping development schedule. With offices separated by 12 hours and tasks separated not only by departments within the company but also by external entities, complete continuous flow scheduling is not a reality. However, a closer analysis of the system does reveal one potential area of continuous improvement. When the purchase order is generated, the shipping dates are agreed upon and are within AAI's judgment to determine shipment method as long as the arrival dates are met. If the shipping department was able to continuously communicate with the customer regarding available ports and requirements for different methods of shipping, the booking of shipping method would not need to be broken into two different processes. A major concern with combining these two processes is the fact that the customer may be inundated with information and inquiries from AAI; typically, only one individual communicates with the customer to provide a uniform presence. However, this concern is internal, and improving communication and information availability internally could lessen this concern.

Moving beyond continuous flow, lean theory suggests "supermarkets" or inventory visibility where continuous flow is not possible. These supermarkets work under a pull, or Kanban pull system to prevent unnecessary WIP. With a staggering WIP in the current system, a pull system is essential. In order to implement a pull system in the AAI shipping schedule

development process an understanding of the several other principles of lean theory is first required.

The required principle is the identification of a bottleneck within the process. In simulation, the shipping department and the external factory become bottlenecks, with the critical path being the bottleneck process. Beyond identifying the bottleneck process, scheduling must occur at the bottleneck process. This is a major concept behind pull scheduling and will be a significant component of the proposed solution. Additional principles require an even distribution of different products and an even production rate. While there is only one product in the AAI shipping schedule development process, the concept of an even production rate will once again be a major component of the proposed solution. The final principal is that scheduling should be pulled into the bottle neck and pushed out of the bottleneck. This prevents unnecessary WIP prior to the bottleneck and prevents bull-whip effects encountered when production is scheduled too far down the production process.

Beyond the lean principles, it is easy to see that while calculated capacity results point to the shipping department and external factory as bottlenecks, the process literally bottlenecks at the customer update. As already discussed, continuous communication would allow the two shipping department tasks to be combined into one task. If the customer update were reorganized so that no process was ever waiting on the update, more direct flows could easily be established. However, continuous contact with a customer, whose sole concern is not the weekly shipping schedule, would require too much involvement from the customer and become a burden.

Instead of engineering control communicating with customer, the suggested improvement is to elevate the customer updates to just below the engineering control level. By making operations transparent and continuously available to the customer and having engineering control

update the customer on an as-needed basis, the literal bottleneck of the process flow diagram would be removed. Making operations transparent would require information consolidation to a viewable format where only one representative from AAI need be involved in the direct communication. This would eliminate the threat of over-communicating with the customer for each department.

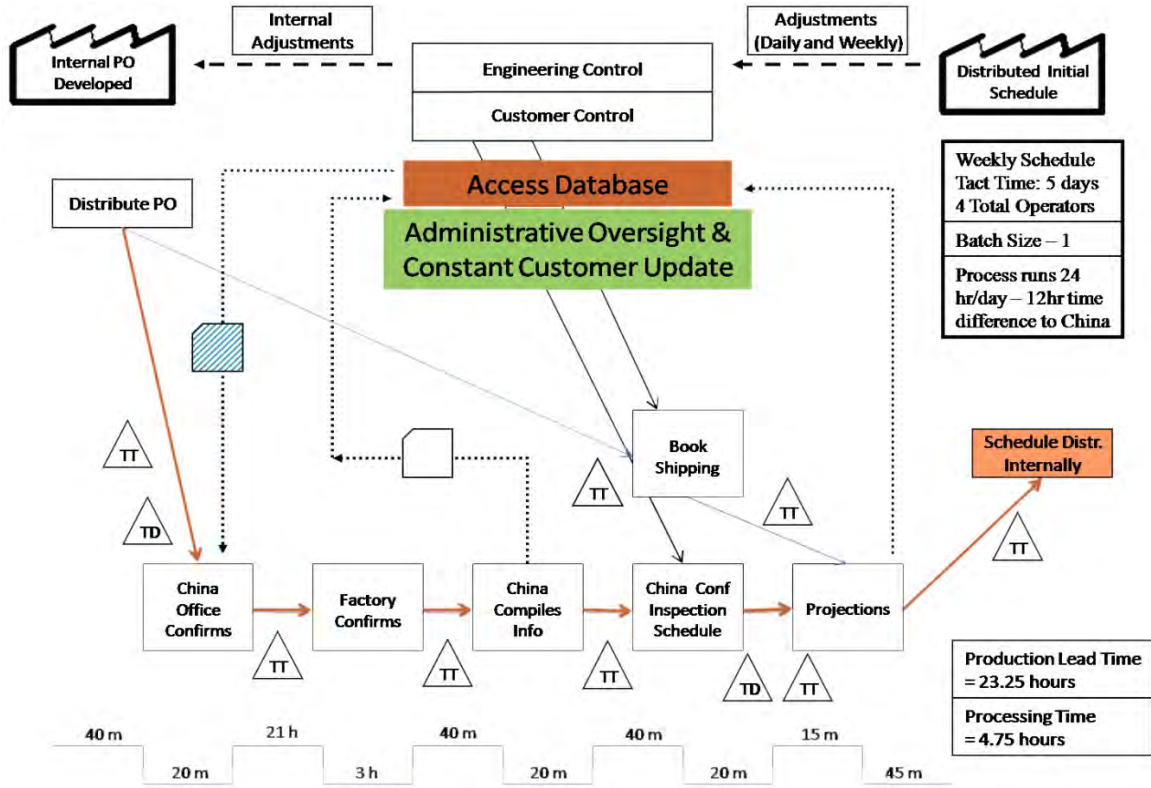
The perfect solution for such an information consolidation would be a content management system, or as suggested, an Access Database. This database would provide continuous access to manufacturing and shipping operations as well as assist engineering control in reviewing the progress of each task. By implementing the database, customer update tasks are removed and it becomes possible to combine the both tasks within the Shipping Department operational flow.

However, the advantages of the database are not limited to removing unnecessary wait times for customer updates. In fact, the database would become the central component of a Kanban pull system that schedules production at the bottleneck. If the shipping department activities are combined, the critical path undeniably lays completely within the manufacturing operational process. The bottleneck of this operational process, as defined by cycle time (wastes are not included in capability calculations), is the confirmation from the external factory. Scheduling cannot occur directly at this process due to the fact that it is an external element. As such, this bottleneck should never be starved for material; hence, scheduling should occur immediately after the factory confirmation. As the factory completes one purchase order, a second is immediately sent so that the factory's utilization is maximized.

It is in this scheduling that the access database would play a central role. Essentially, the database would act as visible inventory, or a supermarket, where engineering control would

easily be able to view the progress of purchase orders through the shipping schedule development process. Once a factory confirmation is received by the China office, the database is immediately updated even before the China office compiles the information. At this point, the database entry immediately triggers the China office to send another purchase order to the factory. This selection of purchase orders even allows engineering control to determine priority. The China office will receive all purchase orders; however, they will only send purchase orders through the system at the capacity of the bottleneck, which is the Chinese factory.

This revised complete system is value stream mapped on the next page in Figure 16, with details of each operation in Figure 16.1. It is readily apparent that the required level of engineering control is significantly reduced. Additionally, upon completion of projections, the database is again updated to ensure up-to-date information is available not only to engineering control but also to the customer on an as-need and as-required basis, determined by engineering control. The total lead time is reduced to 28 hours, with 16.9% of the lead time being processing time. While the majority of the lead time is still waiting, it is important to realize that waiting time has been reduced by almost 35%. Secondly, the chances for time difference delays between the United States and China office have been reduced by 50% (a potential saving of 24 hours).



**Figure 16**

China Office Confirms	Factory Confirms	China Compiles Info	
EST = 1 Hour	EST = 1 Day	EST = 1 Hour	
One Operator	One Operator	One Operator	
C/T = 20 Min	C/T = 3 Hours	C/T = 20 Min	
Min: 0.5 Hours	Min: 1 Hour	Min: 0.5 Hours	
Max: 5 Hours	Max: 3 Days	Max: 5 Hours	
China Conf Inspection Schedule	Book Shipping	Projections	
EST = 1 Hour	EST = 1 Day	EST = 1 Hour	
One Operator	One Operator	One Operator	
C/T = 20 Min	C/T = 1 Hour	C/T = 45 Min	
Min: 0.5 Hours	Min: 1 Hour	Min: 0.5 Hours	
Max: 5 Hours	Max: 2 Days	Max: 5 Hours	

EST – Estimated time until tax completed after sent  
C/T – actual estimated working time  
Min/Max time until completion

TT Indicates Travel Time, Approx 1 min (email) is considered negligible

TD Indicates Time Difference delay, and can range from 1 min to 12 hours due to time zone differences

**Figure 16.1**

With the above adjustments, the critical path is now solely the manufacturing operational process. A value stream map of the critical path is provided in Figure 17. Unlike the initial value stream, where variability and slight difference defined the critical path, the critical path in the future model is significantly longer than the shipping department operational path and thus can be expected to be a much better representation and the bottleneck operation.

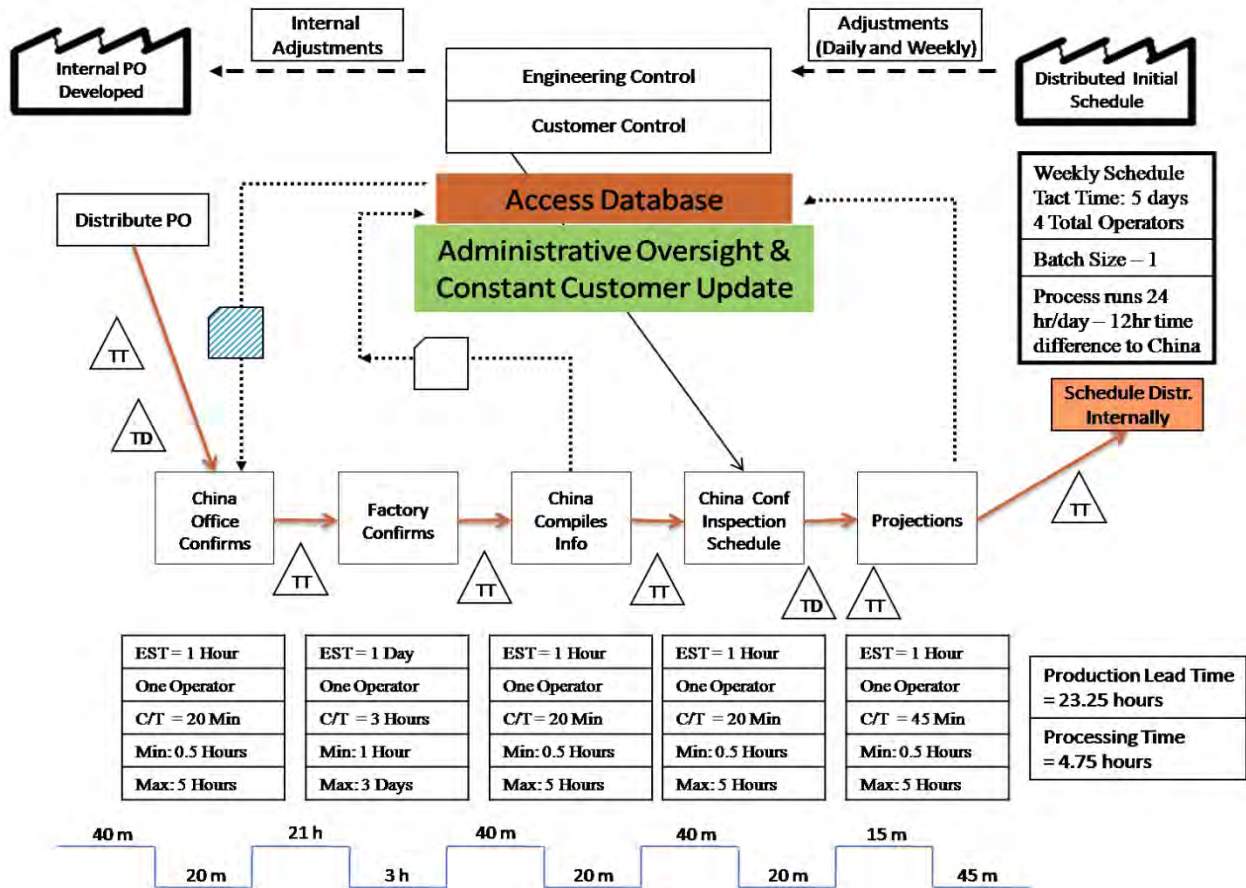


Figure 17



## **Revised Permanent Solution**

In order to have a more simplistic method for the Engineering Department to be more efficient in putting together POs as well as plausibly creating reports useful for determining factory utilization, product category strength/weakness, and many other reports, a database had to first be created. The Engineering Content Management, or ECM for short, was created for the purpose of this project to better centralize information located within the standard AAI PO Packet so that it can be sorted and utilized for creating numerous reports. As a second purpose, it should make the PO Packet and Quotation Generation process simpler to reduce the regular learning curve for new employees.

## ***Adjustments from Suggested Permanent Solution***

The previously proposed department wide enterprise content management system is a detailed and thorough improvement to the current PO process at AAI. However, the development of such an intensive database, which would include not only data storage but schedule generation, production coordination, and the integration of current accounting database systems, is a significant undertaking beyond current resource and time availability.

However, a modified version of the proposed Enterprise Content Management System, labeled the Engineering Content Management System, is within the scope of the project and feasible for implementation. While this system will not allow the complete elevation of clients to Engineering Control, it will enable communications between AAI and the client by increasing data availability and standardizing current operations into a centralized location.

***Boundaries & Function of the ECM Database***

As the Engineering Content Management (ECM) database is a scaled version of the previously suggested system, a clear definition of the boundaries and function of the revised solution is necessary. The proposed solution will not coordinate production or purchase order scheduling within the China office as originally suggested. Integrating a database responsible for scheduling would require functionality that may or may not be accessible in Microsoft Access. Such systems, as designed by SAS or Oracle, are comprehensive, companywide projects requiring significant capital investment. While such an improvement is not discouraged, the implementation is not currently feasible both within the scope of the project and within AAI.

Additionally, the ECM Database will not integrate with the Peachtree ® Accounting Software used within the accounting department. This software maintains all of the financial records; as such, AAI management has explicitly asked that trial systems do not interfere with the Peachtree ® Software. Beyond management requests, integration of engineering and accounting software is again a large project that would require significant capital investment and experience in large relational database construction. Potential future opportunities such as exporting and importing data between both systems are possible, but will not be utilized presently.

Even considering the revised boundaries of the proposed database, the potential functionality of the solution is still beneficial. Ultimately, the completed solution will serve two purposes: document creation and data standardization. The first purpose, document creation, will remove significant manual efforts within the engineering and administrative departments. The ECM database will store the required information and have the capability to generate the entire

purchase order packet. Currently, the purchase order packet is generated from several Microsoft Excel templates that must be manually keyed. This repetitive data entry increases the opportunities for errors and requires significant time investments by the related parties. Additionally, if corrections are made to the documents, each document must be manually changed even if only one piece of data has changed. Utilizing the new database, changes will be made to the data record within the database from which the required documentation is created. Thus, one change will revise each document in a more efficient and cost effective manner.

The second purpose, data standardization, is an important process for AAI. As the process currently stands, “official” copies of the documents do not exist. While it is assumed that the documents received by each department are official, it is still possible to generate multiple official copies. By entering all of the data into one centralized database, an official copy exists and is accessible by each department. If desired, the departments within AAI could even move to reduce paper consumption by utilizing electronic versions from the same database.

Beyond creating official copies, the ECM database will provide an even greater benefit. As all of the data will now be entered into a searchable relational database, each field on the documents is indexed. As such, queries can be run to pull desired information, whether pertaining to a specific record or to summary data. Monthly, quarterly, and yearly reports as well as detailed reports of activities concerning specific buyers, factories, and company employees can now easily be generated. Several of these reports are currently generated manually within the Engineering and Administrative departments and require significant time investment. The new reports will be automatically generated and will make no errors in data collection assuming original data has been correctly entered.

### *Metric Analysis*

Before development, influential projects should not only define the scope of the project, but also an assessment tool to judge the progress of the project. Developing such an assessment tool always begins with brainstorming. Many tools exist to aid the brainstorming process; however, no tool is the “correct” tool to use. Commonly used tools are group sessions, Fish Bone Diagrams, and electronic discussion boards. In this case, a simple list was generated of all aspects of a database implementation that were thought to be important. This list was then supplemented with research from several sources including class slide, the UT Lean Assessment Tool, the Toyota Production Assessment Tool, Quality: A Corporate Force by C. H. Aikens and Methods, Standards, and Work Design by Niebal and Freivalds. The extensive list created through this process was then analyzed and categories were developed.

During this process it became evident that two assessment tools would be necessary. Each metric or category measured performance of either the actual database created or the process of implementing and developing the database. While a standing manufacturing facility enjoys the stability of a relatively constant product, the short term nature and single product of a database implementation does confine itself to a strict product definition. In fact, the product itself is defined throughout the process. Therefore, it is necessary to develop a lean assessment tool for both the end product and the process of developing the end product.

With this realization, each metric and category of importance was classified as pertaining to either the end product or the process of the implementation. These lists were then analyzed and grouped into 5 main categories. It is important to limit the number of overarching categories;

a small number of categories will remain clear and understandable to not only the individuals within the project but also the individuals supervising the project.

Additionally, the overarching categories are not of themselves metrics. In fact, even the main components of each overarching category are not specific metrics but rather important lean concepts. Metrics are tools to measure the successful utilization of each lean principal and they provide specific, quantifiable results. Metrics are suggested throughout the case study; however, these metrics are not limited and many other metrics exist. The metrics suggested in this case study are those thought to be most applicable to the AAI database implementation.

### **Metric Categories**

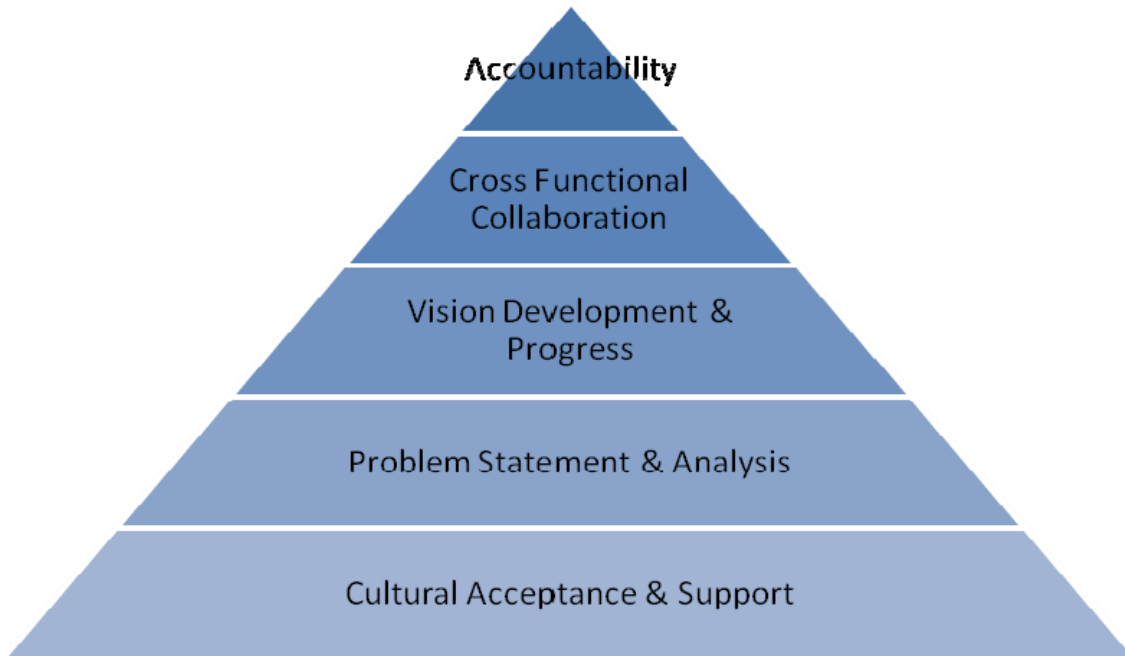
Using the separate lists of criteria and metrics created for the database product and the database implementation, overarching categories have been developed and scorecards for each assessment have been created.

The first assessment conducted is always the database implementation process evaluation. It is important to first analyze the process because the database itself is a product of the process. After concluding the brainstorming sessions the following 5 overarching categories, listed in descending importance, were created:

1. Cultural Acceptance & Support
2. Problem Statement & Analysis
3. Vision Development & Progress
4. Cross Functional Collaboration
5. Accountability

Figure 18 provides a convenient pyramid to visually display the ranking importance. The base of the pyramid is cultural acceptance and support; without this objective, none of the other

objectives are possible. Similarly, Vision Development and Progress is not possible without a Problem Statement and Analysis. The final category, Accountability, is dependant on the existence of each of the categories below it.



**Figure 18**

The first and most important category, cultural acceptance and support, is composed of four subcomponents: Motivation, Awareness, Support, and the use of Open Systems. While the most important to the success of the implementation, the components of this category present the most resistance to quantifiable measurement via metrics. Motivation is largely subjective and thus must be measured through the solicitation of opinions. It is important to ensure that employees do not feel their responses will reflect upon them in order to avoid positive reinforcement. Positive reinforcement is “positive” feedback that does not address the issue but rather complements the positive components of the system. Positive feedback always fails to identify the malfunctioning components of the system.

Awareness provides more avenues of measurement and can be measured through a survey of company employees. If most employees are unaware that a database is even being developed, or that a database is even needed, the culture within the company is unaware. Growing upon awareness is support. Support comes from those above and below the project; both forms of support are necessary. If the end user does not support the database it will never be utilized to its capability. Conversely, if upper management does not support the implementation the necessary resources will be scarce and the end product will suffer.

The final component is the use of open systems. Open systems seek feedback from the environment and adapt to environmental changes. Especially in database development, the end product is ultimately customized to the user's needs. Therefore, it is essential to operate in an environment where interaction with the business environment is a routine process.

Building upon Cultural Acceptance and Support is the Problem Statement and Identification. This overarching category seeks to define the purpose of the project, the goals of the project, and the boundaries of the project. Additionally, needs and requests must be ranked by priority and each party must be satisfied that the implementation team understands their needs.

Beginning with definitions, a clear, written statement of the project purpose, goals, and boundaries are essential. While these definitions may slightly alter throughout the process, it is vital that all parties involved understand expectations. These clear definitions will in turn ensure that all involved parties are satisfied that their needs and wants are understood and addressed. These definitions help developers understand the needs that must be addressed by the project as well as help employees generate realistic expectations of the system once it is implemented.

As the overarching categories build, each category becomes increasingly quantifiable, as is the case with Vision Development and Progress. First, a future state, whether in the format of a value stream map or a database structure map, must be defined. Next, inputs and outputs required of the system must be collected and analyzed. By understanding the inputs and outputs, it is possible to begin a development plan for the proposed database. This plan must be understood not only within the project but also within the business as a whole so as to ensure that the necessary support is generated from end users and upper management.

Included in this plan must be potential obstacles and potential solutions. Technical, Process, and Personnel obstacles will exist as the database is implemented and it is important to forecast the impact of these obstacles and begin considering solutions immediately. Solutions such as investment in equipment, personnel training, and process reorganization may be necessary. Finally, once the database implementation reaches its concluding stages, it is vital that pilot and testing runs be utilized. This ensures that incorrectly programmed portions of the database are found and addressed before the database is completely installed. In turn, this prevents interruptions to the daily business cycle and allows for a smooth transition.

As the vision is developed and realized, it is important to include the next overarching category: cross-functional collaboration. Once the database is in place it will not exist within a vacuum; therefore, it is important that multiple users from multiple departments be included in the implementation process. While each user may not need to be involved equally, constructive input can be found from each department. Individual components and metrics within this category include clearly defined responsibilities, the proportion of existing departments involved in the implementation, the percentage of individuals within each department participating in the implementation, and the frequency at which individuals outside the direct development process



are involved. By including cross-functional teams in the development of the database the end product address needs within each department.

The final overarching category concerns accountability. As responsibilities are defined and fulfilled, successful progress depends on individual accountability. Documentation is central to ensuring accountability; therefore, documentation concerning the problem statement, additional requests throughout the process, progress, and defined responsibilities should not only exist but also be readily available to all employees involved. Timelines and Dates for progress should be established and documented; similarly, the achievement of these timelines and dates should be documented. Documentation allows all parties involved to understand progress and future needs as well as assume personal responsibility.

The previously discussed categories concern the first lean assessment, or the lean assessment concerned with the implementation process. While tailored to database implementations, the previously discussed criterion is not limited to database implementation and could be applied to many implementations.

Conversely, the second lean assessment, or the assessment concerned with the end product, is largely constricted to databases in general. The five categories included in the lean assessment, listed in descending importance, are:

1. Pursuit of Organizational Goals
2. Development of Enabling Environments
3. Ability to Adapt to Environment Changes
4. Long Term Viability
5. Limited Maintenance Requirements

These categories evaluate the final product of the database implementation and thus require the incorporation of technical analysis as well as lean analysis. Figure 19 provides a convenient illustration of the building importance of each of these categories through a pyramid illustration.



**Figure 19**

The first of the database lean assessment categories is the pursuit of organizational goals. It is easy to develop a database that does not exist within organizational goals. Generally, most businesses do not have clearly defined goals and strategies, making this assessment particularly difficult. However, the situation can be compared to the improvement of nonproductive components of lead time. Essentially, it is wasted effort to improve wasteful processes; rather, wasteful processes should be completely eliminated. At no point should the proposed database be an improvement to waste. The development team should always be able to define how an aspect of the proposed database will advance business goals.

