MOTOROLA

Flow Analysis and Facility Design

Final Report

Submitted To:
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Radio Support Center
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Executive Summary

Motorola's Radio Support Center (RSC) in Rockford, IL is planning to expand its current facility of 60,450 square feet to 120,900 square feet. A project team of three senior-level industrial engineering students has completed a complete facility design and flow analysis for the expansion. The major task that was undertaken by the project team was to learn the processes within the RSC, analyze and improve the processes, and design a layout for the expansion. The project team has developed the facility layout in three phases: the placement of departments, the actual design of individual departments, and the installment of conveyors. The objectives of the final layout are to optimize the receiving, login, billing, packaging, and shipping areas, while improving the material flow throughout the facility with the utilization of a conveyor system. The goal of the project team was to develop a facility that can service 4000 units per day on both the FEP and Linx lines. With the use of drafting software, time studies, justifications, and simulation software, the project team has come to a final recommendation for the client. The overall cost of the expansion will be approximately 8.9 million dollars. With the increase in volume of units, the expansion will pay for itself in less than a year. The final recommendations are thoroughly discussed within this report.

Problem Definition

Motorola's Radio Support Center (RSC), located in Rockford, IL, is a service center for products such as two-way radios, two-way cellular phones, cable modem set-top boxes, and many other radio devices. Opened in 1996, the RSC is the first of its type for Motorola and industries alike. Previously, RSC type products could only be repaired in the facility in which the unit was originally manufactured. However, the RSC now serves as a geographically centralized repair center in which all units can be serviced in one location. The facility has 60,450 square feet of ground space, employs 550 technicians and repair specialists, and services approximately 3,600 products each day.

The existing facility has been receiving an increasing amount of products to be repaired. Specifically, an increasing number of two-way cellular phones and cable modems. As a result of these increases, the current facility will not be able to meet future demand. To help meet this increase, the RSC's Technical Operations Team (TOP) is planning to expand the current facility to twice its size. An expansion of the RSC is essential in meeting the increased customer usage of these products, as well as the possibility of expanding the number of products the RSC is able to service.

In the existing facility, the most prevalent problems are product-flow and excess material handling. Specifically, between the departments of receiving, login, billing, packaging, shipping, and Factory Express(FEP), there are many operating procedures that can be redesigned or improved to reduce the inefficient product flow and excess in material handling. Listed below are descriptions by department.

Receiving: The RSC receives packages from 5:00 AM thru 12:00 PM six days a week. Shipments come in from a variety of package handlers. United Parcel Service (UPS) and Federal Express (FedEx) deliver approximately 95% of all packages. Packages arrive containing single or multiple units depending on the customer. Products received through UPS are predominantly two-way radios or cable modems, and FedEx packages are primarily two-way cellular phones.

The receiving department currently consists of two distinct and separate areas, FEP and RSC. The FEP area receives all units that can be immediately replaced and the

RSC area receives all other products. The FEP area is located directly behind the RSC area. During the morning shift, the receiving dock is crammed with workers from both lines. Presently, both groups of workers are able to successfully prepare all products received for their next destination. However, the current setup does not have the capacity to handle the increased number of units forecasted for the facility.

Login: The login department consists of stations located throughout various locations in the building. On top of the mezzanine, two-way radios are logged in and below the mezzanine cable modems and two-way cellular products are logged in. This department staffs 18 associates a day for the first and second shift combined. Within these two shifts, the day's units are usually logged in after about twelve hours of operation. A good majority of the login stations are located on the mezzanine, some are underneath the mezzanine, and there are a few remotely located near the offices. The login department is also surrounded and divided by conveyors that are loud, thus creating an uncomfortable work environment for login associates.

Billing: The billing department is divided over the entire facility. Upon completion of repairing a unit, it is billed in the team in which it was serviced. As a result, the current number of billing stations appears to be underutilized. Once a product is billed it is sent on the conveyor to the packaging department. Currently, a major problem is that the billers are letting their work pile up. Once they have a stack of units to be billed, they process the units and then send them all to packaging at the same time. This is causing a sudden spike of volume in packaging that could be avoided by the billers sending the units to packaging at a constant rate.

Packaging: Packaging takes place on the mezzanine with some bulk shipment packing taking place on the shipping floor. There are four packaging stations on the mezzanine. The first two are separated from the second two by a stopper. This stopper does not allow the workers from the first two stations to place their completed packages back on the conveyor. Their completed packages have to be walked around the next station and handed to the labeling stations. The packages are taped and weighed manually by one of

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the workers. Once the packages are labeled and taped, they are carted onto an elevator and taken down to the shipping area via an elevator lift.

Shipping: The current receiving and shipping processes take place in the same relative area that consists of four bays. Since bays are being shared among the two departments there is confusion among outgoing and incoming products and there is a lot of congestion on the dock.

Objectives

The scope of this project is to design an expanded layout for the RSC. The proposed layout of the facility will contain the optimal positioning of the departments, taking the existing layout facility and constraints into account. The expected capacity for the expanded facility is to process 8,000 units per day (4,000 RSC units and 4,000 FEP units), which is a 120% increase from the existing facility. To attain this goal of 8,000 units per day, the operations within the facility must be optimized while maintaining a high level of quality and throughput rate. The goal of the project team is to improve the following processes: receiving, login, packing, billing, and shipping. Discussed below are the goals for each of the individual departments.

Receiving: RSC and FEP receiving areas must be separated by allotting more floor space to each. The added room would allow the RSC and FEP areas to be separated and adequately spaced. The increase in space will allow for an optimal number of workstations to successfully open, verify, and place the forecasted volume of units into the system each day.

Login: All login stations must be consolidated into one department. The associates should be able to process the day's entire received product in one eight-hour shift. To effectively operate in this consolidated department, each associate must be cross-trained to login the different types of product. In creating an office-like environment for the associates, the sound level in the department must be minimized.

Billing & Packaging: The billing department should be consolidated and combined with the packaging department. This would allow the packaging department to receive a constant flow of products with billing being consolidated to one distinct location. Also, the combination of these departments will allow packaging to be taken off the mezzanine level and placed on the main floor. This will reduce the excess material handling of

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transporting all packaged products to the shipping dock via an elevator. Also, the packaging department will have more packing stations, more labeling stations, and the process will become much more automated.

Shipping: More bay doors must be added to this area. Increasing the amount of bay doors will divide the shipping and receiving departments into separate assigned areas. This setup will eliminate confusion between incoming and outgoing units. Also, this setup will allow for each area to be used exclusively for its designated task.

Implementation of Procedure

The project was broken down into three main phases. Phase one consisted of optimizing the placement of departments in the new facility and then completing the expanded layout. Phase two incorporated working on the individual departmental layouts of receiving, login, packing, billing, and shipping. Phase three consisted of the implementation of a facility-wide conveyor system. On a weekly basis, the project team and TOP representatives would meet to discuss the project. These weekly meetings were used as an opportunity for the project team to get any questions answered, report their status, and to present their ideas or findings on any of the phases. The process of completing each phase is discussed below.

Phase 1(6 weeks): To understand the flow of materials and relationships between departments, the project team had to first observe all the day-to-day functions within the facility. To learn more about the processes the project team spoke regularly with associates and supervisors. The product flow was analyzed from the time it arrived on the dock until it was ready to be shipped.

With the information compiled about the entire process, a complete analysis was been performed using FactoryPLAN software. FactoryPLAN is a tool for designing and analyzing layouts based on how desirable it is for certain departments to be close to each other. Interacting with the AutoCAD drawing of the expanded facility, FactoryPLAN has helped create an arrangement of departments with a maximized score while keeping track of qualitative relationships.

As a modification to phase one, the TOP requested two separate alternatives for the expanded facility. One needed to be an ideal layout, not taking any constraints into account, and for the second layout to take all existing constraints into consideration. Next, the project team and the TOP determined qualitative relationship values between departments. Based on this data, a relationship chart, relationship diagram, and space allotments for the departments were completed. Next, using FactoryPLAN a general layout was developed. This information was a very helpful tool in the design of the ideal

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and actual facility layout. Through FactoryPLAN, the ideal layout was obviously the better choice, but also unattainable. Therefore, through discussions and meetings with the TOP, ideas from the ideal layout and actual layouts were combined and used to come up with a feasible optimal layout.

Phase 2(5 weeks): In order to create an optimal layout for each of the departments, a complete analysis of the departmental processes was completed. This analysis included recognizing the key components in the process and completing time studies of each department. The proposed product flow and the individual workstation capacities also played a role in completing this analysis.

Once the analysis of the product flow was complete, an extensive series of time studies within each department began. The project team spent approximately two weeks completing these time studies. Time studies were done on opening packages, verifying paperwork, toting the product, logging in the unit, and packing the product. See Appendix A for a summary of all time studies. The bulk of the team's time studies were performed in the login area. Upon the completion of login time studies, the login software was upgraded. This required for additional trials to be taken in the login area, causing a slight setback. Time studies were performed to establish a standard time per operation. The capacity of an operator in one eight-hour shift was established from these standards. Then the number of workstations needed for each department was determined.

Next, a layout of conveyors in the departments was completed. The conveyors were placed throughout the departments in a manner that would facilitate the product flow of the facility. With the implementation of these conveyors, the project team also took into consideration the ergonomic issues surrounding new departmental layouts. Anytime a person is removing a tote from a conveyor the conveyor will be located at the same height as the work surface of the person. The conveyors are designed so a worker does not have to reach over his/her head to place or remove a tote. There are also some conveyors that are located underneath certain workstations that allow the associate to conveniently send the unit to next the department. Following the completion of the login department, a simulation was preformed to measure the feasibility of the suggested

number of stations. Time study data and information from receiving and login associates were vital in creating an accurate model.

Phase 3(3 weeks): In developing the facility-wide conveyor system, the project team did some benchmarking. Two other facilities were visited that also receive, ship, and process products. Houghton Mifflin's book distribution center located in Geneva, IL was the first placed visited. This warehouse is approximately 500,000 ft^2 and many of its processes are automated through the use of a warehouse management system. Conveyors automated many of the functions in the warehouse and also reduced material handling throughout the facility. The packing process used tools such as automatic box tapers and in-line weighing scales. The second facility visited was Anixter's wire, cable, and structured product distribution center located in Alsip, IL. This warehouse is approximately 575,000 ft^2 and uses a standard inventory control system for its product. The use of conveyors in this facility was archaic in some parts but did provide a smooth flow of product. Specifically, the use of conveyors made their packaging process very efficient.

With the ideas from these facilities and the knowledge of the RSC's current conveyor system, a conveyor system layout has been added to the facility. The conveyor system is designed to optimize the product flow and allow the RSC to operate at the preferred level. In order to design the preferred conveyor system, a material handling analysis was performed. This helped determine where conveyors were needed most.

Schedule / PERT Chart: The schedule and Performance Evaluation Review Technique (PERT) Chart can be found in Appendix B. For the most part, the project team adhered to the schedule and in PERT Chart. The tasks for phases two and three overlapped because implementing parts of the facility-wide conveyor needed to be done while laying out the individual department. The only major deviation from the schedule occurred during the login time studies. Time studies were completed as scheduled, but the login computer system was updated the following week. As a result, the project team had to

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complete another series of time studies, which doubled the task time to complete the time studies.

Difficulties: During the completion of each phase, the project team encountered its biggest difficulties in gathering information from Motorola employees outside the TOP. On a weekly basis, the project team spent approximately a total of 25 hours combined at the RSC. Within this time frame, it was very difficult to find a time to meet with each of the necessary managers and supervisors. As a result, it was tough to gather some of the data needed. Throughout the entire project this was the only major difficulty encountered by the team, but this did not cause any major setbacks from the original plan.

Analysis and Results

The analysis is broken down into the three phases of the project. A detailed explanation of the project team's findings for each phase is listed below.

Phase I - Overall Facility Layout: The existing facility currently has 60,450 ft^2 of ground space, and 1852 ft^2 of mezzanine space. In order to meet the projected future demand, Motorola would like to expand the facility to 120,900 ft^2. Aside from the existing mezzanine, the new facility will also include another mezzanine that is 3935 ft^2. See Table 1 for the amount of space allocated to each department in the new facility.

