CONCEPTUAL DESIGN OF A MATERIAL HANDLING SYSTEM FOR A COUNTY AIRPORT MAIL CENTER

by

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(ABSTRACT)

The County Airport Mail Center provides air mail services for a large metropolis. The current state of the facility is not keeping up with the growing demand of mail processing in its service area. The purpose of this project is to complete the conceptual design of a material handling system for the County Airport Mail Center. The front-end needs analysis and initial design activity were completed by XYZ Company, contracted by the United States Postal Service to define systems requirements and provide an Operational Systems Layout (OSL) for the County AMC.

The scope of this project was to complete the conceptual design using systems engineering tools to define design characteristics for the County AMC. The Operational Systems Layout delivered by XYZ Company was used as the baseline for defining these characteristics. A detailed discussion of the front-end analysis performed by XYZ Company including their simulation effort is provided to justify using their work as the baseline for completing the conceptual

design. Their project emphasized the use of simulation. My effort to complete the conceptual design included cost analysis to ensure that both operational and financial requirements were met.

A summary of the Systems Engineering activities that were undertaken from needs analysis to definition of design characteristics is also provided as a guidelines for future development of material handling systems.

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1.0 Introduction

1.1 Operational Situation

The County Airport Mail Center (AMC) provides air mail services for a large metropolis and adjoining localities. The current state of the facility cannot keep up with the growth of their service area. The facility is equipped with one bulk conveyor system and two extendible conveyors that allows loading of the mail from the dock area. Mail and parcels are sorted manually. The use of labor intensive mail processing has hindered the growth of the County AMC. The management of this air mail center recognized the problem and requested an upgrade of the mail handling system to include a state-of-the-art sorting system. The activities leading to creation of the Operational Systems Layout (OSL) are discussed in section 2.0 of this report.

The front-end needs analysis and initial design activity were completed by XYZ Company, contracted by the United States Postal Service to define systems requirements and provide an Operational Systems Layout (OSL) for the County AMC.

1.2 Project Objective

The objective of my project is to complete the conceptual design for the required mail handling system. To achieve this objective design characteristics beyond the Operational Systems Layout (OSL) are defined and a detail cost analysis is provided in section 3.0 and summarized in section 4.0. The delivered OSL will be used as the baseline in defining the different design characteristics.

1.3 Project Scope and Methodology

While I was directly involved in the front-end work leading to the OSL and this effort also benefitted directly from my studies in the Systems Engineering degree program, the scope of my project and report is the completion of a conceptual design based on the initial OSL that was delivered by XYZ Company to the United States Postal Service. The simulation analysis discussed in section 2.0 is a further example of OSL development work that directly benefited from my contribution based on my experience in the Systems Engineering degree program. However, a significant part of this project was the development of Guidelines for Future System Development Projects by the XYZ Company which are include in section 5.0.

The scope of my project was to complete the conceptual design using systems engineering tools in defining the different design characteristics. The following tasks were accomplished as part of this conceptual design activity:

1. Identify critical areas that require constant human interfaces.
2. Develop system training guidelines
3. Develop a guideline for system maintenance - equipment access
4. Develop testing and acceptance guidelines
5. Perform system reliability analysis
6. Define system supportability
7. Define system upgrade and disposal
8. Provide economic justification

The results will become part of the specification of the system under design.

Before the different design characteristics are defined, it is important to discuss the design activity that led to the development of the approved Operational Systems Layout (OSL). Emphasis is given to the simulation and its influence on the OSL. It provides an in depth look on the processing time for different material handling operations. The acceptance of the processing time is essential in the continuance of the design.

The completion of the conceptual design will require information beyond the OSL. The abundance of data in this particular field has been a tremendous help in the completion of this project. However, not all the detailed information is available. Using information from similar facilities in operation and the use of correction factors will help overcome the deficiencies. After the adequacy and functional requirements are met, the emphasis will then shift to the cost of the facility. This can only be achieved after all the critical "ilities" have been defined. These critical "ilities" influence the life cycle cost and the criteria for funding.

2.0 Initial Design Work Performed by XYZ Company

XYZ Company has been contracted to prepare the operational systems layout for the County AMC. The task began with needs analysis concluded with the preparation of the final OSL. The delivered OSL is used to define the different design characteristics that eventually lead into the completion of the conceptual design. This scenario is typical in the design of material handling systems, especially with the USPS. Often, an engineering company will collect all the data required and complete an OSL. After that, another company will begin their engineering design activities starting from the OSL and their final product is a conceptual design. A third company completes the project through the 100% design level for construction.

It has also been a practice that the USPS engineers will perform the needs analysis and complete the OSL. The contracted engineering firm will begin with the OSL and not from the data collection associated with the needs analysis. By starting with the OSL, the project can focus on the engineering activities required to define the design characteristics of the material handling system under design.

The steps undertaken by XYZ Company in completing the operational systems layout are described in Figure 1, Design Process (Operational Systems Layout Development). The design process contains an iterative approach that enables the designer to ensure the adequacy of the design before proceeding to the next phase of the design, completion of the conceptual design. The iterative process involves the use of simulation using the different design configurations under different mail processing scenarios.

The design of the County AMC was preempted by the need to expand the facility as described in the United States Postal Service Major Facility Planning Data sheet. This document has identified the projected needs of the facility, using the percentage of population increase from 1984 to the present. In 1994 the facility needs to increase its total building space for mail processing from 92,070 square feet to 180,834 square feet. It was clear that the County AMC has not been providing the mail processing capability that other facilities in similar metropolis offer. Given the constant growth of the population, the facility will need 350,353 square feet of processing space in 10 years with an expansion of 122,624 square feet in 20 years.

Based on experience the projected space increase is directly proportional to the amount of mail that can be processed. The facility is being increased by two folds therefore, the expected revenue will increase by 100%. The current volume of mail being processed is approximately 11,440,000 pieces or $34 million annually. Using the correlation of projected space and annual revenue, the facility should be able to generate $68 million annually in 10 years and approximately $92 million annually in 20 years. Without the new facility, the County AMC will have to use alternative processing schemes to meet customers' demand.

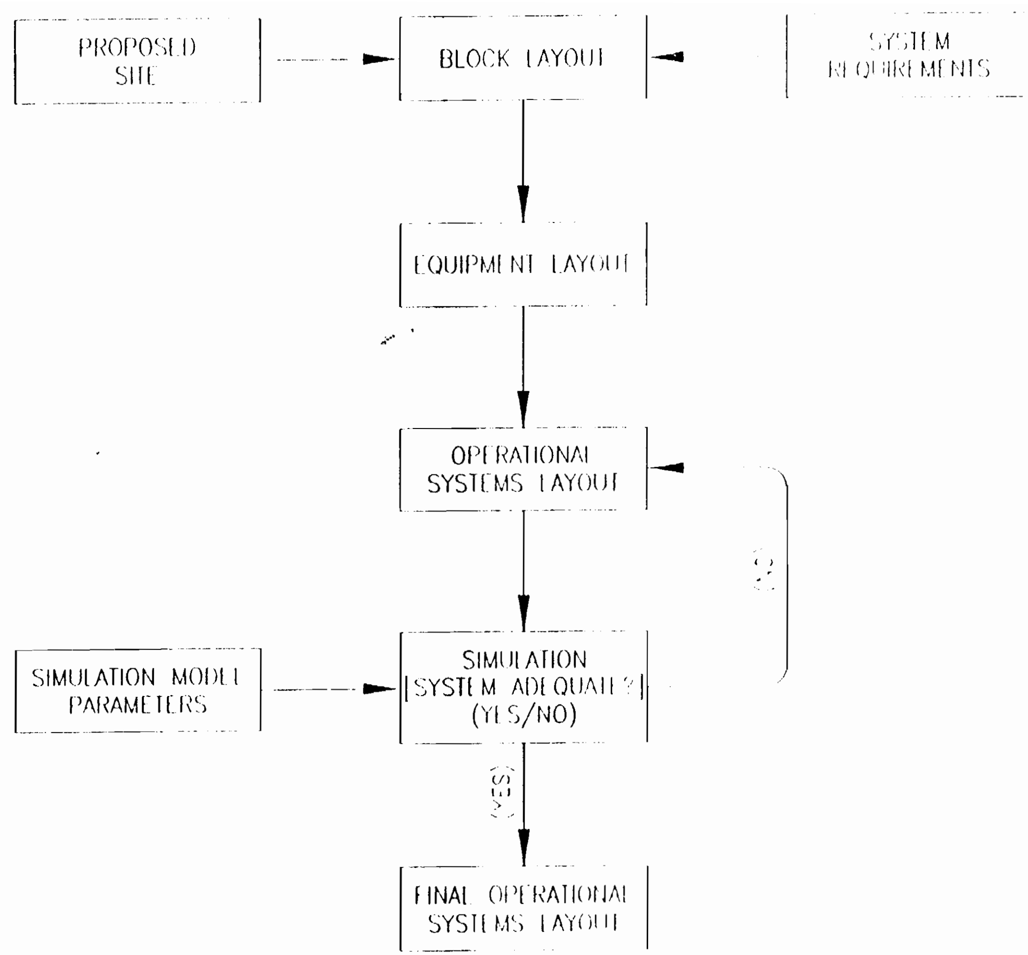


Figure 1. Design Process (Operational Systems Layout Development)

2.1 Designing a Material Handling System for an Airport Mail Center

The airport mail centers (AMC) or air mail facilities (AMF) are created to improve the handling of various mails and parcels that are transported using air carriers. Before a new facility will be created, the capacity of existing area processing and distribution centers (P&DC) have to justify current utilization and projected volumes of mail that they are processing that required only air transport. When there is an increase in the volume of mail being processed for air transport, one has to look into the effectiveness of the current mail flow in the area. Though the P&DCs do a good internal job in handling mail even at critical volume level, the required time to move the mail from the P&DCs to the airport area will increase. Often, the ability to provide the transportation between the centers and airport contributes to the inefficiency of the area mail flow. Figure 2 shows the mail flow process for sending interstate packages.

Traditionally trucks are used to transport mail from different P&DCs to the airport loading area. Amount and nature of traffic between their locations and the loading/unloading time is considered in deciding the available air carrier that will transport certain mail. Since, ground and air transportation are factors that influence on-time delivery, the challenge lies in the material handling system to ensure that the appropriate volume of mail meets this transportation need.