Examples of measurements include, but are not limited to, net overall effect, visibility of operations within the database, enterprise content enhancement, utilization of core competencies, and improvement of core competencies. Largely, these components depend upon the business in which the database is being implemented. However, within all business databases operations should be visible and logical. This allows for errors to be corrected and for management to supervise the process and database without dedicating significant amounts of time or resources.

Also, the contents of the database should be enhanced by the database. If the content is not enhanced by the database, the net overall effect will be minor. Within the AAI implantation, the enhancements to the content will not be perceived in the weekly shipping schedule but rather in the development of the schedule. The required amount of time and oversight to create the schedule will be significantly reduced and the centralized, reliable positioning of the weekly schedules will prevent unofficial copies from circulating between departments and customers.

Building upon content enhancement and organizational goals are enabling environments. Databases and the electronic automation of business process ultimately enable employees to perform tasks with increased efficiency and professionalism. Additionally, the environment allows for feedback and continual improvement to meet changing needs. Components of this overarching category extend from highly specific, such as graphical user interface assessments, or highly general, such as the removal of “functional silo boundaries” or boundaries between functional departments.

Many components compose an enabling environment. Additional suggestions include, but once again are not limited to: feedback system capabilities, appropriate allocation of data entry tasks, standardized data entry procedures, and whether the database organizational structure is evident and understood. The importance is the concept of an enabling environment.

The implantation of a database is a tool for end users that should always allow the end user to perform their job with improved efficiency, capacity, professionalism and quality.

A database that generates an enabling environment will allow for a database that is adaptable to the environment. Especially with respect to AAI's weekly shipping schedule development process, changes in the business process a model do occur. While not a weekly change, they are not infrequent enough to allow for a rigid, inflexible database. Instead, the database must be able to adjust to the needs of the business. Examples of metrics and components of an adaptable database begin with the difficulty involved in customizing the database. If a significant amount of SQL, Visual BASIC, or other code programming is involved the database becomes increasingly difficult to customize.

Similarly, if the database cannot handle ad hoc or unique requests and processes, it will become a burden to the end user. Even beyond ad hoc capabilities and programming requirements, the database must be able to respond to a crisis environment. Potential crisis environment components include awareness of potential failures, response plans to potential failures, and the ability to handle both large and small-scale failures. Often, small scale failures are ignored until they become large scale failures; therefore, it is important to address all failures as they are reached in order to prevent down time or significant damage to stored data.

If a database is able to adjust to the environment, it will then be capable of maintaining long-term viability. A database is a significant investment for a business, and the planning horizon for use of the database should be long. Often, databases will continue to be utilized even after their planned replacement. Therefore, the design and assessment of a database should include an assessment of long-term viability.

Often, analysis of long-term viability will include an analysis of growth capacities. First, equipment capabilities to handle growth are an immediate restriction. Another less obvious restriction is the structure of the data within the database. Table structures, forms, and queries should be designed to allow for significant growth as well as handle archived or aging data. Another restriction involves future upgrades. As software is continually developed upgrades and licensing become a fact of life. A database that is well planned will limit required upgrades and allow easy application of such upgrades.

Designing a database with the previous restrictions in mind will require future projection. It is necessary to project conservative and liberal estimates on future growth so that the database can be designed to handle the majority of future scenarios. Additionally, this future projection will assist with the final overarching category concerning database assessment: limiting maintenance requirements.

Maintenance is required in all systems; however, maintenance does not produce customer utility directly and should therefore be minimized in design. Components and metrics of this category included developed maintenance plans, crisis prevention plans through maintenance and security concerns included backup and restore points. Other concerns are the frequency at which programming errors are found and the exposure and potential damage presented to existing system when the database is in place. If maintenance is planned and responsive, the amount of maintenance should be limited and reduce the company resources used that do not directly create customer utility.

### Assessment Score Cards

The above findings develop 5 overarching categories for the assessment of both the database implementation process and the database product itself. While detailed and applicable, the format of the categories and metrics is difficult to display to upper management in a concise and easily understood format.

It is for this purpose that scorecards have been developed to concisely present a summary of the lean assessment. Figures AA & BB provide scorecards for each assessment.

Figure 20 provides the Product Lean Assessment Scorecard. This scorecard lists the 5 overarching categories explained within the previous section on the first column with the components and metrics of each category listed across the rows. Above each subcomponent is a three level rating system: Excellent, Fair, and Poor. Each subcomponent is rated based on the criteria previously discussed as well as team assessment and judgment.

Product Lean Assessment Scorecard																		
	Core Components (Ranked Excellent, Fair, Poor)																	
	E	F	P	E	F	P	E	F	P	E	F	P	E	F	P	E	F	P
Limited Maintenance	Maintenance Plans Developed?			Crisis Prevention Measures Developed?			Backup and/or restore points in place?			Frequency at which program errors are found			Exposure and Potential Damage of Current Systems					
Long Term Viability	Data Structure capable of growth?			Future upgrade requirements			Equipment capability for expansion			Projected Future system requirements								
Environmental Adaptability	Difficulty in customizing database			System Ability to handle unique/ad hoc requests			Potential Crisis Environment: Awareness			Potential Crisis Environment: Response Plan			Potential Crisis Environment: Large Scale			Potential Crisis Environment: Small Scale		
Develop Enabling Environments	Feedback system capabilities			Graphical User Interface Assessment			Appropriate allocation of data entry tasks			Removal of Functional Silo Boundaries			Standard Data Entry Procedures			Database organizational structure evident and understood		
Pursue Organizational Goals	Net Overall Effect			Visibility of Operations			Enterprise Content Enhancement			Utilization of Core Competencies			Addition to Core Competencies					

**Figure 20**

The rating is color coated, with green for excellent, yellow for fair, and red for poor; as ratings are agreed upon, the corresponding cell (E, F, or P) will be filled with the correct color. This simple method will allow management and users to quickly identify strengths and weaknesses.

Figure 21 provides the Process Lean Assessment Scorecard. This scorecard is structured just like the Product Assessment Scorecard. The specific categories are again listed in the first column with the subcomponents listed across the rows. The card is structured in relation to the pyramid visual representation presented in Figure 18 and Figure 19 with the most important category at the base.

<b>Process Lean Assessment Scorecard</b>																		
	Core Components (Ranked Excellent, Fair, Poor)																	
	E	F	P	E	F	P	E	F	P	E	F	P	E	F	P	E	F	P
Accountability	Documentation of Problem Statement			Documentation of Additional Requests			Documentation of Progress			Documentation of Responsibilities			Timelines/Dates Established			Timelines/Dates Achieved		
Cross Functional Collaboration	Clearly Defined Responsibilities			Input from Different Departments			Input from multiple individuals in a department			Routine Collaboration with end users								
Vision Development & Progress	Potential obstacles defined and plans developed			Required training planned or executed			Inputs/Outputs defined and analyzed			Testing/Pilot Runs			Future State Clearly Defined			Plan created and understood		
Problem Statement Identification	Purpose clearly defined			Goals clearly defined			Boundaries of Proposed System clearly defined			All parties satisfied with understanding of needs & wants			Priority Ranking of Requests					
Cultural Acceptance & Support	Motivation			Awareness			Support			Open System in place								

**Figure 21**

One potential complaint about the provided scorecards is the lack of resolution in the ranking system. A simple Excellent, Fair, Poor does not provide great insight into the current

state. However, the ranking system was developed in accordance with the amount of time and frequency at which this scorecard should be used.

Unlike a scorecard for an initial analysis used by many lean systems consulting firms, these scorecards are for internal use and are continually used. The greatest utility provided by these scorecards is the continual refocus on the cultural acceptance and pursuit of organizational goals. When developing a database it is easy to lose sight of the big picture, which limits collaboration, restricts the view of the future state, and even allows for the designer to forget the problem statement. Through a simple three tier analysis of each category designers can weekly refocus on the task at hand and continually provide a focused response to the task of database design.

The categories of assessment, for both the implementation process and the database product, are the manifestation of lean principles within database design. A close analysis of each assessment quickly reveals they are in fact the lean principles themselves, focusing on the reduction of lead-time and efficient production of the end product.

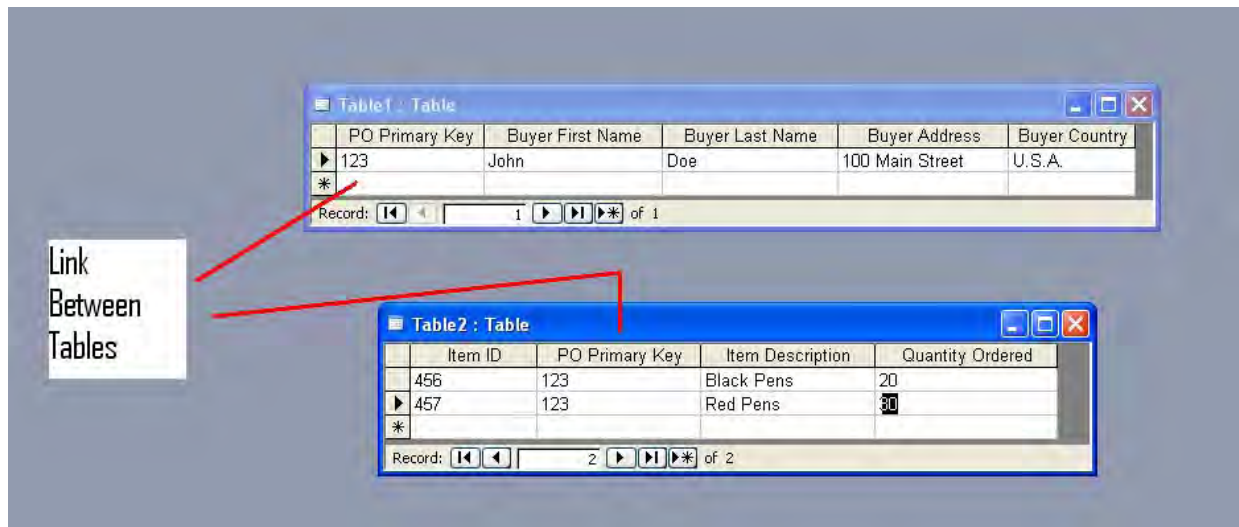
### ***Fundamental Structural Decisions***

Before the fundamental structural decisions of the ECM database can be discussed, it is necessary to understand the benefits and necessity of a relational database management system (RDBMS). Pioneered in the 1970s, an RDBMS moves beyond a functionality of an excel spreadsheet by allowing relationships to be defined between data. Advantages gained through these relationships include elimination of data duplication, simplification of navigation and data standardization. Additionally, updating data within an RDBMS is greatly simplified when multiple records and dependencies exist, as with the PO packet (CITE ACCESS BOOK).



Currently, AAI utilizes Excel spreadsheets to handle document creation and data storage. While Microsoft Excel and other spreadsheet software is a powerful tool, it has many limitations. Large amounts of data are much more suited to storage within an RDBMS as they can be filtered and indexed and they require less storage space. When complex data entry, manipulation, and reporting are required, the standard row-column spreadsheet is unable to quickly respond to user demand in an agile manner.

However, RDBMS can quickly and efficiently respond to complicated data manipulation and reporting requirements. RDBMS work by defining tables that are linked through primary keys. Essentially, primary keys are unique identifiers for every record on the table (comparable to the row number on an excel spreadsheet). If data is linked between two tables, the primary key of the linked record is entered in a column, or field, of the table. For example, purchase orders within AAI involve information such as buyer name and address, as well as several items purchased. Instead of creating a Microsoft Excel spreadsheet in which multiple columns exist for each item on the purchase order, an RDBMS creates two tables, one for the general PO information (buyer name and address) and one for the items. As the items are listed in their respective table, the primary key assigned to the purchase order in its respective table is listed as a column (see Figure 18 below).



**Figure 22**

Since the tables are now linked via the field “PO Primary Key” the relational tables can be searched and pulled into reports. These relationships exist in three forms. The relationship form seen above is a “One-to-Many” form in which one record has many links in another table (one purchase order has many items). “One-to-One” relationships also exist (one purchase order would only have one item); however, these relationships are rare. The final relationship, a “Many-to-Many” relationship, requires a third table that “links” two tables by combining two primary keys. In the previous example, if the item price depended both on the buyer and the item number, a linking table would be created where the price is assigned two foreign primary keys, one for the buyer and one for the item. The majority of relationships within RDBMS are “One-to-Many” relationships.

Finally, before constructing the underlying structure of the database, it was agreed that the database should be built in Microsoft Access. Microsoft Access provides a user-friendly interface than can easily be altered if necessary. Additionally, it provides all of the functionality required by the ECM database. The file format chosen was Microsoft Access 2000. This file format can be run on any Microsoft Access version after Microsoft Access 2000, which



The second set of tables related to the purchase order stage. This stage of tables was similar to the quote stage, but also involved more details and additional tables to handle additional independent data such as labeling and logo information. Portions of these tables were similar to the quote stage, and to prevent re-entry of data, an append query was utilized to move data from the quote stage to the purchase order stage. Any additional information was entered into the purchase order forms.

The third set of tables concerned purchase order revisions. This stage was a replica of the tables during the purchase order stage; however, the tables were thought necessary to keep a record of major changes to the purchase order stage. Again, an append query was utilized to move data from the purchase order stage to the revised purchase order stage.

One of the first and most significant problems with this table structure was the replication of data. Not only would this replication of data require more storage space, but it is also unnecessary. A second problem arose with the append queries. Append queries of linked tables required that a linked field exist for the query to run. Essentially, if one purchase order did not have an entry in every table the append query would fail. To prevent this, default entries were made for each purchase order in every table. Once again, this required more storage space as well as the creation of unnecessary data.

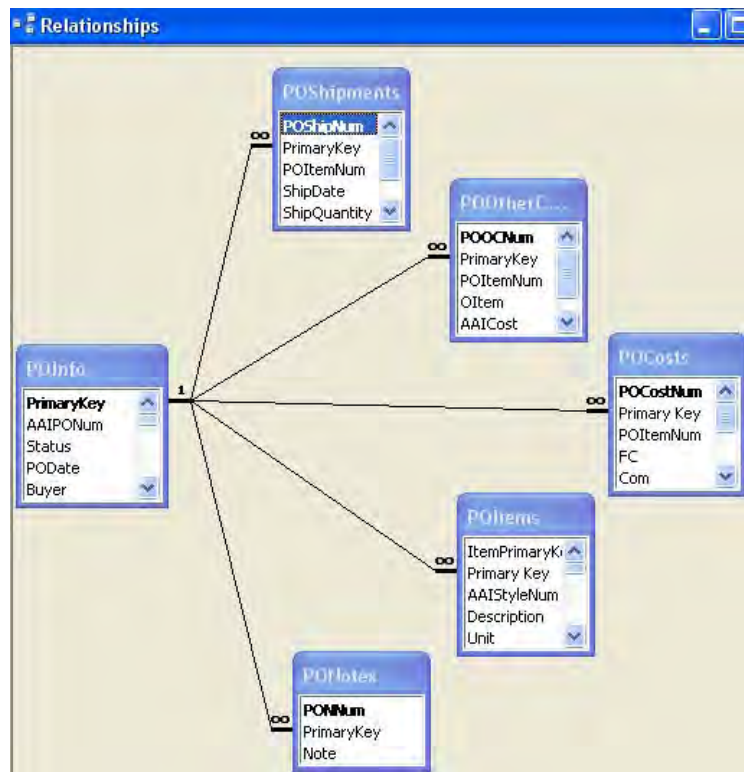
Several attempts were made to adjust the append queries to allow the multiphase table structure to work; however, this system is simply too complicated and repetitive. The repetition of data violates the First Normal Form of data required in all databases. Therefore, alternative table structures were considered.

The first major revision to the table structures was the elimination of the revised purchase order phase. After interviewing several tenured AAI employees it was determined that a record

of revisions was not necessary. Therefore, a separate stage of tables for revised purchase orders was not required; permanent revisions can simply be made to the existing purchase order tables. One of the concerns that drove the creation of the revised purchase order tables was the need for a record of revisions. As purchase orders will still be printed and physical copies kept, an electronic version of revisions is redundant. Electronic records of such revisions may become necessary if future improvements eliminate the filing of physical copies.

Even with the elimination of the revised purchase order set of tables, two sets of tables remained. All of the information in the set of tables representing the quote stage stored data that was directly needed in the purchase order stage. As such, the frequency of append query failure due to incomplete records was significantly smaller, but not impossible. Due to the high degree of similarity between the quote and purchase order stages, the decision was made to combine these tables into one set of tables. Notation of whether the information was part of a quote or a purchase order is became a single field in the central purchase order information table. This field is manually changed by the user when information is being entered. Using the graphical interface described later, users are allowed to move data from the “quote” stage to the “purchase order” stage by simply changing the status of the data. While this changes the manner in which the user views the data, the actual change is simply the edit of a single field in the central table.

The resulting table structure can be seen below in Figure 20. This table structure has been reduced to an easily managed structure that does not repetitively store data. While the table structure is simpler, users still view the progress of information from stage to stage. It was essential to realize that this perception of change does not need to be reflected in the tables, but rather in the graphical user interface. Details on how this is accomplished are discussed in the following section.



**Figure 24**

While table structure as the foundation of any database, several layers exist between the table structure and the graphical interface. While it is possible to edit table data directly in the table, which looks similar to a spreadsheet, this method of entry allows for alterations to all records. Additionally, it is difficult to navigate multiple tables and create records while simultaneously recording the necessary linking primary keys. Therefore, data entry within the ECM database occurs through the use of forms.

Forms allow users to edit both tables and queries through a user friendly interface. While part of the end graphical user interface, these forms are not simply for navigation and operation of the database, but rather editing of database records. Details on specific forms are included in the following section. It should be noted that these forms are restricted to one purchase order. This allows users to view all of the linked data between tables in one central location. Additionally, input masks can be placed on certain fields to “mistake-proof” data entry.

Examples include the limiting of zip coded to five digits (four or six digit entries will display an error).

Another advantage provided by Microsoft Access forms is the sub-forms. Sub-forms allow forms that are linked to separate tables to be imbedded into a form linked to another table. Without sub-forms users would have to open a form for every table in the database. For example, users entering a purchase order would need to open a form to enter information such as the buyer and his/her address and a completely separate form to enter the items on the purchase order. By allowing sub-forms, both of these actions can be combined into one form. Additionally, sub-forms can be linked to the master form using child and master fields. This allows the sub-form to only display data that is linked to the master field. An example of this application within the ECM database is the linking of child and master fields via the purchase order number. Thus, when viewing a form built upon the central purchase order information table, the PO Items sub-form only displays items linked to the specific PO number.

A final convenience provided in forms for users is the use of a combo box. A combo box displays a drop-down menu from which users may only choose from a predefined set of options. A primary example of a combo box is the previously referred to status setting; the use of a combo box only allows users to select "Quote" or "Purchase Order" to prevent misspelling. However, combo boxes are not limited to predefined options. Instead, combo boxes can be built upon queries that return a specified set of information. An example within the ECM database is a combo box in which users select from only the items entered on the purchase order. In order for this combo box to change its options to reflect which purchase order is being entered, a query is utilized that returns items linked to the purchase order based on a field within the form.

The final major building blocks of the ECM database are queries. Queries represent the greatest advantage of an RDBMS. Queries sort and filter data based upon predefined criteria allowing users to pull information from the tables. Additionally, queries can perform summary options of the total data. While spreadsheet programs may only allow sorting by multiple criteria or summation by a single criteria, database queries allow for an infinitely specific sorting and summation criteria. For example, queries can be run the sum total sales by individual over a specified period of time.

As the ECM database stands, queries are limited to those required to build the documents included in the PO Packet. These queries pull data dependent upon a purchase order number and insert the data into reports that match those in the PO Packet. However, substantial opportunities exist to expand these capabilities. Future possibilities will be discussed later, but it can be noted that queries can also be conducted via forms, which allows user limited ad hoc querying capability.

Macros are the final component of the ECM database. Currently, the ECM database only includes one macro within the graphical user interface. Macros run repetitive options for the user. The example within the user interface is the closing of one form and the opening of another when the user clicks a button. This requires two actions that a macro can run for the user. Database programming is continually moving away from macros and towards event driven programming edited via Visual Basic for Applications (VBA). In Microsoft Access 2003, macros were intended for backwards compatibility only; therefore, the use of macros was avoided to ensure the ECM database will function properly in future versions of Microsoft Access.



### *User Interface Development*

Even with a completed database structure including forms for data entry, database navigation can be difficult for many. Additionally, many users will accidentally make permanent changes to the database structure without realizing their actions. Microsoft Access provides a “Database Window” that is used to design and access all forms, queries, reports, macros, modules, and other components of the database when designing the database. However, navigating this Database Windows requires an understanding of how the components displayed are related. This knowledge is not required of, nor would it be useful to, employees. Therefore, most database designs include a Graphical User Interface (GUI) through which users can interact with the data.

The main objective of GUIs is to create a simple, understandable interaction for database users. As such, complicated menus cluttered with multiple options are unnecessary. When designing a GUI, only the options required by users should be included. While many more options and possibilities exist, allowing these combinations could create more trouble not only for user navigation but also for accidental changes to the database structure.

Building GUIs in Microsoft Access is a straightforward process. Just as forms are used to manipulate data in tables, they can also be used to direct users throughout the database. Microsoft Access provides a start-up form wizard titled “Switchboard Manager” that easily allows for the simple creation of a start-up GUI. Essentially, the “switchboard” created by this wizard is a form that opens and closes related objects within the database. Rather utilizing the switchboard manager, which limits some options, the ECM start-up form was built directly as a form.

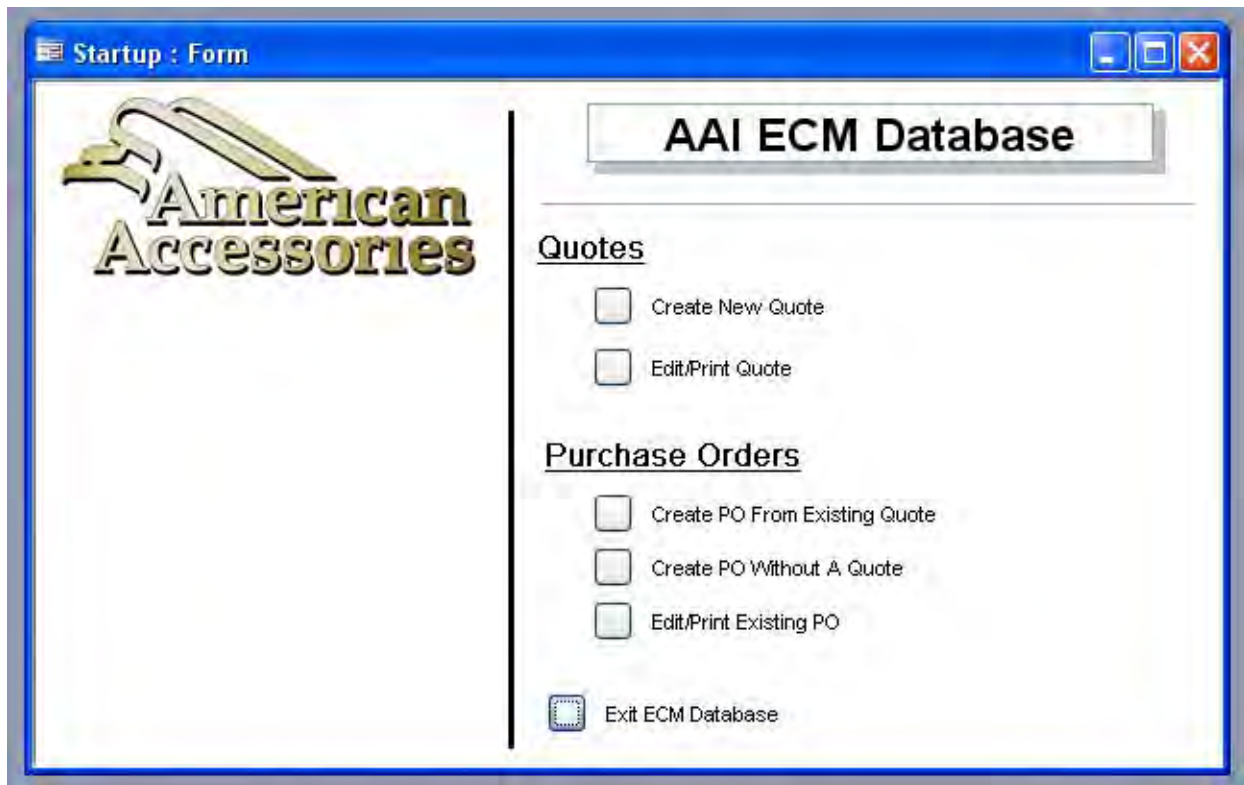
This direct construction allowed for complete customization and control of the start-up form. One such customization was the creation of a start-up “splash” screen to identify the database (below, Figure 25).The only possible navigation from this screen is to the main database menu. This screen simply serves as the entrance to the database.



**Figure 25**

As stated, the main database menu follows the start-up splash screen (below, Figure 26).It is from this screen that users are able to navigate to all possible routine uses of the database. When deciding which navigation options would be included on the main menu, only the most basic operations were considered. Since several users at AAI are slightly apprehensive of new database systems, it was decided that the simpler and easier to understand the main menu, the

better the main menu. Additionally, the appearance of a simple main menu would not intimidate users and would suggest an ease of use that would speed the learning curve.



**Figure 26**

The options on the main menu are grouped by the two phases in the purchase order process. The first phase, the quote phase, required only two options. Since all quotes are new, a simple "Create New Quote" option was included. This option opens the quote data entry form that will be detailed later. The second option under the quote phase is to edit or print the quote. Occasionally, changes are made to the quote to reflect customer interest and commitment. In addition, official quotes are mailed or faxed to clients and must therefore be printed. This option opens a second menu that will also be detailed later.