Table 1: Size of Departments in the New Facility

Department	Area (square feet)	Department	Area (square feet)
Administrative Office - 1	3265	Login	3935
Administrative Office - 2	2930	Mechanical Room	810
Billing	926	Mezzanine Inventory	785
Cafeteria	3410	Packing	926
Computer	980	Receiving	1615
CQA	1135	Receiving Garage	3215
Facilities	365	Repair A	21085
Fitness Room	1950	Repair B	27220
Front Bathroom	1730	Secure Storage	1080
Front Office	10390	Shipping	3120
Human Resources	400	Shipping Garage	3865
Information Systems	850	Showers	1950
Inventory	3280	Training Room	1565
Kitchen	2130	Utility Room	645

Two approaches were taken in developing of the optimal facility layout. The first approach was to develop an ideal layout without any constraints. The second approach was to develop a layout with the given constraints. To determine the appropriate placement of the departments, relationships between departments were assigned. The assigned relationships corresponded with FactoryPLAN, see Table 2 for an explanation of these relationships. Relationships were assigned between departments with help from the TOP. See Appendix C for relationship diagrams of both the ideal and actual layouts

Table 2: FactoryPLAN Departmental Relationships

Relationship	Explanation
A	Absolutely Necessary
E	Especially Important
I	Important
O	Ordinary
U	Unimportant
X	Undesirable
Z	Very Undesirable

Ideal Layout: Given that departments could be placed anywhere within the given space constraints, the project team felt that the ideal layout would have the most efficient material and process flow. Ideally, the receiving and shipping docks would be at separate ends of the facility, repair floors "A" and "B" would be centralized and placed together, the front office would be centralized in the building, and inventory would be close to the receiving dock and repair floors.

The departments, department areas, and departmental relationships were then entered into FactoryPLAN. The software produced scaled departments that were placed according to the desired layout. Once the departments were laid out, the layout was scored according to a weighted scale using the predefined relationships. See Appendix D for the scaled drawing developed through FactoryPLAN. The scaled drawing separates receiving and shipping, combines repair floors "A" and "B", places inventory close to receiving and to the repair floors, and has an overall smooth material process flow. See Table 3 for FactoryPLAN's scoring of the ideal layout.

Table 3: Factory Plan Scores for Ideal Layout

B	LAYOUT	WEIGHTED	E-Score	E%Score	R-Score	R%Score
EPB	None*	-52346	455	73.2	600	64.7

The R-Score calculated by FactoryPLAN represents the correlation between the departments in the scaled drawing. The lower the R-Score number (the higher R%Score),

the higher the correlation between the positioning of the departments. According to FactoryPLAN, the best R%Score achieved by the ideal layout was 64.7%.

Actual Layout: The actual layout must take existing departments and building constraints into consideration. The following departments have to stay in its current location: shipping/receiving dock, computer room, utility room, mechanical room, repair floor "A", existing mezzanine, and front office. Also, the new shipping dock has to be next to the existing receiving dock, and repair floor "B" has to be separate from repair floor "A" in the new facility.

Once again, the departments, department areas, and departmental relationships were entered into FactoryPLAN. See Appendix E for the scaled drawing developed through FactoryPLAN. The receiving dock and shipping dock are placed in the middle of the facility, the mechanical room, utility room, computer room, front office, and repair floor "A" all remain in their current position, and a new mezzanine space is also allocated. See Table 4 for FactoryPLAN's scoring of the actual layout.

Table 4: Factory Plan Scores for Actual Layout

B	LAYOUT	WEIGHTED	E-Score	E%Score	R-Score	R%Score
EPB	None*	153865	11755	43.4	1370	34.0

According to the FactoryPLAN score, the new R-Score was 1370. This is about a 30% decrease from the ideal layout. Nonetheless, it is the optimal layout given the constraints.

Once the optimal facility layout was determined using FactoryPLAN, the departments were then given their actual positioning and shape within the new facility through AutoCAD. See Appendix F for a layout of the optimal expanded facility. The numbers of workstations for each department were determined in Phase II of the project, through time studies, forecasting, simulation, and the current operating processes.

Phase II

RSC Receiving (See Appendix G for drawing): Receiving is allocated four dock doors, mezzanine space, and floor space. Two dock doors are dedicated to a scrap trailer and a

cardboard compactor, leaving the remaining two dock doors for receiving shipments. While keeping RSC and FEP receiving separate, the dock is setup to allocate adequate space for both product lines.

Currently, the existing mezzanine is used to login and package RSC products. In the new facility, the mezzanine is solely dedicated to breaking down RSC products. RSC products will be received from either of the two dock doors and then placed on an inclined conveyor. This conveyor will transport the boxes to the mezzanine and also act as a queue for the mezzanine breakdown process.

On each side of the mezzanine conveyor, there are two breakdown tables, one scanning table, and two verifying tables. The process begins at the breakdown table where the associate opens the package and discards the scrap materials onto the scrap conveyor located above them. At this time, associates will also check the packages for paperwork. If there is not any paperwork, they will walk over to the copy machine on the west end of the mezzanine and make the appropriate copies. Next, the box and paperwork are sent over to the scanning tables where the box's tracking number is scanned. Once the box is scanned, it is placed back on the conveyor until the verification associates are ready to verify the paperwork of each unit in the box. Again, the conveyor serves as the queue space for the verification process.

Upon verification of the paperwork, the box is placed back on the conveyor and transported to the toting area. At the toting station, the toter places all individual units and their paperwork into a bar-coded tote. The tote is bar-coded because the conveyor eyes will read it when determining its appropriate repair floor and repair cell. The empty box is then placed on the cardboard conveyor that is located above the toting area. The conveyor again is used as the queue space for units waiting to be toted. Once it leaves the toting station, via conveyor the tote is sent towards to the RSC login area.

FEP (See Appendix H for drawing): Currently, the space underneath the mezzanine is mainly used for FEP and login of special products. In the new facility the entire ground floor of receiving will be dedicated to FEP receiving, breakdown, and login. Products are received and placed onto a flat conveyor that leads into six FEP breakdown stations. At

each workstation, the associate opens the box, verifies the unit, transfers all the contents into a "pizza box," discards any garbage into the designated bins, and logs the unit into the system. After completion of these steps, the box is placed back on the conveyor and sent to repair floor "B".

Login (See Appendix I for Drawing): The login operation is very crucial to the performance of the RSC. Every unit that is serviced must be logged into the network. The current login department is split up in various locations throughout the facility. The project team is proposing that login be consolidated to one large login area. A large consolidated login department is needed to service the amount of units that the expanded facility will service in a day's period.

The most important detail was determining the number of login stations needed. The results from the time studies were the most crucial information to complete this analysis. An average time of three minutes and four seconds was used to determine the average hourly capacity per associate. Also, an operator downtime of seven minutes per hour was taken into account. This downtime takes into account restroom breaks, socializing, and other time spent not logging in units. See Table 5 further analysis.

Table 5: Analysis of Login Time Studies

Associate Capacity (units/hr)	Stations	Hours / Shift (hours) **	Units Serviced
19	32	6.625	4031.04
19	33	6.625	4157.01

**Calculations

1 Workday = 8.5 - .5(lunch) - .5(breaks) = 7.5 hours

7.5 hours x (53/60) = 6.625 hours *(Downtime is taken into account)*

19 * 6.63 * 33 = 4157.01 total number of units in one shift

The department can meet its desired capacity with 32 login stations, but there is room for one additional station. Therefore, 33 stations have been proposed for maximum efficiency. The number of hours used for a workday of an associate is calculated out to 6.63 hours (shown in table above).

The proposed layout of the department is on a mezzanine that is 3935 ft^2. A conveyor from RSC login transports the units down the middle of department with six separate gravity conveyors running perpendicularly off this main conveyor. Five of the six gravity conveyors will be surrounded by six login stations, while the sixth gravity conveyor will have three login stations and a cube for the supervisor.

Units will flow from the main conveyor onto each gravity conveyor through the means of a diverter. There will be six diverters on the main conveyor that will operate in a cyclic manner. Each login line is a two-tier conveyor system, the top being a gravity conveyor and the bottom being a motor conveyor. The upper tier will be the same height as the login workbenches and the lower tier is fourteen inches from the floor. The associates will be able to pull the totes from the conveyor onto their workstations with ease. Once the units are logged in, the associates will place the totes on the lower tier of the conveyor. The product is then transported to its appropriate repair area. With the proposed setup, the entire login process can be performed in one department with each station having the optimal ergonomic positioning. In an effort to create an office-like environment for the associates, the entire department is enclosed by five-inch walls to help reduce noise levels.

Login Simulation: A simulation was performed to evaluate the performance of the proposed RSC login department. See Figure 1 below for detailed flowchart of the system modeled.

Figure 1: Flowchart of Simulated Model

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┌─────────────┐   ┌─────────────┐   ┌─────────────┐   ┌─────────────┐
│CREATION OF  │   │CREATION OF  │   │CREATION OF  │   │CREATION OF  │
│UPS #1 (5 AM)│   │UPS #2 (7 AM)│   │UPS #3 (8 AM)│   │   OTHER     │
│ 412 boxes   │   │ 574 boxes   │   │ 198 boxes   │   │ 200 boxes   │
└─────────────┘   └─────────────┘   └─────────────┘   └─────────────┘

              ┌──────────────────────────┐
              │     RECEIVING DOCK       │
              │    PACKAGES STAGED       │
              └──────────────────────────┘

              ┌──────────────────────────┐
              │        OPENING           │
              │   PACKAGES OPENED        │
              │   Check for paperwork    │
              │     3-4 Associates       │
              └──────────────────────────┘

┌──────────────────────┐              ┌──────────────────────┐
│   PAPERWORK (.95)    │              │  NO PAPERWORK (.05)  │
│ Sent to verification │              │ Sent to verification │
└──────────────────────┘              └──────────────────────┘

              ┌──────────────────────────┐
              │      VERIFICATION        │
              │ Verified and sent to toting│
              │     5-7 Associates       │
              └──────────────────────────┘

              ┌──────────────────────────┐
              │        TOTING            │
              │ Put in tote, sent to login│
              │     1-2 Associates       │
              └──────────────────────────┘

┌────────┐┌────────┐┌────────┐┌────────┐┌────────┐┌────────┐
│ LOGIN  ││ LOGIN  ││ LOGIN  ││ LOGIN  ││ LOGIN  ││ LOGIN  │
│LINE #1 ││LINE #2 ││LINE #3 ││LINE #4 ││LINE #5 ││LINE #6 │
│6 Assoc ││3 Assoc ││6 Assoc ││6 Assoc ││6 Assoc ││6 Assoc │
└────────┘└────────┘└────────┘└────────┘└────────┘└────────┘
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The ultimate goal of the simulation is to determine if the proposed department has the capacity to process 4,000 RSC units in an eight-hour shift. Using SIMAN simulation software, a model of the unit being processed from receiving to login was developed. See Appendix J for the model file, experimental file, and output of the simulation.

The average amount of boxes entered into the system was established from two weeks of previous shipments. See Appendix K for a breakdown. The RSC receiving department receives three United Parcel Service (UPS) deliveries that occur at the same

time each day, two Federal Express deliveries which usually arrive anytime between 7:00 am - 11:00 am, and an assortment of other carriers that bring in a small amount of boxes from 7:00 am – 11:00 am.

The three UPS shipments were treated separately and the average for each was entered into the system at 5:00 am, 7:00 am, and 8:00 am respectively. Non-UPS shipments do not arrive at specified times and their arrival times change on a day to day basis, a triangular distribution was used to best simulate these arrivals. A triangular distribution was selected because it is very easy to control how close all the items in the shipment are to the mean. This distribution was a good fit to model the non-UPS arrivals because there is not a large variance in arrival times, meaning that the boxes arrived at a constant rate.

On average, the RSC receiving department receives 1.7 units per box received. This factor was used in the verification section of the simulation. See Table 6 for a definition of all the tasks defined in the simulation and the appropriate delay times assigned to each.