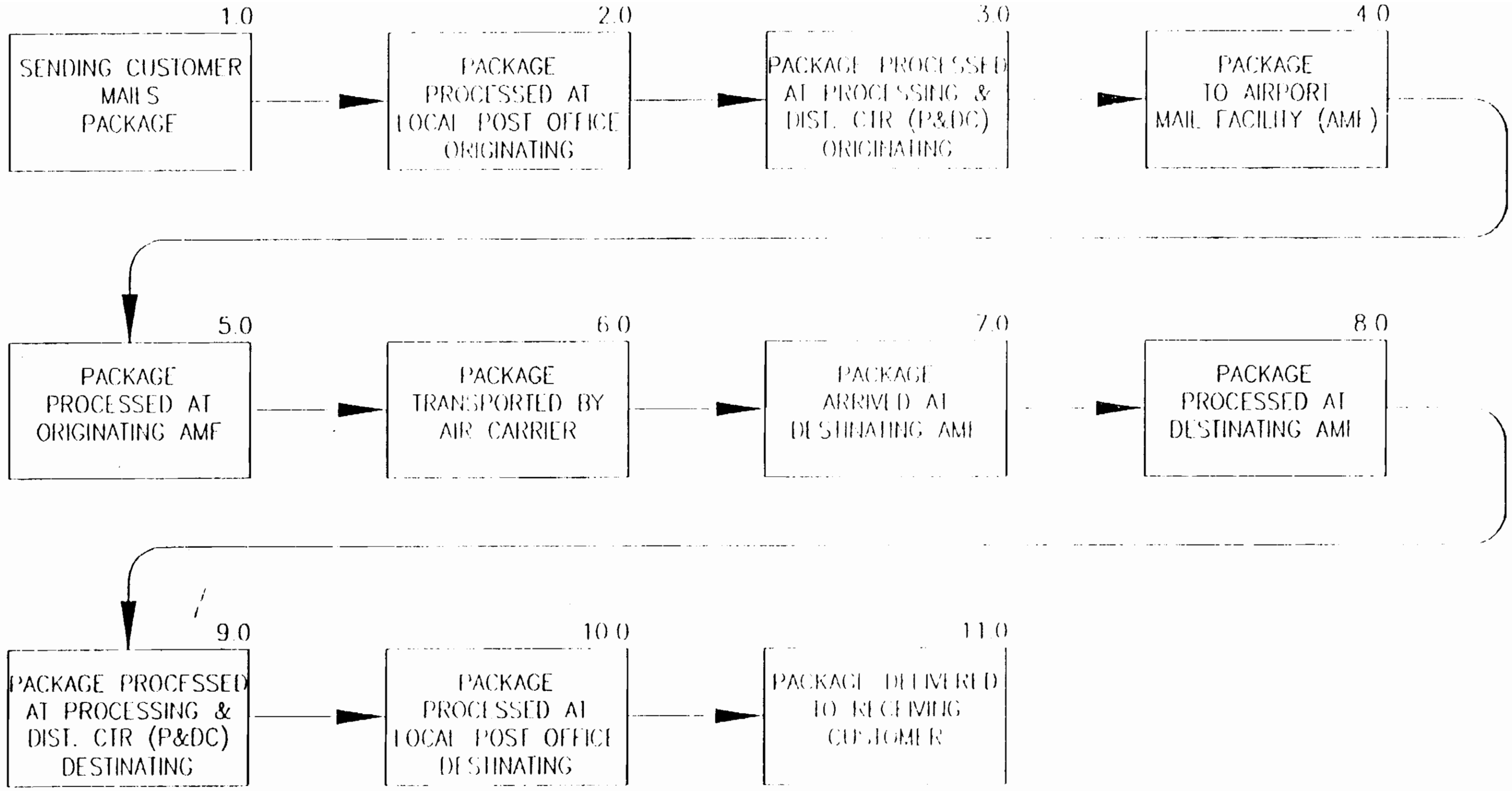


Figure 2. Mail Flow Process (Sending Package Interstate)

Major parcel services use their own aircraft to provide the air transport service, which means that a few minutes' or seconds' delay in ground transport and handling is not critical. However, the cost of providing this service is higher than the use of scheduled flights. USPS uses both scheduled air transport system and their own aircraft. In short, their mail and parcels are transported as part of the cargo of scheduled passenger flights. The challenge is that any ground handling and transportation has to meet the on-time arrival and departure of the scheduled passenger flights.

In contrast with the P&DC, the AMC/AMF's use special loading carts. These carts are similar to the airport ground transport system used for baggage. Since AMC/AMF's are located within the airport zone, the ground transportation requirements and handling time are significantly improved. Figure 3 shows the proposed site. The same baggage handling trucks are used to tow the mail and parcel carts. There is more variability in volume requirements for baggage handling trucks than regular highway trucks. Airport ground trucks can tow a single cart up to four carts at a time. Their volume is only a fraction of the contents of a regular truck. Both air and ground transportations are factors that influenced on-time delivery, however the bulk of the material handling problem needs to be addressed in the processing of the mails.

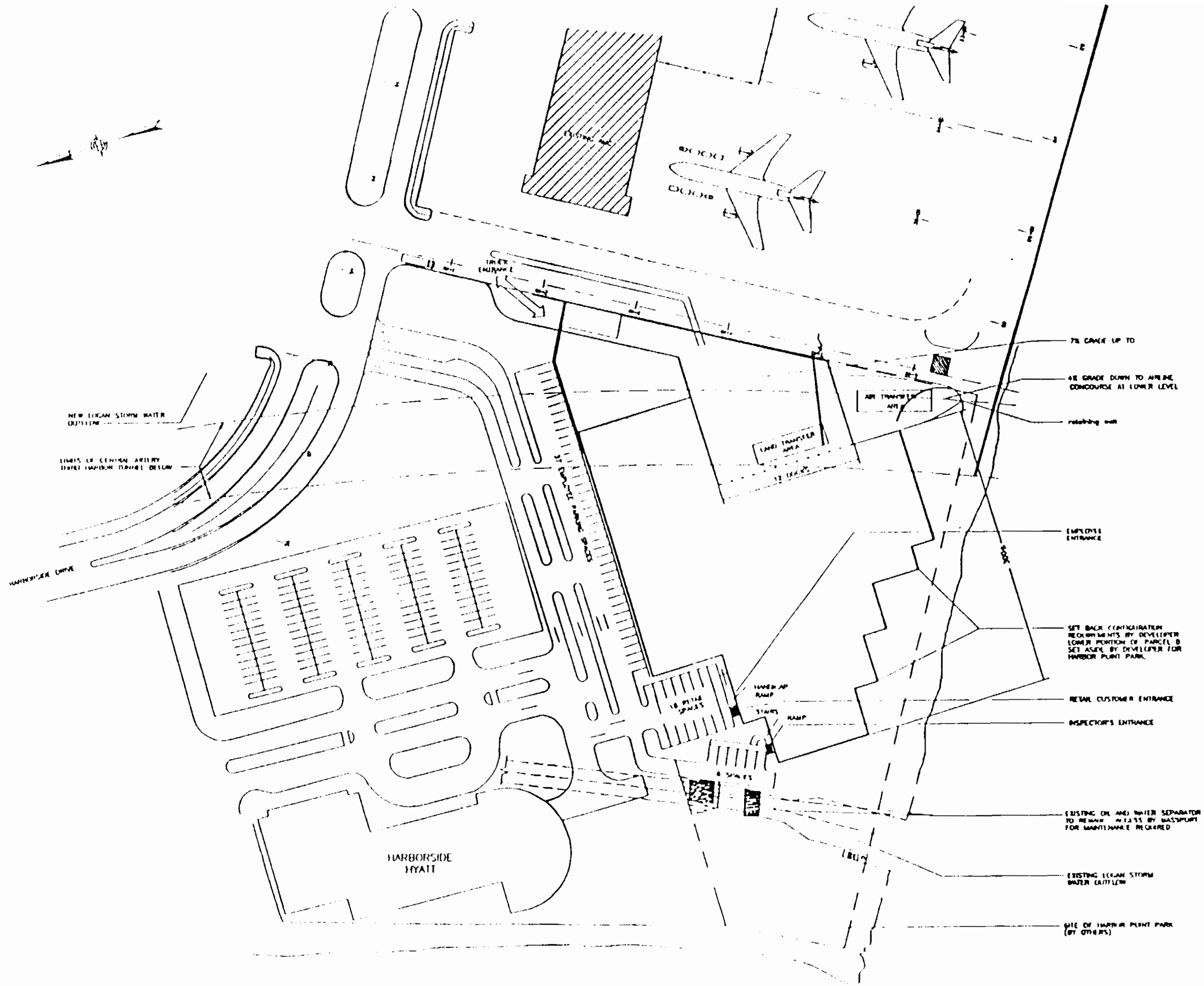


Figure 3. County AMC Proposed Site

Material handling systems have strongly influenced the reduction of the cost of delivering mail and parcel. Customer satisfaction is a benefit that hinges on the timely and careful handling of their valued mail. It is only a part of the automation initiatives that major mail and parcel delivery purveyors (i.e., Fedex, UPS and USPS) have put in place.

Material handling system is a process of transporting a package from its origin to its destination. During this process the package should be transferred using the shortest possible route. The definition of the shortest route will vary among different applications. Time constraints often prevail instead of distance as a yardstick in defining the route. The other element considered in the design is the systems capability to process different sizes, shapes and types of mail. The mail should be processed with care, ensuring that it leaves the system in the same condition as when it entered the system.

Material handling or mail handling system for the postal service can be subdivided into two general categories: bulk mail system and tray mail system. These categories use two different types of material handling equipment. The bulk mail relies heavily on the use of conveyor belts throughout the system. Meanwhile, the tray mail system nowadays uses the powered roller technology as opposed to the belt type conveyors. Both the bulk and tray system use gravity conveyors to interface between different conveyors and delivering the material at the end of the line.

2.1.1 Originating System

Originating mail will be unloaded from the inbound trucks at one of the docks and moved to the staging area. Mail containers will be staged and will be inducted into the system manually or mechanically using one of the ten unloading workstations. These workstations are capable of handling different types of mail container and eliminate manually handling piece by piece. The bulk conveyors (transport) will move sacks and parcels from the unloading area to a bar code reader. A single conveyor line will feed the bulk bar code reader. The tray conveyor system will move the trays and tubs from the unloading area to the bar code reader.

