

UNDERGRADUATE REPORT

Systems Engineering: Quick Dispensing Clinic and Schroeder Industries

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Advisor:

UG 2006-4



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ISR REU Program '06

Systems Engineering:
Quick Dispensing Clinic and Schroeder Industries

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Advisor: Dr. Jeffrey Herrmann

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Introduction:

During the course of our ten-week program, we have been working with Dr. Jeffrey Herrmann on projects involving computer simulations. We have had two projects dealing with applied industrial engineering theories, Brooke Grove Clinic and Schroeder Industries.

Our first assignment was to read and understand the software Dr. Hermann and his team has created over the past five years. The Clinic Generator Software was created from results of numerous simulated vaccinations to help prepare local authorities in case of bio-terrorism or life-threatening infectious diseases. We used and tested the software after reading the user's guide to make sure that there were no errors before the release of the new version. By testing the new version, we were able to help resolve problems such as the ability to open specific files on different computer systems. **Figure 1** is the first screen when the software is opened. This is where the user begins to input their information. **Figure 2** is a sample screen of the results the software will produce after the appropriate information is entered. Simultaneously, we were given the assignment of learning the simulation software program, Arena, so that we could use it for future projects.

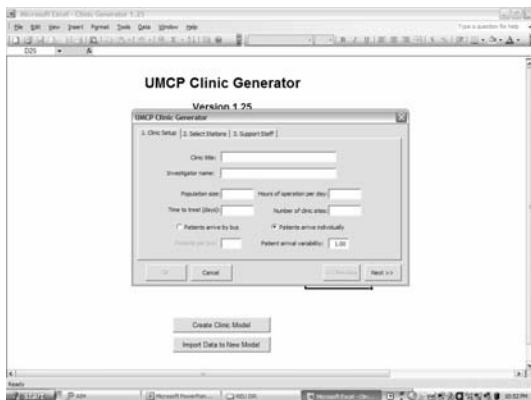


Figure 1

Inputs		Outputs	
Demand		General Performance	
Size of population to be treated:	1	Time in clinic (min)	RCR/VR
Time allocation treatment (days)	1	Average number of patients in clinic	RCR/VR
Daily hours of operation	1	Days between arrival times	VR
Number of clinic sites	1	Clinic capacity (patients per hour)	RCR/VR
Facquied throughput (patients per hour)	1	Total staff per shift across all clinics	2
Staffing (per clinic site)		Station-level Results	
	Staff per	Time (min)	Queue length
	Minimum staff per		Utilization
Triage	1	RCR/VR	RCR/VR
Total Service Staff	1		0.8%
Total Staff	2		

Values in red signify below minimum staffing levels. Values in red denote the "worst" station for that

Figure 2

Brooke Grove

Planning for biological terrorist attacks has been a focus for state and local public health agencies since the terrorist attacks of September 11, 2001. Public health officials must be prepared and capable to provide quick dispensing of medicine to all persons affected by a biological terrorist attack. Currently, plans are being developed for mass dispensing and vaccination clinics, which are referred to as points of dispensing (PODs). Our research has been to find the best layout for PODs so that they are capable of efficiently dispensing treatment to as many patients as possible in the shortest length of time. The most difficult part of this research is to try and take in to account all the different variables that may be involved in different circumstances.

Background:

We began the Brooke Grove assignment by participating in a time study of a quick dispensing clinic held at Brooke Grove Elementary School. (Refer to **Figure 3**) The clinic was designed as it would be in a real situation; volunteers (patients) participated by going through the clinic in order for us to collect realistic data. This specific clinic was set up to demonstrate the dispensing process in case of an anthrax attack. This particular clinic was to operate such that one representative from each family in the county were to go to the clinic site, enter medical information about each family member, and then receive the appropriate medication for each individual in the family. We used 3 timestamp-stations to measure the amount of time it takes the clinic to process a patient at different checkpoints. We were able to collect data on 353 patients for the 92 minutes it took to treat them. Participants included volunteer patients, clinic volunteers from Montgomery County, and 5 students from the University of Maryland.

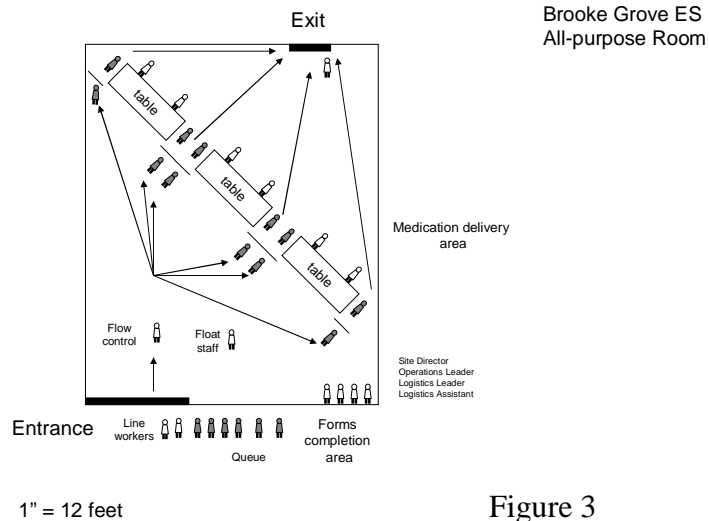


Figure 3

Procedure:

When patients arrived at Brooke Grove, they were first sent to a registration table for the time study where they picked up a timestamp sheet. A student sat outside the entrance to the clinic and stamped each patients form as they went in. When the patients entered the QDC, a clinic volunteer handed out and explained the medical forms. Each patient then filled in medical information about themselves, as well as each of their family members, if any. After they completed the form, they proceeded to the second student who stamped their time sheet before they entered the staging queue where they waited for dispensing. There were 3 dispensing stations with 2 clinic volunteers at each station. Each station included a volunteer to review the forms and a volunteer to distribute the medicine. If a dispensing station were open, a patient would continue there and receive their medicine. If the stations were all occupied, there was a staging area behind each station where one patient was to wait for the station to be available. Once

the patients left the dispensing station, they went to the third student and received their final timestamp before they exited the clinic.

While 3 of the 5 time study students did the time stamps; the other 2 students started out observing single patients and how long they took to fill out their form. After getting sufficient data they started timing how long it took for the greeter to explain the forms and hand them out. Since we did not have enough students to take all of the times, the dispensing station was video taped and we later watched the video to take down data.

Once we returned to University of Maryland we sorted all of the data and input it into excel. (Refer to **Figure 4** for the entrance time, **Figure 5** for the time patients arrive at dispensing, **Figure 6** for the patients exit times, and **Figure 7** to see how the data compares on a single graph) The data was then analyzed to find the average amount of time it took patients to get through different stations. Once we had all of our data sorted and in Microsoft Excel we started to create our simulation in Arena. Creating the simulation was a very in depth process. We first input the data we collected into the process modules in Arena using only averages of the data we collected. Later on, we were able to input the data into the input analyzer, a feature of arena that allows you to fit distributions to a set of values. We input each set of data that we collected, including form explanation time (greeting), form fill out time, and the dispensing times we collected from the videotape. We chose statistical distributions that fit the data most closely and replaced the averages in the process modules with the statistical expressions. (Refer to **Appendix A, Figure 3**)

We came across several difficulties in properly animating different parts of the clinic, but with time and help from Dr. Herrmann and the other students working on the

project we were able to find solutions. After the simulation including animation was completed we changed around several variables to see how these changes affected the clinic, and how we could make the clinic more efficient.