The second phase, the Purchase Order Phase, is a slightly more complicated phase. First, most purchase orders are created from quotes. In this scenario, the correct quote information must be located, the status of the data must be edited to "Purchase Order" from "Quote," and the

Purchase Order data entry form must be opened. The selection of the appropriate quote cannot be automated (users define which quote they are transferring to a purchase order); therefore, a second navigation screen opens once this option is chosen. This navigation screen will also be detailed shortly.

However, not all purchase orders are generated directly from a quote. In this scenario, a blank, new purchase order must be generated, which is available in the second option button. This option opens the Purchase Order data entry form to a blank record that allows the user to create a new quote. Several changes to the SQL code were included in the creation of this button to simultaneously open a new form and navigate the new form to a new record.

The third option in the purchase order phase is to edit or print an existing purchase order. As previously discussed in the fundamental database structure, revisions to purchase orders are possible and do occur. As with the creation of a purchase order from a quote, editing a purchase order requires the user to define which PO they will be editing. This also requires a second navigation screen (for the selection of purchase orders). Also included within this second navigation screen is the opportunity to print or preview any form included within the purchase order packet.

The final option within the main menu is the option to close the database. To ensure that users do not accidentally close the database while they are editing data, the maximize, minimize, and close icons at the top of the screen are disabled. In order to exit the database, users must either follow File>Close, click the close icon for the entire program (not just the main menu) or use the button on the main navigation screen. This button not only closes the main menu but also closes Microsoft Access.

Several forms and secondary navigation screens were referenced throughout the description of the main menu. These forms will be detailed in the sequential order the user would experience as they move throughout the process. Figures demonstrating each view are included.

The first of these forms is the Quote Information form (Figure 27). This form is used to enter information regarding the quote stage, and immediately opens after the “Create New Quote” option is selection on the main menu. The figures below show the three tabs within the quote information form. General information is entered under the first tab, including the buyer, their contact information, the date, and shipping information. While opportunities exist to enter all of this data, it is not required. Since partial quotes or quotes with incomplete general information are often created, requiring these fields would become a hindrance and encourage false data entry.

The second tab within the quote creation form includes a sub-form users may use to enter the items on the quote. While the current form only shows one item, it is possible to add as many items as desired. Whenever an entry is made in the first line, a second line automatically appears for the next items. Lines left blank are not records and will not be included in the quote. There is also the option to delete items from the quote if necessary (this may become more necessary in the editing stage).

The final tab within the quote creation form is for notes. AAI employees often include notes on the employee disclosing details that have not been included. Examples of potential notes include shipping details, price details, and explanations of unusual items. These notes are directly added to the quote just as they would be if the quote were generated manually.

The screenshot shows a window titled "QuoteInfor : Form" with a sub-header "AAI Quote Information". Below the header are three tabs: "General", "Items", and "Notes". The "General" tab is active and contains the following fields:

Buyer	<input type="text"/>	PODate	<input type="text"/>
Buyer Phone:	<input type="text"/>	Receive By:	<input type="text"/>
ConfirmFName:	<input type="text"/>	FreightMethod:	<input type="text"/>
Vendor:	<input type="text"/>	Destination:	<input type="text"/>
Terms:	<input type="text"/>	ShipAddress:	<input type="text"/>
FOB:	<input type="text"/>	ShipCity:	<input type="text"/>
Status:	<input type="text" value="▼"/>	ShipRegion:	<input type="text"/>
		ShipPostalCode:	<input type="text" value="0"/>
		ShipCountry:	<input type="text"/>

**Figure 27**

The screenshot shows the same window with the "Items" tab selected. It displays a table with the following columns: "Item ID", "Description", "Unit", "Unit Price", and "Quantity". There is one row with empty input fields for each column and a delete icon (an 'X' in a square) to the right of the "Quantity" field.

Item ID	Description	Unit	Unit Price	Quantity
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>

**Figure 27.1**

The screenshot shows the same window with the "Notes" tab selected. It features a large text area for entering notes, with a vertical scrollbar on the right side and a delete icon (an 'X' in a square) to the right of the text area.

**Figure 27.2**

Once quotes have been entered into the system, users may need to perform one of three actions on the entered data. These actions are to edit the data, generate the official quote for printing, and transfer the data from the “Quote” stage to the “Purchase Order” stage. All of these

actions can be accomplished through the second option button in the “Quotes” section of the main menu, “Edit/Print Quote”.

When this option button is clicked, the “Quote Selection” form, Figure 28, is opened. This form is a secondary navigation form in that it does not enter, manipulate, or report data; rather, this form displays the quotes in the database and allows users to select the quote and the action they would like to perform on the quote. Quotes are listed and sorted in the bound box; while the option buttons above and below allow the user to perform the previously discussed functions (edit quote information, generate the official quote, and transfer the information to a PO).

PrimaryKey	AAIPONum	PODate	Buyer	CustPONum	ConfirmFName	Engineer	Salesperson
10	2		PMI Russia	0	Kevin		

**Figure 28**

If the user selects to edit the quote information, the quote will be opened in Figure 23, which will display the data specific to the quote. Any of the fields may be edited at this point. Once the fields are edited, the data is immediately changed; users do not need to click a “Save” button. If the user selects to generate an official quote from the quote selected in the list, the Quote report will be automatically opened in Preview form (Figure 29). This form allows users to review the quote before they print. Changes cannot be made to this report; if the user needs to

alter data, they must close the preview and select the “Edit Quote” option button. If the quote is correct, users may proceed to printing in the same fashion as all Microsoft Office programs.

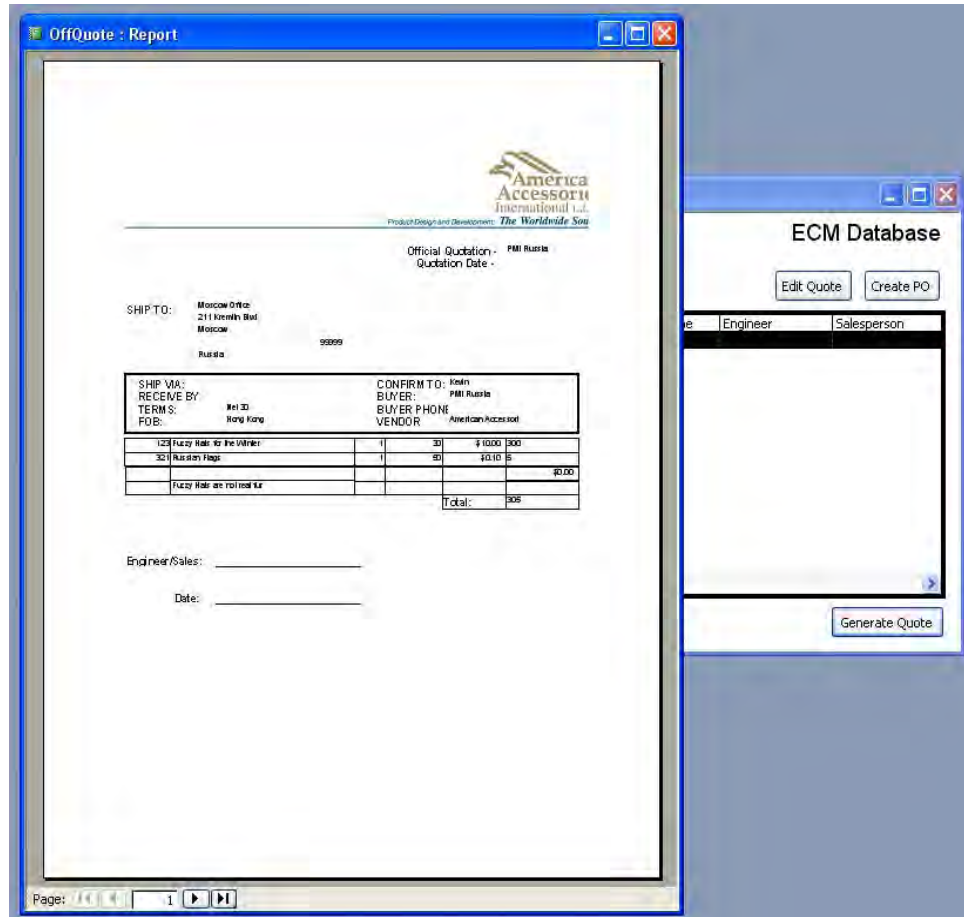


Figure 29

Once the quote has been accepted by the client, the data stored in the “Quote” stage will need to be transferred to the “Purchase Order” stage. As stated, the perceived stages are simply fields within one table denoting the data’s stage. When the user is ready to transfer the data to a purchase order, they will select “Create PO from Existing Quote” option on the main menu. This option will open Figure 28. Thus, the “Quote Selection” form can be accessed from two different option buttons on the main menu. While this is redundant, it does eliminate the need for an extra form and simplify the organization of the main menu.



Once the user has selected the quote they would like to transfer to the Purchase Order stage, they simply click the “Create PO” option button in the top right corner of the screen. This option opens the Purchase Order Packet Information form (Figure 30). All of the data entered during the quote stage will automatically be present in the purchase order form. Additional details required for the purchase order are present on this form, as well as a combo box that displays the status of the data. Users will need to manually change the status to “Purchase Order.” If the user forgets, the information they enter will not be deleted, but the data will still appear in the secondary navigation screen titled “Quote Selection.”

The image shows a screenshot of a web-based form titled "AAI Purchase Order Packet Information". The form is displayed in a browser window with the title "frmPOInfo : Form". At the top, there are two input fields: "AAI PO Number" and "Customer PO Number", both containing the value "0". Below these are several tabs: "General Info", "Contact", "Internal Confirm", "Items", "Item Details", "Labels/Logos", "Shipping", and "Cost Card". The "General Info" tab is currently selected. It contains several input fields: "Buyer:", "Buyer Phone Number:", "End Customer:", "PO Received By:", "Date of PO:", "Terms:", "Vendor:", and "Status:". The "Status" field is a dropdown menu. Below the input fields is a section titled "Notes to Customer (Included on Purchase Order)" with a text area and a red 'X' icon.

**Figure 30**

The first tab in the Purchase Order Packet Information form displays general data for the purchase order as well as notes to be included on the PO. A large portion of this data is directly transferred from the quote stage; however, users can add to or delete this data as necessary. The second tab (Figure 30.1) includes contact information for both the customer and the factory, while the third tab (Figure 30.2) includes internal confirmation information such as the salesperson and the engineer.

The fourth tab displays the items on the purchase order (Figure 30.3). Again, these items are transferred from the quote stage. If necessary, employees may add or delete items in this

stage. Also included on this tab are extra charges, such as commission charges. These items will be entered on the PO directly as a cost and summed into the total cost.

The screenshot shows a web browser window titled 'frmPOInfo : Form'. The main heading is 'AAI Purchase Order Packet Information'. Below the heading are two input fields: 'AAI PO Number' and 'Customer PO Number', both containing the value '0'. A tabbed interface is visible with the following tabs: 'General Info', 'Contact', 'Internal Confirm', 'Items', 'Item Details', 'Labels/Logos', 'Shipping', and 'Cost Card'. The 'Contact' tab is active. It contains two sections: 'Customer Contact Information' and 'Factory Contact Information'. The 'Customer Contact Information' section has three input fields: 'Contact Name', 'Contact Email Address', and 'Contact Fax Number'. The 'Factory Contact Information' section has six input fields: 'Factory Name', 'Factory Address', 'Factory City', 'Factory Region/State', 'Factory Postal Code' (with a '0' in the last digit), and 'FactoryCountry'.

**Figure 31.1**

The screenshot shows the same web browser window as Figure 31.1, but with the 'Internal Confirm' tab selected. The 'AAI PO Number' and 'Customer PO Number' fields remain at '0'. The 'Internal Confirm' tab contains four input fields: 'Engineer', 'Salesperson', 'Delivery By', and 'Special Instructions'. The 'Special Instructions' field is a larger text area.

**Figure 31.2**

The screenshot shows a web browser window titled 'frmPOInfo : Form'. The main heading is 'AAI Purchase Order Packet Information'. Below the heading are two input fields: 'AAI PO Number' with the value '0' and 'Customer PO Number' with the value '0'. A tabbed interface is visible with the following tabs: 'General Info', 'Contact', 'Internal Confirm', 'Items' (which is the active tab), 'Item Details', 'Labels/Logos', 'Shipping', and 'Cost Card'. Under the 'Items' tab, the section 'Items on This Purchase Order:' contains a table with the following columns: 'PO Item #:', 'AAI Style #:', 'Description:', 'Unit Price:', and 'Quantity:'. The first row has an 'AutoNumber' in the 'PO Item #' field, an empty 'AAI Style #' field, an empty 'Description' field, an empty 'Unit Price' field, and an empty 'Quantity' field. To the right of the table is a 'PK' button. Below the table are two input fields: 'Extra Charge Description (i.e. - Buying Commission):' and 'Extra Charge:' with the value '\$0.00'.

**Figure 31.3**

The fifth tab displays the detailed information required for each item listed on the PO. Item details include a “Long Description,” materials, and testing notes. Users are able to “flip” through the items on the purchase order, but they are not able to create or remove items from the purchase order from this screen. This prevents users from accidentally adding or removing items to the purchase order when they are under the belief they are editing details on a currently existing item.

The screenshot shows the same web browser window as Figure 31.3, but with the 'Item Details' tab selected. The 'AAI PO Number' is now '1' and the 'Customer PO Number' is '0'. The 'Item Details' section contains several input fields: 'Description:', 'Size:', 'Long Description:', 'Material:', and 'Testing:'. The 'Item #' field is set to '22'. At the bottom of the form are two buttons: 'Last Item' and 'Next Item'.

**Figure 31.4**

The sixth tab, Figure 31.5, is very similar to the fifth tab. This tab displays logo and label information for each item. Just as with the previous tab, items cannot be added to or remove

from the order in this stage. Also of note are the boxes shaded in gray. These boxes cannot be edited and display information from earlier tabs. This prevents users from editing data they previously entered without recognizing the consequences of such editing.

The screenshot shows a software window titled 'frmPOInfo : Form' with a sub-header 'AAI Purchase Order Packet Information'. At the top, there are two input fields: 'AAI PO Number' with the value '1' and 'Customer PO Number' with the value '0'. Below these are several tabs: 'General Info', 'Contact', 'Internal Confirm', 'Items', 'Item Details', 'Labels/Logos', 'Shipping', and 'Cost Card'. The 'Labels/Logos' tab is currently selected. Underneath, there is a section titled 'PSUB Logo'. It contains several input fields: 'Item #' (with a dropdown menu showing '22'), 'Item Style #' (with the value '7'), and 'Description'. Below these are fields for 'Country of Origin', 'Size', 'Placement', and 'Other Labels'. To the right, there are fields for 'Logo Type', 'Logo Size', 'Logo Color', and 'PMS #'. At the bottom right of this section are two buttons: 'Previous Item' and 'Next Item'.

**Figure 31.5**

The next tab includes information related to shipping (Figure 31.6). This tab includes not only shipping destination and packing information, but also information for a shipping schedule. If the items are to be shipped in multiple partial orders, the shipping schedule can be broken up and entered in the shipping sub-form. Users are allowed to enter the quantity, ship date, method and origin for as many items as they wish. Additionally, users may delete records as they see fit.

The screenshot shows the same software window as Figure 31.5, but with the 'Shipping' tab selected. The 'AAI PO Number' is now '0' and 'Customer PO Number' is also '0'. The 'Shipping' tab is highlighted. The form contains several input fields: 'Destination:', 'Street Address:', 'City:', 'State/Province:', 'Postal Code:', and 'Country:'. To the right, there are fields for 'FOB:', 'Packing Instructions:', and 'Other Instructions:'. Below these is a section titled 'Shipping Schedule' which contains a table with columns for 'Item:', 'Date:', 'Quantity:', 'Method:', and 'Origin:'. The 'Item:' column has a dropdown menu with '0' selected. The 'Quantity:' column has the value '0'. There is a small 'X' icon in a box at the end of the row. At the bottom right of the table is a button with a trash can icon.

**Figure 31.6**

The final tab concerns costs (Figure 31.7). It is on this tab that all of the costs that are later used in the Cost Card are entered. Examples include the First Cost, Commission Cost, and Duty Cost. Additionally, users may enter other costs (most often one-time costs for the entire order), and notes to describe any item on the cost card. Each of these costs are linked to the appropriate item on the purchase order via the information displayed in the gray boxes, which cannot be edited (this data was entered earlier in the form).

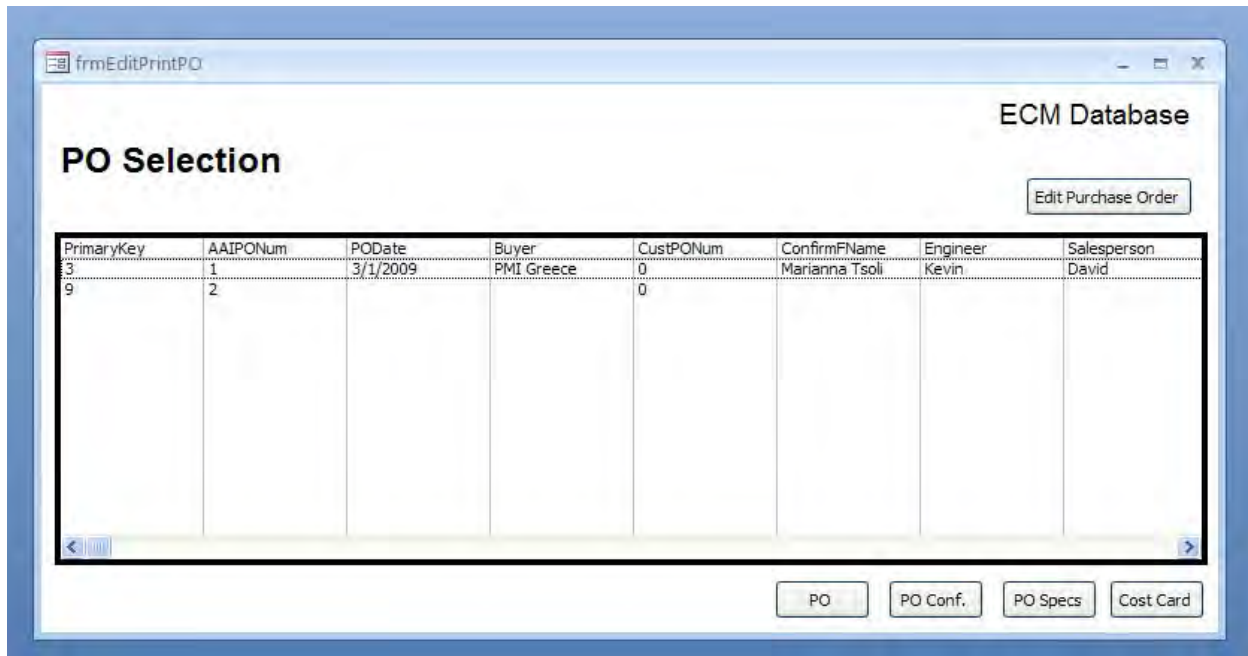
The screenshot shows a software window titled 'frmPOInfo - Form' with a sub-header 'AAI Purchase Order Packet Information'. At the top, there are two input fields: 'AAI PO Number' with the value '1' and 'Customer PO Number' with the value '0'. Below these are several tabs: 'General Info', 'Contact', 'Internal Confirm', 'Items', 'Item Details', 'Labels/Logos', 'Shipping', and 'Cost Card'. The 'Cost Card' tab is active. It contains three main sections: 'Item Costs', 'Other Costs', and 'Cost Card Notes'. The 'Item Costs' section has a table with columns 'PDItemNum' and 'Description'. Below this are input fields for 'FC', 'Com', 'Duty', 'Freight', 'Other', 'EndSell', and 'FreightMethod'. The 'Other Costs' section has a dropdown for 'Item Number' (set to '11'), an input for 'DItem' (set to 'Imaginary Cost'), and inputs for 'AAI Cost' (set to '100') and 'Cust Cost' (set to '100'). There are 'Delete Item', 'Last Item', and 'Next Item' buttons. The 'Cost Card Notes' section is a large empty text area. Navigation buttons 'Last Item' and 'Next Item' are also present at the bottom right of the form.

**Figure 31.7**

Once the required data has been entered and the form closed, users may need to edit the data or print the documents included in the PO Packet. In order to accomplish these tasks, users are directed again to a secondary navigation screen, the “PO Selection” screen (Figure 31). This screen appears very similar to the “Quote Selection” navigation screen. This similarity was intentionally included to create a comfortable, repetitive feel of the database for users.

Once users have selected the appropriate PO from the list box, they may use the option buttons to perform the previously defined tasks. The option button in the top right corner of the screen allows users to open the selected purchase order in the Purchase Order Information form and edit any of the data. The option buttons in the lower right corner of the screen each represent

one item in the Purchase Order Packet. Users may select any of these forms to open the respective document.



**Figure 32**

These respective documents have been previously discussed in detail. Additionally, examples of each form can be found in Appendix 1. For convenience, the preview format of each form can be found in Figure 33 & 34. If the document requires more than one page, the navigation buttons in the lower left corner of the screen can be used to navigate through the pages. Most documents require more than one page as they have a page for each item on the purchase order.

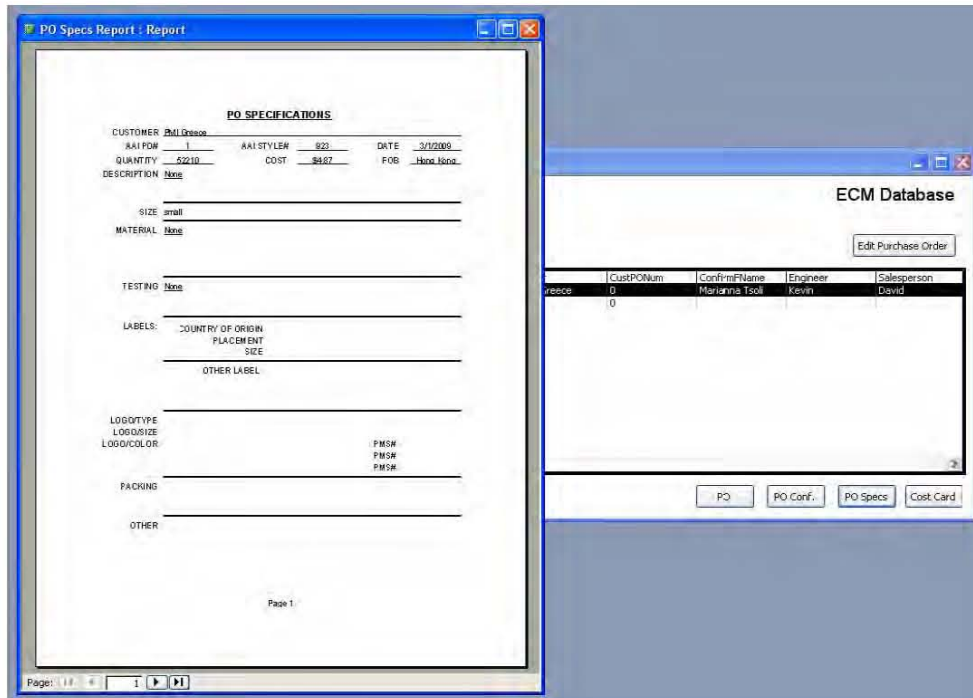


Figure 33 (PO Specs)

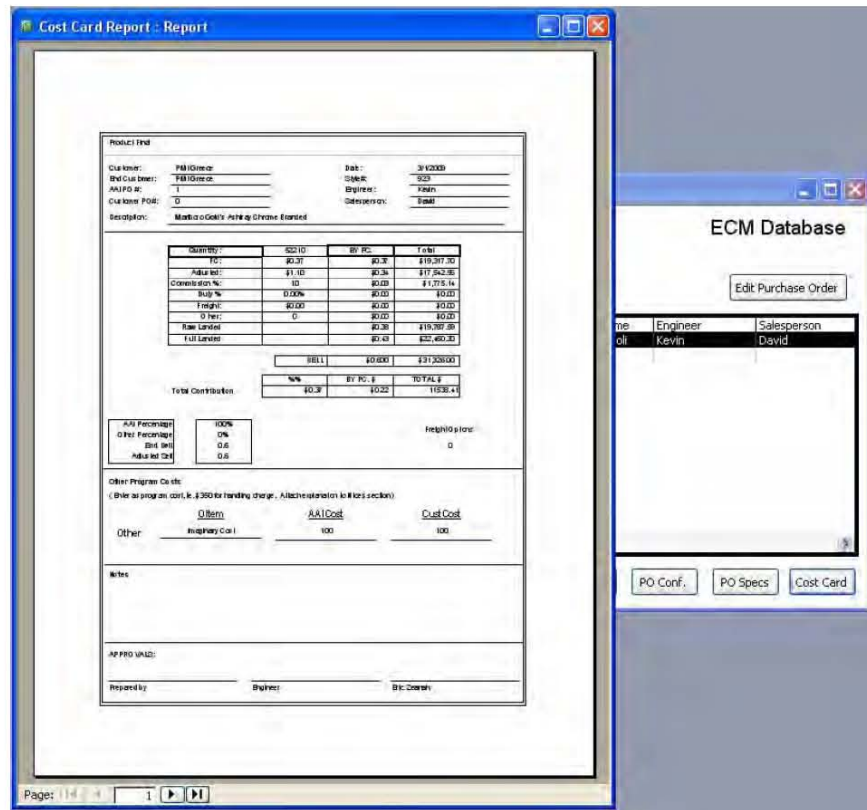


Figure 34.1 (Cost Card)