Table 6: Task Times

Task	Time (Seconds)
Opening box	29.712
Processing box with no papers	20.538
Verifying paperwork	26.256
Toting unit	9.81
Logging in unit	185.00

Three separate scenarios were simulated for the department. Scenario one doubled the current number of boxes received, scenario two tripled this number, and scenario three quadrupled this number. The detailed results of each trial can be seen in Appendix L. Listed below is a summary of each scenario.

Table 7: Summary of Simulation Scenarios

Shipment	Average Box Count	Scenario #1 (2X)	Scenario #2 (3X)	Scenario #3 (4X)
UPS #1	206	412	618	824
UPS #2	287	574	861	1148
UPS #3	99	198	297	396
Other	100	200	300	400
Total Boxes		1384	2076	2768
Total Units Verified		2458	3642	4824
% Logged in		95.60%	95.20%	90.50%

Table 8: Staffing for Each Scenario

	Receivers	Toters	Loggers
Scenario #1	11	1	33
Scenario #2	11	2	33
Scenario #3	15	2	33

Each of the three scenarios was able to successfully handle the amount of units in the system. The only major queue in each scenario was at the toting area. The results show this to be the major bottleneck in the system, while the wait times in the other queues were not nearly as large. In scenario three, 4,824 units were entered and verified 4,824 units into the system, and approximately 90% of these units were logged in. In other words, this login setup successfully logged in 4,341 units in an eight-hour shift. These numbers successfully validate the proposed layout.

Billing/Packaging (See Appendix M for Drawing): Once service on a unit has been completed, it is billed, packaged, and shipped. In the current facility, billing stations are located in different areas throughout. In the proposed layout, eight Scantron billing stations are in place. Currently, the facility is updating its entire billing process to a more automated technology. This process is known as the Scantron billing system, and every unit in the new facility will be billed on this system. Table 9 shows the collected data for billing.

Table 9: Analysis of Scantron Billing Time Studies

Associate Capacity (units/hr)	Stations	Hours / Shift (hours) **	Units Serviced
32	4	6.625	1697.3
32	8	6.625(2 shifts)	3394.56

**Calculations

1 Workday = 8.5 - .5(lunch) - .5(breaks) = 7.5 hours

7.5 hours x (53/60) = 6.625 hours *(Downtime is taken into account)*

19 * 6.63 * 33 = 4157.01 total number of units in one shift

In the proposed layout, billing is placed in conjunction with the packaging department. Conveyors from repair floor "A" and repair floor "B" enter the room from opposite ends and form two small "U" type shapes. On each side, there are four billing stations that feed into four packaging stations.

A majority of packaging is currently located on the mezzanine, and some also takes place on the shipping dock. The combination of both billing and packaging is placed under the new mezzanine in the proposed layout.

The packaging department is broken down into four primary processes: packing, taping, weighing, and labeling. From all the data and information gathered, it was determined that eight packing stations, one automatic taping machine, one weight in motion scale, and two labeling stations are needed in the new packaging department. The justification for the packaging stations can be viewed Table 10.

Table 10: Analysis of Packaging Time Studies

	Associate Capacity units/hr)	Stations	Hours/Shift	Units Serviced
Packing	60	8	6.625	3180

**Calculations

1 Workday = 8.5 - .5(lunch) - .5(breaks) = 7.5 hours

7.5 hours x (53/60) = 6.625 hours *(Downtime is taken into account)*

60 * 6.625 * 8 = 3180 total number of units in one shift

After the product is billed, it is put back on the conveyor and sent to packaging. At this point, units stay in queue until packers are able to package the product. Upon completion of packaging the product, the packer places the box on the bottom tier, and sends it to be taped, weighed, and labeled. Similar to the billing stations, the packaging stations are mirrored on both sides of the room. However, once the product has been packaged, the conveyor lines merge into one line and put the package through a weight in motion scale, automatic taper and finally labeled. After being labeled, the product is sent via conveyor to the shipping dock.

Shipping (See Appendix N for Drawing): In the proposed facility shipping is allocated three docks that are located right next to the receiving docks. Packages arrive to the shipping dock via a declined conveyor from the Billing & Packaging Area. An associate picks the packages from the conveyor and places it in the appropriate staging area or into the staged feeder. A wall with a door that is large enough for a forklift separates the receiving and shipping docks. The shipping has an area for a locked cage that can be used for storing special products between shifts or shipping times. There is also floor space available for staging products in gridded areas. These grids act as designated staging areas and separate packages by shipping times, priority, or product type.

Phase III – Overall Conveyor System

The implementation of a conveyor system throughout the entire proposed facility layout was an ongoing process that overlapped with Phase II. In Phase II general conveyors were implemented into the layouts. However, the details of the conveyors were finalized in Phase III.

The first step was determining the different types of conveyors needed. These include: inclined/declined, flat, two-tiered, gravity, and any combination of them all. The conveyors are standardized to be 2' wide throughout the entire facility. With the inclined/declined conveyors, measurements were needed to make sure enough space was given for the desired incline height. The standard height would be a conveyor starting at 40" high from the ground, inclining to about 150" high from the ground, with a horizontal

span of about 268". In other words, to reach a height of about 150" (12.5'), starting at 40" (3.33') high, the conveyor needs at least 268" (22.33') of ground space.

From the floor, one-tier flat conveyors have a height of 33" and a bed height of 30". The bed height is the height from of the conveyor's rollers from the floor. For a two-tier flat conveyor, the top conveyor height will also be 33" high from the floor (30" bed height), and the bottom conveyor will have a height of 17" from the floor with a 9" bed height. The gravity conveyors can not be longer than 33' long. In standardizing the gravity conveyors, the conveyors begin at 45" high from the floor (41" bed height), span a horizontal distance of 29' long, and end at 37" high from the floor (33" bed height). If there is a flat lower tier, then the height will remain at 17" from the floor (9" bed height).

The next step was looking at the actual departmental layouts with the conveyors. Once the conveyor leaves the respective areas, the conveyors cross over aisle space, other departments, and even over each other. In order to cross over other departments and aisle space, there must be at least 10' of overhead clearance. Column posts will not be necessary to support the conveyor because it will be hanging and supported from the ceiling. There will also be about 2' of clearance between conveyor crossings. With this, conveyors will either be 10', 12.5', 15', or 17' high. This will give enough clearance over aisles and departments, as well as give clearance for conveyor crossings and two-tiered strips.

RSC receiving includes an inclined conveyor that will reach a height of 12.5'. On the mezzanine, there will be a flat conveyor servicing the workstations. A metal bar that is locked into place on the conveyor will hold the queue lines. Once the packages are done in one queue, they are placed over the bar onto the same conveyor. Then they are transported to the next queue, particularly for breakdown, verification, and toting. When units are toted, they are placed back on the 12.5' high conveyor that goes out into the facility (See Appendix O). FEP Receiving includes a flat conveyor, a two-tier, and an incline reaching a height of 15'. This will cross over a 10' and 12.5' high conveyor, and cross under a 17' conveyor.

Login will be fed from a 12.5' high conveyor from RSC receiving. It will then have a two-tier conveyor with six queues diverging from the main line. The queue lines

will be two-tiered as well. The top will be gravity and the bottom will be powered leading back to the main line. Once the products leave the login area, they are either placed on the conveyor transporting to repair floor "A" on a 17' high conveyor or repair floor "B" on a 15' high conveyor.

Billing and packaging receive repaired products from repair floor "A" on a declined conveyor from 10' high. Repaired products from repair floor "B" come in on a flat conveyor. The conveyors in billing and packaging include flat conveyors, two-tiered conveyors, and then an incline to a 12.5' high conveyor. Once packages are packed, they leave the billing and packaging area and enter the shipping area on a decline from 12.5' high.

Economic Analysis: From a financial point of view, the estimated number of products being repaired annually is 750,000 units. This number is very conservative in comparison to the forecasted numbers and the current throughput of the facility. With the proposed facility expansion, there will be an incremental annual increase of 300,000 units. This will bring the facilities annual repair rate to 1,050,000 units/year. Assuming no price degradation and an average unit selling price of $115.00/unit, the additional forecasted revenue to Motorola is $34,500,000/year. However, there is a unit variable cost of $78.00/unit, which adds up to a variable cost of $23,400,000/year.

Motorola is leasing the current facility, and the lessor will take on the burden of expense of the expansion. The new lease will cost $800,000/year. Motorola will also invest $10,000,000 on capital equipment, primarily for testing equipment and workstations, and $3,300,000 of which will be the annual depreciation on the equipment. Therefore, the total fixed costs are approximately $4,100,000/year.

Since there is no fixed expansion cost due to a lease, and the capital investment depreciates, the new facility will have to repair at least 110,811 units every year to break even. If the facility operates 355 days a year, including weekend shifts and holidays off, the RSC can repair an average of 2284 units a day. Currently at 750,000 units and 355 working days, the RSC repairs an average of 2113 units daily. With the expansion, it is forecasted that the facility can repair 2958 units/day. If the new facility repairs units at

2958 units/day, then they can achieve the break-even point of 110,811 units in 38 days.
(See Appendix P for a summary).

Conclusions and Recommendations

The purpose of this project was to develop a facility expansion design that will meet the increasing demand of Motorola's Radio Support Center. In the project proposal, the project team aimed to design an expanded layout that would decrease congestion within the facility while improving process flow. Improved departmental layouts and implementation of a facility-wide conveyor system were also objectives of the project team.

The objectives were met in three phases. Upon completion of these phases, the project team has delivered an optimal facility layout in Phase 1, an improved departmental process flow in Phase 2, and implemented a facility-wide conveyor system in Phase 3. The RSC's Technical Operations team was a significant factor in developing the optimal layout in Phase 1. Time studies and knowledge of processes were essential factors in the departmental layouts and implementation of the conveyor system for the final two phases.

For future studies, the TOP should further analyze the technical functionality of the proposed login department's conveyor system. One possibility of this system is to have units enter queue lines based on the least number in queue. Another possibility is being able to shut down certain queue lines due to low utilization. Also, the receiving and shipping of products can be improved through the implementation of a software system. Such systems will enable the RSC to automate its receiving process and improve its ability to better track products.

Bibliography

Hoffer, Jeffrey A. Modern Systems Analysis and Design. New York: Addison-Wesley;
    1999.

Pegden, Dennis C. Introduction to Simulation Using SIMAN. St. Louis: McGraw-Hill,
    Inc; 1995.

APPENDIX A

❖

Summary of Time Studies

Time Study Summary Table

Receiving Time Studies

Operation	# of Trials	Average (min)	Houly Rate
Opening	46	0.825	72 boxes
Verifying	43	0.729	82 units
Toting	56	0.272	220 units

Login Time Studies

Operation	# of Trials	Average (min)	Houly Rate
Radius Login	16	3:02	19 units
Branded Login	15	3:19	18 units
Iden Login	16	2:39	22 units
Cable Modem Login	15	3:11	18 units
Overall Login	62	3:04	19 units

Packaging Time Studies

Operation	# of Trials	Average (min)	Houly Rate
Packing	15	1:00	60 boxes
Labeling	32	0.521	115 boxes
Scantron Billing	30	1:50	32 units

APPENDIX B

❖

PERT Chart

Performance Evaluation Review Technique (PERT) Chart
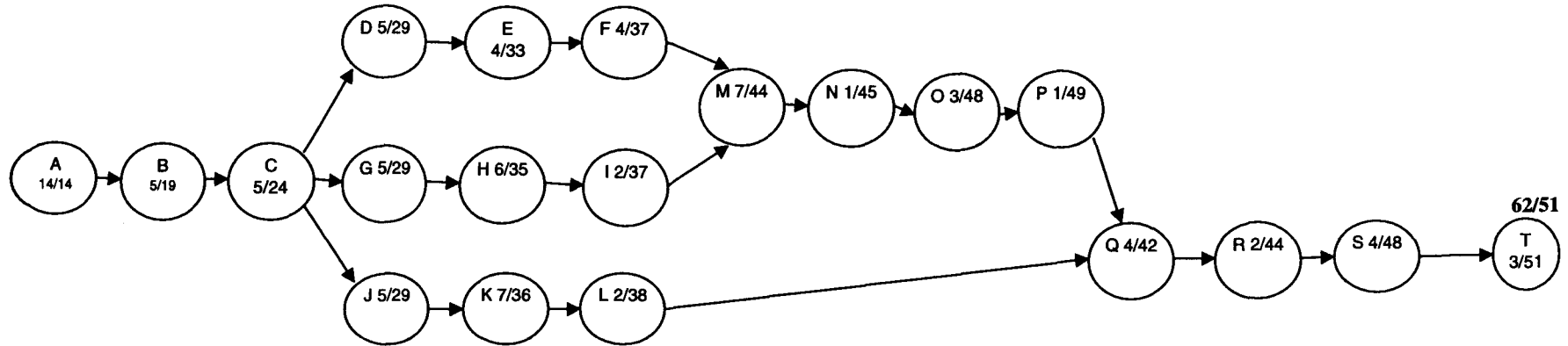
Critial Path - A - B - C - J - K - L - Q - R - S - T
With a duration of 51 Days, establishing 11 days of slack time.