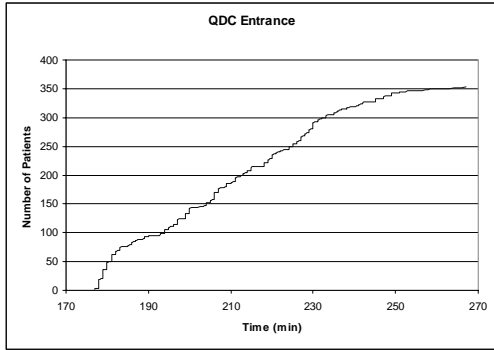


Figure 4

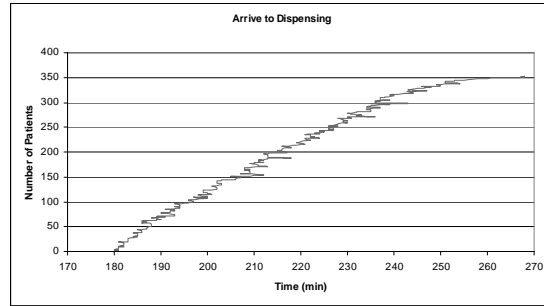


Figure 5

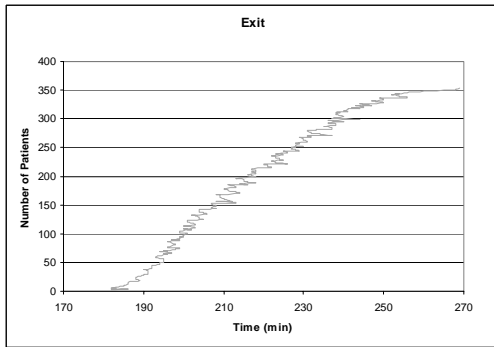


Figure 6

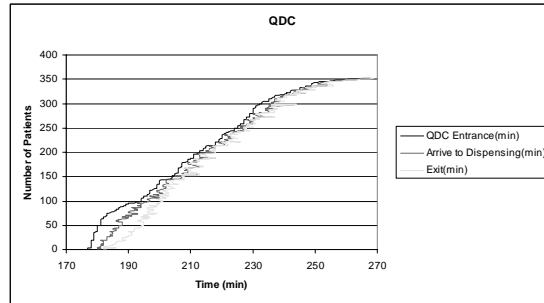


Figure 7

Simulation Set-Up:

We started our simulation by creating a basic layout of the actual clinic. This basic layout became quite detailed as we added more of the specifics of the clinic. We looked for times where the number of patients was fairly constant and broke the total clinic time into 9 intervals. We then averaged the arrival rates during each interval and put the data into 9 separate create blocks. The greeting station represents where one of the clinic volunteers handed out forms and explained how to fill them out. This station has a capacity of ten because in real life the greeter could explain the forms to multiple people at once and we wanted to reflect this in the simulation. The patients then proceed to go to form fill out. (Refer to **Figure 9**) Here the patient is stored until they are finished filling out their form and then they are un-stored. The

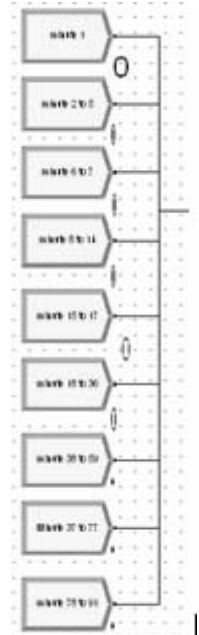


Figure 8

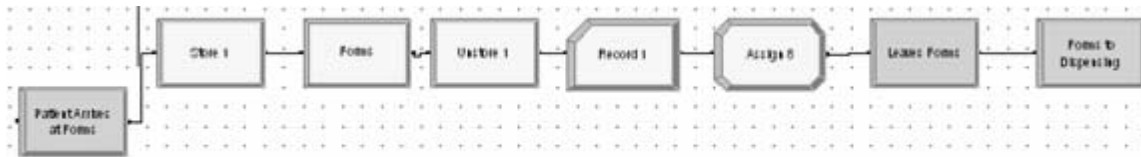


Figure 9

store block was used because the patient is still in the simulation but is not using a resource. The next block is a record block and this represents the first time stamp, and gives us data after the simulation has run so that we can compare it to the data from the actual clinic. The patient then moves from forms to dispensing. (Refer to **Figure 10**)

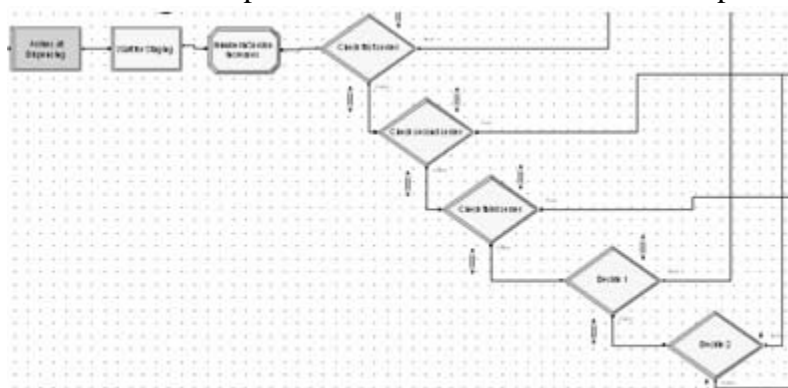


Figure 10

Once the patient arrives at dispensing they wait in a line. There are several decision blocks which determine where the

patient should go next. There are 3 dispensing stations that can serve 1 patient at a time. There is also an area for 1 patient to wait behind each of the 3 dispensing areas, in what we call the staging area. (Refer to **Figure 11**) This is where in the simulation the patients are dispersed to each station depending on the number of open locations at the station. From the dispensing area the patients go to the exit. After we finished the basic logic we used route and station blocks to create an animation of the clinic. We also added assign and record blocks to represent the 3 different time stamps we had at the Brooke Grove time study.

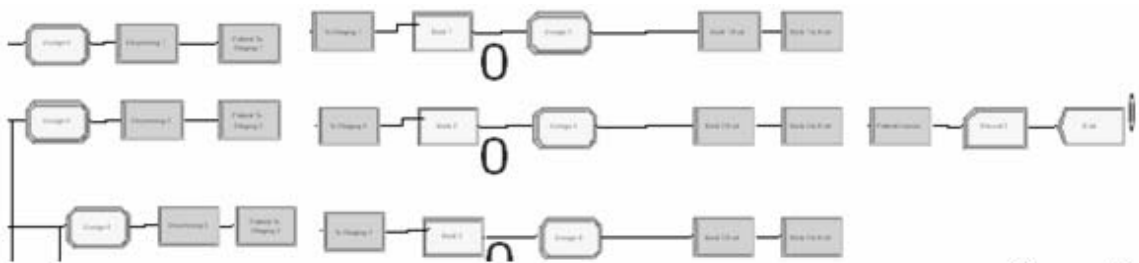


Figure 11

Analysis:

While creating the simulation of the Brooke Groove QDC, we tried to make sure the times in the simulation were as close to the times from the actual clinic as was possible. However, this proved to be difficult for a few reasons. First of all, the time stamps we used in the time study only had minute accuracy, making our results less accurate. Also, the actual clinic was much less consistent than the simulation. For example, walking times between stations varied greatly at the QDC and also, patients and clinic volunteers often talked and caused delays in the flow of patients.