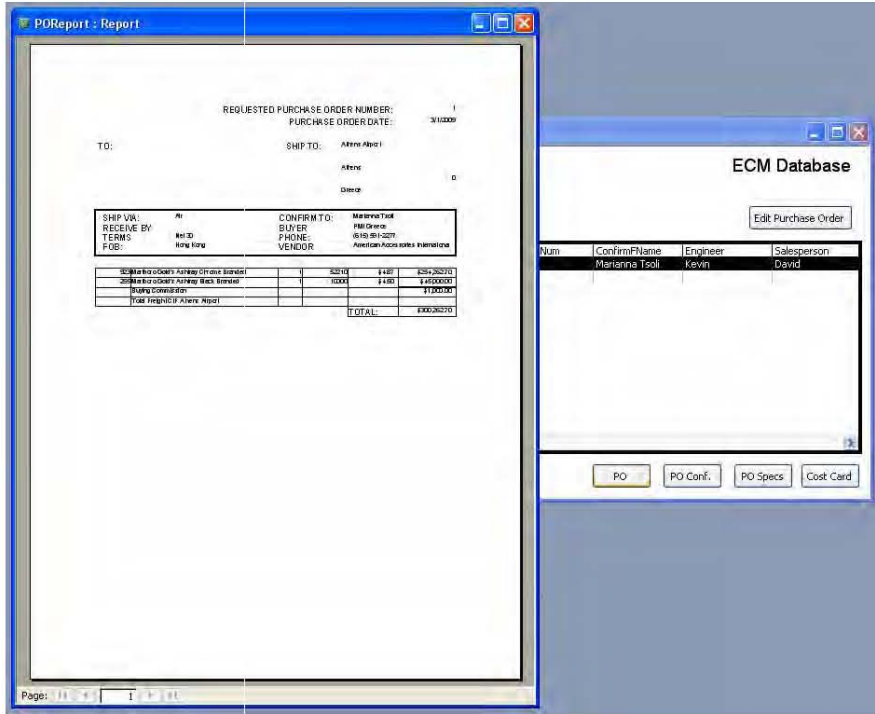


Figure 34.2 (PO)

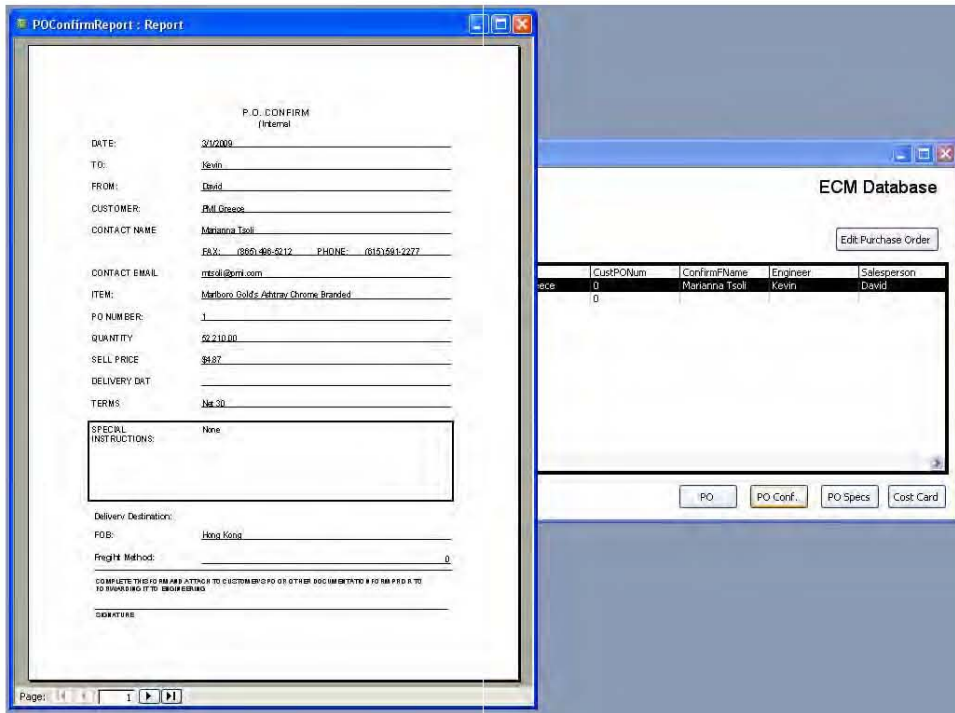


Figure 34.3 (PO Confirm)



## **Continuing Improvement**

While the current database is functional and provides many benefits, total development has not been completed. Many opportunities exist to gain even further benefit from the database and the information stored. Two categories of continuing improvement exist: future development and long term application. Future development is primarily concerned with the next steps the design team should take in order to gain the full benefit of the database. Long term application outlines a theoretical long term approach to the ECM database as well as future total enterprise management systems. Both are detailed in the following sections.

### ***Future Development***

As the database currently stands, data can be entered and the PO Packet can be created. While this does provide cost and time savings for AAI employees, the true benefit of a RDBMS is in its capacity to provide reports. Reports can provide detailed results of all transactions, summary statistics, and time related data. While many reports are currently generated within the AAI office, these reports could be automated to be a part of the ECM Database. This integration would not be difficult as the data required is already contained in database records.

However, before the responsibilities of the database are expanded, the database should be put into a trial period. A pilot period for the database, in which select AAI employees begin working with the database, is highly recommended. With a limited number of employees testing the database, the design team will be able to handle problems as they arise without becoming overwhelmed. Selection of particular employees should include a sample of users who are both confident and unconfident with the new program to provide a wide sample.

Additionally, the pilot period will not interfere with or sacrifice current operations. The database should not be immediately implemented across the engineering department because database failures could result in business failures. By implementing a trial period, errors within the programming can be corrected before such errors become costly to the business.

During this trial period, the database can be tried in several manners. One possible manner is to provide a copy of the database to every user. This creates segmented data that would need to be combined before it is searched. As the indexing capability of the database is one of its greatest strengths, this manner is not recommended.

A second option is to move the database to the public server. This would allow all entries to be made into one database. However, potential problems can arise if multiple users are attempting to use the database at the same time. Additionally, if multiple users are attempting to edit the same record at the same time, the database will encounter further problems. Once the database is brought to all employees at AAI this problem will need to be address (as discussed shortly); however, the usage during the trial period will be substantially less, and it may be possible to simply publish the current database as-is to a public server and allow all of the selected users to use the same database during the trial period.

While every effort has been made throughout the design of the database to ensure that errors will not be encountered by users once the database is put into place, many unpredictable errors will occur throughout its useful life. In fact, several of these errors have already begun to occur.

The first of these errors concerns up-to-date computer software. The database was purposely designed in a Microsoft Access 2000 file format. This format does restrict some options available to newer versions of the software, but it also allows for compatibility with all

versions of Microsoft Access since 2000. Unfortunately, the database was built in a version of Microsoft Access that had been updated to Jet 4.0. Jet, or Joint Engine Technology, is a major component of the Microsoft Access program. While no new features were included in the programming of the ECM Database, several of the formulas in the SQL code were altered with the publication of Jet 4.0. Thus, in order for all of the reports to function properly, all operating stations must have Jet 4.0 installed.

The upgrade to Jet 4.0 is easy and free, so this error does not incur extra costs on AAI. However, it does represent the multitude of problems that will arise as the database experiences a “trial by fire.” As with any project, revisions are a necessary reality. Another potential problem arises from the database file format. Currently, the database is in the Access Database file format, or \*.mdb. This file format stores the entire contents of the database in one file. While this is convenient for design and small, single-user applications, larger databases with multiple users will need a modified file structure.

As the database will be shared between multiple users as well as administrators with the capability to edit the structure of the database, it will be necessary to split the database into back-end and front-end \*.mdb files. When databases are split in the \*.mdb file format, the back-end component of the database will contain all of the tables while the front end will contain all of the remaining components of the database. The back-end of the database will be stored on a server that will be accessed by individual users. Conversely, the front-end of the database will be stored on each individual’s computer. Both files will have the \*.mdb extension, and all front-end copies will be linked to the back-end copy.

This setup allows multiple users to access the database at the same time. Additionally, this setup increases security and allows for usernames and passwords. When a user interacts with

the database, all actions, such as queries, will be performed by their workstation; however, all data will be stored on the server. Many other database configurations exist, including upsized databases utilizing Microsoft SQL Server Desktop Engine (MSDE), Microsoft SQL Server, Microsoft SharePoint, and Microsoft Access Data Projects; however, the complexity of such configurations is not necessary for the currently projected AAI usage.

Opportunities for future development do exist beyond resolving unforeseen problems. Many problems that arise will be user oriented problems dealing with user knowledge of the database. Since many employees at AAI have not worked with an Access database before, it would be useful to develop a user's manual that could be referenced when operating the database. This User's Manual should include two parts: an operating section and a trouble shooting section.

The operating section should include any and all operations the user would encounter. This obviously contains day-to-day operations, such as entering and editing quote information, but it should also include more technical instructions. Examples of technical instruction extend from the editing of current forms and reports to the development of new queries, forms, and reports. As the functions of the organization change, the database will need to change with the organization to remain viable. Thus, it is important that a User's Manual be created to assist users in adapting the database to the organization (rather than adapting the organization to the database).

The second section should be included for troubleshooting problems. Often, users will encounter problems to which they are unable to identify the cause. In the case of such problems, a trouble shooting guide should be developed to help users navigate through commonly experienced problems. One of the best ways to compose this troubleshooting guide is to keep a

record of problems encountered as the database is introduced to employees. Once employees are comfortable with the database, these commonly experienced problems can be combined into one trouble shooting guide that future new users can reference as needed.

Once the database is fully functional and the majority of unanticipated errors have been resolved, it will be possible to expand the application of the database. Several simple expansions exist that alter the use of, but not the structure, the database. The first of these expansions is to create user names and passwords. This would allow individual employees to log into the database under a user name. Activity by users can be restricted as needed to ensure that employees only perform the actions they need. Additionally, user names can improve security by ensuring that only specified users have the ability to edit data or the database structure.

Another option to be explored is the ability to access the database when the employee is away from the office. While remote desktop connections are possible, easier methods exist. One of the simplest methods is the display of database information via the internet. Microsoft Access Data Pages can be created that allow users to view predefined information via secure, log-in websites. Static HTML pages can be used, where users are only able to view reports and data as-is; or, interactive pages that allow users to manipulate data and print reports can also be created.

The database also contains the possibility to input data via the internet. However, whenever internet applications are considered, safety should also be considered. In-house server applications of databases are much less exposed to viruses and harmful users than externally published databases. Security checks can be put into place to help prevent the use of the database by unauthorized users.

One method to ensure that data within the database is protected is to create a backup schedule. Information in the database can be resaved to a multitude of data storage forms,

ranging from external hard drives to tapes. Backing up the database is highly recommended. If the database was to crash and data were lost, a backup ensures that the database can be restored. A database backup is not simply copying the entire database to another hard drive; rather, it is the saving of data or tables only to an external, uninfluenced medium that is assured safety independent from the office computer system.

Beyond publishing data via the internet, options to publish data to other Microsoft Office programs should also be considered. If Clients request a form in a specific file format, such as Microsoft Excel, the required import/export functions can be defined. All of the data within the access database can be exported to other Microsoft Office programs. Another beneficial export would be to export the PO Packet to an Adobe PDF.

Another category of database improvements is improving the user experience. One concept central to improving the user experience is Poke-a-Yoke, or “mistake-proofing” the database. These fail-safes prevent users from accidentally entering incorrect data or from accidentally performing operations they did not intend. Several applications of this concept have already been installed; however, as users encounter problems, opportunities for the application of “mistake-proofing” will undoubtedly arise.

Another user experience that could potentially become difficult is the PO Selection and Quote Selection secondary navigation screen. Currently, these screens sort purchase orders and quote automatically, and the sorting cannot be changed by the user (although they can be changed by the designer). Creating a user interface that allows users to sort by criteria would assist users in searching through the lists once they become extensive. Just as filters can be applied to spreadsheets, they can also be applied within a database. This effort may require the use of queries, queries by forms, or a set of forms. However, the ability to filter data would

improve the user experience by simplifying their search. It should be noted that these capabilities are directly part of current versions of Microsoft Access since 2007.

A final aspect in which the user experience could be improved is the segmentation of international consolidation orders. These orders are grouped together, and the database could be designed to display this group of orders in several different fashions. Currently, only the total consolidation is entered, and the breakouts cannot be seen (other than in the shipping schedule). Interviews with office employees would help determine the necessity and potential benefit arising from such an option.

The final and most important manner in which the ECM Database can be improved is the design of useful business reports. A substantial amount of data is stored within the database. As has been stated, the strongest point of the database is the ability to search this data and pull information required by or useful to company employees.

The manner in which this data is pulled is through the use of queries. Queries are fairly easy to design and implement, and it is possible to provide queries that operate through the use of forms. However, query results need to be provided in a medium other than a list. The results of such queries can be published to reports built within access that summarize the data in understandable terms. While these reports are not difficult to construct, they will require input from AAI employees as to which information will be beneficial. Also, there may be a period before these reports become useful as data is gathered and entered into the database.

Finally, employees at AAI may wish to design queries to their own specifications on an ad hoc basis. Such as hoc querying capabilities can be dangerous as employees may design overly complicated queries that overload the database or computer. However, limited ad hoc

query capabilities can be introduced through the use of forms. Again, input from AAI employees concerning which capabilities would be useful should be gathered before such an option is built.

### ***Long Term Application***

Overall, the long term potential of the ECM database is limited. As defined in the boundaries and function section, the ECM database is largely constrained to Engineering and Development. As such, potential benefits are also limited.

The original proposed solution (a comprehensive content management system) is still the ideal solution to the development process from purchase order to shipping schedule. Such a solution could even extend beyond this process into complete enterprise management. The advantage of such systems is their standardization of data, documents, and protocol throughout the company. This provides benefits ranging from increased search capacities to increased security checks and balances.

However, such a system is not currently feasible for AAI. Complete enterprise management systems incur large capital costs and require experienced development teams. Additionally, the current systems AAI do not require such an implementation. As the company continues to grow and expand, such a system may become necessary, beneficial, and even required. Therefore, the proposed ideal solution as well as the potential to expand the database into an enterprise wide solution should not be discarded but become included in strategic future planning.

If such plans are included, AAI will be adequately poised to make the necessary transitions when appropriate. Companies that experience rapid growth are often unable to make such changes because of a lack of planning and awareness. This is perhaps great advantaged to



the current solution (the ECM Database). This database begins to store data and orient company culture to database use. When the transitions to companywide content management systems become necessary, the process will have in fact already been initiated.

### **Concluding Remarks**

The strengths and benefits arising from RDBMS are too large to be ignored. Companies expanding and growing in the twenty first century must incorporate such advantages into their business in order to remain competitive. As the global market place becomes increasingly competitive and fast pace, the need to quickly access and analyze company information is essential.

With such advantages understood, an RDBMS must be carefully applied to AAI. One of the greatest strengths in the AAI business strategy is its flexibility to a competitive and fast paced global economy. A rigid and inflexible RDBMS will hinder such flexibility and any potential advantage gained will be outweighed by advantages lost.

These concerns are not insurmountable. By beginning with a small and flexible solution, such as the ECM Database, AAI can determine where such a system is a liability or an asset. Additionally, the creation of such a database in Microsoft Access allows the application to be flexible in design. The operation of Microsoft Access does not require significant prior knowledge, and can thus easily be edited by a few employees with the basic required skill set.

Finally, even the current ECM Database can increase global flexibility by connecting globally distributed offices and individuals. As AAI employees continue to travel to many global destinations, database applications like the ECM Database will allow individuals to access

required information whenever an internet connection is available. A global distribution of not only employees but also information would only serve to increase AAI's ability to survive and compete in a global marketplace.

# **Appendix 1**

*PO Packet Contents*

REQUESTED PURCHASE ORDER NUMBER: 7701232

PURCHASE ORDER DATE: 2/12/09

TO: Rich & Safe

SHIP TO: S Web

<b>SHIP VIA: Best way</b>	<b>IFIRM TO:</b>
<b>RECEIVE BY:</b>	<b>BUYER:</b>
<b>TERMS: TT</b>	<b>PHONE</b>
<b>F.O.B.: Yantian</b>	<b>VENDOR:</b>

ITEM I.D.	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	TOTAL PRICE
S920734	18/8 Brushed stainless insert for		1,490,000	\$0.191	\$284,590.00
	silicon				\$0.00
	10% buying commission				\$28,459.00
					\$0.00
					\$0.00
	HTSU: 3924.90.5500				
	Ship dates				
	3/7/07: 114k				
	3/14/07: 228k				
	3/21/07: 342k				
	3/28/07: 342k				
	4/7/07: 342k				
	4/14/07: 122k				
	TO SHIP TO SKY TO PACK INSIDE				
	SILICONE, PO 770223				
	Change order due to quantity increase.				
				SUBTOTAL:	\$313,049.00
				TOTAL:	\$313,049.00

**Appendix 1-A**

**P. O. CONFIRM**  
**(Internal)**

DATE: March 5, 2009

TO: Hyung/Rich

FROM: Cassie

CUSTOMER: USA

CONTACT NAME: John Doe

CONTACT: FAX: \_\_\_\_\_ PHONE: \_\_\_\_\_

ITEM: Silicone w/ Metal Insert

PO NUMBER: 7702

QUANTITY: 1,490,000

SELL PRICE: 1.25

DELIVERY DATE: 5/7/09

TERMS: Net 30

<b>SPECIAL INSTRUCTIONS:</b> _____
_____
_____

DELIVERY DESTINATION (CIRCLE ONE)

F.O.B. FACTORY  DESTINATION  S Web  PORT  OTHER

FREIGHT: AIR   OCEAN  OTHER

COMPLETE THIS FORM AND ATTACH TO CUSTOMER'S PO OR OTHER DOCUMENTATION  
FORM PRIOR TO FORWARDING IT TO ENGINEERING.

SIGNATURE \_\_\_\_\_

**Appendix 1-B**

Company  
22/2-1  
5009 Moscow  
Russian Fed.

PURCHASE ORDER / ЗАКАЗ				
PO/Номер заказа <b>50026356</b>	Date/Дата <b>24.12.2008</b>	Changed/Изменен	ChangeNo	CBF: 2895
Contract reference/Номер контракта: Quotation/Номер коммерческого предложения:		AAI-01		

Vendor/Поставщик: AMERICAN ACCESSORIES INTERNATIONAL, VendorNo/Код поставщика: 2563 Address/Адрес: 550 W. MAIN STREET, SUITE 825 City/Город: KNOXVILLE P.C./Индекс: 37902 Country/Страна: USA Contact/Для контактов: ERIC ZEANAH Telephone/Телефон: (865) 525-9100 Fax/Факс: 865 5250889	Currency/Валюта: USD United States Dollar Delivery terms/Условия поставки: DEQ St.Peresburg Transport means/Детали поставки: Payment terms/Условия оплаты: 30 cal. days after act of accept. and inv. receipt
--	--

Place of delivery/Место доставки : SALES AND MARKET  
Address/Адрес : Tverskaya CITY/Город : Moscow P.C./Индекс: 12500

ITEM Линия	MATERIAL Материал	DESCRIPTION Описание товаров	DLV DATE Дата доставки	QUANTITY Количество	UNIT Ед.изм.	PRICE Цена, без НДС	PER UNIT За ед. изм.	TOTAL AMOUNT Сумма, без НДС
1	600295	Small (Branded) Chrome Matt	30.04.2009	50,000.00	PC	2.68	1 PC	134,000.00
2	600295	Small (Branded) Antracite	30.04.2009	50,000.00	PC	2.68	1 PC	134,000.00
3	600294	(Branded) Antracite	30.04.2009	10,000.00	PC	49.45	10 PC	49,450.00
Collect. Freight								10,800.00
<b>Total net of VAT/Итого без НДС: 328,250.00 USD</b>								

Buyer/Покупатель \_\_\_\_\_  
Approved/Утверждено \_\_\_\_\_

Supplier stamp & signature/Подпись и печать Поставщика \_\_\_\_\_  
Date/Дата \_\_\_\_\_

Просим подтвердить заказ в течение 3х рабочих дней  
Please confirm this order within 3 working days



## Appendix 1-C

# PO SPECIFICATIONS

CUSTOMER USA

AAI PO# 7701798

AAI STYLE# S920709

DATE 02/12/07

QUANTITY 1,490,000

COST \$.191 + 10% comm.

FOB Guangzhou, China

DESCRIPTION .5mm 18/8 brushed stainless insert to fit silicone

SIZE Per samples already created

MATERIAL .5mm 18/8 stainless

TESTING Perform all stadard Heavy Metals Testig, Shipping Testing, etc

LABELS: COUNTRY OF ORIGIN: Made In China

PLACEMENT Bottom

SIZE 7mm

OTHER LABELS: \_\_\_\_\_

LOGO/TYPE \_\_\_\_\_

LOGO/SIZE \_\_\_\_\_

LOGO/COLOR \_\_\_\_\_

PMS# \_\_\_\_\_

PMS# \_\_\_\_\_

PMS# \_\_\_\_\_

PMS# \_\_\_\_\_

PACKING 10 pc/master; master carton size 20x23x25cm.

Each piece poly bagged.

OTHER \_\_\_\_\_

**Appendix 1-D**

1

Product Final       Quantity Revision       Sell Price Revision  
 Weight Average       First cost Revision       Other ( See Notes)

Customer	USA	Date	2/12/2009
End Customer		Style#	S920732
AAI PO#	770212	Engineer	Rich/Ellen/Hyung
Customer PO#	3435234	Salesperson	Eric
Description	Silicone with insert		

QUANTITY	1,490,000	BY PC.	TOTAL
First Cost	\$0.665	\$0.665	\$990,850.00
Adjusted	1.00	0.665	990,850.00
Commission %		0.000	0.00
Duty %	3.40%	0.023	34,270.00
Freight	\$0.036	0.036	53,640.00
Other1	\$0.227	0.227	338,230.00
Raw Landed		\$0.968	\$1,442,320.00
Full Landed		\$1.058	\$1,576,420.00

<b>SELL</b>	<b>\$1.250</b>	<b>\$1,862,500.000</b>
-------------	----------------	------------------------

%%	BY PC. \$	TOTAL \$
22.56%	\$0.282	\$420,180.000

Total Contribution

Sell Price	
AAI Percentage	100%
Other Percentage	0%
End Sell	\$1.250
Adjusted Sell	\$1.250

**Freight Options**  
Ocean Included in Cost ▼

**Other Program Costs**  
( Enter as program cost, ie. \$350 for handling charge. Attach explanation to Notes section)

Other2	Item	AAI Cost	Customer Pays
Other3	_____	_____	_____

**Notes**

Other1 is \$8000 for molds, \$600 for testing, and \$.221/pc for raw landed of insert

Brushed stainless insert coming from Jiahua, PO 7701

APPROVALS:

Prepared by _____	Engineer _____	Corporate Approval _____
-------------------	----------------	--------------------------

**Appendix 1-E**



**\*Purchasing Delivery Schedule (Switzerland)**

\*Vendor Name: American Accessories International LLC  
 \*Date: 04/22/09  
 Contact Person: Eric Zeanah  
 Telephone #: 865-525-9100

*Record Type	Application	Version	Vendor Number	Date
H		0001	25698	03/12/2009

*Record Type	PO Number	Item Number	Item Description	Total PO Line Qty	PO Line Number	UoM	Plani/Actual	Ship Quantity	Ship Date	Plani/Actual	Customs Clearance Date	Method of Shipment	Container #	Target Delivery Date	Original Receipt No.	Original Receipt Date
D	71000	60034573	Small Black Square Silicon	20,000	1	EA	P	20,000	05/05/2009	P	N/A	OCEAN	N/A	06/05/2009		
D	71000	60034574	Large Black Square Silicon	10,000	2	EA	P	10,000	05/05/2009	P	N/A	OCEAN	N/A	06/05/2009		

*Record Type
T

CONTACT: James.Doe@customer.com  
 DELIVERY ADDRESS:

Customer  
 MARKETING  
 Lausanne, Switzerland  
 -413 (55) 2425555

# **Appendix 2**

*Raw Data For Simulation Model*

---

PO Receiving Schedule

---

Number Of Work  
Days (January  
26th to April 1st)

Number of PO's  
Received From  
Customers

---

1	2
2	3
3	0
4	0
5	4
6	0
7	1
8	1
9	1
10	3
11	0
12	0
13	0
14	1
15	2
16	0
17	2
18	0
19	0
20	0
21	0
22	0
23	5
24	2
25	2
26	1
27	0
28	0
29	1
30	0
31	1
32	0
33	0
34	3
35	0
36	3
37	0
38	0
39	0
40	0
41	1

---

Continued...