Task	Precedence	Duration (days)
A	-	14
B	A	5
C	B	4
D	C	5
E	D	4
F	E	4
G	C	5
H	G	6
I	H	2
J	C	5
K	J	7
L	K	2
M	F, I	7
N	M	1
O	N	3
P	O	1
Q	L, P	4
R	Q	2
S	R	4
T	S	3

PERT - Description of Tasks

Phase 1
Task A - Observation and analysis of entire facility
Task B - FactoryCAD analysis of departmental relationships
Task C - Optimal facility layout developed

Phase 2
Task D - Shipping/Receiving analysis / time study
Task E - Layout proposals / alternatives
Task F - Final shipping/receiving layout developed
Task G - Login analysis / time study
Task H - Layout proposals / alternatives
Task I - Final login layout developed
Task J - Packaging / Billing analysis / time study
Task K - Layout proposals / alternatives
Task L - Final packing / billing layout developed
Task M - Gathering of simulation data
Task N - Development of flowchart and simple logic
Task O - Development of code and alternatives
Task P - Analysis of simulation results

Phase 3
Task Q - Analysis of current conveyor system
Task R - Benchmarking, visited two other facilities
Task S - Analysis of departmental conveyor constraints
Task T - Final facility layout developed (with final departmental and conveyor layouts)

APPENDIX C

❖

Relationship Diagrams

IDEAL RELATIONSHIP DIAGRAM

1 ADMIN1
2 ADMIN2
3 BILLING
4 CAFETERIA
5 COMPUTER
6 CQA
7 FACILITIES
8 FITNESSROOM
9 FRONTBATH
10 FRONTOFFICE
11 HR
12 IS
13 INVENTORY
14 KITCHEN
15 LOGIN
16 MECHANICAL
17 PACKING
18 RECEIVING
19 REPAIRA
20 REPAIRB
21 SHIPPING
22 SHOWERS
23 TRAINING
24 UTILITY

ACTUAL RELATIONSIP DIAGRAM

1 ADMIN1
2 ADMIN2
3 BILLING
4 CAFETERIA
5 COMPUTER
6 CQA
7 FACILITIES
8 FITNESSROOM
9 FRONTRAIL
10 FRONTOFFICE
11 HUMANRESOURCE
12 INFOSYSTEMS
13 INVENTORY
14 MEZZINVENTORY
15 KITCHEN
16 EDGIN
17 MECHANICAL
18 PACKAGING
19 RECEIVING
20 RCVGARAGE
21 REPAIRA
22 REPAIRB
23 SECURESTORAGE
24 SHIPPING
25 SHIPGARAGE
26 SHOWERS
27 TRAINING
28 UTILITY
29 REPAIRE

APPENDIX D

❖

General FactoryPLAN Layout - Ideal

RECEIVING

LOGIN

MECHANICAL

FITNESSROOM   SHOWERS   CQA   HR   SHIPPING

UTILITY

FACILITIES

PACKING

BILLING

REPAIRA   REPAIRB

INVENTORY

CAFETERIA

KITCHEN

IS

TRAINING   FRONTBATH

COMPUTER   ADMIN1   ADMIN2
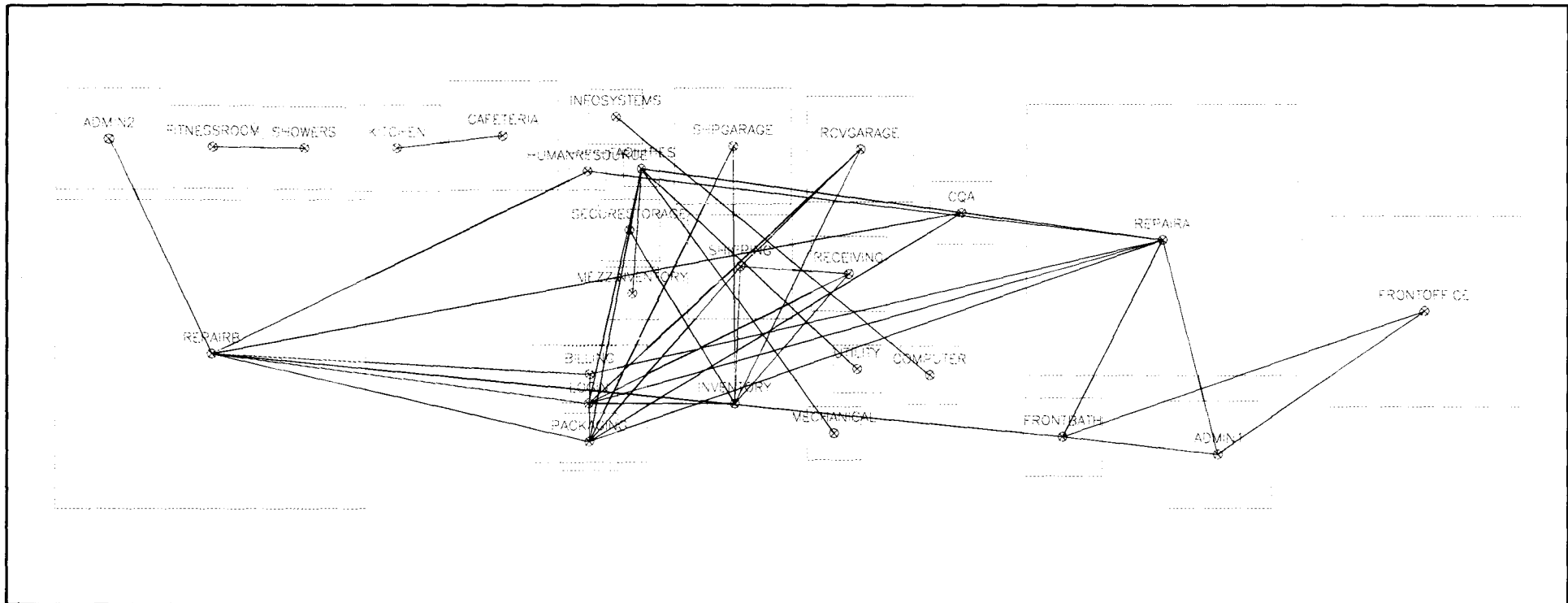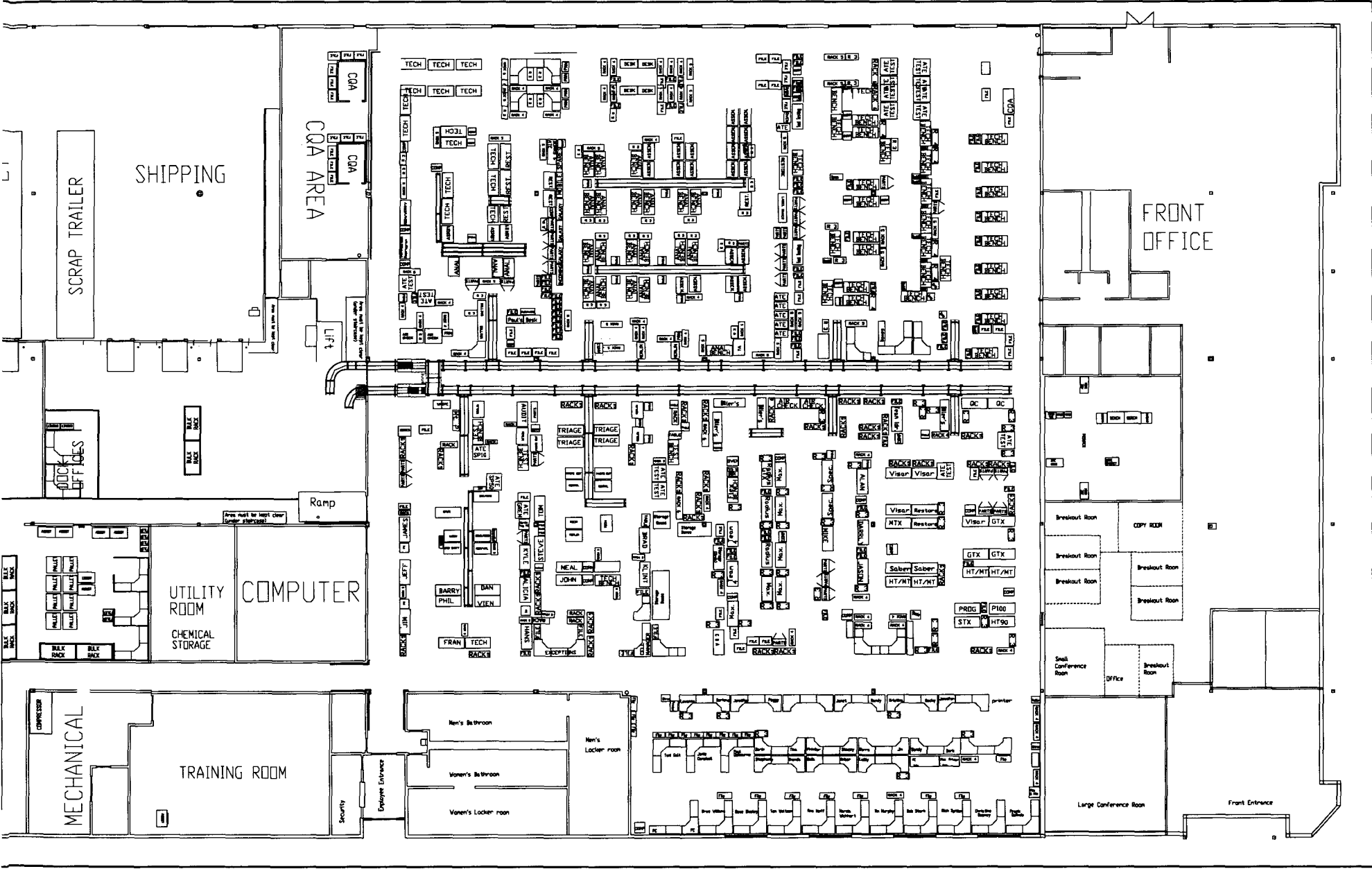
FRONTOFFICE

APPENDIX E

❖

General FactoryPLAN Layout - Actual

APPENDIX F

❖

Expanded Optimal Facility Layout

SCRAP TRAILER

SHIPPING

CQA AREA

CQA

CQA

FRONT OFFICE

Lift

DOCK OFFICES

BULK RACK

Ramp

Area must be kept clear (under staircase)