In the actual clinic it took a patient on average 6.05 minutes to go through the entire clinic. In the simulation it took the patient approximately 3.34 minutes, a much shorter time.

After the simulation was created and running properly we changed different variables in the clinic to see how the changes would compare to the data of the original design. The original clinic capacity was 562.5 people per hour. We changed the simulation so that, at dispensing, while one person was receiving their medicine, the patient that was waiting behind them was having their forms reviewed. Then behind them, there was still another patient waiting in the staging area. With this change the maximum clinic capacity became 714.3 people per hour. This shows that by having the clinic set up this way more people could go through the clinic in a fixed amount of time. After we changed the variables it took only 2.52 minutes for a patient to get from start to finish, even less time as we had expected.

Next we calculated the maximum capacity of revised clinic. We determined the number of patients arriving per hour when the clinic was at 80%, 90%, 95% and 100% capacity. We removed the 9 create blocks specific to the Brooke Grove QDC and replaced them with one create block. We then ran the simulation for 24 hours at each of the capacities, long enough for the clinic to reach steady-state. We then compared the values obtained for total process time, total wait time, queue times, and resource utilization from each of the different capacities.

First, we compared the total time in clinic as well as the total process times and the total wait times between each of the simulation runs at different capacities. (Refer to **Appendix A, Figure 4**) As the simulation was run at higher capacities, the total time in

clinic increased. However, looking at the other times, only the total wait time increased as the capacity increased while the total process time stayed the same. This was due to the fact no matter how many people are in the clinic at one time, the volunteers will only be able to review forms and dispense the vaccines so quickly; therefore, the process time stayed constant and only the wait times changed. We also observed that as the rate of patients entering the clinic increased, backups occurred mainly at the greeting queue, which had drastic time increases. The staging, form review, and dispensing queue times increased only slightly with greater capacities. Next, looking at the utilization percentages of each of the resources, the values increased consistently as the capacity the simulation was run at increased. Finally, we compared the time study results from the Brooke Grove QDC with the simulation results. Overall, the total time in the clinic was much larger in the actual QDC demonstration than in the simulation. Interestingly, the first time stamp in the QDC from greeting to the end of forms was reasonably close to the results obtained in the simulation. However, the second time stamp in the QDC from the end of forms to the clinic exit was more than 5 times larger than the results from the simulation.

Conclusion:

From the simulation results, we were able to validate our simulation model and better understand the interactions between the amount of patients required to be treated, time allowed for treatment, and the allocation of given resources.

Schroeder Industries

Background:

Create a simulation layout of the Schroeder company plant using the Arena software. First create a simulation of the current plant, and then change the simulation to see how certain new equipment will help to increase the efficiency of the plant. The last step is to change the layout of the plant to maximize the number of pieces produced by the plant each day. We are to observe where backups occur in the system and how we can rid the process of these backups.

Process:

We were approached with this project a few weeks into the summer REU program. It was an excellent representation of what a career in industrial engineering might be like. Our first step to accomplishing this assignment was to take a trip to the Schroeder Industries in Cumberland, Maryland to observe how the plant functioned, take down data on how parts were sent through the factory and how much time they took at different stations. 4 students from UMD accompanied by Ron Hawkins, an employee from Maryland Technology Enterprise Institute took the trip up to Cumberland. After we arrived at the plant, we sat down with a few of the Schroeder employees and they told us a little about why they wanted the simulation and what they were expecting from the finished simulation. After our short meeting, Bryan Johnson, the production supervisor, took us on a tour of the factory. He showed us each station and gave a brief explanation of what was done there. Each of us took notes on the different processes; we also made sure to ask lots of questions dealing with process times, batch sizes, and the general flow of pieces through the factory. We concluded the visit by returning to the meeting room

and showing the people from Schroeder some example factory simulations in Arena so that they could have a better understanding of what the final product would look like.

Once we returned from the plant the 4 students working on this project sat down to combine our notes and make sure we all had the same understanding of how the process took place in the factory. At our first meeting, we took the information we had each written down and created a master set of notes. We then created a flowchart of the information on the white board, and then recreated it in Microsoft Visio, displaying our understanding of the data more clearly. (Refer to **Appendix B, Figure 1**) The flowchart included the order of the stations that each part went through, the time it takes at each station, and the number of parts that could be served at one time. We worked with the existing layout that Schroeder Industries had given us on our visit and our memories of the factory layout to create a new, to-scale CAD drawing of the factory floor. (Refer to **Appendix B, Figure 2**) While combining our data and creating these documents we made sure to highlight all of the information we were missing and also came up with a list of questions for Schroeder Industries. We emailed them our questions, along with the CAD drawing and flowchart we had created of the factory to receive more information and make sure we had a correct understanding of the factory. After hearing back from Schroeder, we then began to create an animated simulation of the current factory layout that would include all of the data we had collected over the past few weeks. Due to the fact that most of the data we were given were averages and approximations, we created a list of assumptions to follow when designing the simulation.

Assumptions:

- The number of pieces created each working day average about 2,150; but the number of work orders and size of these work orders varies greatly from day to day.
- The time difference to create different sized filters is minimal; therefore, we do not take into account these time differences in the simulation.
- One work order is started and kept together throughout the entire process. It may be sent through the system in smaller batch sizes but they start all batches of one work order before starting a batch from a separate work order.
- In our simulation work orders are sent through the factory floor in batches of 50, the average batch size is actually 63 pieces.

Simulation Set-Up:

The creation of filters begins with two separate tasks occurring simultaneously at opposite sides of the factory. At one side of the factory the end caps have information printed on them at the video jet printer. There is one employee at this station and one end cap is printed at a time. Printed caps are cured in an oven for 15 minutes. The average batch size for the ovens is approximately 250 caps per batch based on the cap size.

Typically whole work orders are moved to the next station. If there is a work order for 500 elements the cap filling station would not receive the caps until all 500 caps are printed and cured. The epoxy dispensing station would then receive 1000 caps (top and bottom); 500 printed and 500 plain. The scrap rate on the printed caps is less than 1%. In our simulation we batch the end caps before they are cured and then un-batch them once they have finished curing. (Refer to **Figure 12**)