---

42	1
43	1
44	2
45	0
46	0
47	0
48	2
49	0
50	3
51	0
52	3

Per Day PO Break Out

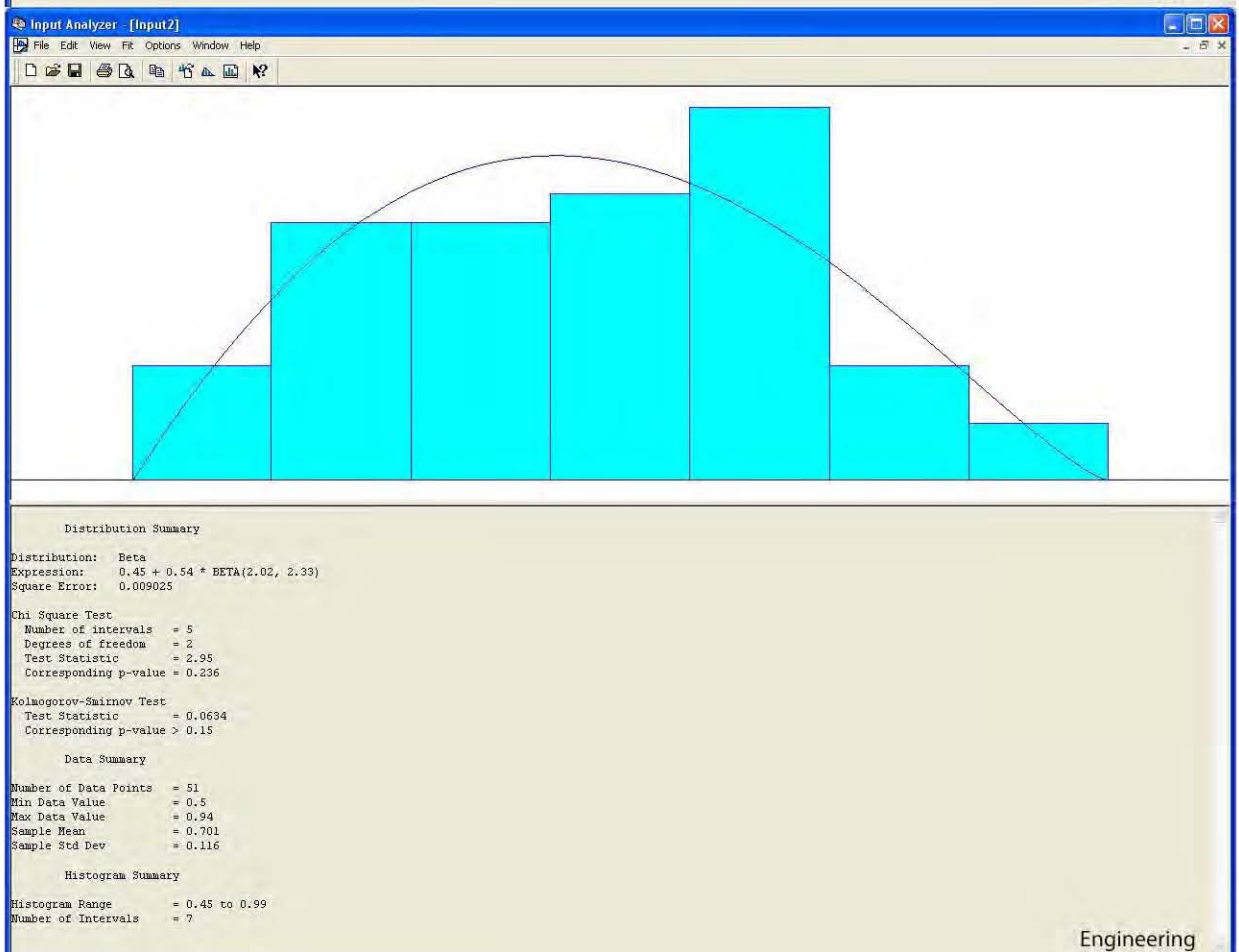
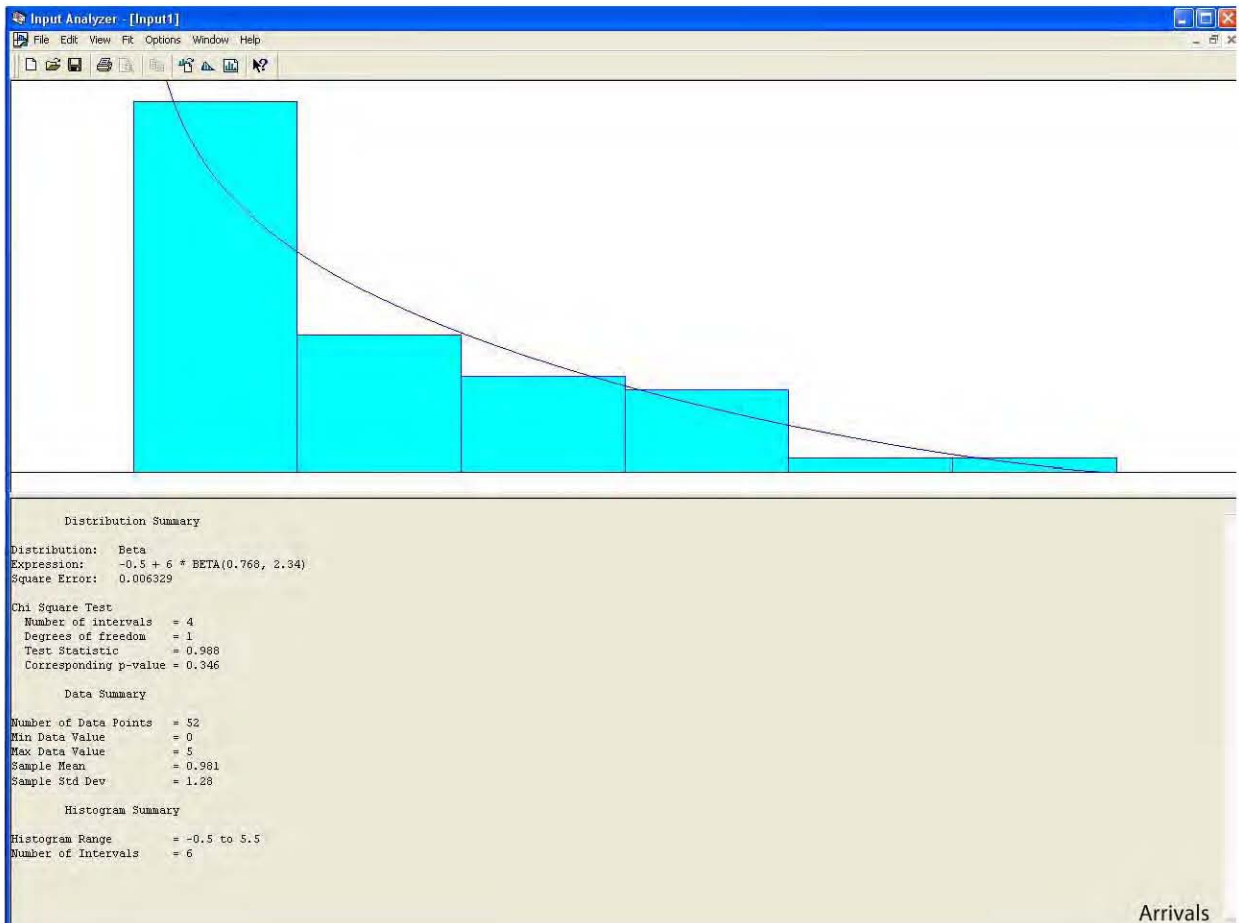
(Days in which no PO was received are not listed)

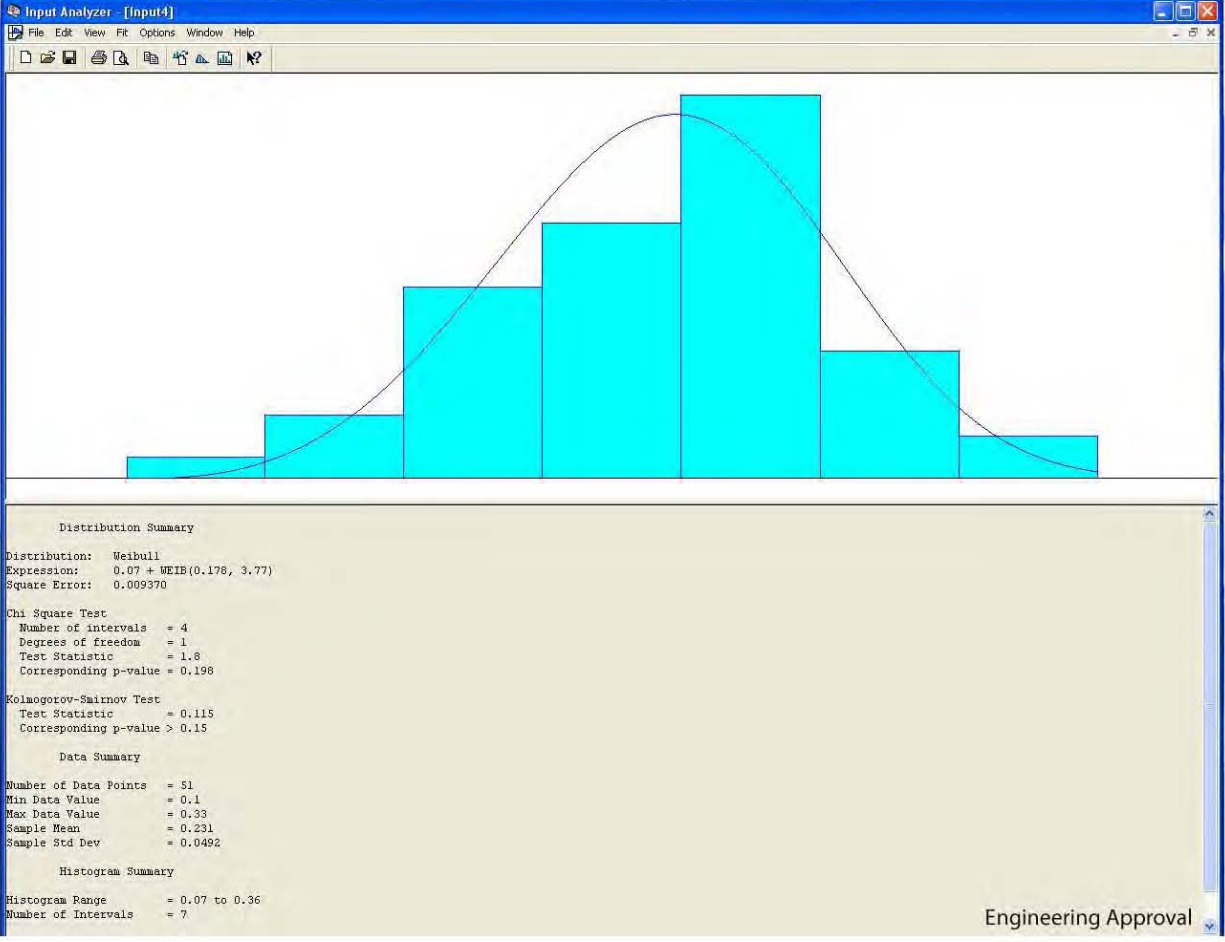
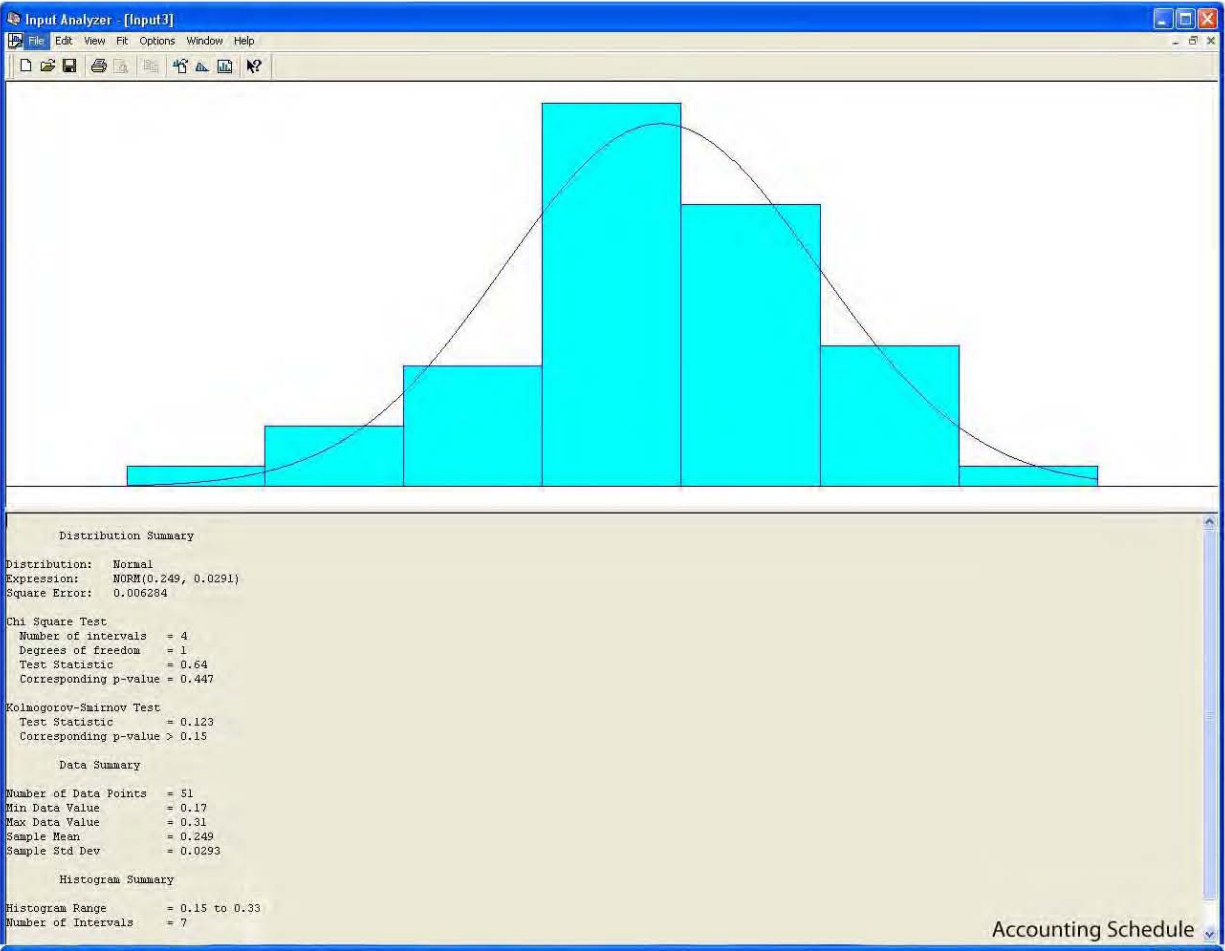
Day	IG #	Engineering	Accounting	Engineering Approval	Corporate Approval	Administration	Book Keeping	Flight Forwarder	China Office Confirmation	Factory Confirmation	China Confirmation	Projector Development	Admin Delivery/Upload
1	01	0.74	0.24	0.25	0.21	0.16	0.348	5.21	0.546	4.54	4.11	2.93	0.21
2	08	0.27	0.26	0.19	0.33	0.19	0.238	3.28	0.514	4.26	3.44	2.92	0.21
3	08	0.45	0.26	0.25	0.32	0.19	0.272	4.63	0.485	3.53	4.23	2.37	0.34
4	08	0.45	0.27	0.33	0.29	0.16	0.243	2.07	0.408	3.56	3.95	3.04	0.32
5	07	0.73	0.27	0.24	0.28	0.11	0.246	2.57	0.507	7.06	4.86	3.02	0.32
6	07	0.86	0.28	0.21	0.28	0.11	0.313	4.1	0.314	7.29	3.77	3.07	0.31
7	08	0.82	0.27	0.26	0.22	0.12	0.224	3.24	0.312	7.02	4.5	2.51	0.25
8	08	0.68	0.24	0.19	0.22	0.13	0.334	6.99	0.343	7.48	4.86	2.33	0.32
9	07	0.57	0.24	0.19	0.22	0.13	0.378	3.44	0.343	7.15	4.11	2.29	0.31
10	06	0.61	0.23	0.22	0.22	0.13	0.386	2.24	0.374	7.04	4.06	2.95	0.16
11	06	0.66	0.25	0.22	0.22	0.13	0.413	5.6	0.242	7.05	5.09	2.63	0.34
12	06	0.53	0.25	0.22	0.22	0.13	0.379	2.93	0.242	7.13	4.5	2.15	0.2
13	06	0.64	0.27	0.24	0.22	0.13	0.343	1.87	0.244	6.34	4.2	3.04	0.27
14	06	0.71	0.28	0.23	0.22	0.13	0.364	2.26	0.268	6.31	4.2	2.51	0.28
15	06	0.75	0.28	0.23	0.22	0.13	0.364	2.26	0.268	6.31	4.2	2.51	0.28
16	06	0.66	0.24	0.22	0.22	0.13	0.372	2.23	0.306	2.77	1.74	2.02	0.33
17	06	0.88	0.25	0.24	0.22	0.13	0.372	2.23	0.306	2.77	1.74	2.02	0.33
18	06	0.56	0.23	0.17	0.27	0.12	0.382	1.89	0.344	3.01	1.57	2.18	0.22
19	06	0.55	0.23	0.17	0.27	0.12	0.382	1.89	0.344	3.01	1.57	2.18	0.22
20	06	0.54	0.23	0.17	0.27	0.12	0.382	1.89	0.344	3.01	1.57	2.18	0.22
21	06	0.54	0.23	0.17	0.27	0.12	0.382	1.89	0.344	3.01	1.57	2.18	0.22
22	06	0.54	0.23	0.17	0.27	0.12	0.382	1.89	0.344	3.01	1.57	2.18	0.22
23	06	0.54	0.23	0.17	0.27	0.12	0.382	1.89	0.344	3.01	1.57	2.18	0.22
24	06	0.54	0.23	0.17	0.27	0.12	0.382	1.89	0.344	3.01	1.57	2.18	0.22
25	06	0.54	0.23	0.17	0.27	0.12	0.382	1.89	0.344	3.01	1.57	2.18	0.22
26	06	0.54	0.23	0.17	0.27	0.12	0.382	1.89	0.344	3.01	1.57	2.18	0.22
27	06	0.54	0.23	0.17	0.27	0.12	0.382	1.89	0.344	3.01	1.57	2.18	0.22
28	06	0.54	0.23	0.17	0.27	0.12	0.382	1.89	0.344	3.01	1.57	2.18	0.22
29	06	0.54	0.23	0.17	0.27	0.12	0.382	1.89	0.344	3.01	1.57	2.18	0.22
30	06	0.54	0.23	0.17	0.27	0.12	0.382	1.89	0.344	3.01	1.57	2.18	0.22
31	06	0.54	0.23	0.17	0.27	0.12	0.382	1.89	0.344	3.01	1.57	2.18	0.22
32	06	0.54	0.23	0.17	0.27	0.12	0.382	1.89	0.344	3.01	1.57	2.18	0.22
33	06	0.54	0.23	0.17	0.27	0.12	0.382	1.89	0.344	3.01	1.57	2.18	0.22
34	06	0.54	0.23	0.17	0.27	0.12	0.382	1.89	0.344	3.01	1.57	2.18	0.22
35	06	0.54	0.23	0.17	0.27	0.12	0.382	1.89	0.344	3.01	1.57	2.18	0.22
36	06	0.54	0.23	0.17	0.27	0.12	0.382	1.89	0.344	3.01	1.57	2.18	0.22
37	06	0.54	0.23	0.17	0.27	0.12	0.382	1.89	0.344	3.01	1.57	2.18	0.22
38	06	0.54	0.23	0.17	0.27	0.12	0.382	1.89	0.344	3.01	1.57	2.18	0.22
39	06	0.54	0.23	0.17	0.27	0.12	0.382	1.89	0.344	3.01	1.57	2.18	0.22
40	06	0.54	0.23	0.17	0.27	0.12	0.382	1.89	0.344	3.01	1.57	2.18	0.22
41	06	0.54	0.23	0.17	0.27	0.12	0.382	1.89	0.344	3.01	1.57	2.18	0.22
42	06	0.54	0.23	0.17	0.27	0.12	0.382	1.89	0.344	3.01	1.57	2.18	0.22
43	06	0.54	0.23	0.17	0.27	0.12	0.382	1.89	0.344	3.01	1.57	2.18	0.22
44	06	0.54	0.23	0.17	0.27	0.12	0.382	1.89	0.344	3.01	1.57	2.18	0.22
45	06	0.54	0.23	0.17	0.27	0.12	0.382	1.89	0.344	3.01	1.57	2.18	0.22
46	06	0.54	0.23	0.17	0.27	0.12	0.382	1.89	0.344	3.01	1.57	2.18	0.22
47	06	0.54	0.23	0.17	0.27	0.12	0.382	1.89	0.344	3.01	1.57	2.18	0.22
48	06	0.54	0.23	0.17	0.27	0.12	0.382	1.89	0.344	3.01	1.57	2.18	0.22
49	06	0.54	0.23	0.17	0.27	0.12	0.382	1.89	0.344	3.01	1.57	2.18	0.22
50	06	0.54	0.23	0.17	0.27	0.12	0.382	1.89	0.344	3.01	1.57	2.18	0.22
51	06	0.54	0.23	0.17	0.27	0.12	0.382	1.89	0.344	3.01	1.57	2.18	0.22
52	06	0.54	0.23	0.17	0.27	0.12	0.382	1.89	0.344	3.01	1.57	2.18	0.22

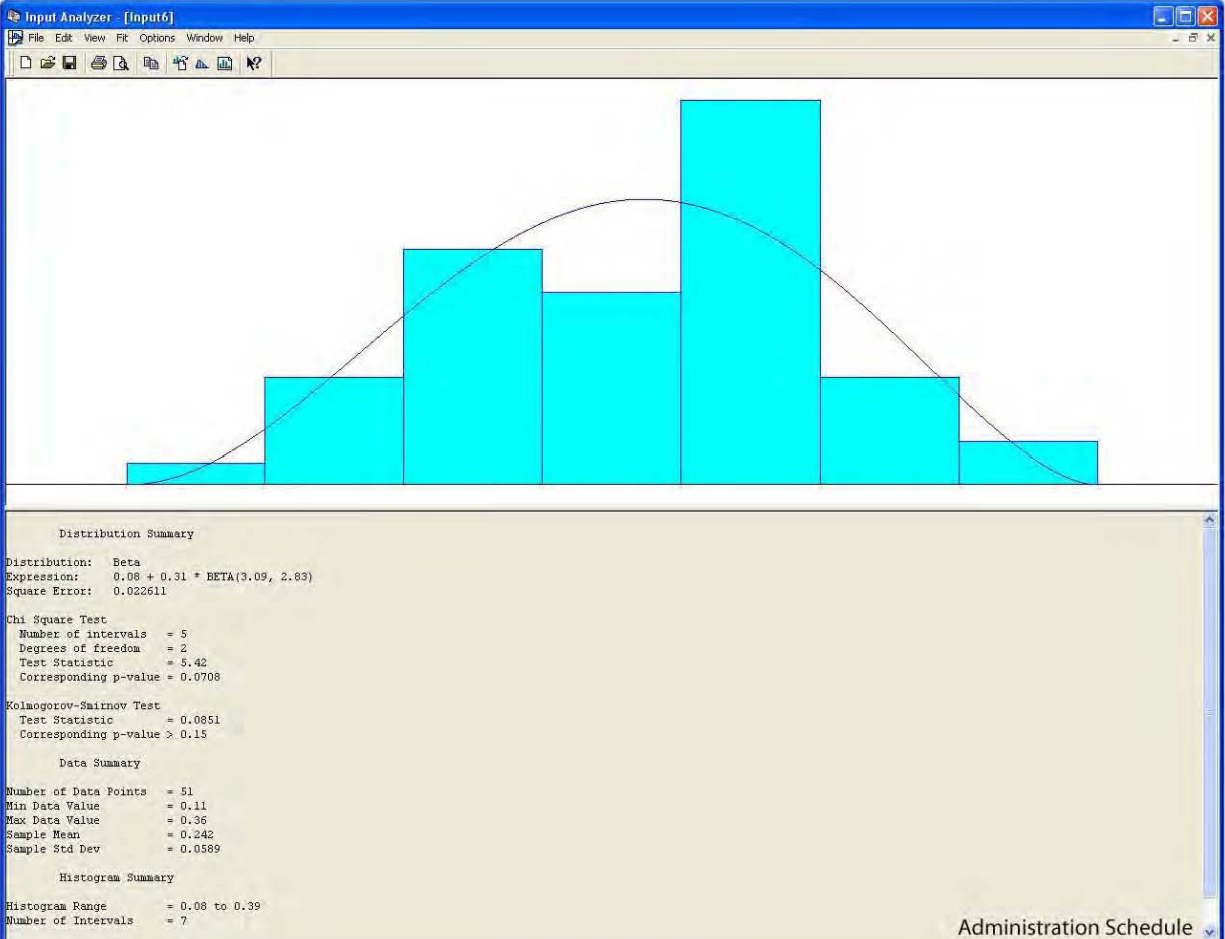
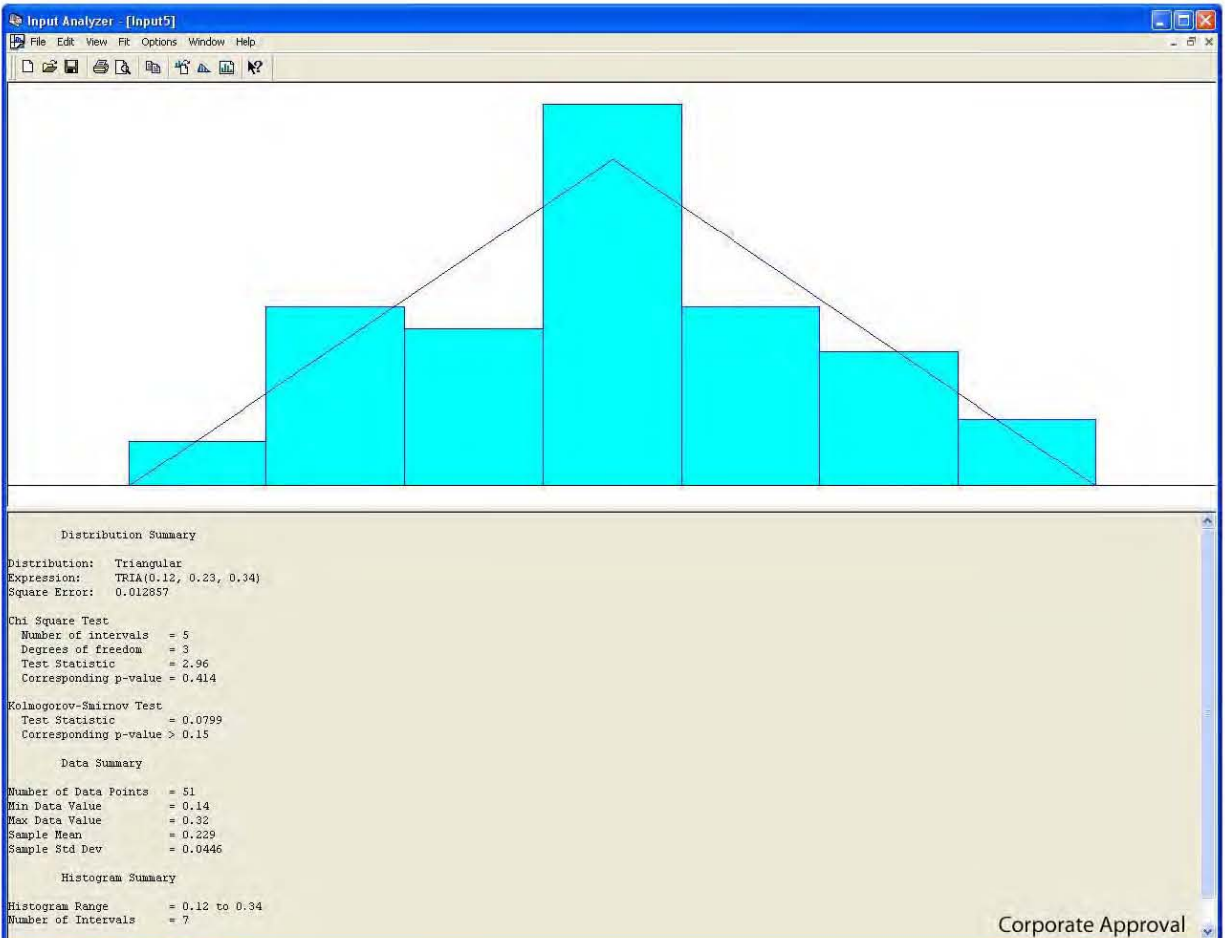
Notes: Time during Chinese New Year Holiday that process times are skewed \*