TECH TECH TECH

TECH TECH TECH

TECH

H031 TECH

TECH

TECH TECH TECH

TECH TECH

ATE TEST

ATE TEST

Paul & Brick

TRIAGE TRIAGE

TRIAGE TRIAGE

AUDIT

ATE SP16

Biler's

RACK3 RACK3

RACK3 RACK3

RACK3 RACK3

QC QC

Visar Visar

ATE ATE TEST TEST

Visar Restore

MTX Restore

Visar GTX

ALAN

Saber Saber

HT/MT HT/MT

GTX GTX

HT/MT HT/MT

PROG P100

STX HT90

RACK3

Breakout Room

COPY ROOM

Breakout Room

Breakout Room

Breakout Room

Breakout Room

Small Conference Room

Office

Breakout Room

MECHANICAL

TRAINING ROOM

UTILITY ROOM

COMPUTER

CHEMICAL STORAGE

BULK RACK

BULK RACK

COMPRESSOR

Security

Employee Entrance

Men's Bathroom

Men's Locker room

Women's Bathroom

Women's Locker room

JIM JEFF JAMES

BARRY PHIL

DAN VIEN

FRAN TECH

NEAL JOHN

KLINT

BRAD

KYLE ALICIA

HAAS

EXCEPTIONS

TECH BENCH

printer

Large Conference Room

Front Entrance

PC PC

APPENDIX G

❖

Receiving Drawing
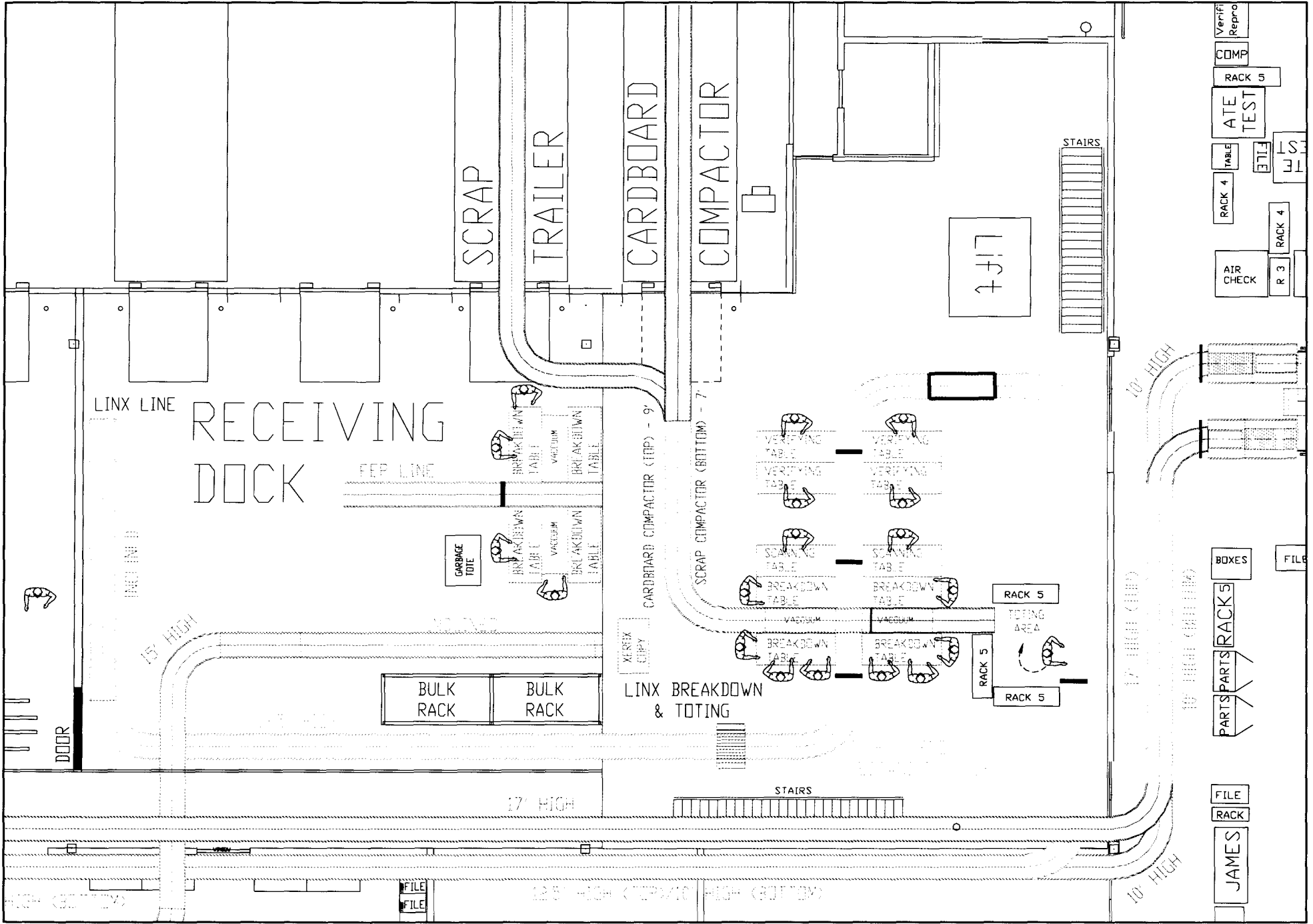
APPENDIX H

❖

FEP Drawing
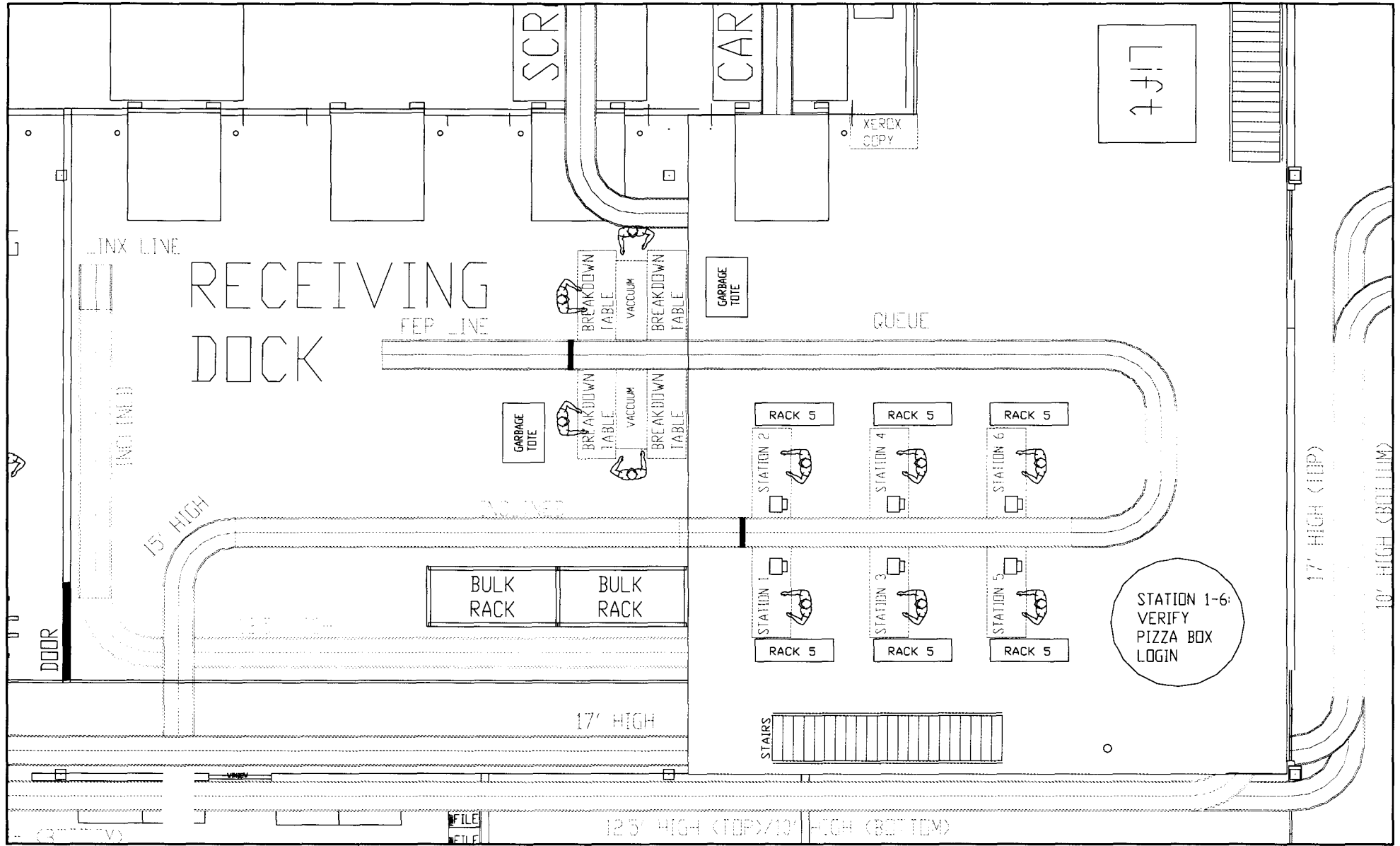
APPENDIX I

❖

Login Drawing

17' HIGH

TWO-TIER — 17' (TOP)/12.5' (BOTTOM)
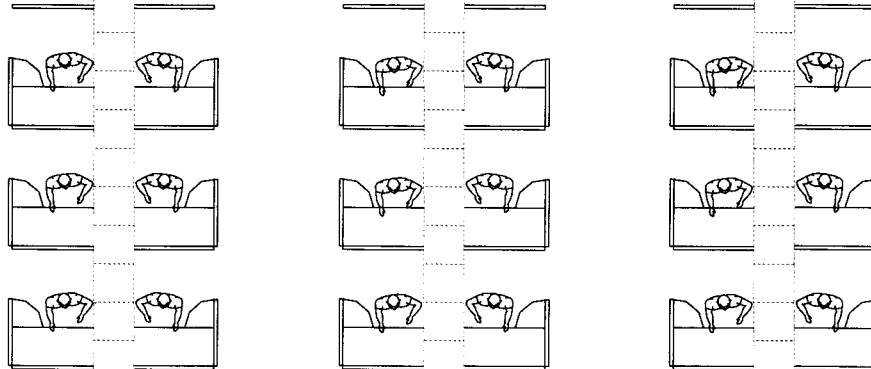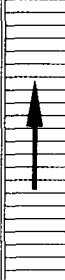
INCLINED

LOGIN

STAIRS

WASTE

FILE

RACK

BACKS

DAWN

STAIRS

BAR

PHI

STORAGE RA
STORAGE RA

STORAGE RA
STORAGE RA

STORAGE RA
STORAGE RA

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SUPERVISOR'S
CUBE

TWO-TIER
TOP — GRAVITY
BOTTOM — POWER

ELEVATOR

STAIRS

KERS

15' HIGH

APPENDIX J

❖

Simulation

Receiving & Login Simulation
Model File

CREATE, 412,0:,1:MARK(Arr_Time): NEXT (DOCK);

CREATE, 574,120:,1:MARK(Arr_Time): NEXT (DOCK);

CREATE, 198,210:,1:MARK(Arr_Time): NEXT (DOCK);

CREATE, 1,0:TRIA(7,8,9),200:MARK(Arr_Time): NEXT (DOCK);

DOCK
    QUEUE, OPENQ;
    SEIZE: OPENER;
    DELAY: 49.52/100;
    BRANCH, 1:

        WITH, .95, PAPERS:
        WITH, .05, NOPAPERS;

NOPAPERS
    DELAY: 34.23/100;
    RELEASE: OPENER: NEXT(VERIFY);

PAPERS
    RELEASE: OPENER:NEXT(VERIFY);

VERIFY
    DUPLICATE: 1.7;
    COUNT: NUMBER OF UNITS VERIFIED, 1;
    QUEUE, VERIFYQ;
    SEIZE: VERIFIER;
    DELAY: 43.76/100;
    RELEASE: VERIFIER: NEXT (TOTE);