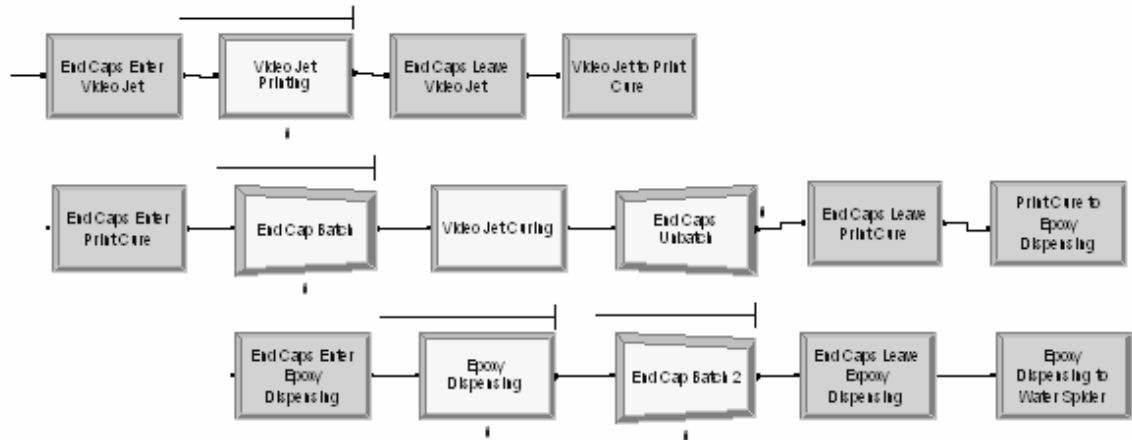


Figure 12

Once the caps are sent to the epoxy dispensing machine they are filled with epoxy. There is only one epoxy dispensing machine, with one employee, but two caps are filled at once at a 10 second processing time. The batch size at this station would be twice the work order quantity. For example: if the work order called for 200 elements the batch size would be 400 (2 end caps per element). On a statistical basis the batch size would be 125 for the next week (149 work orders, 9,324 total elements scheduled to build x 2 end caps). The new equipment will have epoxy dispensing stations at each hot plate and the caps will be filled on the line not off line (4 stations in total). The caps are then placed on a cart to be taken to the water spider. The water spider is the employee that all the parts for a work order are together. In our simulation we show the caps being placed together on the cart by batching them together.

On the other side of the factory floor the mesh packs are being made. There are three pleater machines that make the mesh packs, two manual and one automatic. The amount of time for these mesh packs to be created is 45 seconds per sheet. They are then cut to size. Depending on what the work order requires all of the mesh packs for that work order are either cut using a band saw or the media length cutter. 97% of the mesh

packs are cut with the band saw, which takes 15 seconds, and there are two servers which each cut one piece at a time. The factory also has one media length cutter which cuts the remaining 3% of the mesh packs. This machine takes time to warm up and then requires 45 seconds for each piece. The advantage of the media cutter is that it creates a cleaner more precise cut. There is a decision block in the simulation which sends 97% of the mesh packs to the band saw and 3% to the media length cutter. The mesh packs are not moved until the quantity required per the work order is complete. Statistically this would be a batch size of 63. The mesh packs are placed on a cart and taken to another part of the factory where they measure the length. This takes about 20 seconds for each piece, and only one mesh pack can be measured at a time. The mesh packs being placed on the cart is also simulated by a batch block. This way they enter the inspection and leave the inspection as one batch instead of several separate pieces. (Refer to **Figure 13**)

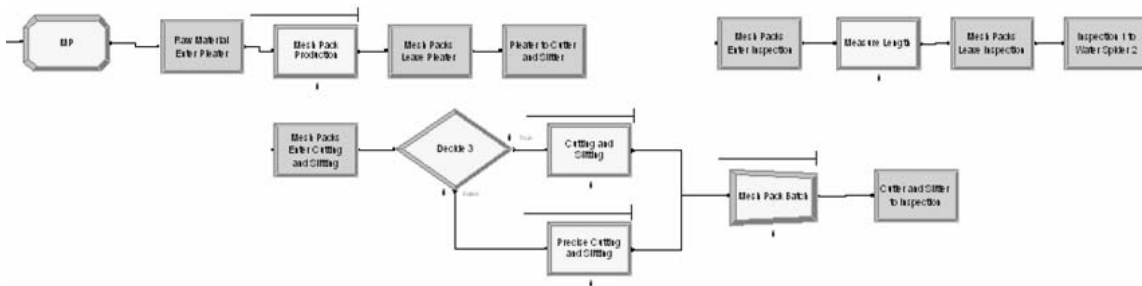


Figure 13

The water spider is the next station and is very important in making sure that all pieces of a work order are together and ready to be assembled. At this station all of the end caps and mesh packs for a work order are organized on a cart to be sent through the remainder of the factory floor. The water spider has a copy of that days schedule and work orders, so he places the appropriate size and number of mesh packs and caps onto the cart. They are placed together in batch sizes; in our simulation about 50 elements can

be made with the pieces placed on the cart. To make 50 filters there must be 50 mesh packs and 100 end caps, since one end cap is placed on each side of the mesh pack. This station will change once the new equipment is placed in the factory. In our simulation once the caps and mesh packs arrive at the water spider station they both become unbatched. There is a decision block which separates the end caps evenly into two groups. The first group goes to the rolling station and the second group of end caps goes to hot plate 2. All of the mesh packs are sent to the rolling station. (Refer to **Figure 14**)

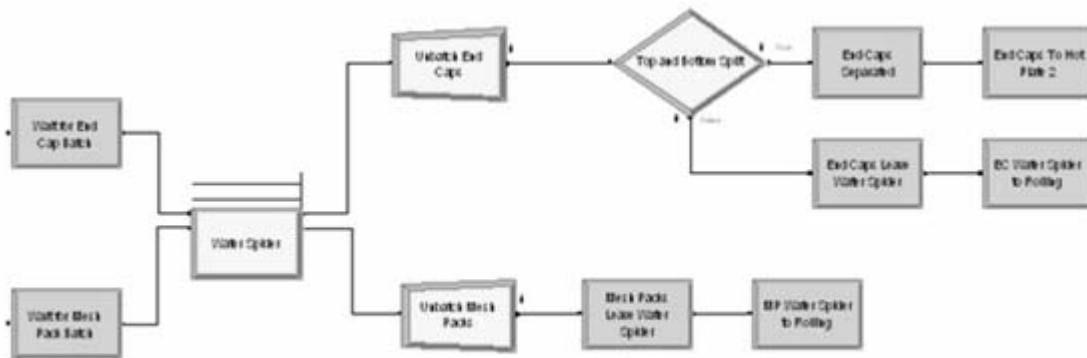


Figure 14

From the water spider the batches are sent to the rolling station. There are two work stations, and both have two servers. The total amount of time needed at the rolling station is 20 seconds, and this station is broken into two processes. The first process is rolling which takes 15 seconds, and there are 2 servers each rolling 1 piece. The second process at the rolling station is End Caps, where the first end cap is placed on 1 side of the mesh pack. This process takes 5 seconds and there are 2 servers each placing 1 end cap on a mesh pack at a time. The rolling station is a continuous process, as elements are built they are placed on the hot plates. After this station there is about a 3% scrap rate. The simulation shows these events taking place by using a match block; matching 1 cap and 1 mesh pack together. There is then a batch block which will make these 2 parts stay

together permanently throughout the remainder of the simulation. The end cap and mesh pack combination is then sent to hot plate 1. (Refer to **Figure 15**)

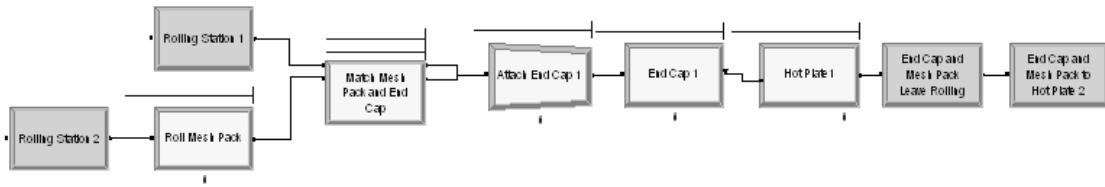


Figure 15

The next station is hot plate 1. The mesh pack with an end cap on 1 side is placed on the hot plate to dry the epoxy so that these 2 pieces will stay together. There are 2 hot plates. Each take about 10 minutes, and have a maximum capacity averaging 45 pieces.