# **Appendix 3**

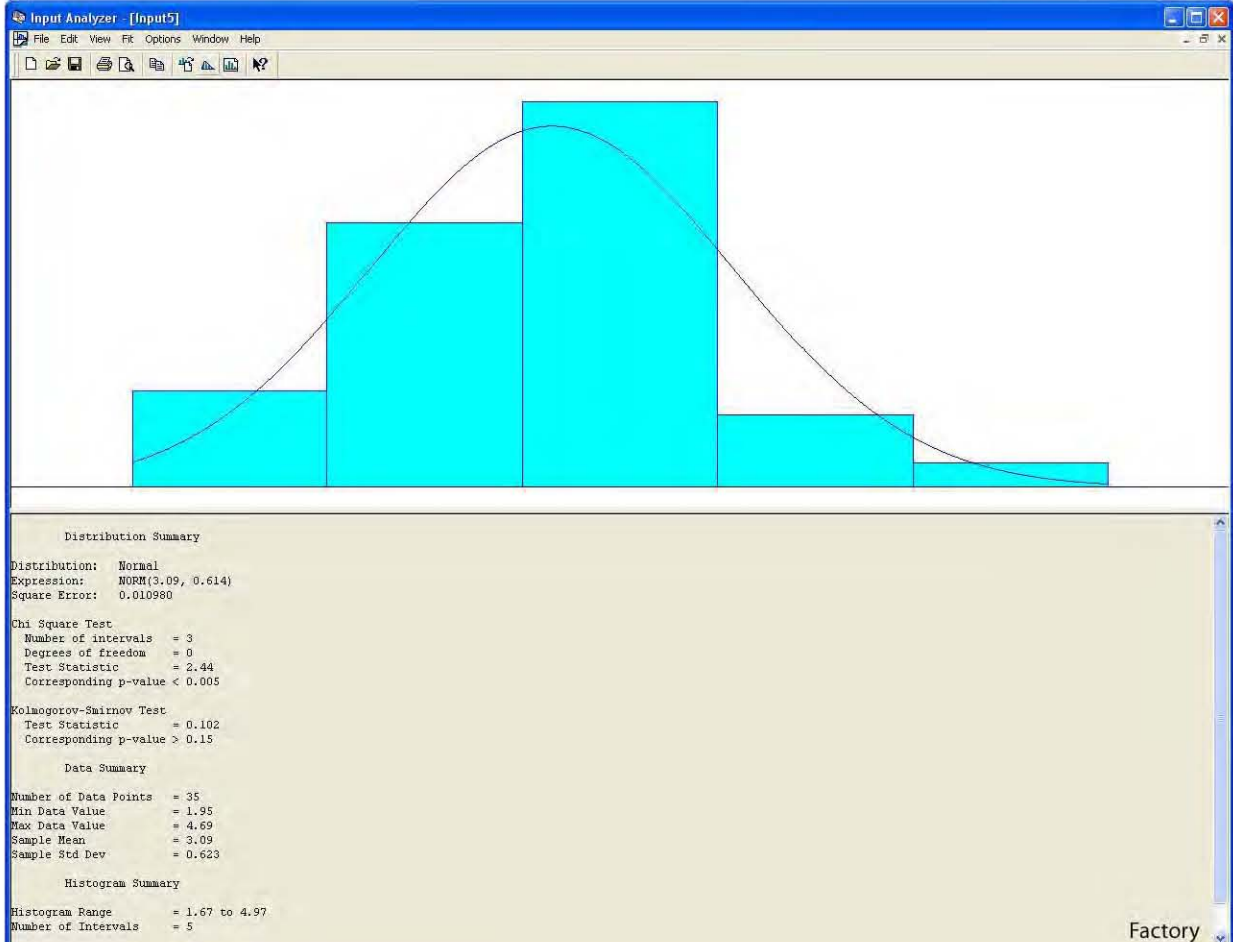
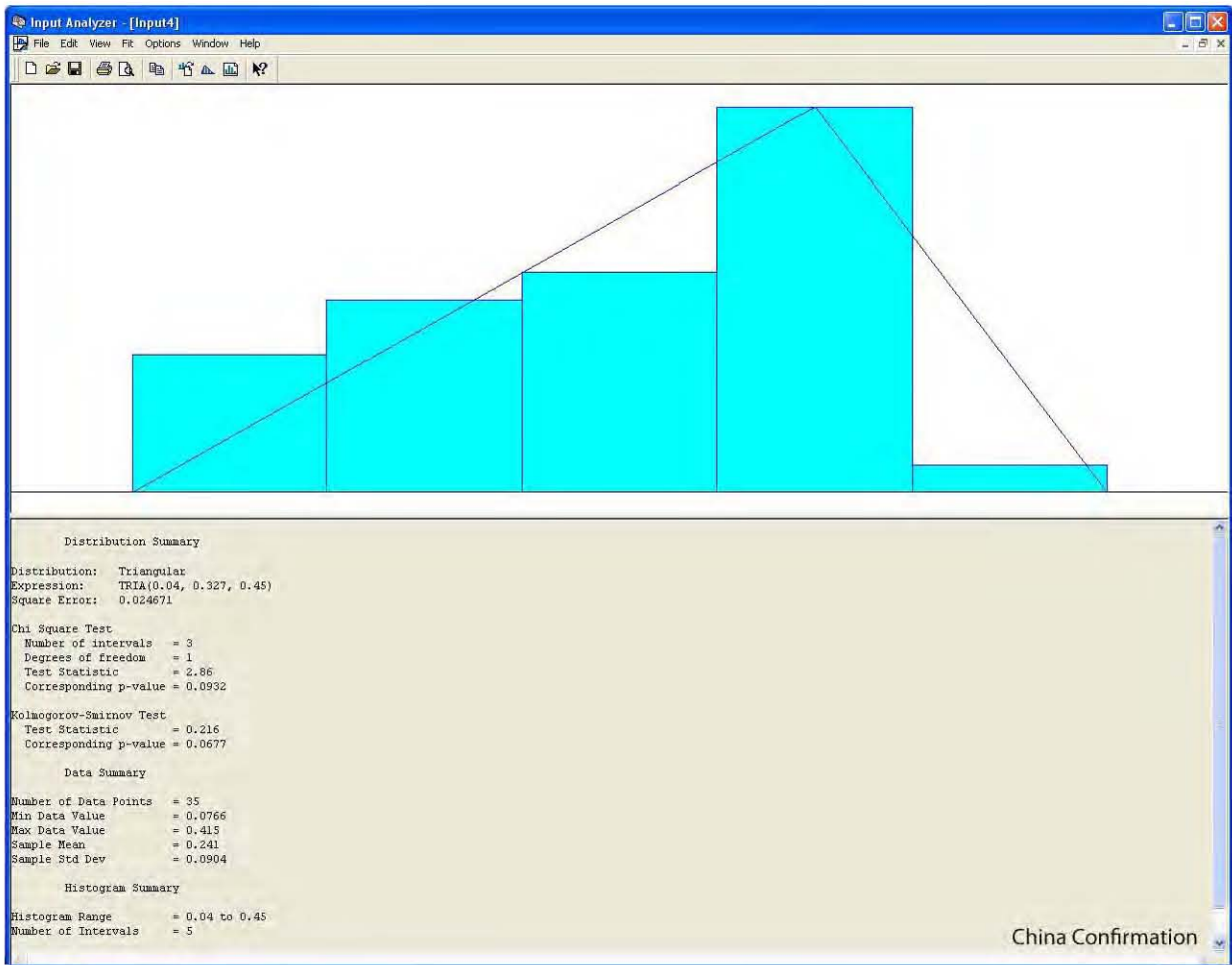
## *Arena Distributions for Simulation Model*

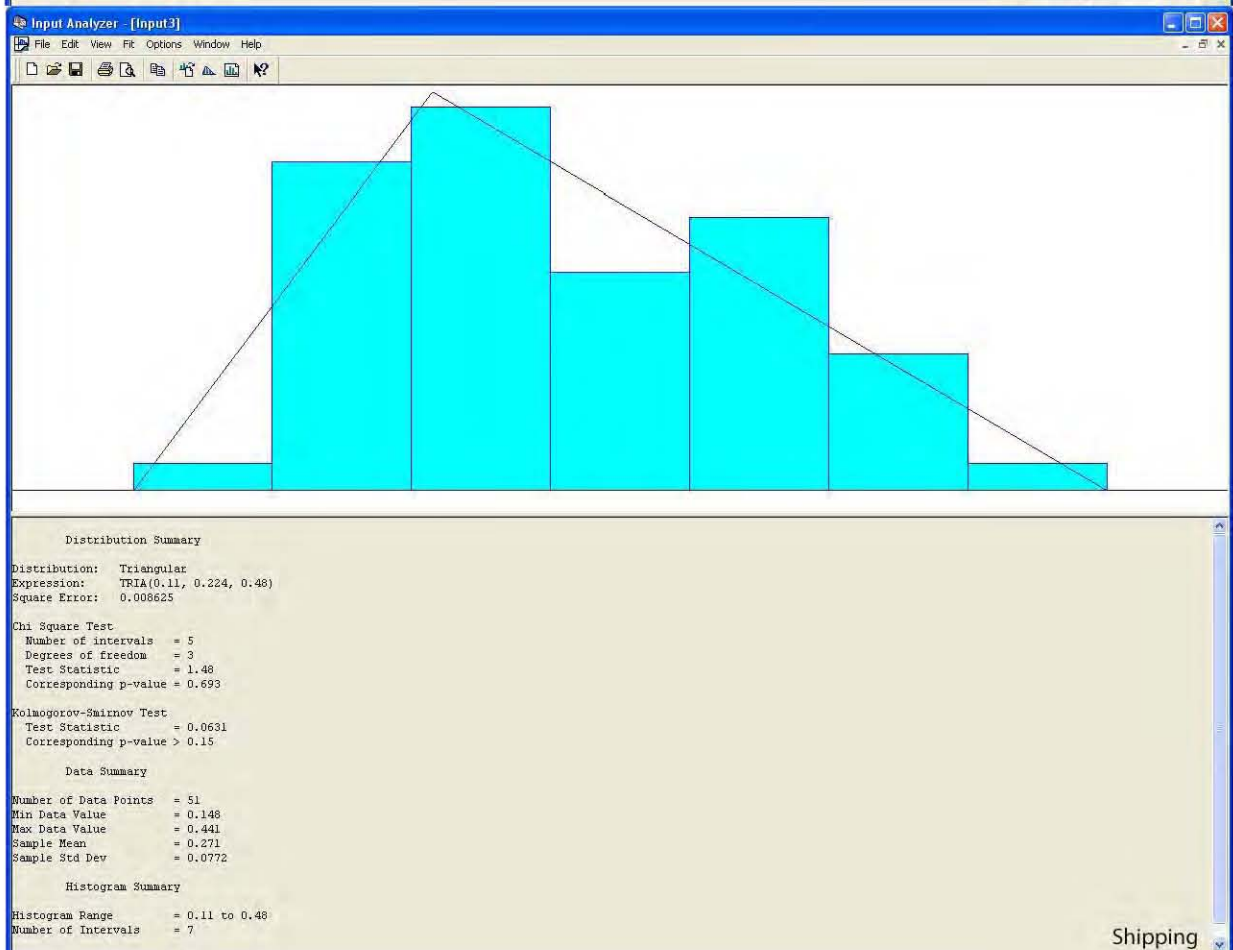
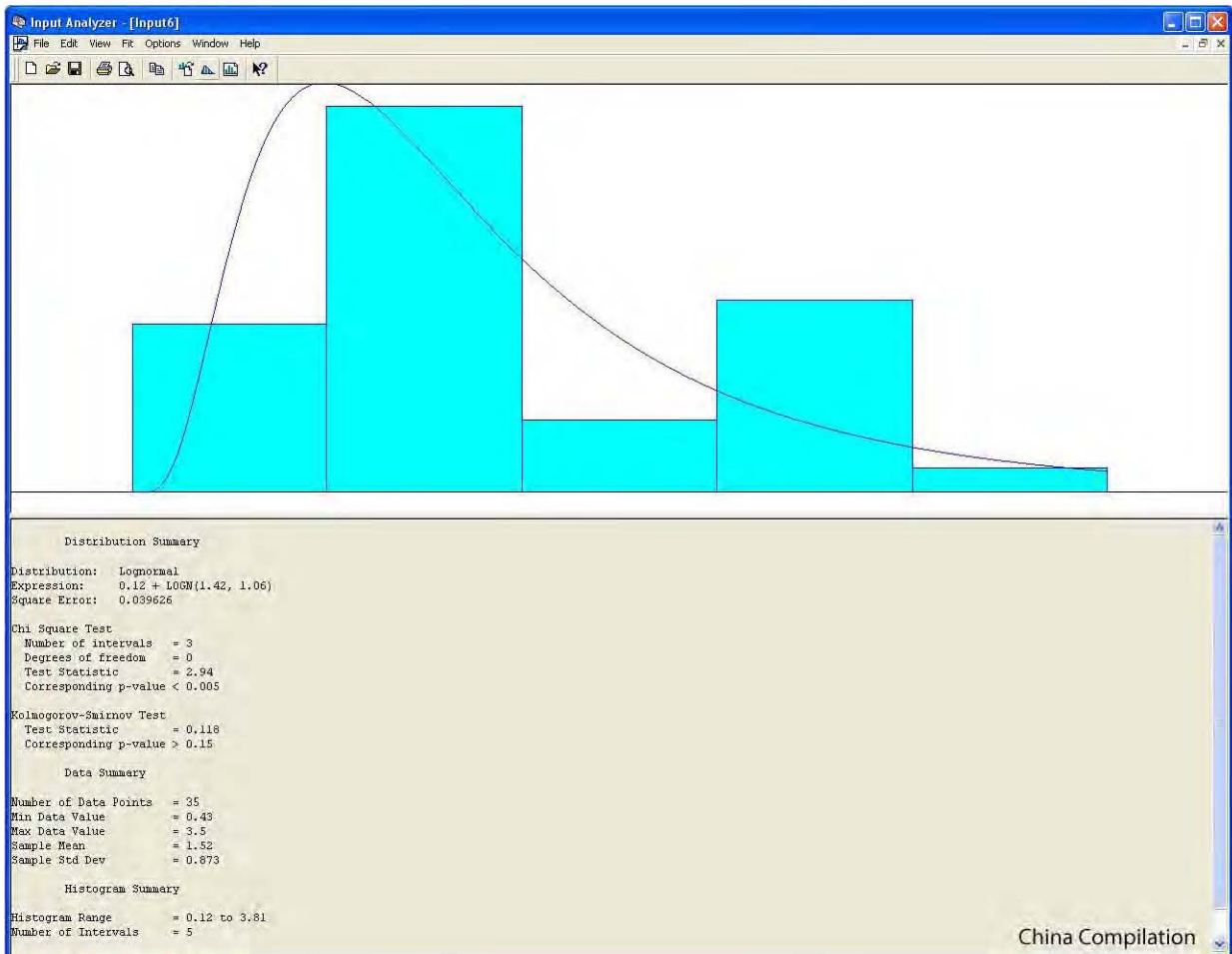


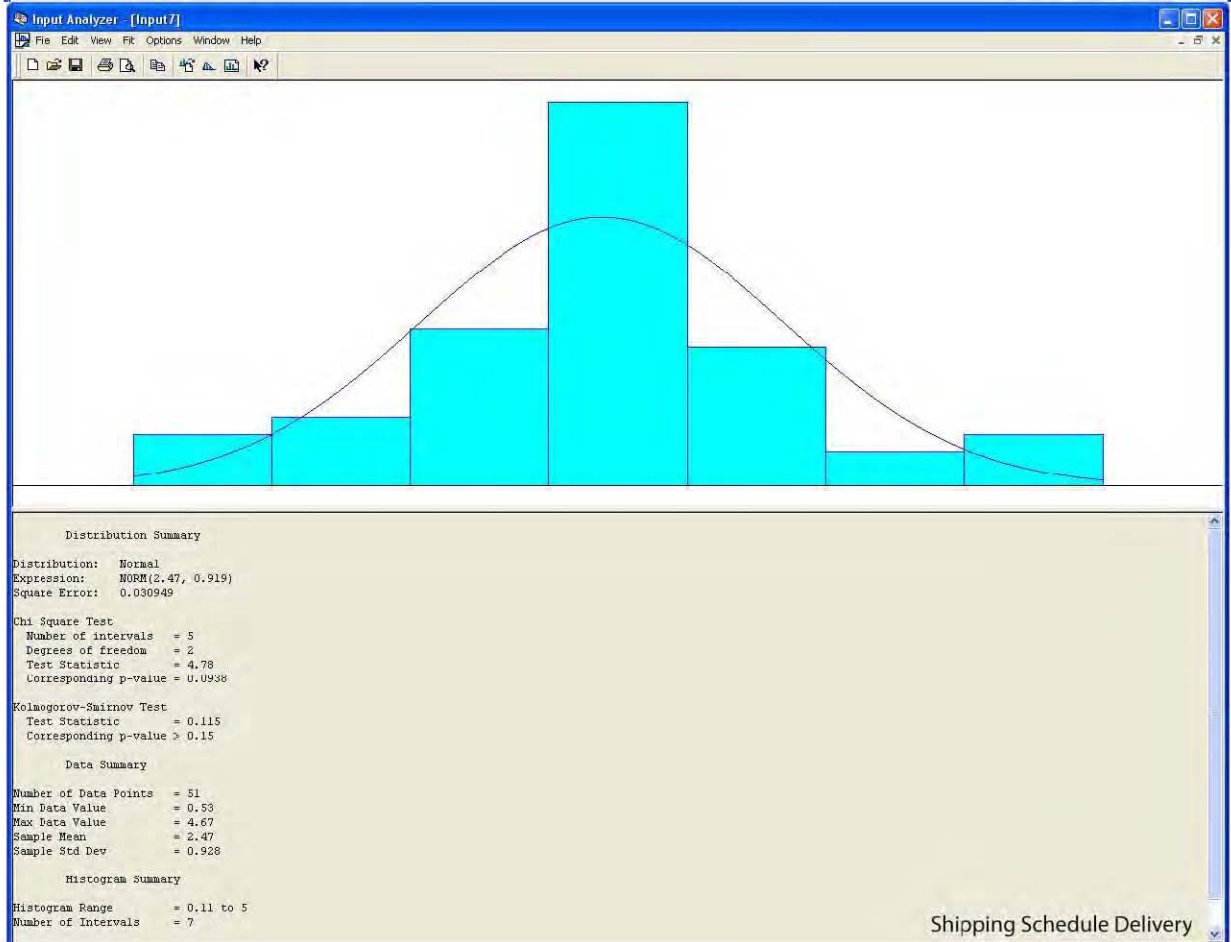
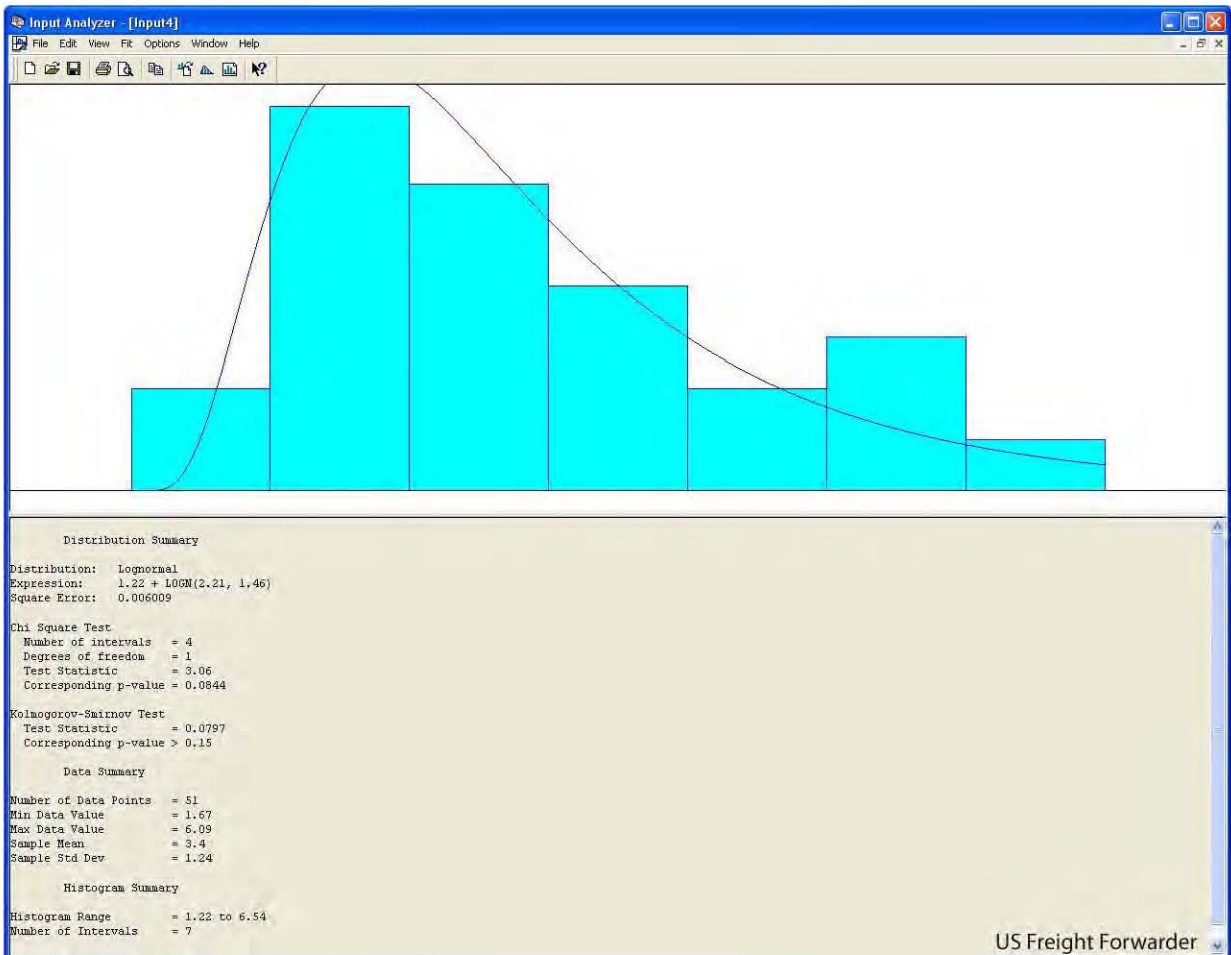


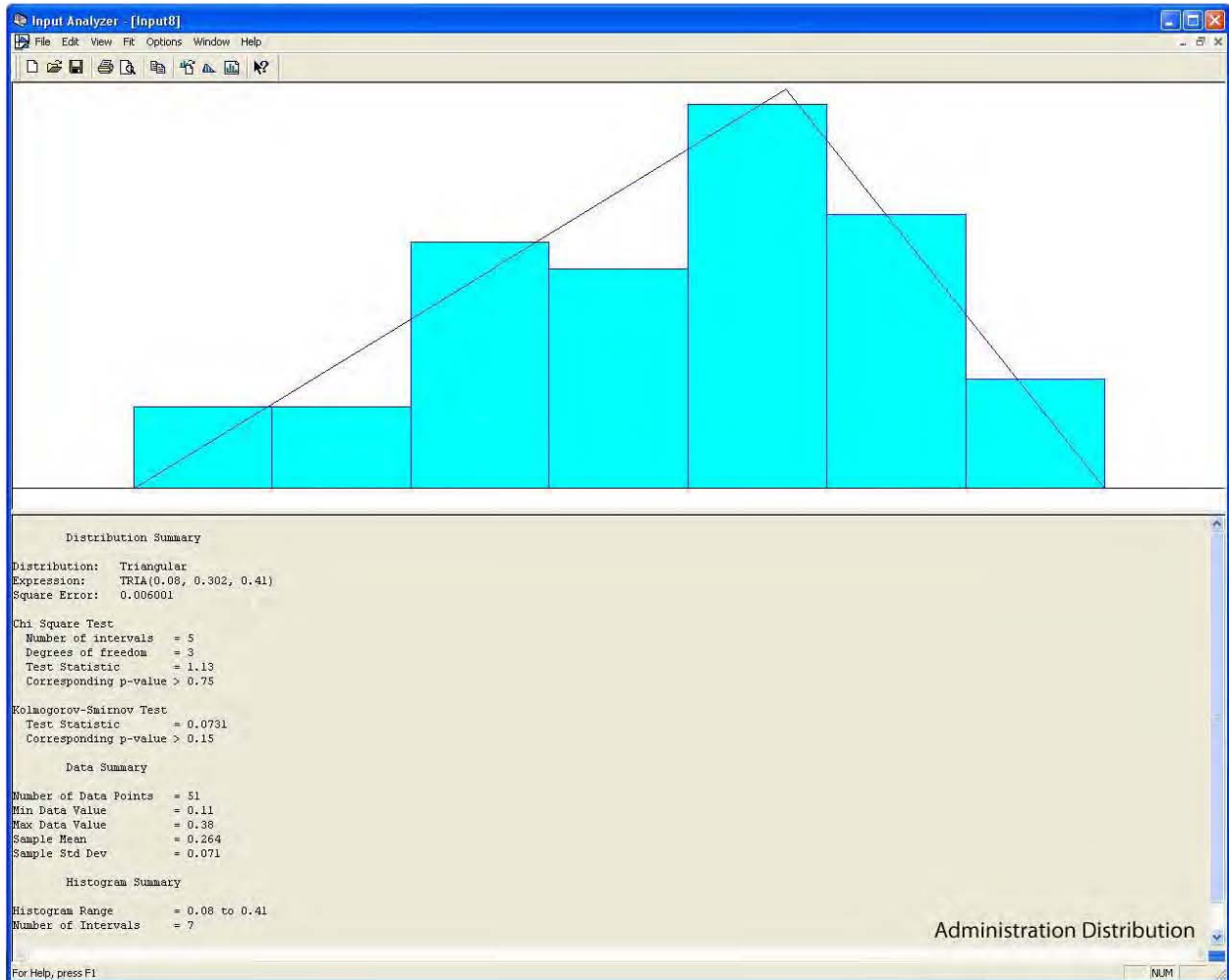












# **Appendix 4**

*Arena Results for Simulation Model  
(Fitted Distribution Data)*

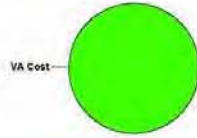
Unnamed Project

Replications: 35 Time Units: Hours

Key Performance Indicators

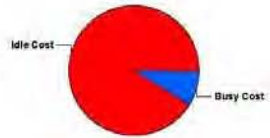
All Entities

	Average
Non-Value Added Cost	0
Other Cost	0
Transfer Cost	0
Value Added Cost	8,842
Wait Cost	0
Total Cost	8,842



All Resources

	Average
Busy Cost	8,842 *
Idle Cost	94,742
Usage Cost	0



Total Cost	103,584
------------	---------

\* these costs are included in Entity Costs above.