TOTE
    QUEUE, TOTEQ;
    SEIZE: TOTER;
    DELAY: 16.35/100;
    RELEASE: TOTER;
    DELAY: .0143125 * 156: NEXT (LOGIN);

```
LOGIN
      BRANCH, 1:

            WITH, .1667, LINE1:
            WITH, .1667, LINE2:
            WITH, .1667, LINE3:
            WITH, .1667, LINE4:
            WITH, .1667, LINE5:
            WITH, .1667, LINE6;

LINE1
      DELAY:  .0143125 * 10.0625: NEXT (LINE1A);

LINE1A
      QUEUE,  LINE1AQ;
      SEIZE:  LOGGER1;
      DELAY:  3.05;
      RELEASE: LOGGER1: NEXT(DONE);

LINE2
      DELAY:  .0143125 * 18.02: NEXT (LINE2A);

LINE2A
      QUEUE,  LINE2AQ;
      SEIZE:  LOGGER2;
      DELAY:  3.05;
      RELEASE: LOGGER2: NEXT(DONE);

LINE3
      DELAY:  .0143125 * 33.0625: NEXT (LINE3A);

LINE3A
      QUEUE,  LINE3AQ;
      SEIZE:  LOGGER3;
      DELAY:  3.05;
      RELEASE: LOGGER3: NEXT(DONE);

LINE4
      DELAY:  .0143125 * 38.0625: NEXT (LINE4A);

LINE4A
      QUEUE,  LINE4AQ;
      SEIZE:  LOGGER4;
```

```
        DELAY:  3.05;
        RELEASE: LOGGER4: NEXT(DONE);

LINE5
        DELAY:   .0143125 * 43.02: NEXT (LINE5A);

LINE5A
        QUEUE,  LINE5AQ;
        SEIZE:  LOGGER5;
        DELAY:  3.05;
        RELEASE: LOGGER5: NEXT(DONE);

LINE6
        DELAY:   .0143125 * 48.02: NEXT (LINE6A);

LINE6A
        QUEUE,  LINE6AQ;
        SEIZE:  LOGGER6;
        DELAY:  3.05;
        RELEASE: LOGGER6: NEXT(DONE);

DONE
        COUNT: NUMBER OF UNITS LOGGED IN, 1;
        TALLY: OVERALL SYS TIME, INT(ARR_TIME);


DISPOSE;


END;
```

Receiving & Login Simulation
Experimental File

BEGIN,   Yes, No;

PROJECT, Receiving and Login Simulation, IENG 495, 4/27/00, Yes;

ATTRIBUTES: ARR_TIME;

QUEUES: OPENQ:
           VERIFYQ:
           TOTEQ:
           LINE1AQ:
           LINE2AQ:
           LINE3AQ:
           LINE4AQ:
           LINE5AQ:
           LINE6AQ;

RESOURCES: OPENER, SCHEDULE(OPENINGSCHD):
           VERIFIER, SCHEDULE(VERIFYINGSCHD):
           TOTER, SCHEDULE(TOTERSCHD):
           LOGGER1, SCHEDULE(LOGGER1SCHD):
           LOGGER2, SCHEDULE(LOGGER2SCHD):
           LOGGER3, SCHEDULE(LOGGER3SCHD):
           LOGGER4, SCHEDULE(LOGGER4SCHD):
           LOGGER5, SCHEDULE(LOGGER5SCHD):
           LOGGER6, SCHEDULE(LOGGER6SCHD);

SCHEDULES: OPENINGSCHD,3*53, 0*7, 3*39.75, 0*5.25, 0*15, 4*106, 0*14, 0*15,
           4*39.75, 0*5.25, 2*53, 0*7, 0:

           VERIFYINGSCHD,4*53, 0*7, 5*39.75, 0*5.25, 0*15, 7*106, 0*14,
           0*15, 7*39.75, 0*5.25, 3*53, 0*7, 0:

           TOTERSCHD,1*53, 0*7, 1*39.75, 0*5.25, 0*15, 1*106, 0*14, 1*53, 0*7,
           1*53, 0*7, 1*26.5, 0*3.5, 0*30, 1*53, 0*7, 0:

           LOGGER1SCHD, 0*60, 6*53, 0*7, 6*53, 0*7, 0*15, 6*39.75,
           0*5.25,6*53, 0*7, 0*15, 6*39.75, 0*5.25, 6*53, 0*7, 0*30, 6*26.5, 0*3.5,
           6*53, 0*7, 6*26.5, 0*3.5:

LOGGER2SCHD,0*60, 3*53, 0*7, 3*53, 0*7, 0*15,
3*39.75,0*5.25,3*53, 0*7,0*15, 3*39.75, 0*5.25, 3*53, 0*7, 0*30,
3*26.5, 0*3.5, 3*53, 0*7, 3*26.5, 0*3.5:

LOGGER3SCHD, 0*60, 6*53, 0*7, 6*53, 0*7, 0*15, 6*39.75,
0*5.25,6*53, 0*7,0*15, 6*39.75, 0*5.25, 6*53, 0*7, 0*30, 6*26.5, 0*3.5,
6*53, 0*7, 6*26.5, 0*3.5:

LOGGER4SCHD,0*60, 6*53, 0*7, 6*53, 0*7, 0*15, 6*39.75, 0*5.25,
6*53, 0*7, 0*15, 6*39.75, 0*5.25, 6*53, 0*7, 0*30, 6*26.5, 0*3.5, 6*53,
0*7, 6*26.5, 0*3.5:

LOGGER5SCHD, 0*60, 0*60, 0*60, 6*53, 0*7, 6*53, 0*7, 0*15,
6*39.75, 0*5.25, 6*53, 0*7, 0*30, 6*26.5, 0*3.5, 6*53, 0*7, 0*15,
6*39.75, 0*5.25, 6*53, 0*7,6*26.5, 0*3.5:

LOGGER6SCHD, 0*60, 0*60, 0*60, 6*53, 0*7, 6*53, 0*7, 0*15,
6*39.75, 0*5.25,6*53, 0*7, 0*30, 6*26.5, 0*3.5, 6*53, 0*7, 0*15,
6*39.75, 0*5.25, 6*53, 0*7, 6*26.5, 0*3.5;

DSTATS: NQ(OPENQ), Length of Open Q:
            NQ(VERIFYQ), Length of Verify Q:
            NQ(TOTEQ), Length of Tote Q:
            NQ(LINE1AQ), Length of Line 1A Q:
            NQ(LINE2AQ), Length of Line 2A Q:
            NQ(LINE3AQ), Length of Line 3A Q:
            NQ(LINE4AQ), Length of Line 4A Q:
            NQ(LINE5AQ), Length of Line 5A Q:
            NQ(LINE6AQ), Length of Line 6A Q:

            NR(OPENER), Opening Assoc. Busy:
            NR(VERIFIER), Verifying Assoc. Busy:
            NR(TOTER), Toting Assoc. Busy:
            NR(LOGGER1), Login Assoc. #1 Busy:
            NR(LOGGER2), Login Assoc. #2 Busy:
            NR(LOGGER3), Login Assoc. #3 Busy:
            NR(LOGGER4), Login Assoc. #4 Busy:
            NR(LOGGER5), Login Assoc. #5 Busy:
            NR(LOGGER6), Login Assoc. #6 Busy;

COUNTERS: NUMBER OF UNITS VERIFIED,,REPLICATE:
          NUMBER OF UNITS LOGGED IN,,REPLICATE;

2

TALLIES: Overall Sys Time;

REPLICATE, 1,0.0, 690;

APPENDIX K

❖

Shipment Breakdown

Two Weeks of Shipments Into RSC Recieving

Carrier	Mon 3/20	Tue 3/21	Weds. 3/22	Thur. 3/23	Fri 3/24	Mon. 3/27	Tue 3/28	Weds. 3/29	Thurs. 3/30	Fri 3/31
UPS #1	313	185	209	203	210	215	180	180	225	181
UPS #2	190	280	349	318	339	128	344	279	320	315
UPS #3	110	102	58	103	58	60	133	165	95	102
FEDEX Total	102	36	47	29	24	143	167	90	127	29
US MAIL	22	8	10	14	28	19	9	7	11	16
AIRBORNE	6	8	15	10	1	9	16	6	6	7
RPS	7	4	7	3		4	1	1	3	1
DHL	3	2	1	2			1			1
BAX GLOBAL			1	1			1	1		3
EMERY										
Total for Other	140	58	81	59	53	175	195	105	147	57