Bar code readers will attempt to read the bar code on the mail piece. If the mail piece has a readable bar code label, it will be diverted and moved to the originating universal sorting machine. Pieces with unreadable bar code or absence of it will then be diverted to the surge conveyors before reaching the manual keying stations. Transient pieces that need final destination information will also be manually keyed in. The surge conveyor gives the operator time to manually key in the information required without stopping the operations. Once the accepted bar code is applied to the mail piece then it is inducted to the sorting machine.

The surge conveyor allows the system to run continuously. It is equipped with sensors to provide the man machine interface. Normally called an "inching conveyor". It provides accumulation and incremental movement based on the demand of the operator. This prevents jam and spillage of the material being processed, providing a solution to the complex problem of synchronizing the human motions and machine operations.

A carousel sorting machine has been selected for the final design layout for both the originating and destinating system. Mail pieces inducted to the sorter either by automatic induction or from the manual keying stations will be tracked and transported to the appropriate run-out. Figure 4 shows the Originating System functional diagram.

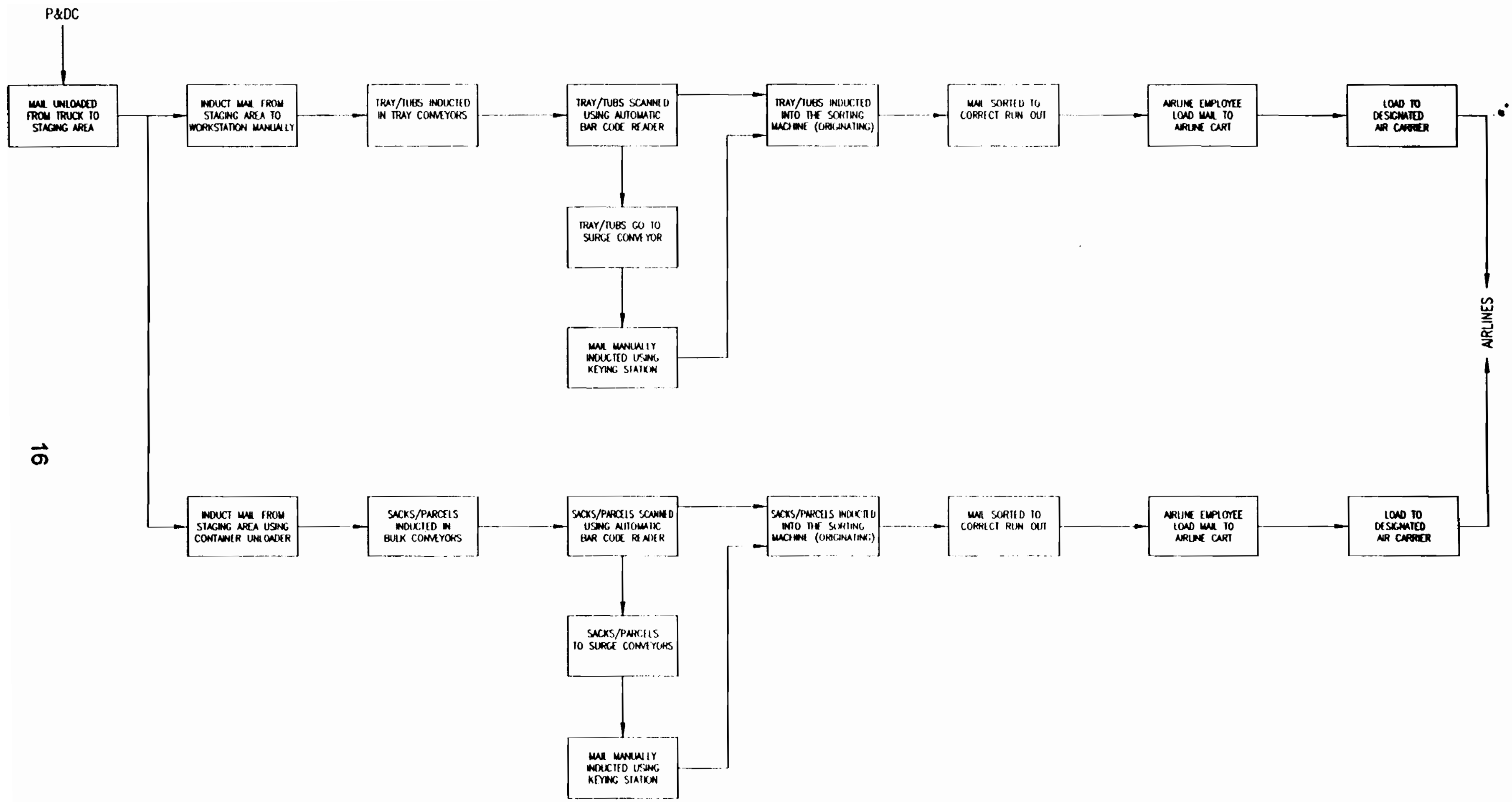


Figure 4. Originating System Functional Diagram

2.1.2 Destinating System

The destinating system will be configured with the same sorting machine as the originating system. Mail will be unloaded by the airline employees using two sets of belt conveyors. Each set of belt conveyors consists of a bulk conveyor for sacks and parcels and tray conveyors for letter trays and "flats tubs". The tray conveyors will carry letter trays and "flat tubs" to the automatic bar code reader. If the labels are readable then they are inducted to the destinating sorting machine. Similar to the originating system, pieces with unreadable bar codes are diverted to the manual keying station before their induction to the sorting machine. The bulk conveyor will also have the same feature described in the originating system. Figure 5 shows the Destinating System functional diagram.

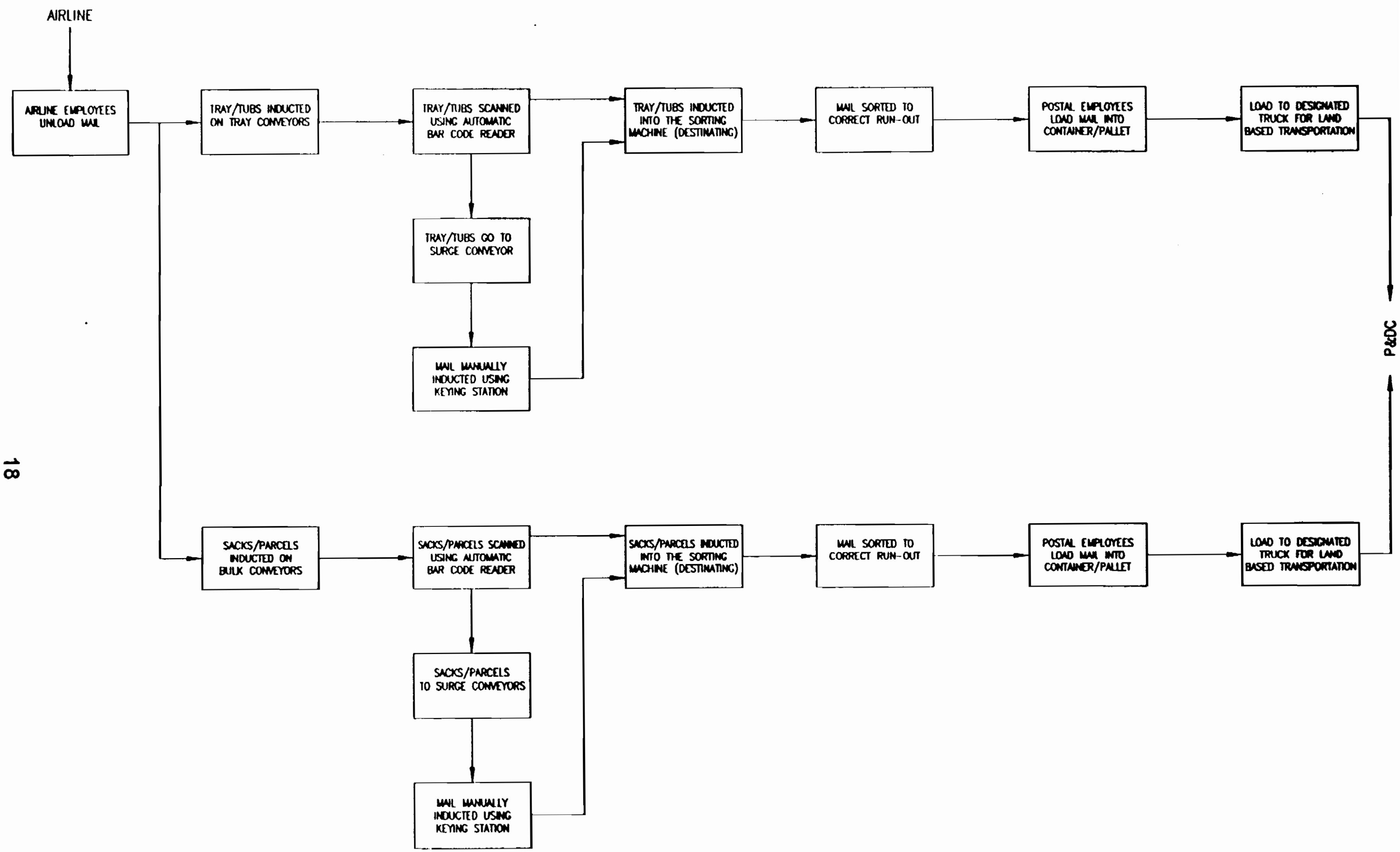


Figure 5. Destinating System Functional Diagram

2.1.3 Bulk Mail System

To ensure efficient handling of the mail, it is important to separate the mail into two major types. The bulk mail consists of sacks and parcels. The sacks should weight no more than 70 pounds. Sacks are also called "greenies". The parcels also referred as "outsides" can be as small as checkbook box to a box that has a maximum dimension of 30" W x 36"L x 24"H, and weight of 100 lbs. Sack has the lowest percentage of scan rate success, since the bar codes can be obscured during transportation. Handling of the bulk mail is totally different from the tray mail system. At times the bulk system can be designed to only transport sacks or parcels and not mix. The current systems being developed and deployed are capable of handling mixed (i.e., combinations of sacks and parcels). The significant difference in the design criteria is the transfer drop between transport/surge belt conveyors. The sack's transport will require a higher drop and impact cones to prevent system damage. The dedicated parcel system on the other hand requires lower drop heights and belt guides only.