It is now time to place the second end cap onto the mesh pack. There is only 1 server who can do 2 pieces at a time, which takes about 5 seconds. The filters now go onto hot plate 2 so that the epoxy in the second end cap can dry. Again there are two hot plates that can hold an average maximum of about 45 pieces, and they each take roughly 10 minutes. All of the assembled elements are batched to show them being placed on the cart. The delay for cooling takes place and then the elements are un-batched and sent to seaming. (Refer to **Figure 16**)

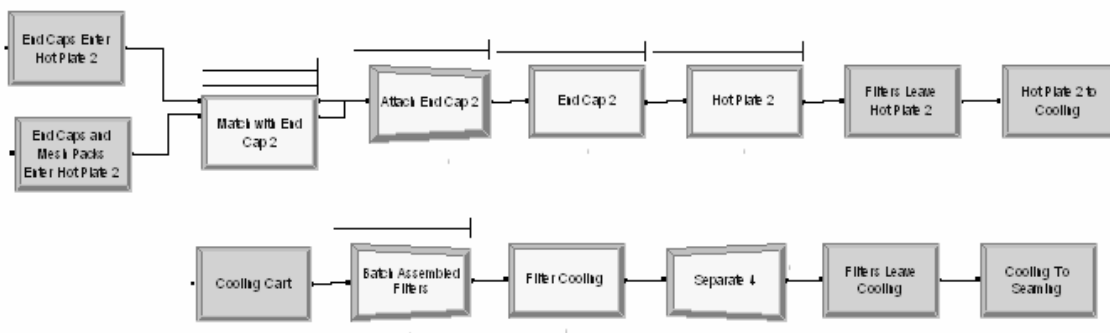


Figure 16

The next station is seaming which is also broken into 2 processes, seaming and the oven. The seaming process takes 10 seconds and there are 2 servers each doing one piece. There are also 2 ovens, which takes about 2 minutes. The oven heats the seam so that it dries and holds the mesh pack together. This is where the filters come to their second delay which lasts for 20 minutes. The elements are batched together after they have been seamed and gone through the ovens for this second delay. They remain batched for the next process in the simulation. (Refer to **Figure 17**)

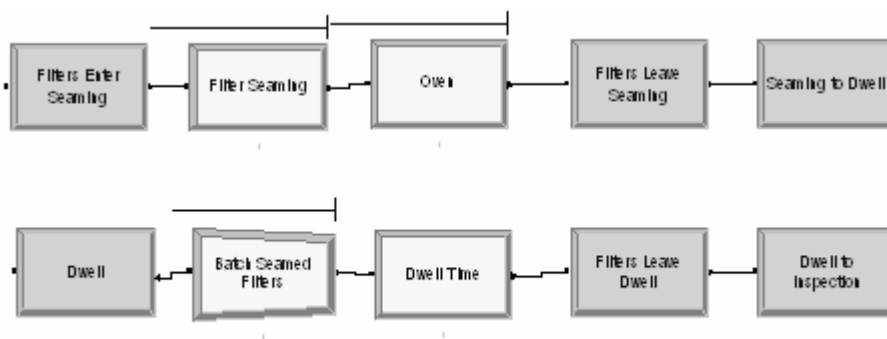


Figure 17

The filters are now placed together on a cart and sent to the parallel and perpendicularity test. This test takes about 45 seconds and 1 piece is done at a time. Schroeder Company has found that their product has a 1% Acceptable Quality Level (AQL), which means statistically 1.5% of their product is defective after the inspection. They have charts that specify how many elements are to be inspected to reach a 1% AQL depending on the size of the work order. The next test is the bubble point test which takes roughly 5 minutes and again only tests 1 piece at a time, and goes by the 1% AQL. The purpose of this test is to make sure that the filters do not allow too much air to go through. After the test is finished the elements are un-batched. (Refer to **Figure 18**)

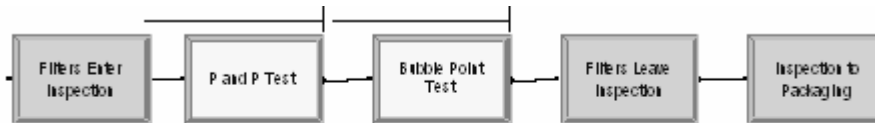


Figure 18

The last station the filters are sent to is packaging. The packaging station is continuous on the first shift and is not in use on the second shift. At this station there are 2 processes, shrink wrapping and boxing. The entire station takes about 35 seconds, and there is 1 server which packages 1 piece at a time. The first process, shrink wrapping, takes approximately 15 seconds. The second process, boxing, takes about 20 seconds. When the entire order is produced and packaged the filters are ready to be sent out. The factory has found from past results that by the end of entire process there is about a 7% scrap rate. This station has a dispose block showing that it is the end of the simulation.

(Refer to **Figure 19**)



Figure 19

(Refer to **Appendix B, Figure 3** to see all simulation modules together, Refer to **Appendix B, Figure 4** for Animation)

Future Progress:

Unfortunately, we were not able to see the Schroeder project through to completion. However, we were able to create most of the simulation of the current factory layout and we were also able to import the CAD drawing into Arena and make progress on the animation. We finished the first part of the report that will be given to

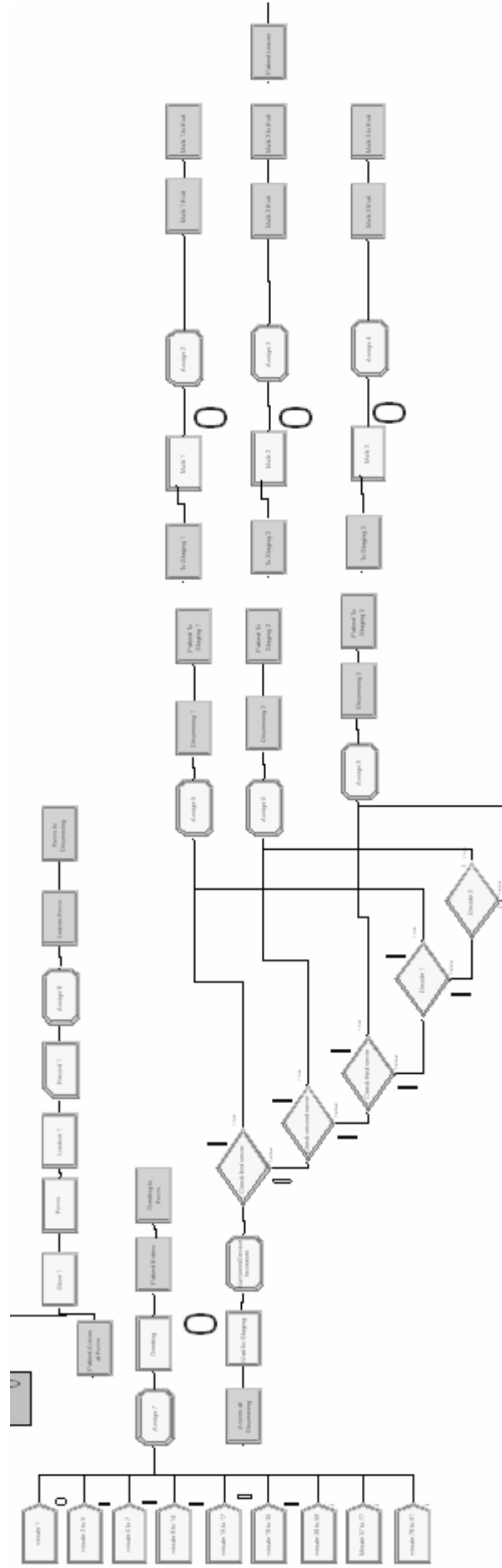
Schroeder along with the finished simulation in order to explain how the simulation was created and the logic and assumptions we used to design it.