Two Week Average for Other   99.27272727   100

Two Week Average for UPS #1   205.818181   206

Two Week Average for UPS #2   286.2   287

Two Week Average for UPS #3   98.6   99

2X	
Other	200
UPS #1	412
UPS #2	574
UPS #3	198

3X	
Other	300
UPS #1	618
UPS #2	861
UPS #3	297

4X	
Other	400
UPS #1	824
UPS #2	1148
UPS #3	396

APPENDIX L

❖

Simulation Output

```
                        ARENA Simulation Results
                        O.R.Lab - License #8810476

SCENARIO #1                 Summary for Replication 1 of 1

Project:  Recieving and Login         Run execution date :  5/ 2/2000
Analyst:  IENG 495                     Model revision date:  4/27/1900

Replication ended at time      : 690.0

                          TALLY VARIABLES

Identifier          Average   Half Width  Minimum   Maximum   Observations
_____

Overall Sys Time    187.31    (Corr)      53.170    426.10    2350

                     DISCRETE-CHANGE VARIABLES

Identifier          Average   Half Width  Minimum   Maximum   Final Value
_____

Length of Open Q     70.302   (Corr)      .00000    577.00    42.000
Length of Verify Q   12.915   (Corr)      .00000    152.00    .00000
Length of Tote Q     409.78   (Corr)      .00000    1068.0    108.00
Length of Line 1A Q  6.6959   (Insuf)     .00000    55.000    .00000
Length of Line 2A Q  43.765   (Corr)      .00000    88.000    .00000
Length of Line 3A Q  6.3429   (Insuf)     .00000    54.000    .00000
Length of Line 4A Q  5.2816   (Insuf)     .00000    53.000    .00000
Length of Line 5A Q  44.653   (Corr)      .00000    175.00    .00000
Length of Line 6A Q  36.289   (Corr)      .00000    148.00    .00000
Opening Assoc.Busy   .90733   (Corr)      .00000    4.0000    .00000
Verifying Assoc.Busy 1.5588   (Corr)      .00000    7.0000    .00000
Toting Assoc.Busy    .55685   (Corr)      .00000    1.0000    .00000
Login Assoc.#1 Busy  1.7769   .91506      .00000    6.0000    .00000
Login Assoc.#2 Busy  1.8300   (Insuf)     .00000    3.0000    .00000
Login Assoc.#3 Busy  1.7858   .87608      .00000    6.0000    .00000
Login Assoc.#4 Busy  1.6222   .85260      .00000    6.0000    .00000
Login Assoc.#5 Busy  1.6929   (Insuf)     .00000    6.0000    .00000
Login Assoc.#6 Busy  1.6797   (Insuf)     .00000    6.0000    .00000

                             COUNTERS

          Identifier              Count    Limit
          _____

          NUMBER OF UNITS VERIFI   2458    Infinite
          NUMBER OF UNITS LOGGED   2350    Infinite


Simulation run time: 0.02 minutes.
Simulation run complete.
```

```
                        ARENA Simulation Results
                        O.R.Lab - License #8810476

SCENARIO #2              Summary for Replication 1 of 1

Project:  Recieving and Lo              Run execution date :  5/ 2/2000
Analyst:  IENG 495                      Model revision date:  4/27/1900

Replication ended at time     : 690.0

                         TALLY VARIABLES

Identifier           Average    Half Width  Minimum    Maximum   Observations

──────────────────────────────────────────────────────────────────────────────

Overall Sys Time     206.42     (Corr)      45.750     564.90    3470

                    DISCRETE-CHANGE VARIABLES

Identifier           Average    Half Width  Minimum    Maximum   Final Value

──────────────────────────────────────────────────────────────────────────────

Length of Open Q     191.27     (Corr)      .00000     948.00    41.000
Length of Verify Q   59.061     (Corr)      .00000     151.00    3.0000
Length of Tote Q     87.544     (Corr)      .00000     409.00    .00000
Length of Line 1A Q  33.536     (Corr)      .00000     98.000    .00000
Length of Line 2A Q  227.48     (Corr)      .00000     373.00    166.00
Length of Line 3A Q  52.885     (Corr)      .00000     140.00    .00000
Length of Line 4A Q  27.655     (Corr)      .00000     83.000    .00000
Length of Line 5A Q  151.98     (Corr)      .00000     296.00    .00000
Length of Line 6A Q  127.74     (Corr)      .00000     258.00    .00000
Opening Assoc.Busy   1.3485     (Corr)      .00000     4.0000    .00000
Verifying Assoc.Busy 2.3078     (Corr)      .00000     7.0000    .00000
Toting Assoc.Busy    .86228     (Corr)      .00000     2.0000    .00000
Login Assoc.#1 Busy  2.6433     (Insuf)     .00000     6.0000    .00000
Login Assoc.#2 Busy  2.0421     (Insuf)     .00000     3.0000    3.0000
Login Assoc.#3 Busy  2.8422     (Insuf)     .00000     6.0000    .00000
Login Assoc.#4 Busy  2.6123     (Insuf)     .00000     6.0000    .00000
Login Assoc.#5 Busy  2.6919     (Insuf)     .00000     6.0000    .00000
Login Assoc.#6 Busy  2.5063     (Insuf)     .00000     6.0000    .00000

                             COUNTERS

           Identifier              Count    Limit

           ─────────────────────────────────────────

           NUMBER OF UNITS VERIFI   3642    Infinite
           NUMBER OF UNITS LOGGED   3470    Infinite


Simulation run time: 0.02 minutes.
Simulation run complete.
```

```
                        ARENA Simulation Results
                        O.R.Lab - License #8810476

SCENARIO #3              Summary for Replication 1 of 1

Project:   Recieving and Lo              Run execution date :   5/ 2/2000
Analyst:   IENG 495                      Model revision date:   4/27/1900

Replication ended at time      : 690.0

                          TALLY VARIABLES

Identifier           Average    Half Width  Minimum    Maximum    Observations


Overall Sys Time     264.52     (Corr)      63.050     564.90     4392

                      DISCRETE-CHANGE VARIABLES

Identifier           Average    Half Width  Minimum    Maximum    Final Value


Length of Open Q     173.75     (Corr)      .00000     1144.0     42.000
Length of Verify Q   196.14     (Corr)      .00000     692.00     .00000
Length of Tote Q     494.95     (Corr)      .00000     1289.0     126.00
Length of Line 1A Q  74.550     (Corr)      .00000     138.00     .00000
Length of Line 2A Q  288.83     (Corr)      .00000     443.00     305.00
Length of Line 3A Q  89.151     (Corr)      .00000     173.00     .00000
Length of Line 4A Q  53.237     (Corr)      .00000     112.00     .00000
Length of Line 5A Q  227.98     (Corr)      .00000     341.00     .00000
Length of Line 6A Q  209.01     (Corr)      .00000     322.00     .00000
Opening Assoc.Busy   1.7858     (Corr)      .00000     6.0000     .00000
Verifying Assoc.Busy 3.0606     (Corr)      .00000     9.0000     .00000
Toting Assoc.Busy    1.1137     (Corr)      .00000     2.0000     .00000
Login Assoc.#1 Busy  3.4610     (Insuf)     .00000     6.0000     .00000
Login Assoc.#2 Busy  2.0421     (Insuf)     .00000     3.0000     3.0000
Login Assoc.#3 Busy  3.6158     (Insuf)     .00000     6.0000     .00000
Login Assoc.#4 Busy  3.3284     (Insuf)     .00000     6.0000     .00000
Login Assoc.#5 Busy  3.5141     (Insuf)     .00000     6.0000     .00000
Login Assoc.#6 Busy  3.4522     (Insuf)     .00000     6.0000     .00000

                            COUNTERS

            Identifier              Count   Limit


            NUMBER OF UNITS VERIFI   4826   Infinite
            NUMBER OF UNITS LOGGED   4392   Infinite


Simulation run time: 0.00 minutes.
Simulation run complete.
```
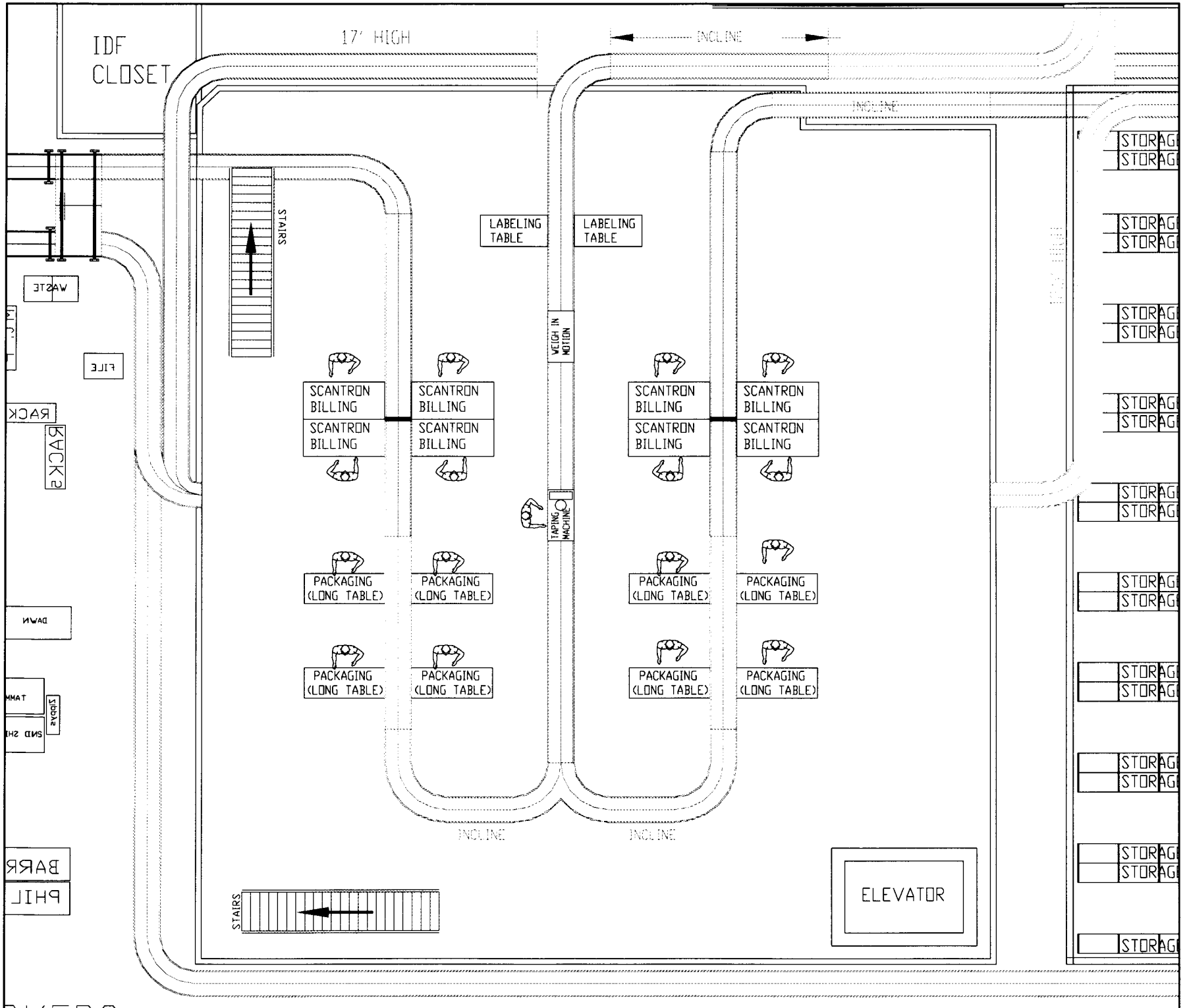
APPENDIX M

❖

Billing/Packaging Drawing

IDF
CLOSET

17' HIGH

INCLINE

INCLINE

STORAGE
STORAGE

STORAGE
STORAGE

STAIRS

LABELING
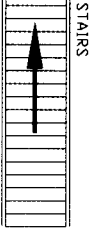TABLE

LABELING
TABLE

STORAGE
STORAGE

WASTE

STORAGE
STORAGE

FILE

WEIGH IN MOTION

SCANTRON
BILLING

SCANTRON
BILLING

SCANTRON
BILLING

SCANTRON
BILLING

STORAGE
STORAGE

RACK

PACKS

SCANTRON
BILLING

SCANTRON
BILLING

SCANTRON
BILLING

SCANTRON
BILLING

STORAGE
STORAGE

TAPING MACHINE

DAWN

PACKAGING
(LONG TABLE)

PACKAGING
(LONG TABLE)

PACKAGING
(LONG TABLE)

PACKAGING
(LONG TABLE)

STORAGE
STORAGE

TAMM

2ND SHI

PACKAGING
(LONG TABLE)

PACKAGING
(LONG TABLE)

PACKAGING
(LONG TABLE)

PACKAGING
(LONG TABLE)