2.1.4 Tray Mail System

The tray mail system must be capable of processing different type of trays including letter trays and flat tubs. The system will accept the following:

- **Corrugated fiberboard Managed Mail (MM) trays**

  Nominal size: 4 3/4" high, 10-1/4" wide at the bottom, and 22" long

  Weight: 1 to 20 pounds

- Corrugated plastic Managed Mail (MM) trays

  Nominal size: 4 3/4" high, 10-1/8" wide at the bottom, and 23-1/4" long

  Weight: 1 to 20 pounds

- Corrugated plastic Extended Managed Mail (MM) trays

  Nominal size: 6-1/4" high, 11-3/4" wide at the bottom, and 22-1/8" long

  Weight: 1 to 25 pounds

- Flat Tubs

  Nominal size: 11-1/2" high, 13-1/4" wide at the top, and 18-3/4" long at the top

  Weight: 3 to 50 pounds

- Trays for small parcel and bundles

  Nominal size: 14" high, 18-3/4" wide at the top, and 20-1/2" long at the top

  Weight: 3 to 40 pounds

The tray mail is more standardized than the bulk mail. The flexibility offered by sacks, and the undefined size of parcels lead to this dichotomy of the material handling system. It is appropriate to identify the mail to be processed ahead of time so as the two different systems can be adequately designed to handle the anticipated mail volume. The difference in the bulk and tray mail systems is not only focused on the use of the different conveying system but also on the system controls. The design of the tray mail system requires attention, especially on the incline and decline. During this condition the tray has the possibility of tipping that could cause mail spillage and damage to the system. To prevent such occurrence, tray mails are sleeved and banded.

The new technology being deployed uses sophisticated computer controls called a "smart" system. It allows the system to track the tray while in the system. When the requirement only calls for a simple tray transport, the computer control modules are not used.

2.2 Influence of Concurrent Engineering in the Design Activity

The key elements in providing a design in the material handling industry is timeliness and meeting the customer's requirements with a high degree of quality and reliability. These elements are cited as benefits attributed to the implementation of concurrent engineering. In the late '80s, the Department of

Defense issued a report, prepared by the Institute for Defense Analysis, defining concurrent engineering as:

> "... systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support. This approach is intended to cause the developers, from the outset, to consider all elements of the product life cycle from conception through disposal, including quality, cost, schedule and user requirements." [1]

Concurrent engineering is the solution to any fast track projects. These projects are time sensitive from design to deployment. This is true with the material handling industry. When designing a system, it is imperative that we capture valuable information regarding the different technologies deployed and their performances. Also equally important is the consideration of feedback from the workers that interface with systems that have similar functions and applications. This information based on experience is more valuable than any experimental results.

The concept of concurrent engineering is present in the use of the computer conferencing to keep every team members informed about the project progress and unresolved issues. During the design process it is essential that there is an open channel of communication between the team members. The County AMC was designed with a constant exchange of digital information. First, the architect has to create the conceptual building design, with the input from the mechanization design team on the minimum height requirements. After that, the organization needs to assess the progress of the design development before any formal design reviews. E-mail communication is the common link between different team members. The E-mail also reduces the cost of delivery of drawings through "attachment". Discussion about different design concepts can be sent and received in no time. Comparing this effort several years ago, the designers have to wait at least overnight to verify whether his/her design is feasible. Now it can be accomplished in a matter of minutes at a fraction of the cost.

The use of E-mail has improved the time required for receiving information and sharing of the different database has been also eased. It should be noted that during the design of any project that other disciplines from the organization who has a stake in the project are included in the dialogue (i.e., purchasing, logistic support, quality assurance, facility management, etc.).

2.3 Organization's Commitment

Success of any project relies heavily on the organization's commitment. However, in material handling and automation, the resistance might be felt more on the floor rather than the management. Nowadays, the workers welcome every opportunity to improve their working conditions. The threat of reduction in force is diminished once the organization embraced the quality concept of improving the quality of work life. It should be noted that the organization has always advocated promotion from within, and retraining then replaced reduction in force. This commitment is important for the mechanization design team for they have to determine the amount of mechanization that will be included in the project. Also, equally important is the climate. Will the prevailing condition permit a successful design project? Everyone in the organization should understand that they are all stakeholders.

The USPS is totally committed to improve customers' satisfaction and reduce operational cost. This commitment is evident from the rank in file employees to the head of the organization. "These capital investments will help us provide more consistent, high-quality service while reducing the costs and providing the opportunities to increase revenue", Post Master Marvin Runyon said in his remarks at the monthly of the Board. "For example, the $3.6 billion we proposed to invest in new technology will more than pay for itself of the course of the five-year plan in improved efficiency and customer satisfaction." [2]

2.4 Capturing the County AMC's Need

The need to build a facility or enhance its automation capability is often preempted by the growing demand for interstate transport of mail. However, here it was coupled with the current lease that will be expiring in a few years. This means that the new AMC must be operational before the existing AMC's lease expires. The local facility normally petitions the regional office for expansion. The request has to be supported by data and projections in the next ten years. Unfortunately, this information is difficult to obtain since it's an internal document that the customers themselves used to justify a request for automation improvement. Once the request is approved, the regional office forwards the request for automation to the head office for material handling engineering. This office begins its task by assigning a project manager who is responsible for the coordination of the different disciplines and overseeing the project from concept to acceptance.

In the County AMC, the design kickoff meeting was held at the head office. Present in the meeting were the architects, mechanization design engineers, industrial engineers and operations personnel from County AMC, and the project manager. Since the request was for a new facility, the project manager did not see the need to have the meeting at the site. Local representatives from the County AMC discussed the actual numbers of workstation (input) and run-outs (output) they need to sustain operation and which can generate enough revenue to pay for the system in the next five years. Provided also were the site plan and the number of floor levels that they need. The current volume of mail being processed and mail arrival profiles were also provided so that the mechanization design engineers can start laying out a configuration that would best meet the requirements. During the kickoff meeting everyone was expected to work with each other to meet a common objective, provide a design that would meet the initial requirements. After that, a series of design refinements from different disciplines occurred simultaneously. Each discipline was also expected to work with each other concurrently. Exchanging database and electronic documents during the design process is not only encouraged but mandatory.

Focusing on the needs of automation also called fixed mechanization; the material handling system will be divided into two components and will be located on separate floors. The upper level can accept and process sacks, pouches, outside parcels, sleeved and banded letter trays, lidded and banded small parcel and roll tubs, and lidded and banded flats trays from the truck dock and workroom floor to the airline loading platforms in the concourse on the lower level. The lower level can accept and process sacks, pouches, outside parcels, sleeved and banded letter trays, lidded and banded small parcel and roll tubs, and lidded and banded flats trays from the airline concourse to the Bull Ring roller tables and Automatic Container Loaders on the second floor.

Fixed mechanization projects shall follow the following standards set forth by the USPS: MD-15 Fixed Mechanization Guidelines, M-5000 Specification Standards for Mail Processing Equipment, AS-504 Space Requirement Handbook, and AS-505 Mechanization Design Specifications. These standards shall be used always where applicable and shall be followed not only by the designers but also the contractors that will fabricate and install the automation requirements for the County AMC.

The initial assessment of the need was that the system shall consist of two subsystems that will be labeled as Originating System and Destinating System. Each subsystem shall consist of the bulk conveyors, tray conveyors and sorting machine. The lower level shall be able to handle the airline carts while the upper level shall be used by the trucks that transport the mail on land. The system shall incorporate in the design the use of D&R (Destinating and

Routing) labels and other bar code labels currently in use.

2.4.1 Systems Requirements

The system will be housed in a two-story building. The system should be capable of processing sacks, parcels, trays and tubs that will be received by the AMC and distributed locally (destinating). The destinating mail arrival profile shows that the system should be capable of handling at least 15,800 pieces in a day. In addition it should be able to process the same type of mail that originates from the area (originating). The originating mail arrival profile shows that the systems should be capable of handling at least 23,800 pieces in a day. It is important that the time mail spends in the system be reduced to a minimum to meet the scheduled flights that will be used to transport interstate mail. Thus, the timing of the delivery of the mail using the land transportation (i.e., airline carts and trucks), the time required to introduce the mail to the system, and the time required to purge the system need to be studied in detail. To ensure that systems requirements are met, a simulation of the design was completed before the completion of the final operational systems layout (OSL).

2.5 Ensuring Customers Needs Are Met

XYZ's mechanization design team was concerned that there might be some issues that were not considered in the initial design phase. An outside consultant was contracted to determine the different configuration that will meet the County AMC's requirement. This provided an untainted analysis of the customers need. Quality of design focuses on determining the quality characteristics of products suited to the needs of the market, at a given cost: that is, quality of design develops from a customer orientation [7]. After that, the mechanization team and the simulation team started exchanging data.

The simulation was conducted to validate the adequacy of the different configurations used in the fixed mechanization. The model was developed using the parameters and system logic supplied by the USPS and the operational systems layout created by the mechanization team. The analysis was accomplished by creating simulation models representing proposed configurations and evaluating their performance under certain mail arrival conditions.

The simulation aspects of this project, involved a three-step process. The first activity was to gather performance data. This activity required reviewing pages of computer printout from both the site and simulation consultant. Design specifications and requirements from similar facilities were used as a guide in preparation of this project.

The second activity required synthesis and analysis of the different information. The relevant information was entered into a spreadsheet software for analysis. During the analysis, the building physical constraints (i.e., clearance height, and floor space), were established together with the different parameters required for processing. The model focused on the definition of the processing times of different operations. Besides the analysis that the spreadsheet offers, the same information was used in the preparation of the tables shown in the Appendix.

The last activity was to summarize the results. The ranges of processing times were defined. This information was vital in the determination of the adequacy of the design. The different runs were reviewed and the accepted scenarios were summarized. The simulation results and summary kept the different mail processing operations separate, so that process improvements can be performed at the next design level.

2.5.1 Simulation

The input data was based on twenty-four hour volume arrival profiles. The destinating volumes were provided by the County AMC office. Originating volumes were derived from the data provided by the County AMC office. The mail types assumed to be entered to the sorting systems were priority, outsides, green sacks, letter trays, and flat tubs. It was also assumed that express mail will be treated independently. Express mail would have its own processing window when it enters the sorting machine.

The destinating data used to represent the volume of mail sorted by the destinating system came from a seven-day hourly pieces count performed during the week of August 1-7, 1994, and averaged to represent a 24 hour data summary. By increasing the seven-day count piece by 25%, this accounts for the peak volume and future volume growth. The destinating volumes used in the simulation model show the different type of mail processed with the total piece count and are given in Table A-1.