System

	Average
Total Cost	103,584
Number Out	52



Values Across All Replications

## Unnamed Project

Replications: 35 Time Units: Hours

## Entity

### Time

VA Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
DistSig	0.00	0.00	0.00	0.00	0.00	0.00
Entity 1	16.4434	0.11	15.6682	17.2260	10.6917	28.1764
NVA Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
DistSig	0.00	0.00	0.00	0.00	0.00	0.00
Entity 1	0.00	0.00	0.00	0.00	0.00	0.00
Wait Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
DistSig	0.00	0.00	0.00	0.00	0.00	0.00
Entity 1	259.79	34.85	152.41	571.45	50.1538	841.52
Transfer Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
DistSig	0.00	0.00	0.00	0.00	0.00	0.00
Entity 1	0.2108	0.00	0.2039	0.2181	0.2000	0.3000
Other Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
DistSig	0.00	0.00	0.00	0.00	0.00	0.00
Entity 1	0.00	0.00	0.00	0.00	0.00	0.00
Total Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
DistSig	0.00	0.00	0.00	0.00	0.00	0.00
Entity 1	203.64	21.49	136.17	390.11	45.6843	553.59

### Cost

VA Cost	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
DistSig	0.00	0.00	0.00	0.00	0.00	0.00
Entity 1	174.17	1.79	163.58	184.79	101.74	370.98
NVA Cost	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
DistSig	0.00	0.00	0.00	0.00	0.00	0.00
Entity 1	0.00	0.00	0.00	0.00	0.00	0.00

## Appendix 4-B

**Unnamed Project**

Replications: 35      Time Units: Hours

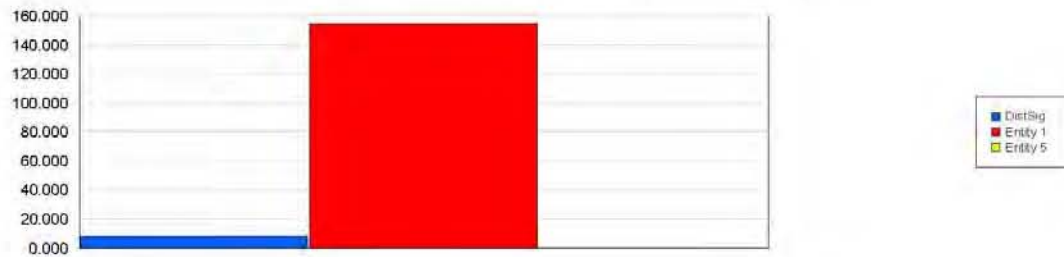
**Entity**

**Cost**

Wait Cost	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
DistSig	0.00	0.00	0.00	0.00	0.00	0.00
Entity 1	0.00	0.00	0.00	0.00	0.00	0.00
Other Cost	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
DistSig	0.00	0.00	0.00	0.00	0.00	0.00
Entity 1	0.00	0.00	0.00	0.00	0.00	0.00
Transfer Cost	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
DistSig	0.00	0.00	0.00	0.00	0.00	0.00
Entity 1	0.00	0.00	0.00	0.00	0.00	0.00
Total Cost	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
DistSig	0.00	0.00	0.00	0.00	0.00	0.00
Entity 1	174.17	1.79	163.58	184.79	101.74	370.98

**Other**

Number In	Average	Half Width	Minimum Average	Maximum Average
DistSig	8.0000	0.00	8.0000	8.0000
Entity 1	154.57	8.72	107.00	203.00
Entity 5	0.00	0.00	0.00	0.00





*Values Across All Replications***Unnamed Project**

Replications: 35      Time Units: Hours

**Entity****Other**

Number Out	Average	Half Width	Minimum Average	Maximum Average		
DistSig	8.0000	0.00	8.0000	8.0000		
Entity 1	131.40	6.10	87.0000	162.00		
Entity 5	0.00	0.00	0.00	0.00		
WIP	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
DistSig	0.00	0.00	0.00	0.00	0.00	1.0000
Entity 1	21.5179	3.01	10.6356	48.6292	0.00	89.0000
Entity 5	0.00	0.00	0.00	0.00	0.00	0.00

## Unnamed Project

Replications: 35      Time Units: Hours

## Process

### Time per Entity

VA Time Per Entity	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Accounting	0.2495	0.00	0.2408	0.2610	0.1508	0.3565
Administration	0.2417	0.00	0.2258	0.2562	0.0967	0.3764
China Compilation	1.6381	0.25	0.00	3.3002	0.00	9.4032
China Compilation T1	1.5795	0.05	1.3021	1.8591	0.2665	15.0748
China Office Confirmation T1	0.2735	0.00	0.2504	0.2941	0.04831780	0.4370
China Office Confirmation T2	0.2766	0.03	0.00	0.3885	0.00	0.4267
Corporate Approval	0.2300	0.00	0.2172	0.2464	0.1215	0.3378
Distribute Shipping Schedules	0.2635	0.00	0.2434	0.2873	0.08789691	0.4090
Engineering	0.6927	0.01	0.6634	0.7267	0.4587	0.9628
Engineering Approval	0.2283	0.00	0.1996	0.2460	0.08026956	0.4172
FA Error	0.1218	0.01	0.00	0.1481	0.00	0.1718
Factory Confirmation	3.0570	0.02	2.9274	3.1996	0.8973	5.1262
FE Error	0.3355	0.02	0.00	0.3983	0.00	0.4761
Overflow Engineering	0.1408	0.10	0.00	0.8601	0.00	0.8601
Overseas FF	3.3286	0.05	2.9902	3.5953	1.2272	6.4193
Shipping Beg	3.4205	0.08	3.0062	3.8224	1.5222	15.4307
Shipping Cons	0.2744	0.00	0.2486	0.2965	0.1139	0.4797
Shipping Schedule Development	2.4715	0.05	2.1650	2.8075	0.00	5.4475
US FF	3.2133	0.17	2.0552	4.3606	1.5972	12.6523

Values Across All Replications

## Unnamed Project

Replications: 35 Time Units: Hours

## Process

### Time per Entity

Wait Time Per Entity	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Accounting	0.2188	0.07	0.00	0.6186	0.00	15.0000
Administration	0.2635	0.06	0.00281240	0.6340	0.00	15.0176
China Compilation	1.2743	0.59	0.00	7.5000	0.00	15.0000
China Compilation T1	1.9457	0.23	0.8262	3.4672	0.00	40.7668
China Office Confirmation T1	0.3141	0.07	0.07981740	1.2872	0.00	9.4456
China Office Confirmation T2	0.00	0.00	0.00	0.00	0.00	0.00
Corporate Approval	0.2251	0.08	0.00206505	1.0228	0.00	15.1487
Distribute Shipping Schedules	9.3565	0.06	8.9349	9.6758	8.5000	13.1233
Engineering	5.8476	0.31	3.9893	8.4089	0.00	18.8750
Engineering Approval	0.7823	0.16	0.0967	2.4579	0.00	18.0240
FA Error	3.1101	0.89	0.00	9.9861	0.00	12.1256
Factory Confirmation	5.6955	1.10	1.7470	16.7214	0.00	72.7447
FE Error	2.4640	0.81	0.00	7.5000	0.00	17.6386
Overflow Engineering	1.2397	1.06	0.00	14.8680	0.00	14.8680
Overseas FF	9.9260	0.36	7.1420	11.9987	3.0158	48.3058
Shipping Beg	29.4110	6.54	9.1520	87.3642	0.00	163.76
Shipping Cons	28.4427	7.14	8.3081	89.6904	0.00	161.50
Shipping Schedule Development	26.0337	7.45	1.7838	92.4993	0.00	165.12
US FF	6.3051	1.20	0.6000	15.0000	0.00	31.0000

Values Across All Replications

## Unnamed Project

Replications: 35 Time Units: Hours

## Process

### Time per Entity

Total Time Per Entity	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Accounting	0.4683	0.07	0.2453	0.8675	0.1508	15.3207
Administration	0.5052	0.06	0.2458	0.8597	0.0967	15.3550
China Compilation	2.9124	0.75	0.00	10.4130	0.00	24.4032
China Compilation T1	3.5252	0.25	2.4416	5.1334	0.2665	42.5094
China Office Confirmation T1	0.5876	0.07	0.3694	1.5452	0.05043901	9.7302
China Office Confirmation T2	0.2766	0.03	0.00	0.3885	0.00	0.4267
Corporate Approval	0.4552	0.08	0.2252	1.2541	0.1245	15.4380
Distribute Shipping Schedules	9.6201	0.06	9.1845	9.9470	8.5938	13.2989
Engineering	6.5404	0.31	4.7160	9.1082	0.4708	19.4077
Engineering Approval	1.0106	0.16	0.3303	2.6949	0.08026956	18.2904
FA Error	3.2319	0.90	0.00	10.1131	0.00	12.2620
Factory Confirmation	8.7525	1.11	4.7470	19.8555	0.9789	76.3997
FE Error	2.7995	0.81	0.00	7.8386	0.00	18.0508
Overflow Engineering	1.3805	1.14	0.00	15.4522	0.00	15.4522
Overseas FF	13.2546	0.39	10.2695	15.4882	4.8259	52.5849
Shipping Beg	32.8315	6.56	12.4512	90.9794	1.6876	167.02
Shipping Cons	28.7171	7.14	8.5820	89.9839	0.1566	161.69
Shipping Schedule Development	28.5052	7.44	4.3956	94.9423	0.00	167.01
US FF	9.5183	1.25	3.0552	18.4273	1.5972	43.6523

### Accumulated Time



*Values Across All Replications***Unnamed Project**

Replications: 35      Time Units: Hours

**Process****Cost per Entity**

VA Cost Per Entity	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Accounting	3.7432	0.02	3.6115	3.9152	2.2617	5.3476
Administration	2.4168	0.03	2.2577	2.5623	0.9674	3.7644
China Compilation	19.6568	3.00	0.00	39.6027	0.00	112.84
China Compilation T1	18.9540	0.60	15.6254	22.3093	3.1982	180.90
China Office Confirmation T1	3.2825	0.04	3.0049	3.5297	0.5798	5.2438
China Office Confirmation T2	3.3192	0.30	0.00	4.6623	0.00	5.1202
Corporate Approval	8.0510	0.08	7.6026	8.6231	4.2532	11.8230
Distribute Shipping Schedules	2.6355	0.03	2.4340	2.8732	0.8790	4.0896
Engineering	16.6260	0.13	15.9218	17.4407	11.0082	23.1078
Engineering Approval	5.4795	0.08	4.7915	5.9039	1.9265	10.0120
FA Error	1.8274	0.12	0.00	2.2216	0.00	2.5777
Factory Confirmation	0.00	0.00	0.00	0.00	0.00	0.00
FE Error	8.0520	0.52	0.00	9.5581	0.00	11.4256
Overflow Engineering	3.3790	2.39	0.00	20.6418	0.00	20.6418
Overseas FF	0.00	0.00	0.00	0.00	0.00	0.00
Shipping Beg	61.5683	1.45	54.1116	68.8033	27.3990	277.75
Shipping Cons	4.9384	0.07	4.4746	5.3364	2.0500	8.6354
Shipping Schedule Development	44.4872	0.90	38.9706	50.5359	0.00	98.0542
US FF	0.00	0.00	0.00	0.00	0.00	0.00

## Unnamed Project

Replications: 35      Time Units: Hours

## Process

### Cost per Entity

Wait Cost Per Entity	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Accounting	0.00	0.00	0.00	0.00	0.00	0.00
Administration	0.00	0.00	0.00	0.00	0.00	0.00
China Compilation	0.00	0.00	0.00	0.00	0.00	0.00
China Compilation T1	0.00	0.00	0.00	0.00	0.00	0.00
China Office Confirmation T1	0.00	0.00	0.00	0.00	0.00	0.00
China Office Confirmation T2	0.00	0.00	0.00	0.00	0.00	0.00
Corporate Approval	0.00	0.00	0.00	0.00	0.00	0.00
Distribute Shipping Schedules	0.00	0.00	0.00	0.00	0.00	0.00
Engineering	0.00	0.00	0.00	0.00	0.00	0.00
Engineering Approval	0.00	0.00	0.00	0.00	0.00	0.00
FA Error	0.00	0.00	0.00	0.00	0.00	0.00
Factory Confirmation	0.00	0.00	0.00	0.00	0.00	0.00
FE Error	0.00	0.00	0.00	0.00	0.00	0.00
Overflow Engineering	0.00	0.00	0.00	0.00	0.00	0.00
Overseas FF	0.00	0.00	0.00	0.00	0.00	0.00
Shipping Beg	0.00	0.00	0.00	0.00	0.00	0.00
Shipping Cons	0.00	0.00	0.00	0.00	0.00	0.00
Shipping Schedule Development	0.00	0.00	0.00	0.00	0.00	0.00
US FF	0.00	0.00	0.00	0.00	0.00	0.00

Values Across All Replications

**Unnamed Project**

Replications: 35 Time Units: Hours

**Process****Cost per Entity**

Total Cost Per Entity	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Accounting	3.7432	0.02	3.6115	3.9152	2.2617	5.3476
Administration	2.4168	0.03	2.2577	2.5623	0.9674	3.7644
China Compilation	19.6568	3.00	0.00	39.6027	0.00	112.84
China Compilation T1	18.9540	0.60	15.6254	22.3093	3.1982	180.90
China Office Confirmation T1	3.2825	0.04	3.0049	3.5297	0.5798	5.2438
China Office Confirmation T2	3.3192	0.30	0.00	4.6623	0.00	5.1202
Corporate Approval	8.0510	0.08	7.6026	8.6231	4.2532	11.8230
Distribute Shipping Schedules	2.6355	0.03	2.4340	2.8732	0.8790	4.0896
Engineering	16.6260	0.13	15.9218	17.4407	11.0082	23.1078
Engineering Approval	5.4795	0.08	4.7915	5.9039	1.9265	10.0120
FA Error	1.8274	0.12	0.00	2.2216	0.00	2.5777
Factory Confirmation	0.00	0.00	0.00	0.00	0.00	0.00
FE Error	8.0520	0.52	0.00	9.5581	0.00	11.4256
Overflow Engineering	3.3790	2.39	0.00	20.6418	0.00	20.6418
Overseas FF	0.00	0.00	0.00	0.00	0.00	0.00
Shipping Beg	61.5683	1.45	54.1116	68.8033	27.3990	277.75
Shipping Cons	4.9384	0.07	4.4746	5.3364	2.0500	8.6354
Shipping Schedule Development	44.4872	0.90	38.9706	50.5359	0.00	98.0542
US FF	0.00	0.00	0.00	0.00	0.00	0.00

**Accumulated Cost**

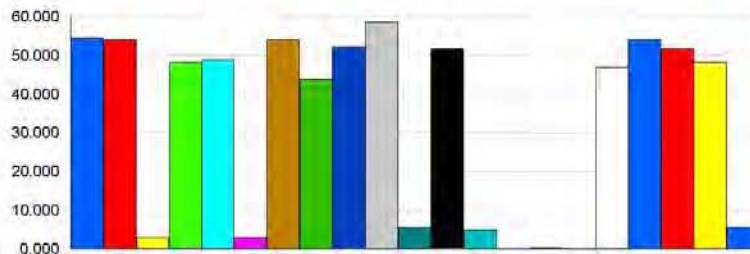
Unnamed Project

Replications: 35 Time Units: Hours

Process

Other

Number In	Average	Half Width	Minimum Average	Maximum Average
Accounting	54.3714	3.31	38.0000	74.0000
Administration	54.0571	3.38	38.0000	75.0000
China Compilation	2.9143	0.52	0.00	6.0000
China Compilation T1	48.2000	3.05	31.0000	66.0000
China Office Confirmation T1	48.9143	3.14	31.0000	67.0000
China Office Confirmation T2	2.9143	0.52	0.00	6.0000
Corporate Approval	54.0571	3.38	38.0000	75.0000
Distribute Shipping Schedules	43.8000	2.03	29.0000	54.0000
Engineering	52.1714	3.08	36.0000	70.0000
Engineering Approval	58.5714	3.70	39.0000	79.0000
FA Error	5.4286	0.98	0.00	13.0000
Factory Confirmation	51.8000	3.08	35.0000	70.0000
FE Error	5.0286	0.85	0.00	11.0000
Overflow Accounting	0.00	0.00	0.00	0.00
Overflow Engineering	0.2286	0.17	0.00	2.0000
Overflow Engineering Approval	0.00	0.00	0.00	0.00
Overseas FF	46.8857	2.70	32.0000	63.0000
Shipping Beg	54.0286	3.40	37.0000	75.0000
Shipping Cons	51.7143	2.97	36.0000	69.0000
Shipping Schedule Development	48.1429	2.44	34.0000	59.0000
US FF	5.5429	0.85	1.0000	11.0000



Appendix 4-K



*Values Across All Replications***Unnamed Project**

Replications: 35      Time Units: Hours

**Process****Other**

Number Out	Average	Half Width	Minimum Average	Maximum Average
Accounting	54.3714	3.31	38.0000	74.0000
Administration	54.0286	3.40	37.0000	75.0000
China Compilation	2.9143	0.52	0.00	6.0000
China Compilation T1	47.9143	3.00	31.0000	65.0000
China Office Confirmation T1	48.8857	3.12	31.0000	67.0000
China Office Confirmation T2	2.9143	0.52	0.00	6.0000
Corporate Approval	54.0571	3.38	38.0000	75.0000
Distribute Shipping Schedules	43.8000	2.03	29.0000	54.0000
Engineering	51.7143	3.06	36.0000	70.0000
Engineering Approval	58.5714	3.70	39.0000	79.0000
FA Error	5.3714	0.97	0.00	13.0000
Factory Confirmation	51.1143	3.01	35.0000	69.0000
FE Error	5.0000	0.85	0.00	11.0000
Overflow Accounting	0.00	0.00	0.00	0.00
Overflow Engineering	0.2286	0.17	0.00	2.0000
Overflow Engineering Approval	0.00	0.00	0.00	0.00
Overseas FF	46.2571	2.67	32.0000	63.0000
Shipping Beg	52.4286	2.99	36.0000	69.0000
Shipping Cons	50.1429	2.67	36.0000	63.0000
Shipping Schedule Development	47.1143	2.38	33.0000	58.0000
US FF	5.4571	0.84	1.0000	10.0000

**Unnamed Project**

Replications: 35      Time Units: Hours

**Resource**

**Cost**

Busy Cost	Average	Half Width	Minimum Average	Maximum Average
Admin	246.18	13.42	178.55	327.96
Consolidation Engineer	1222.65	74.06	845.48	1643.89
Cut N Sew Engineer	69.2846	17.05	0.00	248.75
Engineer 1	3.8464	2.85	0.00	32.7157
Engineer 2	0.00	0.00	0.00	0.00
Engineer 3	0.00	0.00	0.00	0.00
Engineer 4	0.00	0.00	0.00	0.00
Factory	0.00	0.00	0.00	0.00
OSFF	0.00	0.00	0.00	0.00
PO Accountant	213.51	13.23	144.45	284.54
Shipping Consultant	5582.21	297.20	3986.12	7264.80
Sundry Engineer	1068.35	70.70	673.86	1476.10
USFF	0.00	0.00	0.00	0.00
Vice President	435.61	28.23	297.44	611.12
Wire Accountant	0.00	0.00	0.00	0.00



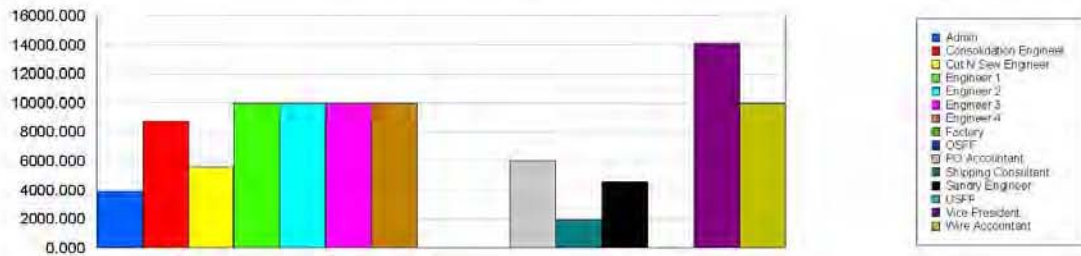
**Unnamed Project**

Replications: 35 Time Units: Hours

**Resource**

**Cost**

Idle Cost	Average	Half Width	Minimum Average	Maximum Average
Admin	3913.82	13.42	3832.04	3981.45
Consolidation Engineer	8761.35	74.06	8340.11	9138.52
Cut N Sew Engineer	5546.72	17.05	5367.25	5616.00
Engineer 1	9980.15	2.85	9951.28	9984.00
Engineer 2	9984.00	0.00	9984.00	9984.00
Engineer 3	9984.00	0.00	9984.00	9984.00
Engineer 4	9984.00	0.00	9984.00	9984.00
Factory	0.00	0.00	0.00	0.00
OSFF	0.00	0.00	0.00	0.00
PO Accountant	6026.49	13.23	5955.46	6095.55
Shipping Consultant	1905.79	297.20	223.20	3501.88
Sundry Engineer	4547.65	70.70	4139.90	4942.14
USFF	0.00	0.00	0.00	0.00
Vice President	14124.39	28.23	13948.88	14262.56
Wire Accountant	9984.00	0.00	9984.00	9984.00



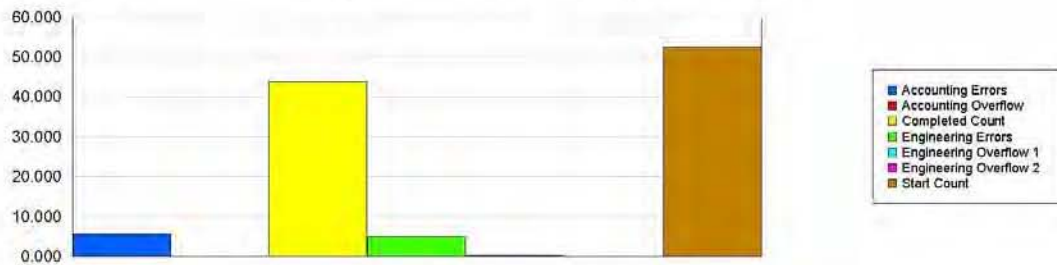
**Unnamed Project**

Replications: 35      Time Units: Hours

**User Specified**

**Counter**

Count	Average	Half Width	Minimum Average	Maximum Average
Accounting Errors	5.4571	0.97	0.00	13.0000
Accounting Overflow	0.00	0.00	0.00	0.00
Completed Count	43.8000	2.03	29.0000	54.0000
Engineering Errors	5.0571	0.86	0.00	11.0000
Engineering Overflow 1	0.2286	0.17	0.00	2.0000
Engineering Overflow 2	0.00	0.00	0.00	0.00
Start Count	52.4000	3.11	36.0000	70.0000



**Time Persistent**

Variable	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
WIP	8.1537	1.20	3.8455	18.5686	0.00	34.0000

**Output**

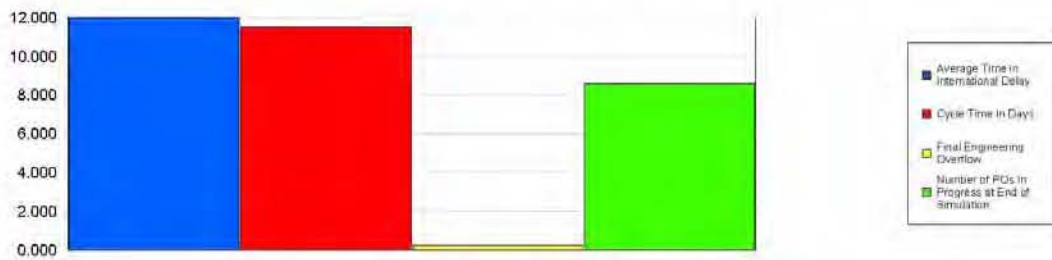
**Unnamed Project**

Replications: 35      Time Units: Hours

**User Specified**

**Output**

Output	Average	Half Width	Minimum Average	Maximum Average
Average Time in International Delay	11.9968	0.15	10.9334	12.7487
Cycle Time In Days	11.5187	1.45	7.0324	24.5131
Final Engineering Overflow	0.2286	0.17	0.00	2.0000
Number of POs In Progress at End of Simulation	8.6000	2.07	1.0000	24.0000



# **Appendix 5**

*Arena Results for Simulation Model  
(Triangular Distribution Data)*

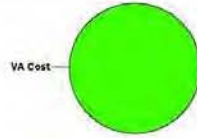
## Unnamed Project

Replications: 35      Time Units: Hours

### Key Performance Indicators

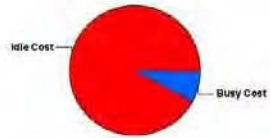
#### All Entities

	Average
Non-Value Added Cost	0
Other Cost	0
Transfer Cost	0
Value Added Cost	7,937
Wait Cost	0
Total Cost	7,937



#### All Resources

	Average
Busy Cost	7,937 *
Idle Cost	95,647
Usage Cost	0



Total Cost	103,584
------------	---------

\* these costs are included in Entity Costs above.