STORAGE
STORAGE

INCLINE

INCLINE

STAIRS

ELEVATOR

BARR

PHIL

STORAGE

APPENDIX N

❖

Shipping Drawing

SHIPPING/STAGING DOCK

STORAGE RACK

STAGE AREA 1

STAGE AREA 2

STAGE AREA 3

LINX LINE

SHIPPING CAGE

BULK RACK

BULK RACK

FORK TRUCK
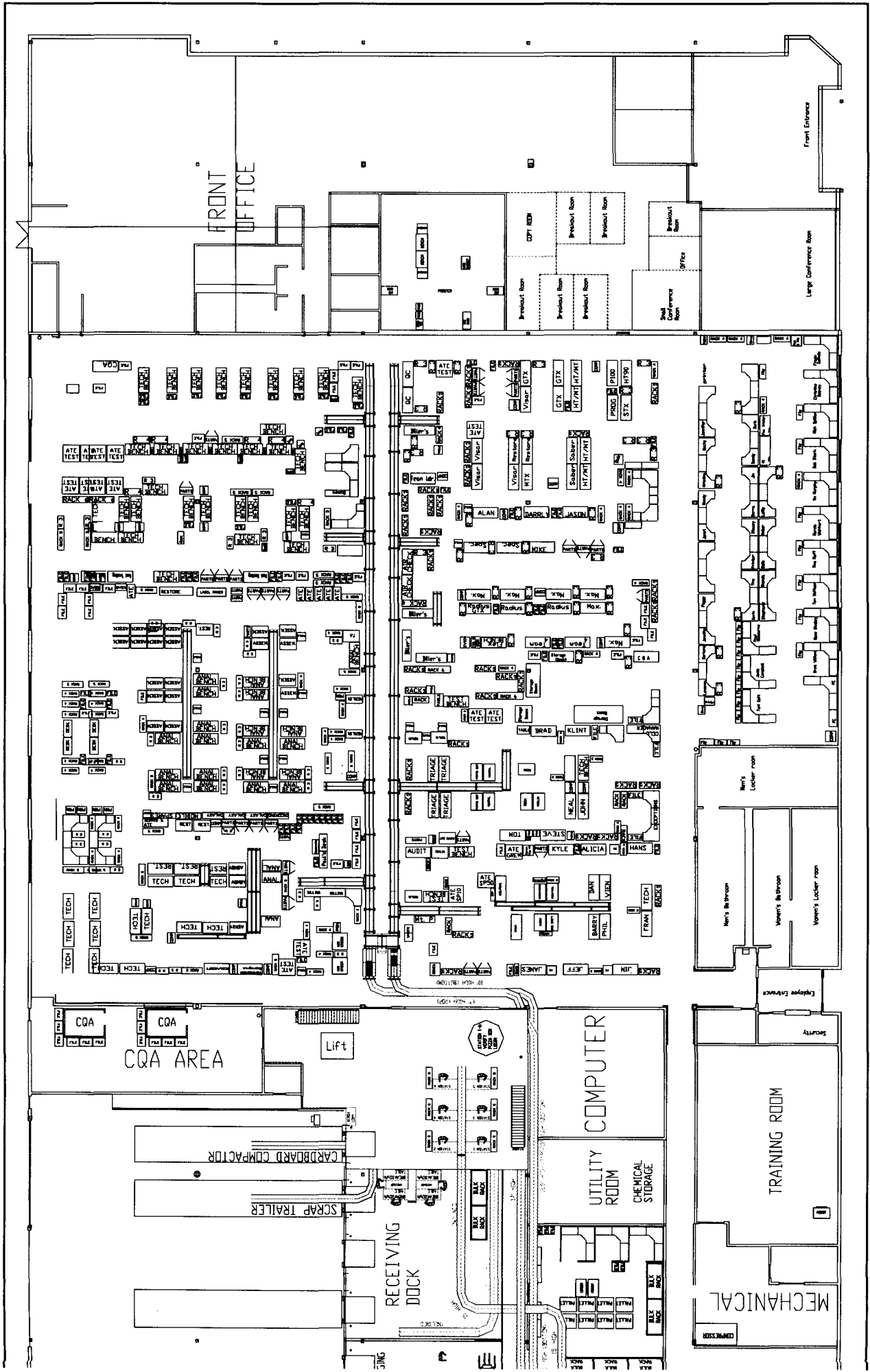
DOOR
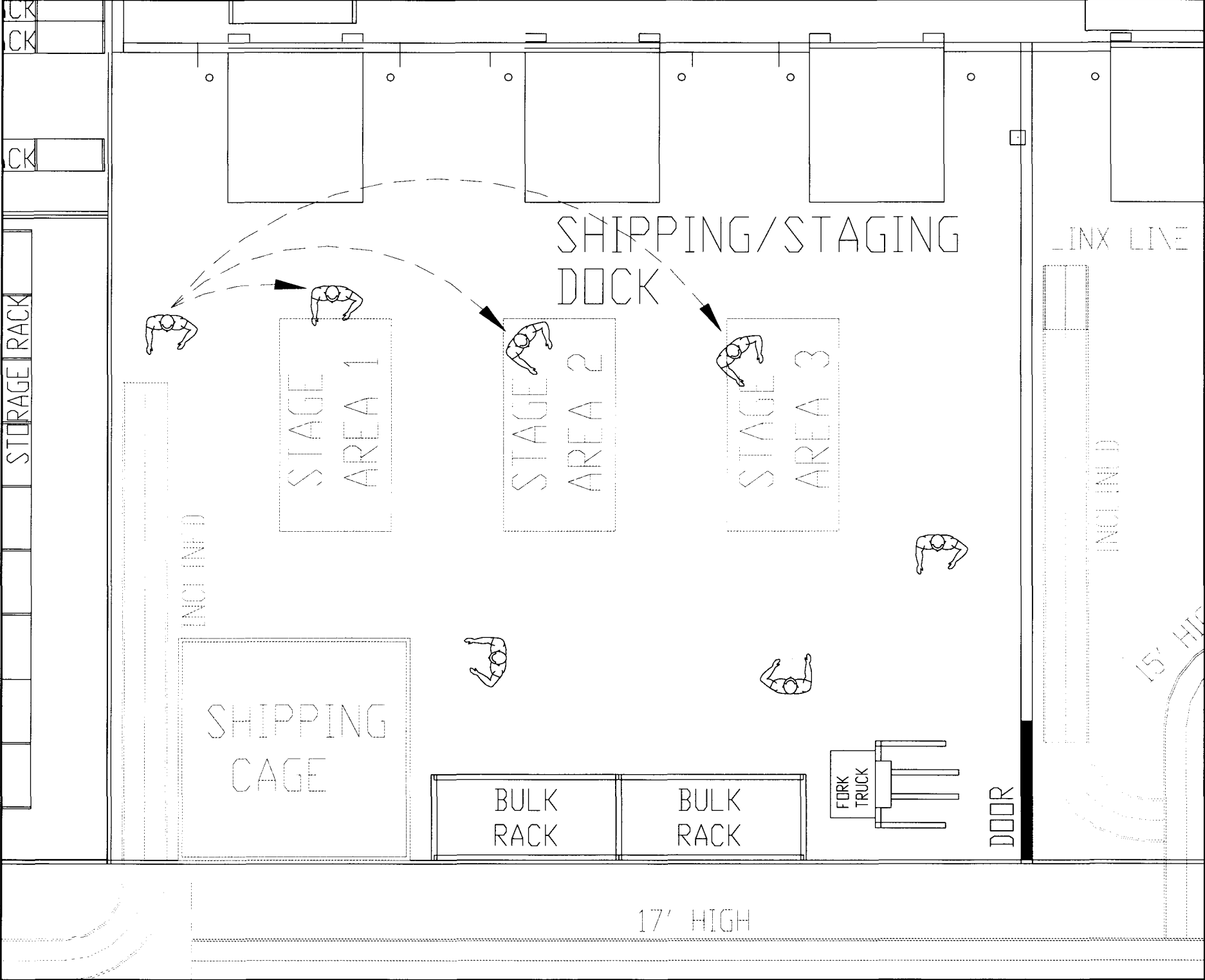
17' HIGH

APPENDIX O

❖

Conveyor Drawings

■ 10' HIGH

■ 13' HIGH

■ 15' HIGH

■ 17' HIGH

■ FLAT

■ GRAVITY

■ INCLINE

■ SCRAP – 7' HIGH
OFF MEZZANINE
FLOOR

■ CARDBOARD – 9'
HIGH
OFF MEZZANINE
FLOOR

■ TWO-TIER
(HIGH AND LOW)

□ TWO-TIER
(GRAVITY &
POWER)

FRONT OFFICE

FRONT Entrance

CQA AREA

Lift

CARDBOARD COMPACTOR

SCRAP TRAILER

RECEIVING DOCK

UTILITY ROOM

CHEMICAL STORAGE

COMPUTER

TRAINING ROOM

MECHANICAL

COMPRESSOR

Men's Bathroom

Women's Bathroom

Men's Locker room

Women's Locker room

Employee Entrance

Security

Large Conference Room

Small Conference Room

Breakout Room

Office

COPY ROOM

This is an architectural floor plan / facility layout drawing. The major labeled areas and rooms include:

FRONT OFFICE

Front Entrance

Large Conference Room
Small Conference Room
Breakout Room (multiple)
COPY ROOM
PROPER
Office

CQA AREA
CQA

Lift

CARDBOARD COMPACTOR
SCRAP TRAILER

RECEIVING DOCK

COMPUTER
UTILITY ROOM
CHEMICAL STORAGE

Men's Locker room
Women's Locker room
Men's Bathroom
Women's Bathroom

Employee Entrance
Security

TRAINING ROOM

MECHANICAL
COMPRESSOR

Numerous workstation and equipment labels throughout the main floor including: ATE TEST, RACK, BENCH, TECH, ANAL BENCH, ASSEM, SCREW, TRIAGE, RESTORE, AUDIT, RACKS, and personnel name labels such as ALAN, DARRL, JASON, MIKE, BRAD, KLINT, NEAL, JOHN, STEVE, TOM, KYLE, ALICIA, HANS, DAN, VIEN, BARRY, PHIL, FRAN, JANES, JEFF, JIM, as well as product/model labels such as Visor, GTX, HT/MT, MTX, Saber, Radus, Max., P100, P190, STX, PROG.

APPENDIX P
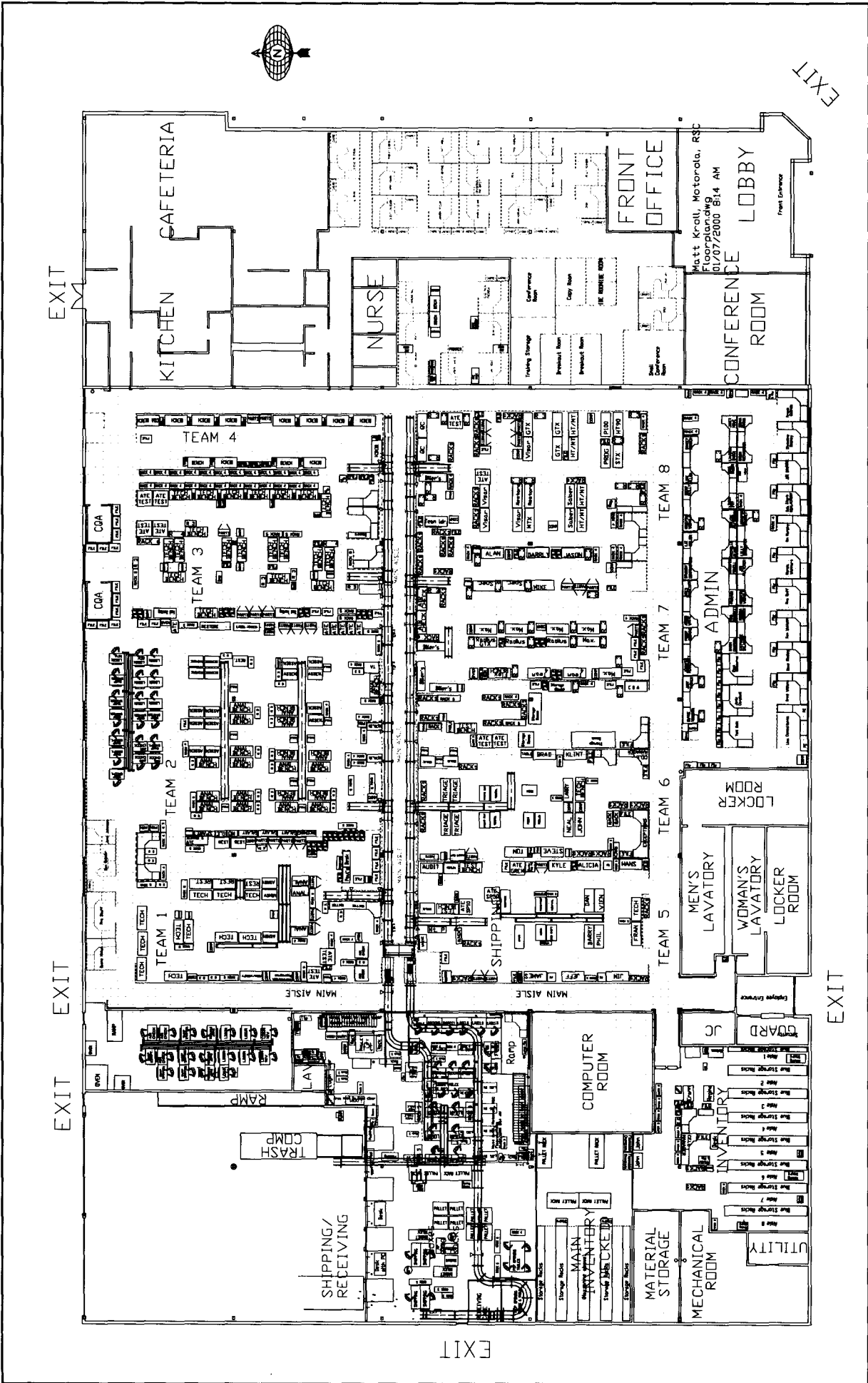
❖

Economic Analysis

Economic Analysis

Current Unit Volume	750,000
Incremental Unit Volume (Double Current less 40% due to warranty)	300,000
Increased Total Unit Volume	1,050,000
Operating Days/Year	355
Current day repair rate (units/day)	2113
Projected new day repair rate (units/day)	2958
Unit Repaired Break-Even Output Level/Year	110,811
Yearly Break-Even Point = output level/repair rate	38 days
Unit Average Selling Price	$115.00
Unit Variable Cost	$78.00
Operating Lease	$800,000
Projected Net Profit/Year	$2,600,00

APPENDIX Q

❖

Existing Facility Layout

EXIT

EXIT

EXIT

EXIT

EXIT

EXIT

N

CAFETERIA

KITCHEN

NURSE

FRONT OFFICE

LOBBY

CONFERENCE ROOM

Matt Krall, Motorola, RSC
Floorplan.dwg
01/07/2000 8:14 AM
Front Entrance

TEAM 4

TEAM 3

TEAM 2

TEAM 1

CQA

CQA

TEAM 8

TEAM 7

TEAM 6

TEAM 5

ADMIN

MAIN AISLE

MAIN AISLE

SHIPPING

MEN'S LAVATORY

WOMAN'S LAVATORY

LOCKER ROOM

LOCKER ROOM

GUARD

JC

Employee Entrance

COMPUTER ROOM

Ramp

RAMP

TRASH COMP

SHIPPING/ RECEIVING

MAIN INVENTORY

MATERIAL STORAGE

MECHANICAL ROOM

UTILITY

INVENTORY