Final Reflections:

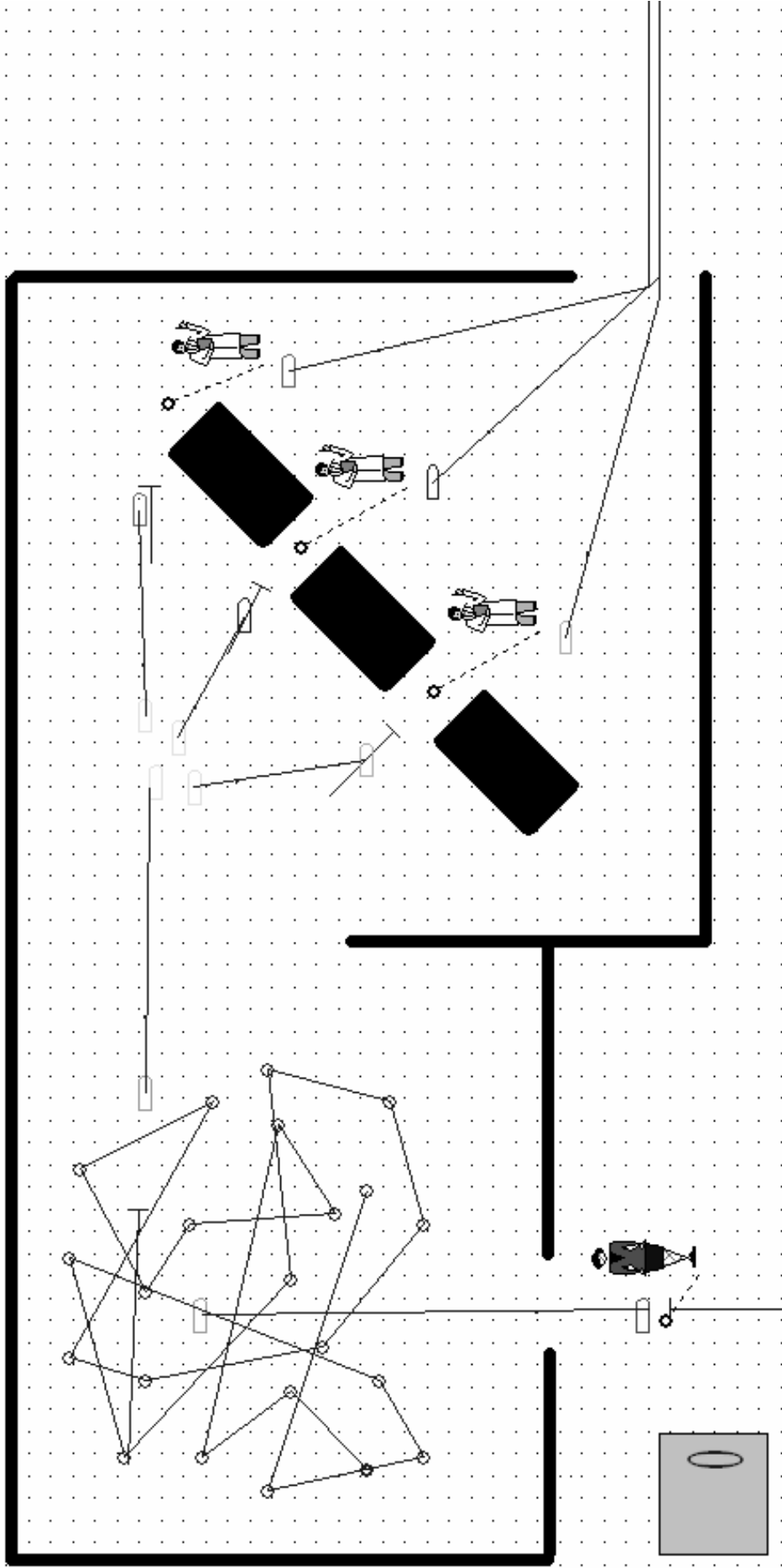
Overall, we both found this summer's REU experience to be positive and rewarding, especially for two Industrial and Systems Engineering students. Having two different projects that we worked on together gave us a great opportunity to experience system engineering in two very different ways. The Brooke Grove project gave us both our first research experience and our first practical operations research assignment, something we are both sure to come across again in the future. It was a preview of what graduate school for Industrial Engineering might be like, and it definitely gave us a lot to consider about our futures. The Schroeder Industries project gave a realistic look into the kind of job an Industrial and Systems Engineer might have.