The originating volume arrival profile was constructed by combining "Star Cluster" data and transportation schedules using a two-step process. The Processing and Distribution Centers (P&DCs) data generated by the "scan-where-you-band" (SWYB) and the transportation schedules were used to determine the arrival times at the AMC.

For each P&DCs serviced by the County AMC, an hourly report of pieces scanned was obtained from the “Star Cluster” system. The “Star Cluster” report gave weekly total counts of pieces scanned each hour. Hourly averages were determined by dividing the hourly totals by 5.5, which is the number of processing days in a week.

Contract truck schedules were also obtained for each of the P&DC. The volumes for each P&DC were matched with a truck trip from that P&DC. It was assumed that pieces scanned up to one-half hour before a truck departure would be transported on that truck to the County AMC. The volumes scanned between truck departures (from one half-hour before the first truck departure up to one-hour before the second departure) were added and the total was assigned as the load to the later truck departure. To ensure proper correlation between number of pieces and truckload, the mail piece volume was converted to General Mail Purpose Container (GPMCs) by dividing priority count (priority plus outsides) by 20 and the first class counts (trays, tubs and green sacks) by 26. The truck schedule determines the arrival of the mail at the facility. The originating arrival profile consisted of truck arrival times and associated loads of priority and first class GPMCs. To represent peak volume and possible future growth, the model was run with a 25% increase in the volume. The originating volume arrival profile is given in Table A-2.

Table 1 details the parameters used in the simulation models. The parameters are coupled with the configuration detailed in OSL drawings, see Figure 8 and 9. The computer package used as the platform for the simulation models was WITNESS, a graphics-oriented computer package provided and supported by AT&T ISTEL. The output from the simulations was imported into spreadsheets for analysis and inclusion in this report.

TABLE 1 Simulation Model Parameters

Parameter Description	Value
Unloading Rate (system induction)	300 pieces per hour
Bulk Conveyor Speed	70 feet per minute (4200 sacks/hr)
Tray Conveyor Speed	100 feet per minute (2400 trays/hr)
Keying Rate (Originating)	400 pieces/hr.
Keying Rate (Destinating)	600 pieces/hr.
Automatic Scan and Induction Rate	2100 pieces/hr.
Scan Success Rate (sacks)	5%
Scan Success Rate (parcels)	50%
Scan Success Rate (trays and tubs)	95%
Sorting Machine Throughput (Maximum)	6000 pieces/hr.

The simulation should be able to predict with the set of site specific input and the proposed design layout, whether the design meets the customer's needs. It was also assumed that the destinating arrival profile, given as hourly total was available for processing at the beginning of the hour. This is the best case scenario. The worst case is that the entire volume each hour arrives at the last minute of the hour. The result of the realization of the worst case scenario would be to delay the finishing time by one hour or less. For unloading the destinating mail, it was assumed that airline employees would make mail available quickly enough to keep pace with system. This means that a sufficient number of personnel would be unloading mail at a rate no less than that of the conveyors.

Since the objective of the simulation is to ensure the adequacy of the design compared with the needs of the facility, two configurations and several options were modeled. The original proposed system consisted of six unloading stations, two tray lines that merged to one, and a sorting machine with a throughput of 2400 pieces per hour. Scenarios for this system included increasing the number of unloading stations to eight, ten, and twelve and increasing the throughput of the sorting belt to 3600 and 4800 pieces per hour. The second configuration, included two tray lines with no merge, twelve system induction stations, and a sorting machine with a throughput of 6000 pieces per hour. Scenarios again included changing the number of system induction stations and sorting machine throughput.

2.5.2 Simulation Analysis and Results

Simulation runs for the first configuration OSL (Option A), see Figure 6 and 7, demonstrated that the merge points for the tray lines would be a system bottleneck. The merging of tray lines caused backups on the conveyor due to the assumption that each tray requires 30 inches of conveyor space. It was assumed that the sacks could be piled on the conveyor and singulated at the merge points, avoiding backups. Scenarios with fewer than ten unloading stations resulting in staging over 100 containers at each set of conveyors. Lower throughput resulted in inefficient use of the three keying stations and three automatic bar code readers. The first configuration showed a serious system bottleneck and efficiency below the customer's expectation.

Based on these deficiencies a second configuration OSL (Option B), see Figure 8 and 9, was developed and evaluated with simulation model. This configuration included twelve system inductions and a sorter with throughput of 6000 pieces per hour. These results are discussed in the following sections.

Using the simulation model and the second configuration OSL (Option B) the evaluation focused on throughput of the system, surge requirements, and determination of the necessary number of system induction stations. Several critical measures of system performance were identified and statistics on each collected. The measures were:

- Maximum time in system
    - (trays/tubs -originating system)
    - (sacks/parcels - originating system)
- Average time in system
    - (trays/tubs -originating system)
    - (sacks/parcels - originating system)
- Maximum time in system
    - (trays/tubs -destinating system)
    - (sacks/parcels - destinating system)
- Average time in system
    - (trays/tubs -destinating system)
    - (sacks/parcels - destinating system)
- Utilization of the sorting machine
- Keying station utilization
- Surge requirements
- Platform staging (originating system)
- Hourly purge schedule for airline run-outs