#### System

	Average
Total Cost	103,584
Number Out	53



Values Across All Replications

## Unnamed Project

Replications: 35 Time Units: Hours

## Entity

### Time

VA Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
DistSig	0.00	0.00	0.00	0.00	0.00	0.00
Entity 1	16.2940	0.11	15.7578	17.0145	10.6576	21.5767
NVA Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
DistSig	0.00	0.00	0.00	0.00	0.00	0.00
Entity 1	0.00	0.00	0.00	0.00	0.00	0.00
Wait Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
DistSig	0.00	0.00	0.00	0.00	0.00	0.00
Entity 1	181.92	7.94	143.60	239.28	41.1698	440.52
Transfer Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
DistSig	0.00	0.00	0.00	0.00	0.00	0.00
Entity 1	0.2102	0.00	0.2035	0.2192	0.2000	0.3000
Other Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
DistSig	0.00	0.00	0.00	0.00	0.00	0.00
Entity 1	0.00	0.00	0.00	0.00	0.00	0.00
Total Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
DistSig	0.00	0.00	0.00	0.00	0.00	0.00
Entity 1	157.37	5.26	131.05	193.45	42.4958	338.38

### Cost

VA Cost	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
DistSig	0.00	0.00	0.00	0.00	0.00	0.00
Entity 1	161.02	1.27	151.69	170.18	95.4624	229.00
NVA Cost	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
DistSig	0.00	0.00	0.00	0.00	0.00	0.00
Entity 1	0.00	0.00	0.00	0.00	0.00	0.00

## Appendix 5-B



**Unnamed Project**

Replications: 35      Time Units: Hours

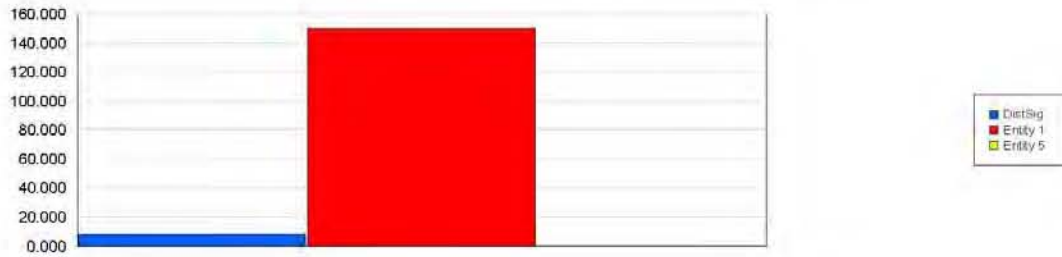
**Entity**

**Cost**

Wait Cost	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
DistSig	0.00	0.00	0.00	0.00	0.00	0.00
Entity 1	0.00	0.00	0.00	0.00	0.00	0.00
Other Cost	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
DistSig	0.00	0.00	0.00	0.00	0.00	0.00
Entity 1	0.00	0.00	0.00	0.00	0.00	0.00
Transfer Cost	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
DistSig	0.00	0.00	0.00	0.00	0.00	0.00
Entity 1	0.00	0.00	0.00	0.00	0.00	0.00
Total Cost	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
DistSig	0.00	0.00	0.00	0.00	0.00	0.00
Entity 1	161.02	1.27	151.69	170.18	95.4624	229.00

**Other**

Number In	Average	Half Width	Minimum Average	Maximum Average
DistSig	8.0000	0.00	8.0000	8.0000
Entity 1	150.09	7.07	111.00	189.00
Entity 5	0.00	0.00	0.00	0.00



*Values Across All Replications***Unnamed Project**

Replications: 35      Time Units: Hours

**Entity****Other**

Number Out	Average	Half Width	Minimum Average	Maximum Average		
DistSig	8.0000	0.00	8.0000	8.0000		
Entity 1	133.71	6.89	96.0000	171.00		
Entity 5	0.00	0.00	0.00	0.00		
WIP	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
DistSig	0.00	0.00	0.00	0.00	0.00	1.0000
Entity 1	16.4557	1.20	9.6974	24.0132	0.00	66.0000
Entity 5	0.00	0.00	0.00	0.00	0.00	0.00

Values Across All Replications

## Unnamed Project

Replications: 35 Time Units: Hours

## Process

### Time per Entity

VA Time Per Entity	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Accounting	0.2431	0.00	0.2322	0.2500	0.1709	0.3079
Administration	0.2379	0.00	0.2244	0.2505	0.1166	0.3587
China Compilation	1.7552	0.20	0.00	2.7168	0.00	3.3563
China Compilation T1	1.7981	0.03	1.5583	1.9854	0.4649	3.4979
China Office Confirmation T1	0.2448	0.00	0.2264	0.2613	0.07974521	0.4127
China Office Confirmation T2	0.2382	0.03	0.00	0.3928	0.00	0.4022
Corporate Approval	0.2291	0.00	0.2145	0.2418	0.1453	0.3183
Distribute Shipping Schedules	0.2515	0.00	0.2388	0.2780	0.1138	0.3714
Engineering	0.7128	0.00	0.6792	0.7418	0.5148	0.9289
Engineering Approval	0.2225	0.00	0.2124	0.2342	0.1034	0.3275
FA Error	0.1196	0.01	0.00	0.1400	0.00	0.1526
Factory Confirmation	3.2447	0.02	3.0775	3.3691	2.0217	4.6157
FE Error	0.3629	0.01	0.3330	0.4044	0.2540	0.4618
Overflow Engineering	0.07734944	0.08	0.00	0.7207	0.00	0.8002
Overseas FF	3.6906	0.04	3.3935	3.9317	1.7155	6.0412
Shipping Beg	0.2846	0.00	0.2623	0.3023	0.1512	0.4347
Shipping Cons	2.5303	0.04	2.3004	2.8073	0.6738	4.6485
Shipping Schedule Development	2.5204	0.05	2.1172	2.8015	0.5383	4.6534
US FF	3.5467	0.25	0.00	4.7511	0.00	5.8914

Values Across All Replications

## Unnamed Project

Replications: 35 Time Units: Hours

## Process

### Time per Entity

Wait Time Per Entity	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Accounting	0.1562	0.06	0.00	0.7500	0.00	15.0000
Administration	0.2327	0.07	0.00824442	0.7286	0.00	15.0392
China Compilation	1.0263	0.57	0.00	7.0000	0.00	14.0000
China Compilation T1	2.0693	0.22	0.9773	3.8220	0.00	14.5337
China Office Confirmation T1	0.2474	0.03	0.08951351	0.4932	0.00	4.5890
China Office Confirmation T2	0.00	0.00	0.00	0.00	0.00	0.00
Corporate Approval	0.1797	0.06	0.00237372	0.6413	0.00	15.0346
Distribute Shipping Schedules	9.2663	0.04	9.0463	9.5110	8.5000	12.7437
Engineering	5.7874	0.28	4.1467	7.8529	0.00	18.0891
Engineering Approval	0.6776	0.14	0.1180	1.9423	0.00	17.7942
FA Error	2.7916	0.80	0.00	8.5595	0.00	15.0000
Factory Confirmation	5.7012	0.75	1.6644	10.3517	0.00	51.2136
FE Error	1.9517	0.79	0.00	9.0852	0.00	18.5277
Overflow Engineering	0.4511	0.61	0.00	9.0764	0.00	9.0764
Overseas FF	14.0264	0.77	10.3847	18.2930	3.0638	75.6492
Shipping Beg	6.9574	1.28	1.6131	17.9441	0.00	71.7695
Shipping Cons	12.8890	1.23	8.0898	22.2172	0.00	62.0646
Shipping Schedule Development	12.9323	1.50	5.5116	23.7771	0.00	71.5384
US FF	7.0508	1.39	0.00	16.8194	0.00	20.4583

Values Across All Replications

**Unnamed Project**

Replications: 35 Time Units: Hours

**Process****Time per Entity**

Total Time Per Entity	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Accounting	0.3993	0.06	0.2387	0.9910	0.1709	15.3008
Administration	0.4707	0.07	0.2530	0.9669	0.1166	15.3621
China Compilation	2.7815	0.65	0.00	9.1293	0.00	16.7545
China Compilation T1	3.8674	0.23	2.5983	5.6988	0.4649	17.4979
China Office Confirmation T1	0.4921	0.03	0.3225	0.7485	0.08344053	4.8199
China Office Confirmation T2	0.2382	0.03	0.00	0.3928	0.00	0.4022
Corporate Approval	0.4088	0.06	0.2261	0.8722	0.1453	15.3108
Distribute Shipping Schedules	9.5178	0.04	9.2874	9.7680	8.6207	13.0129
Engineering	6.5002	0.28	4.8476	8.5578	0.5148	18.6836
Engineering Approval	0.9001	0.14	0.3432	2.1625	0.1090	17.9698
FA Error	2.9112	0.81	0.00	8.6789	0.00	15.1135
Factory Confirmation	8.9459	0.75	4.7952	13.5289	2.0217	54.4128
FE Error	2.3147	0.79	0.3429	9.4707	0.2540	18.8936
Overflow Engineering	0.5284	0.67	0.00	9.6820	0.00	9.6820
Overseas FF	17.7170	0.79	14.2462	21.9495	5.1900	80.5774
Shipping Beg	7.2419	1.28	1.9059	18.2295	0.1573	71.9303
Shipping Cons	15.4192	1.23	10.5458	24.8546	0.9489	65.6729
Shipping Schedule Development	15.4527	1.53	7.7560	26.2617	0.7478	73.9262
US FF	10.5976	1.50	0.00	20.8334	0.00	24.8132

**Accumulated Time**



## Unnamed Project

Replications: 35      Time Units: Hours

## Process

### Cost per Entity

VA Cost Per Entity	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Accounting	3.6470	0.02	3.4836	3.7497	2.5640	4.6185
Administration	2.3791	0.02	2.2436	2.5047	1.1661	3.5873
China Compilation	21.0619	2.42	0.00	32.6016	0.00	40.2762
China Compilation T1	21.5771	0.41	18.6994	23.8253	5.5784	41.9754
China Office Confirmation T1	2.9373	0.04	2.7170	3.1362	0.9569	4.9518
China Office Confirmation T2	2.8581	0.34	0.00	4.7135	0.00	4.8259
Corporate Approval	8.0187	0.08	7.5081	8.4645	5.0864	11.1406
Distribute Shipping Schedules	2.5152	0.03	2.3880	2.7804	1.1380	3.7145
Engineering	17.1072	0.12	16.3016	17.8040	12.3560	22.2942
Engineering Approval	5.3397	0.05	5.0972	5.6212	2.4828	7.8609
FA Error	1.7933	0.11	0.00	2.0999	0.00	2.2890
Factory Confirmation	0.00	0.00	0.00	0.00	0.00	0.00
FE Error	8.7108	0.16	7.9917	9.7046	6.0968	11.0822
Overflow Engineering	1.8564	1.81	0.00	17.2979	0.00	19.2048
Overseas FF	0.00	0.00	0.00	0.00	0.00	0.00
Shipping Beg	5.1221	0.06	4.7221	5.4410	2.7209	7.8246
Shipping Cons	45.5452	0.78	41.4076	50.5320	12.1284	83.6737
Shipping Schedule Development	45.3674	0.89	38.1096	50.4272	9.6898	83.7606
US FF	0.00	0.00	0.00	0.00	0.00	0.00

## Unnamed Project

Replications: 35      Time Units: Hours

## Process

### Cost per Entity

Wait Cost Per Entity	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Accounting	0.00	0.00	0.00	0.00	0.00	0.00
Administration	0.00	0.00	0.00	0.00	0.00	0.00
China Compilation	0.00	0.00	0.00	0.00	0.00	0.00
China Compilation T1	0.00	0.00	0.00	0.00	0.00	0.00
China Office Confirmation T1	0.00	0.00	0.00	0.00	0.00	0.00
China Office Confirmation T2	0.00	0.00	0.00	0.00	0.00	0.00
Corporate Approval	0.00	0.00	0.00	0.00	0.00	0.00
Distribute Shipping Schedules	0.00	0.00	0.00	0.00	0.00	0.00
Engineering	0.00	0.00	0.00	0.00	0.00	0.00
Engineering Approval	0.00	0.00	0.00	0.00	0.00	0.00
FA Error	0.00	0.00	0.00	0.00	0.00	0.00
Factory Confirmation	0.00	0.00	0.00	0.00	0.00	0.00
FE Error	0.00	0.00	0.00	0.00	0.00	0.00
Overflow Engineering	0.00	0.00	0.00	0.00	0.00	0.00
Overseas FF	0.00	0.00	0.00	0.00	0.00	0.00
Shipping Beg	0.00	0.00	0.00	0.00	0.00	0.00
Shipping Cons	0.00	0.00	0.00	0.00	0.00	0.00
Shipping Schedule Development	0.00	0.00	0.00	0.00	0.00	0.00
US FF	0.00	0.00	0.00	0.00	0.00	0.00

Values Across All Replications

**Unnamed Project**

Replications: 35 Time Units: Hours

**Process****Cost per Entity**

Total Cost Per Entity	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Accounting	3.6470	0.02	3.4836	3.7497	2.5640	4.6185
Administration	2.3791	0.02	2.2436	2.5047	1.1661	3.5873
China Compilation	21.0619	2.42	0.00	32.6016	0.00	40.2762
China Compilation T1	21.5771	0.41	18.6994	23.8253	5.5784	41.9754
China Office Confirmation T1	2.9373	0.04	2.7170	3.1362	0.9569	4.9518
China Office Confirmation T2	2.8581	0.34	0.00	4.7135	0.00	4.8259
Corporate Approval	8.0187	0.08	7.5081	8.4645	5.0864	11.1406
Distribute Shipping Schedules	2.5152	0.03	2.3880	2.7804	1.1380	3.7145
Engineering	17.1072	0.12	16.3016	17.8040	12.3560	22.2942
Engineering Approval	5.3397	0.05	5.0972	5.6212	2.4828	7.8609
FA Error	1.7933	0.11	0.00	2.0999	0.00	2.2890
Factory Confirmation	0.00	0.00	0.00	0.00	0.00	0.00
FE Error	8.7108	0.16	7.9917	9.7046	6.0968	11.0822
Overflow Engineering	1.8564	1.81	0.00	17.2979	0.00	19.2048
Overseas FF	0.00	0.00	0.00	0.00	0.00	0.00
Shipping Beg	5.1221	0.06	4.7221	5.4410	2.7209	7.8246
Shipping Cons	45.5452	0.78	41.4076	50.5320	12.1284	83.6737
Shipping Schedule Development	45.3674	0.89	38.1096	50.4272	9.6898	83.7606
US FF	0.00	0.00	0.00	0.00	0.00	0.00

**Accumulated Cost**



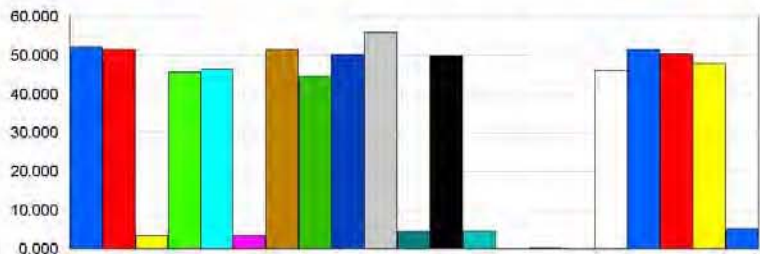
**Unnamed Project**

Replications: 35 Time Units: Hours

**Process**

**Other**

Number In	Average	Half Width	Minimum Average	Maximum Average
Accounting	52.1429	2.43	39.0000	67.0000
Administration	51.5143	2.45	37.0000	66.0000
China Compilation	3.3714	0.73	0.00	10.0000
China Compilation T1	45.8571	2.07	34.0000	60.0000
China Office Confirmation T1	46.4857	2.07	34.0000	61.0000
China Office Confirmation T2	3.4000	0.74	0.00	10.0000
Corporate Approval	51.5143	2.45	37.0000	66.0000
Distribute Shipping Schedules	44.5714	2.30	32.0000	57.0000
Engineering	50.2857	2.50	37.0000	66.0000
Engineering Approval	55.8857	2.68	40.0000	71.0000
FA Error	4.6571	0.74	0.00	9.0000
Factory Confirmation	49.8857	2.37	37.0000	66.0000
FE Error	4.5429	0.65	1.0000	9.0000
Overflow Accounting	0.00	0.00	0.00	0.00
Overflow Engineering	0.2000	0.20	0.00	2.0000
Overflow Engineering Approval	0.00	0.00	0.00	0.00
Overseas FF	46.2000	2.14	32.0000	59.0000
Shipping Beg	51.5143	2.45	37.0000	66.0000
Shipping Cons	50.4000	2.41	37.0000	64.0000
Shipping Schedule Development	48.0857	2.20	37.0000	61.0000
US FF	5.0857	0.94	1.0000	12.0000



*Values Across All Replications***Unnamed Project**

Replications: 35      Time Units: Hours

**Process****Other**

Number Out	Average	Half Width	Minimum Average	Maximum Average
Accounting	52.1143	2.42	39.0000	67.0000
Administration	51.5143	2.45	37.0000	66.0000
China Compilation	3.3714	0.73	0.00	10.0000
China Compilation T1	45.4857	2.04	34.0000	60.0000
China Office Confirmation T1	46.4857	2.07	34.0000	61.0000
China Office Confirmation T2	3.4000	0.74	0.00	10.0000
Corporate Approval	51.5143	2.45	37.0000	66.0000
Distribute Shipping Schedules	44.5714	2.30	32.0000	57.0000
Engineering	49.8000	2.38	37.0000	66.0000
Engineering Approval	55.8286	2.66	40.0000	71.0000
FA Error	4.6286	0.74	0.00	9.0000
Factory Confirmation	49.0571	2.36	37.0000	65.0000
FE Error	4.5429	0.65	1.0000	9.0000
Overflow Accounting	0.00	0.00	0.00	0.00
Overflow Engineering	0.2000	0.20	0.00	2.0000
Overflow Engineering Approval	0.00	0.00	0.00	0.00
Overseas FF	45.4000	2.15	32.0000	59.0000
Shipping Beg	51.2857	2.38	37.0000	64.0000
Shipping Cons	49.7143	2.31	37.0000	63.0000
Shipping Schedule Development	47.3143	2.26	35.0000	61.0000
US FF	5.0000	0.95	0.00	12.0000

Values Across All Replications

## Unnamed Project

Replications: 35 Time Units: Hours

## Resource

### Cost

Busy Cost	Average	Half Width	Minimum Average	Maximum Average
Admin	234.44	10.95	171.31	295.01
Consolidation Engineer	1190.09	55.38	893.07	1576.18
Cut N Sew Engineer	83.5530	18.03	0.00	233.26
Engineer 1	1.7945	1.76	0.00	17.8713
Engineer 2	1.5030	1.72	0.00	19.2048
Engineer 3	0.00	0.00	0.00	0.00
Engineer 4	0.00	0.00	0.00	0.00
Factory	0.00	0.00	0.00	0.00
OSFF	0.00	0.00	0.00	0.00
PO Accountant	198.57	9.31	144.30	250.29
Shipping Consultant	4696.23	236.79	3425.25	5900.27
Sundry Engineer	1118.28	51.87	852.23	1502.89
USFF	0.00	0.00	0.00	0.00
Vice President	412.84	19.35	287.62	520.58
Wire Accountant	0.00	0.00	0.00	0.00



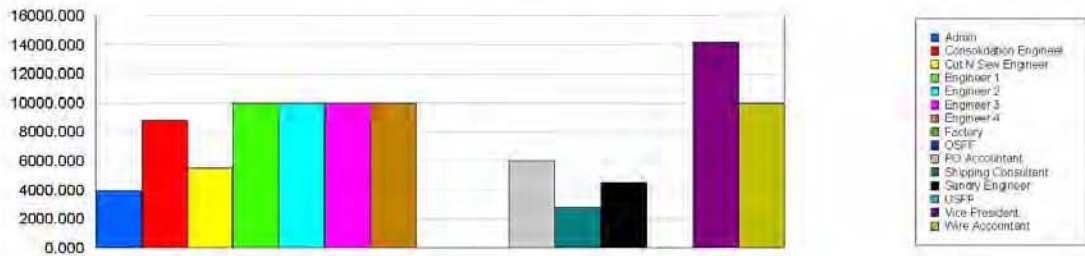
**Unnamed Project**

Replications: 35      Time Units: Hours

**Resource**

**Cost**

Idle Cost	Average	Half Width	Minimum Average	Maximum Average
Admin	3925.56	10.95	3864.99	3988.69
Consolidation Engineer	8793.91	55.38	8407.82	9090.93
Cut N Sew Engineer	5532.45	18.03	5382.74	5616.00
Engineer 1	9982.21	1.76	9966.13	9984.00
Engineer 2	9982.50	1.72	9964.80	9984.00
Engineer 3	9984.00	0.00	9984.00	9984.00
Engineer 4	9984.00	0.00	9984.00	9984.00
Factory	0.00	0.00	0.00	0.00
OSFF	0.00	0.00	0.00	0.00
PO Accountant	6041.43	9.31	5989.71	6095.70
Shipping Consultant	2791.77	236.79	1587.73	4062.75
Sundry Engineer	4497.72	51.87	4113.11	4763.77
USFF	0.00	0.00	0.00	0.00
Vice President	14147.16	19.35	14039.42	14272.38
Wire Accountant	9984.00	0.00	9984.00	9984.00



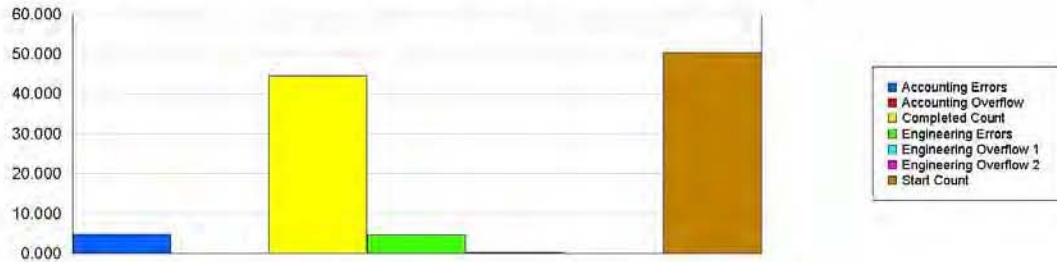
**Unnamed Project**

Replications: 35      Time Units: Hours

**User Specified**

**Counter**

Count	Average	Half Width	Minimum Average	Maximum Average
Accounting Errors	4.7143	0.74	0.00	9.0000
Accounting Overflow	0.00	0.00	0.00	0.00
Completed Count	44.5714	2.30	32.0000	57.0000
Engineering Errors	4.6000	0.64	2.0000	9.0000
Engineering Overflow 1	0.2000	0.20	0.00	2.0000
Engineering Overflow 2	0.00	0.00	0.00	0.00
Start Count	50.4857	2.51	37.0000	66.0000



**Time Persistent**

Variable	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
WIP	6.0066	0.45	3.7066	8.8168	0.00	26.0000

**Output**



**Unnamed Project**

Replications: 35      Time Units: Hours

**User Specified****Output**

Output	Average	Half Width	Minimum Average	Maximum Average
Average Time in International Delay	11.7284	0.14	10.9181	12.5894
Cycle Time In Days	8.2676	0.33	6.6745	10.6530
Final Engineering Overflow	0.2000	0.20	0.00	2.0000
Number of POs In Progress at End of Simulation	5.9143	1.06	2.0000	17.0000