Appendix A

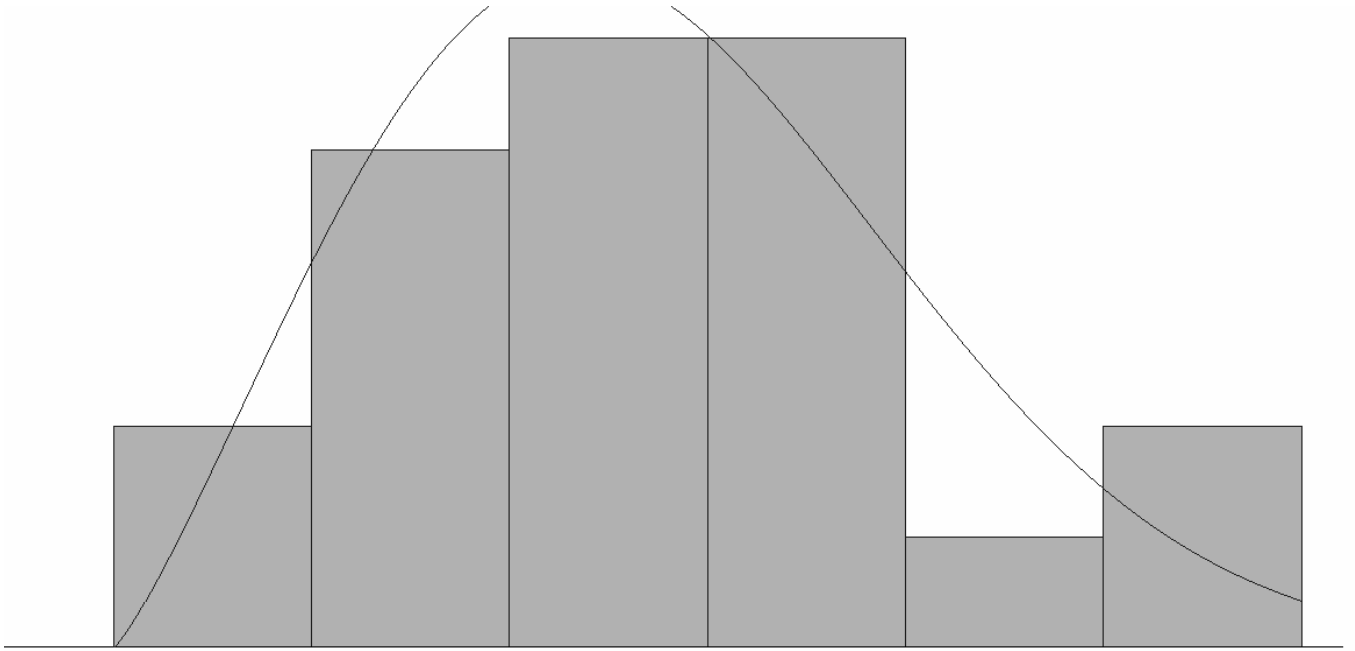
Brooke Grove



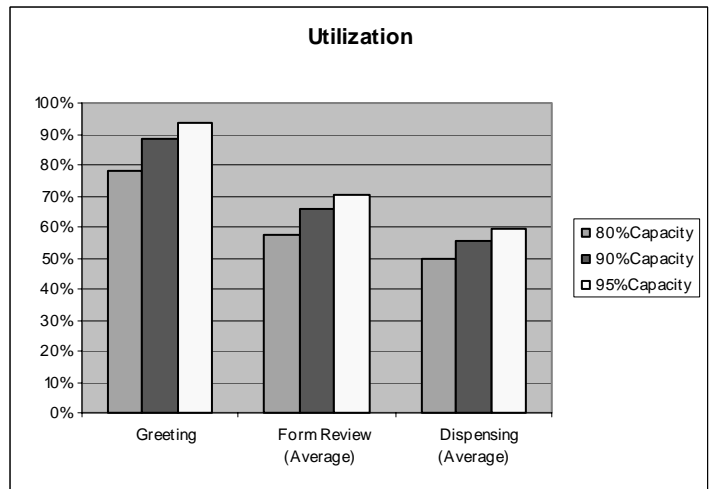
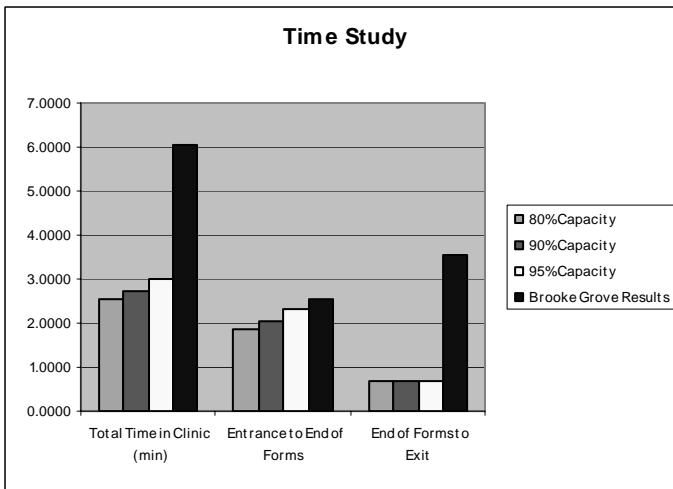
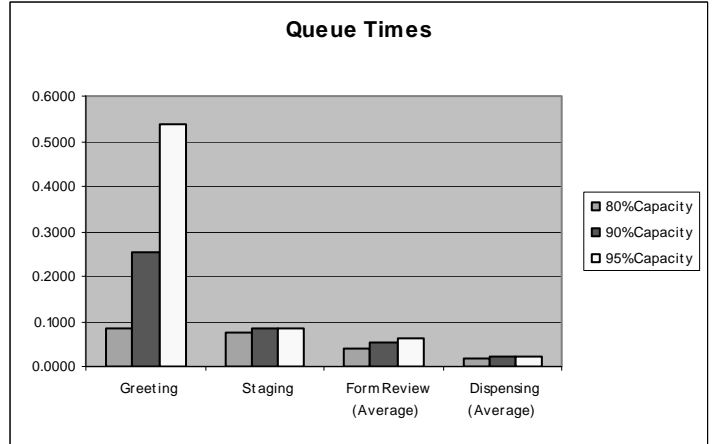
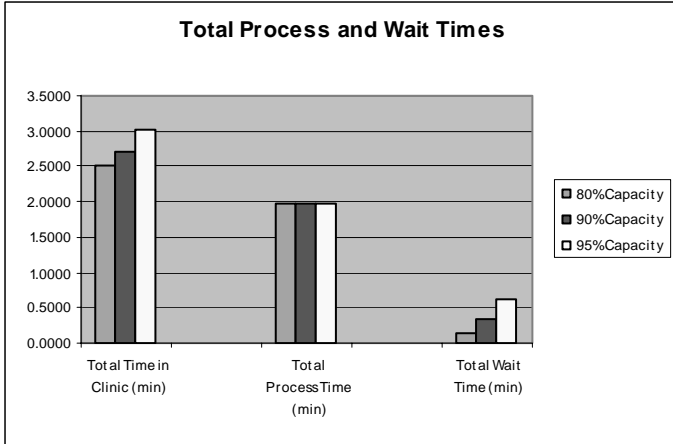
Appendix A, Figure 1