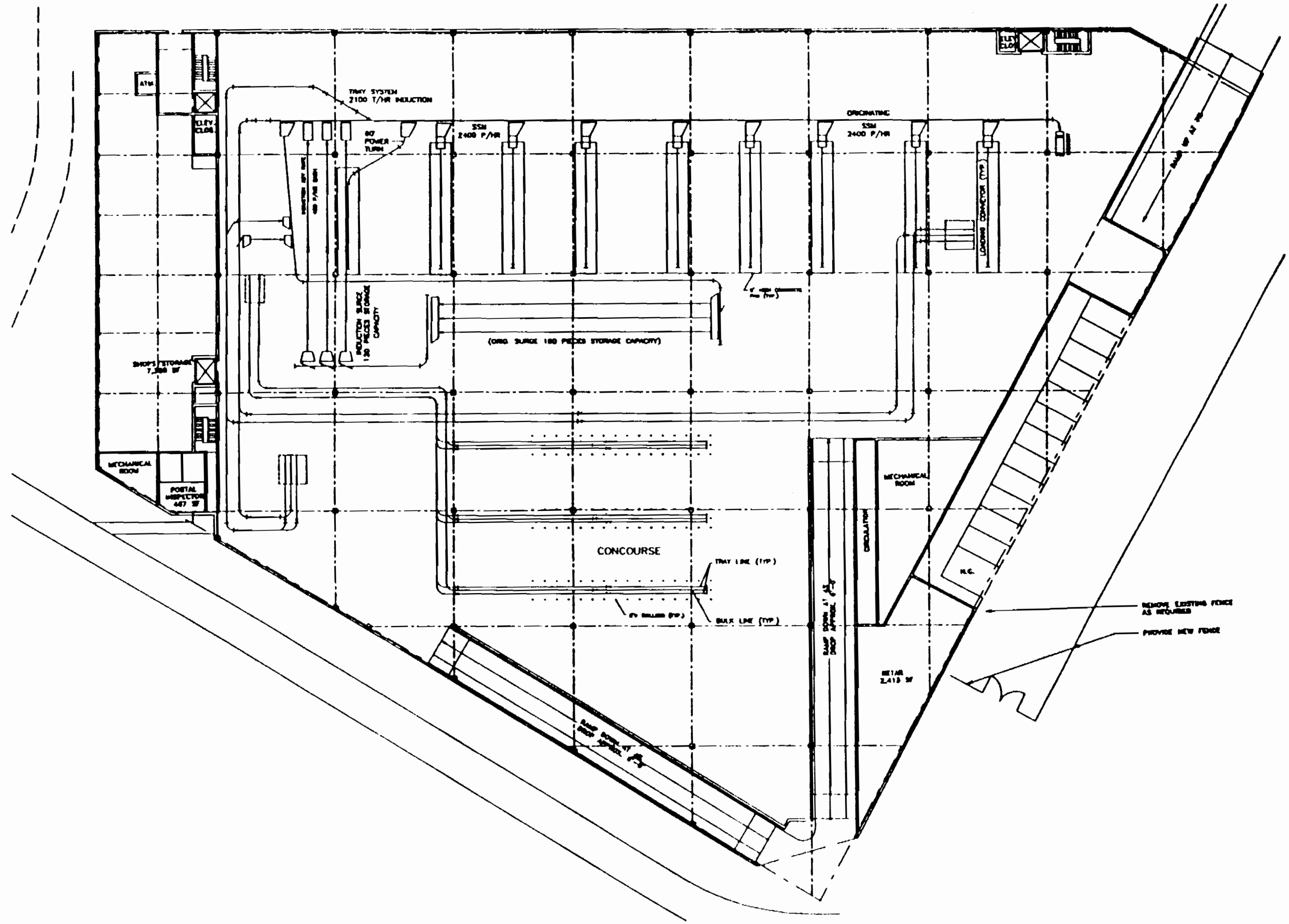


Figure 6. Operational Systems Layout (Option A) First Floor Plan

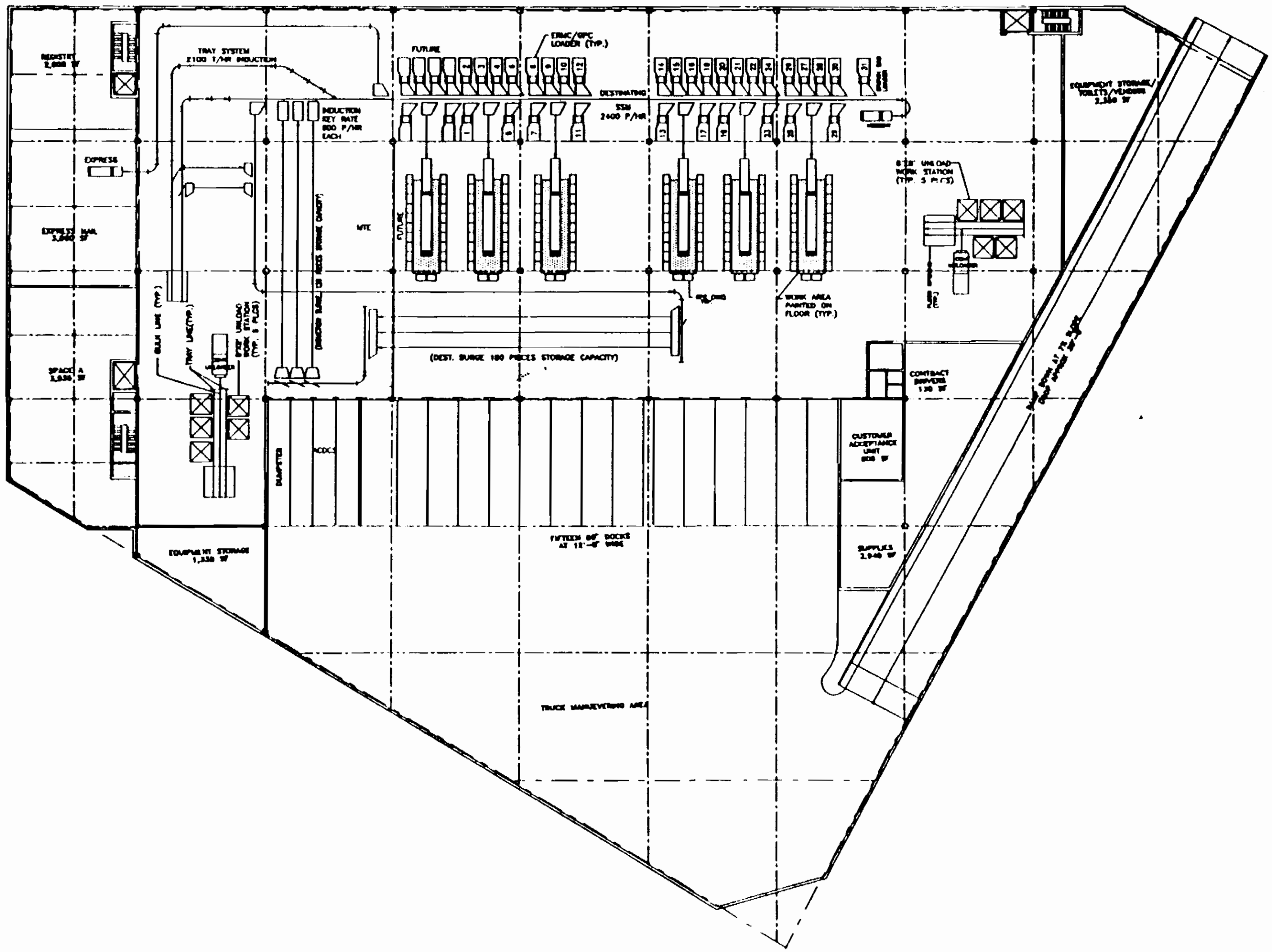


Figure 7. Operational Systems Layout (Option A) Second Floor Plan

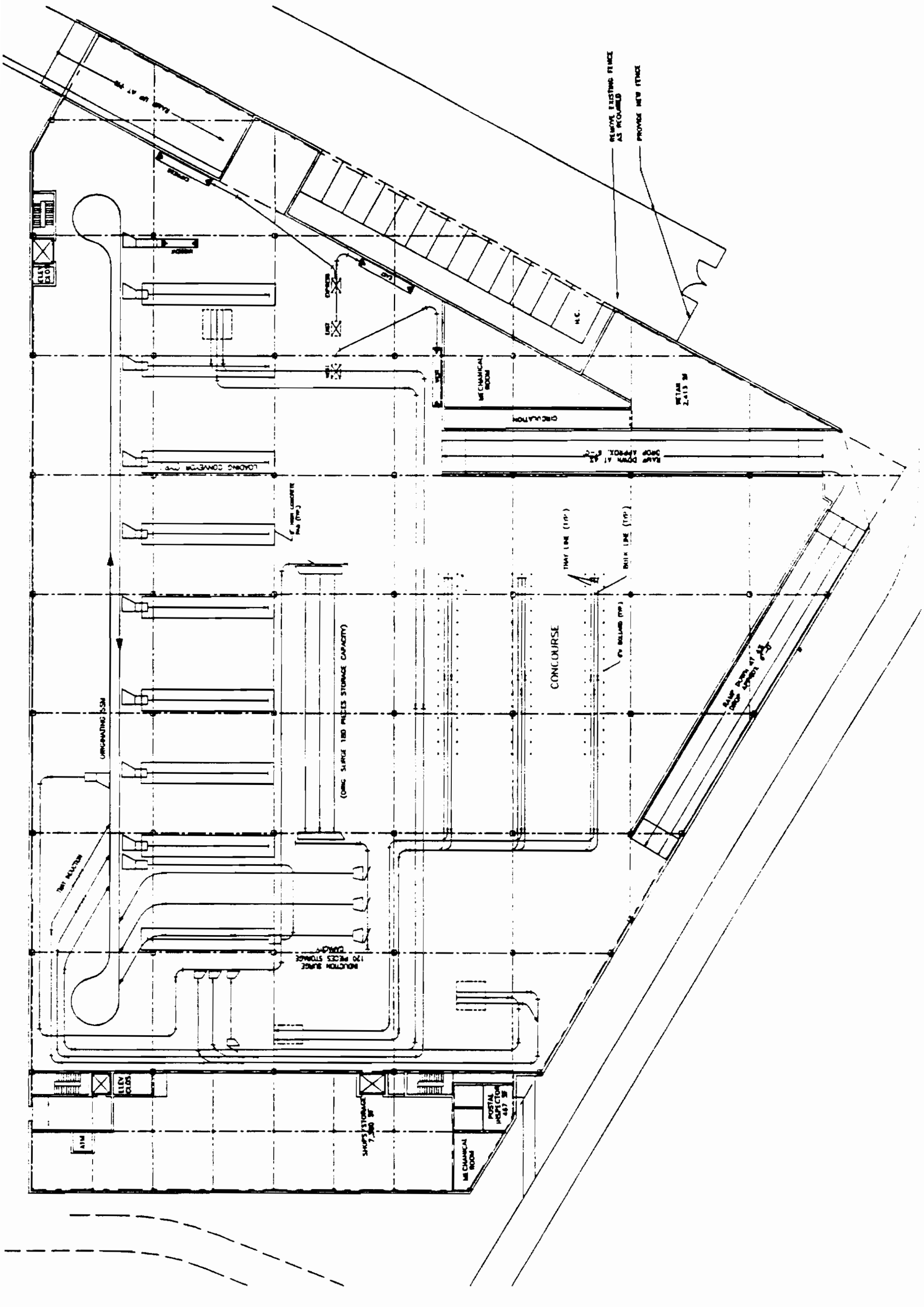


Figure 8. Operational Systems Layout (Option B) First Floor Plan

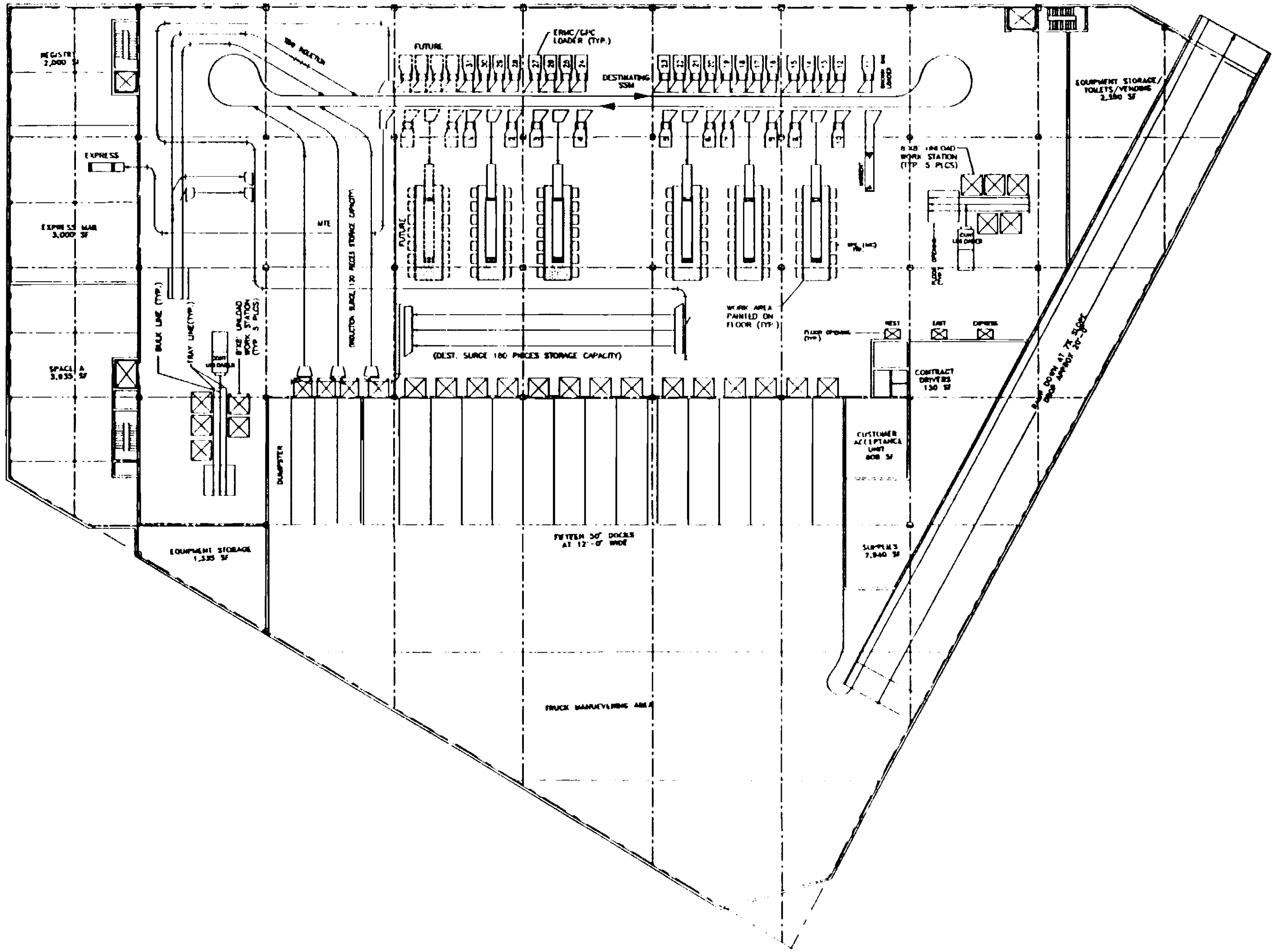


Figure 9. Operational Systems Layout (Option B) Second Floor Plan

2.5.2.1 Maximum Time in System (Originating System)

The time in the system was measured for each mail piece. Time in the system was calculated as the difference between the time the piece arrived at the inbound and the time the piece was sorted to the appropriate run-out. The maximum time in system was determined and collected for each hour.

During peak processing hours (0100 through - 0500) and normal volume, trays and tubs may spend up to 44 minutes in the system. When peak volumes were experienced, the time in the system went up to 60 minutes. Table A-3 gives an hourly listing of the maximum time in the system for trays and tubs. Statistics for manual induction and automatic induction are provided in Appendix A. During peak processing time the time in the system between the manual induction and automatic induction may differ by 10 minutes or more.

During the peak processing hours (0100 through 0500) and normal volume, sacks and parcels may be in the system up to 55 minutes. When peak volumes are experienced, sacks and parcels may be in the system for up to 63 minutes. Since most of the sacks and parcels are manually inducted, the pieces were not separated. Table A-4 gives an hourly listing of the maximum time in the system for sacks and parcels.

2.5.2.2 Average Time in System (Originating System)

The average time in the system was also calculated hourly. Each hour of the simulation, a running total of time in system for different mail type sorted was kept. The average was determined by dividing the total time in system for the hour by the number of pieces sorted during the hour. For trays and tubs, the average time in the system ranged from less than 5 minutes to approximately 25 minutes. For peak volume, the average time in system ranged from less than 5 minutes to approximately 41 minutes. For sacks and parcels, the average time in system ranges from 5 to 31 minutes. For peak volume, the average time in system ranged from 6 to 41 minutes. The hourly average times in system statistics are given in Table A-3 and A-4.

2.5.2.3 Maximum Time in System (Destinating System)

For the destinating system, the time in the system was calculated as the difference between the time a piece was unloaded by the airline personnel (assumed to be the beginning of the hour during which the piece arrived) and the time the piece was sorted to the appropriate run-out. The maximum time in the system was determined and reported for each hour.

During the destinating processing hours (0700 through 2200) and normal volume, the arrival profile was fairly constant. Trays and tubs may spend up to 23 minutes in the system. When peak volumes are experienced, trays and tubs may be in the system for over 29 minutes. Table A-5 gives an hourly listing of the maximum time in system for trays and tubs. There is no significant difference between the maximum time in the system for manual induction and automatic induction.

For sacks and parcels, the maximum time in the system during destinating processing hours (0700 through 2200) and normal volume was 38 minutes. When peak volumes are experienced, sacks and parcels may be in the system for up to 47 minutes. Table A-6 gives an hourly listing of maximum time in system for sacks and parcels.

2.5.2.4 Average Time in System (Destinating System)

The average time in the system for the destinating system was calculated hourly in the same way as in the originating system. For trays and tubs, the average time in system ranged from less than 5 minutes to approximately 12 minutes. For peak volume, the average time in the system ranged from less than 5 minutes to approximately 15 minutes. For sacks and parcels, the average time in the system ranged from less than 5 to 19 minutes. For peak volume, the average volume time in the system ranged from less than 5 minutes to approximately 23 minutes. The hourly average times in system statistics are given in Table A-5 and A-6.

2.5.2.5 Utilization of Sorting Machine

Sorting machine utilization for the originating system was measured as a count of the number of pieces sorted by hour and as a percent of total sorting capacity (assumed to be 6000 pieces per hour). During the peak processing hours (0100 through 0500) and normal volume, the utilization ranged from 2230 pieces per hour to 4249 pieces per hour. This utilization represented 37% and 71% of the maximum. During peak hours and peak volume, utilization ranged from 3118 to 3706 which was 42% and 74% of the maximum. The complete statistics for peak hours and peak volume were unavailable.

For the destinating system, during the processing hours (0700 through 2200) and normal volume, the utilization ranged from 392 pieces per hour to 1664 pieces per hour. This utilization represented 7% and 28% of the maximum. During peak hours and peak volume, the utilization ranged from 493 to 2083 which was 8% and 35% of the maximum. Detailed results are provided in Table A-7 and A-8.

2.5.2.6 Keying Station Utilization

Keying station utilization was measured by counting the number of pieces through each keying station. During the originating peak processing hours (0100 through 0500) and normal volume, the utilization ranged from 293 pieces per hour to 400 pieces per hour. Since the maximum keying rate was assumed to be 400 pieces per hour, this utilization represented 73% and 100% of the maximum. During peak hours and peak volume, the utilization ranged from 250 to 400 which was 63% and 100% of the maximum.

During the destinating processing hours (0700 through 2200) and normal volume, the utilization ranged from 27 pieces per hour to 244 pieces per hour. Since the maximum keying rate was assumed to be 600 pieces per hour, this utilization represented 5% and 41% of the maximum. During peak hours and peak volume, the utilization ranged from 43 to 307 which was 7% and 51% of the maximum. The complete statistics for peak hours and volume were unavailable. The detailed results are given in Table A-9 and A-10.

2.5.2.7 Surge Requirements

In the simulation model, the surge was represented as a buffer of unlimited capacity. Therefore, the numbers reported as surge requirements give the largest demand for surge experienced during the simulation runs. The originating system maximum surge capacity required during the normal volume period was 344 pieces and during the peak volume period the maximum was 455 pieces. The complete statistics for peak volume were unavailable. The destinating maximum surge capacity required during the normal volume period was 185 and during the peak volume period the maximum was 233 pieces. Statistics are given in Table A-7 and A-8.

2.5.2.8 Platform Staging

Platform staging was required for each of the two sets of system induction stations. These platform staging areas were modeled as a buffer with unlimited capacities. Staging requirements were measured and recorded each hour. The maximum platform staging capacity required during the normal volume period was 35 GPMCs at each of the unloading stations and during the peak volume period the maximum was 50 GPMCs.

2.5.2.9 Hourly Purge Schedule for Airline Run-outs

In the originating system, pieces were assigned to airlines based on the density profile for the major airlines servicing the County Airport. The following are the densities:

Table 2 Airline Density Profile	
Airline	Density
American Airlines	23%
USAir	17%
Delta Airline	15%
Northwest Airlines	15%
United Airlines	14%
Continental Airlines	9%
Transworld Airlines	7%

To develop the hourly purge schedules for the airline run-outs, it was assumed that four containers would be removed at a time and that containers would fill with combinations equivalent to 35 sacks, tubs, or trays and 70 parcels. Airline run-out densities for the seven major airlines servicing County Airport were derived from data supplied by the County AMC personnel. Table A-11 gives the number of pickups necessary for each airline during each hour.

2.5.3 Use of Simulation to Design the Operational Systems Layout

During the simulation analysis of Option B, several intermediate configurations were developed. This analysis started with the baseline OSL and modified it using the results from the different runs of the simulation model as defined above. This exercise ensured that the design could transform the simulation results. The final simulation results were used to influence the prefinal operational systems layout. After, the completion of this layout a formal design review was conducted with the customer and the different team members of this project. The final OSL was completed after all of the comments generated during the design review had been incorporated and everyone had accepted the final layout. See Figure 8 and 9, Operational Systems Layout (Option B).

The simulation in this project only ensured that the system being designed met the throughput requirements adequately. It was the responsibility of the mechanization design team to assure during the next design phase that all of the components used would ensure that there was no bottleneck in the system. This can only be achieved by using standardized components and material handling experiences.

During technical assessment reviews and design reviews of different projects, USPS employees normally vent their frustrations and share success stories of different design configurations' performance. These are valuable inputs from the operational personnel are unsolicited and unbiased. These feedbacks are vital to the mechanization design team. Lessons learned in previous projects, should be incorporated in the next succeeding projects, a "continuous improvement process". For example in some cases the selection of transfer chute can cause a potential bottleneck (i.e., spiral chute or a box transfer). Some sites have also their preference. This is a result of experience in their operations. The geographic location of the site has an influence on the success of the system. A humid environment can cause jam points that normal don't occur in non-humid environment. These situations warrant some adjustments in the design and selection of the standardized components. This type of information is vital to the success of the system that the simulation model cannot provide.

In summary, maximum times in the system were heavily influenced by unloading times. If large volumes entered the facility simultaneously, the processing time for the last pieces would be high. Table A-12 gives the arrival time for each truck, the time at which unloading started and finished, and the total time elapsed when the last piece was unloaded. This table shows that unloading times may account for over half the time in system.

Adding more unloading stations can lower the unloading times by up to 10 minutes during peak hours. If consideration was given to adding more system induction, it should be verified that the conveyors would be able to move volumes away from the stations in a timely manner.

The following was intended to clarify the time in system issue. The throughput of the system was limited by the unloading stations to 3600 pieces per hour. The system, beginning from an empty state, could process a batch of 3600 pieces in one hour. The last piece in the batch would be in the system for an hour plus processing time at each station. If the arrival of 3600 pieces occurred at a steady rate of 60 per minute, the last of the 3600 pieces would only be in the system one minute plus processing time at each station. These were the two extremes.

During the peak hour of the normal volume period, the simulated system processed 4250 pieces. The system began the hour in a loaded state and received more pieces during the hour. While it would be difficult to do a static calculation for the maximum time in the system for pieces processed during the hour, it could be seen that time in system will depend on stacking of arrivals. Further, the design had met the adequacy requirement defined by both the destinating and originating arrival volumes with accommodations for future growth.

2.6 Baseline for Completion of Conceptual Design

An evaluation and confirmation of XYZ Company's systems approach in developing the final OSL led to my project, to complete the conceptual design of the County AMC.

Critical analysis of the engineering activities of the XYZ Company was important to determine whether they have addressed the needs of airport mail center under design. It was identified that XYZ Company has started the design and needs analysis before employing the services of a simulation consultant. The objective of the simulation consultant was to validate and verify the information gathered by XYZ Company in the developing the design for the County AMC.

The simulation consultant was not present at the kickoff meeting. This can be viewed as an unacceptable practice of concurrent engineering. However, the decision to hire the simulation group after the kickoff meeting was appropriate. Another view of the needs was important and their view was untainted. If the simulation engineers were present in the kickoff meeting, their activity would be directly influenced by the USPS view of the problem. This might have a negative effect in the identification of the facility's needs and the extent of mechanization required. The activities of the simulation consultant started with the briefing conducted by XYZ's designers. After that, the data gathering began and constant interface between designers and the simulation engineers started.

The result of the simulation had addressed all the requirements of the project. In the early stage of the simulation activities, the need for a high speed sorting machine had surfaced. This forced the mechanization designers to identify a different source of sorting machine. Since the simulation engineers were only concerned in meeting the target number for the facility's capability, the partnership between the engineering activities had enabled the team to provide a design that addressed the needs of the County AMC.