Appendix A, Figure 2



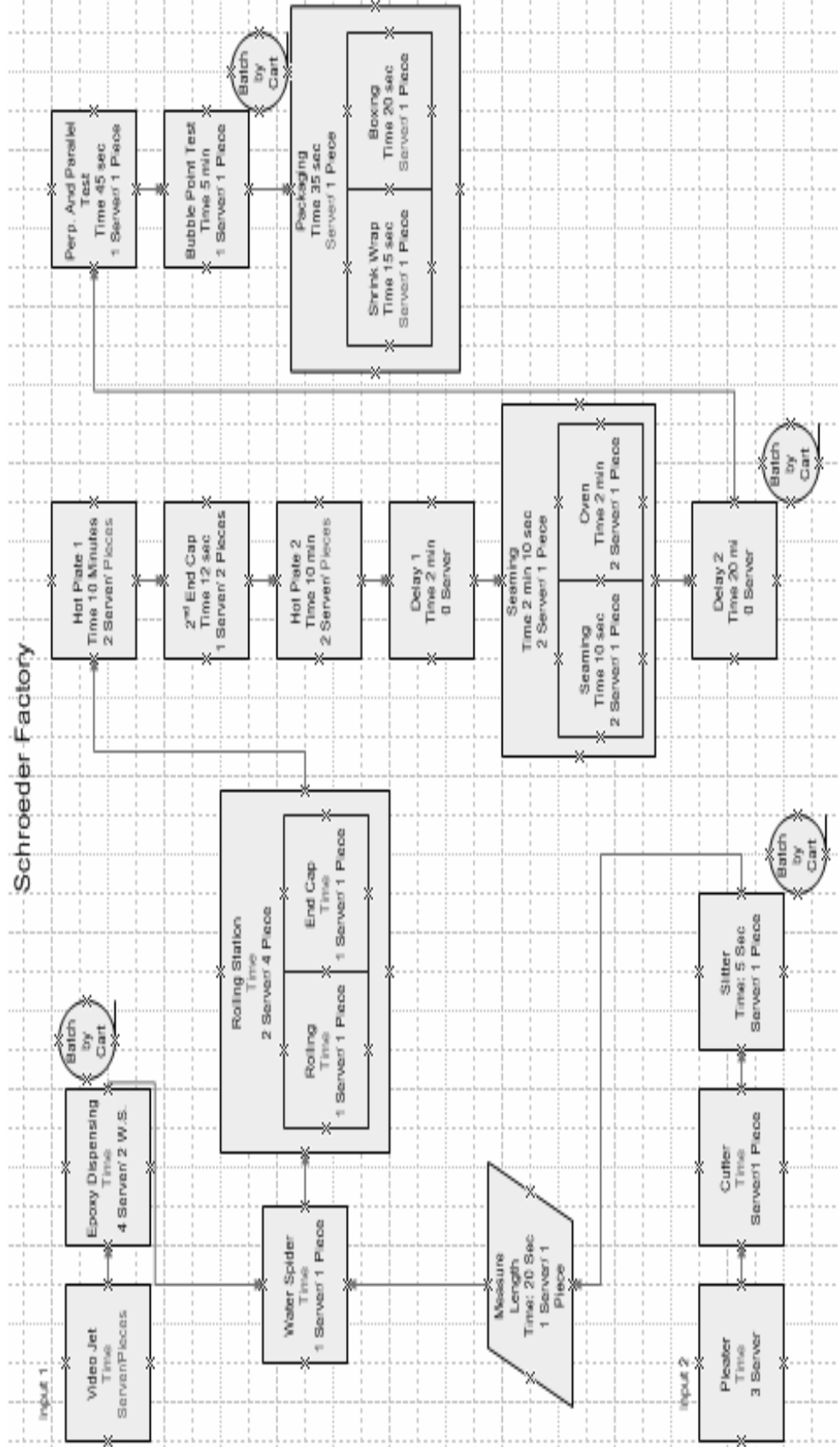
Appendix A, Figure 3



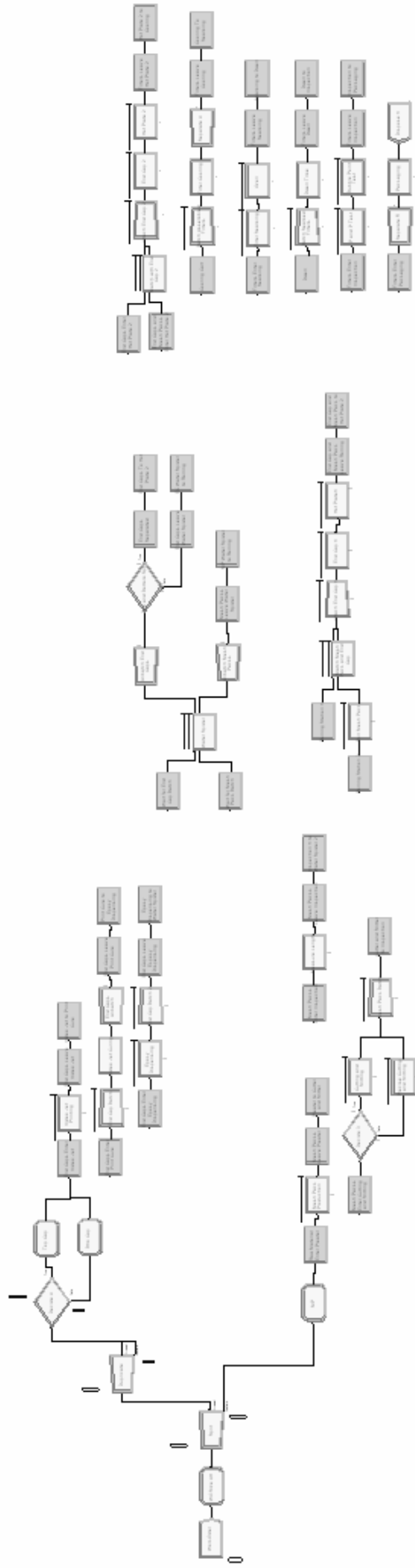
Appendix A, Figure 4

Appendix B

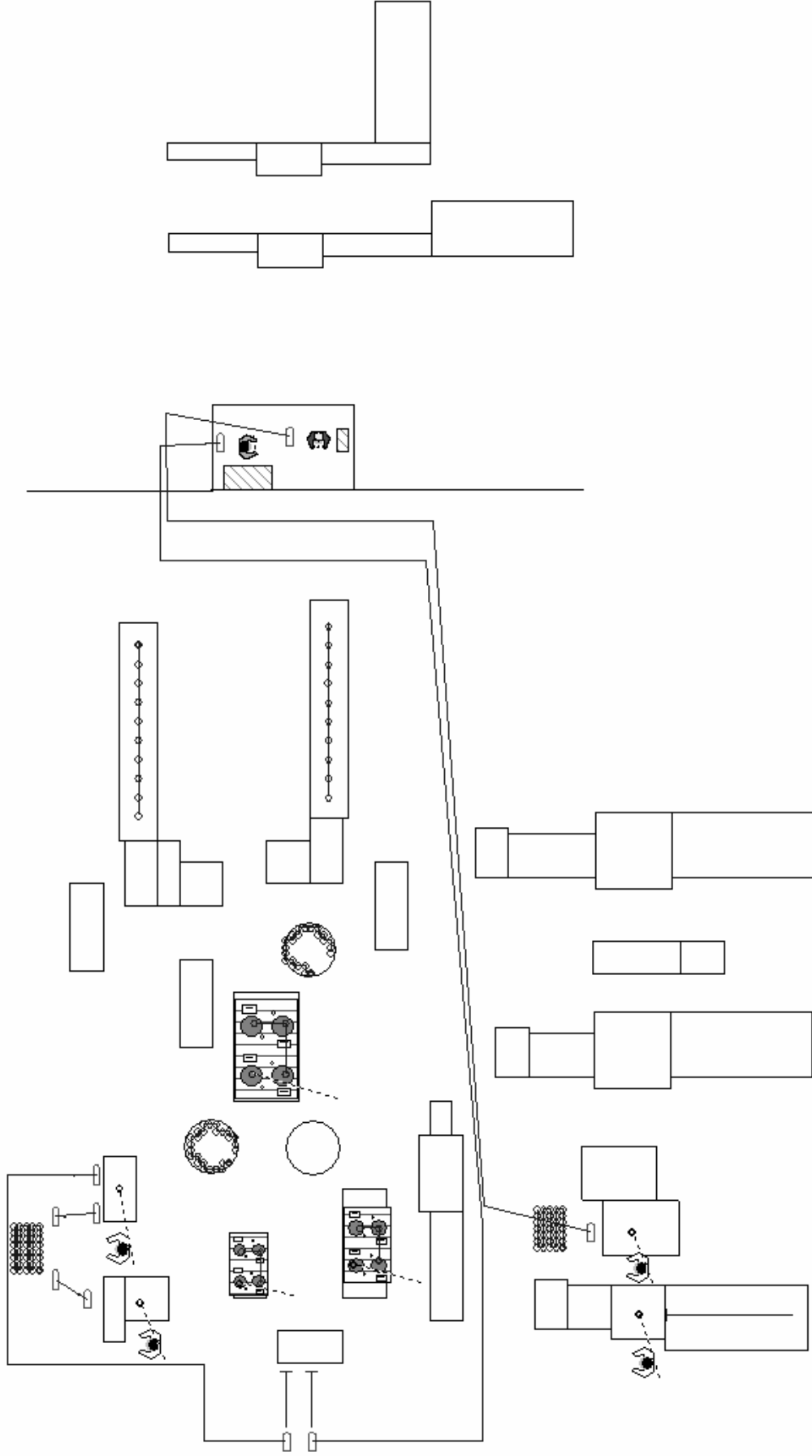
Schroeder Industries



Appendix B, Figure 1



Appendix B, Figure 3



Appendix B, Figure 4

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