The employment of the simulation consultants and the timeliness of their presence in the project were factors that led to a successful needs analysis. Another factors that can be attributed to the success of the project were the effective communication activities engaged by both engineering discipline. This open channel of communication and working towards a common goal was the main ingredient in the success of the design activities.

3.0 Completion of the Conceptual Design

Consistent with the principles of conceptual design, the scope of this original effort is limited to the critical areas of concern to be included in the contract requirements for the next design phase. Using the Operational System Layout created by XYZ Company, the conceptual design was completed by addressing additional characteristics, which are critical areas of concern that will eventually become part of the system specification. In completing the conceptual design the following area were addressed:

1. Identify critical areas that require constant human interfaces.
2. Develop system training guidelines
3. Develop a guideline for system maintenance - equipment access
4. Develop testing and acceptance guidelines
5. Perform system reliability analysis
6. Define system supportability
7. Define system upgrade and disposal
8. Provide economic justification

In each area, guidelines for further detailed design to be accomplished during the preliminary and final design phases are outlined. More specific design details are provided in subsections 3.1, 3.5 and 3.6. The economic analysis which justifies continuing forward in the next design effort is discussed in subsection 3.8.

The success of a manned operation system requires both human interface and operations of the system complement each other. The presence of physiological or psychological problems compromised the success of the system. This problem was addressed in the design criteria for human engineering. Beyond the issue of human engineering, the system's success also hinges in the rigorous specifications that consider the design for reliability, maintainability, supportability and disposal. Ultimately, the single factor that can decide whether the project will be deployed or tabled is the total cost of the project. Can the project justify its existence? Can the project sustain itself over its anticipated life? These are questions that should be answered by the cost estimates and operational expenses.

The cost of the system will be the bottom line in this effort. The different "ilities" will influence the price tag of the material handling system. In this conceptual design effort only the critical aspects of the design were addressed. After these critical "ilities" are considered, the cost of the features were evaluated for the monetary influence on the design.

In preparing the cost analysis, the criteria assume that the new facility will be able to pay for itself in the next five years. The preliminary cost estimate is established by using the conveyor types and lengths, and the different equipment identified in the design. The information used to prepare the cost analysis is the combination of the mechanization cost estimate, cost of leasing, building construction cost, and cost of operation. Correction factors will be used to generate the most current data. In some instances, reasonable dollar figures were used to complete the cost analysis calculation and proof of capital recovery.

The cost analysis model is based on the models described in the systems engineering textbook, "Life-Cycle Cost Analysis" on page 661 [9]. The preliminary cost of the system will be defined in ten-year and five-year capital recovery time period. The detailed analysis is described in subsection 3.8. This allows the decision makers to have an insight should unforeseen situations occur.

A good systems engineer should consider all design criteria to ensure the success of the project. The success of the project is reflected in the quality of workmanship of the design team, a marketing tool that rewards only the best company in this market niche.

3.1 Human Engineering Considerations

The critical concerns with respect to the human engineering aspects of the design were defined using configurations that are designed using current ergonomics guidelines and currently deployed at various AMCs. Human engineering design requirements are incorporated in the delivered OSL. The spaces required to operate and maintain the system safely were addressed in the development of the OSL. For example, the distance between run-outs and inductions accounted for the safe storage and staging of empty and loaded containers. It also ensures that there are ample spaces for the workers to move around. Furthermore, the space requirements also accounted for the safe operation of forklifts and jitneys that transport that containers.

Once the design reflects the required spaces to operate safely and efficiently, the local representatives normally have concerns on some areas of the design. Here, the concerns are at the 1) Keyer Induction area and 2) Concourse area. These areas are constantly staffed during operations and are critical in the success of the system.

3.1.1 Keyer Induction Area

The ability to interface the human interaction and the conveyor feeds for the manual key induction presents a major problem. A fast keyer will be under utilized and be bored if there is not enough mail coming to him for processing. On the other hand if the keyer is a little bit slow then, he or she will be overwhelmed and the mail just gets piled up. The system allows the operator to use fixed overhead scanners, hand held scanners or voice activated encoder. This option allows the operator to select his preference and eliminate repetitive tasks.

When the mails are inducted to the surge subsystem, the induction conveyor uses an indexing surge conveyor. The surge conveyor shall discharge the mail onto an orientation table at the induction workstation. See Figure 10. The operator shall orient the mail, and code it, either by scanning the Destinating & Routing (D&R) tags or bar coded Dispatch label under some fixed, overhead scanners, by hand held scanner or by reading the 10 digit CIN code from the dispatch label aloud into the "Verbex" keying station. In the event that the dispatch label is scanned or the CIN code is entered through the keystation. The system will generate a D&R tag at the printer local to the operator. After that, the mail is pushed to the induction unit.

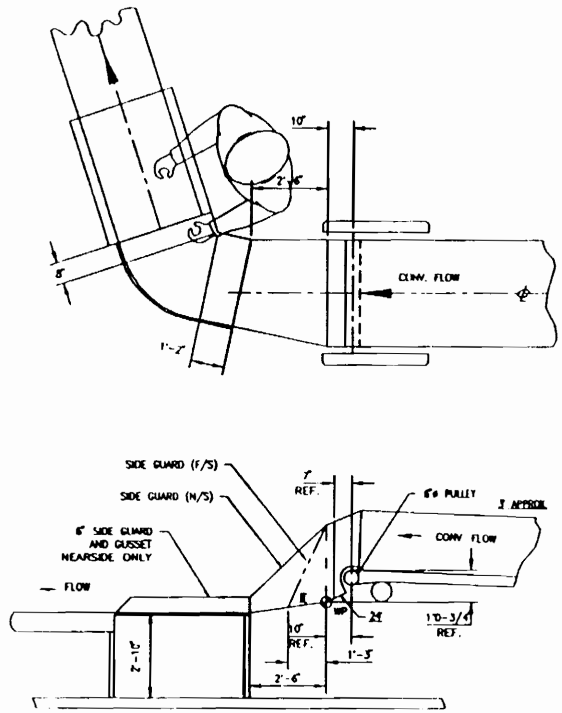
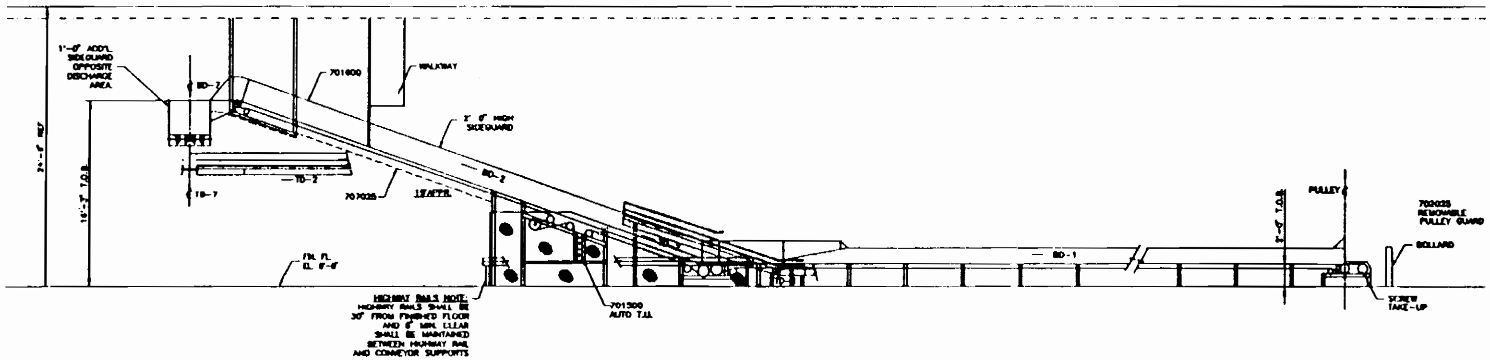


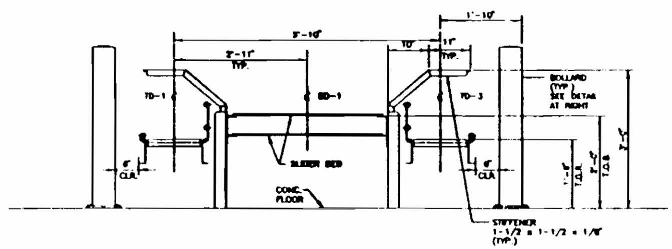
Figure 10. Keyer Induction Station

3.1.2 Concourse Area

At the airline course area, three bulk conveyors are transferred to a common conveyor where the mail passes a series of bar code scanners. Six tray mail conveyors are provided, two at each of the induction bulk conveyor. Two conveyors each are located side by side below each bulk conveyor to provide easy access from either side. This configuration shown on Figure 11, reduces the lift over height for both the bulk conveyor and the tray conveyor. The lift over height and the distance from the conveyor and the user's reach have always been a challenge in the design of the airport mail center. This configuration is currently deployed at the Washington National Airport. The designs addressed not only the lift over and reach requirements but also eliminate the unnecessary moving of the airline carts. Conveyor system is designed to accommodate carts parked alongside the conveyor, during unloading. Bollards are installed to protect the conveyors for any accidental run-in or bumps resulting from the movement of the different airline carts. The distances between bollards are also defined to be 4 feet so that airline employees can unload their cart with ease. Four feet will also prevent the airline cart from accidentally hitting the system, since the cart is about 5 feet minimum in length. The concourse area has provided enough maneuverability room for the airline carts. This allows better use of the system and further reduces any damage that can result to unscheduled downtime.



<u>**ELEVATION OF CONVEYORS BD-1 & BD-2**</u>



<u>**SECTION A-A**</u>

Figure 11. Concourse Loading Conveyor Configuration

3.2 Training Guidelines

The following guidelines should be helpful in completing a detailed training plan during the final design phase. For every system designed a training plan shall be incorporated in the design. The training plan shall include manuals and actual training on the operations and maintenance of the equipment. It is the responsibility of the contractor to provide the training on-site to the employees who will operate and maintain the system. The training program shall include a pre-training and post-training test. This assessment shall ensure the appropriateness of the training program. The training program should precede the installation testing. It is important that the postal employees who will be working with the system have "hands-on" training before any system testing. The training shall include handling of defective components as part of the classroom training. The instruction shall cover both the electrical and mechanical aspects of the operation and maintenance of the system. Training methodology shall include formal class work, experiential work, and instructional materials. Training courseware must consider how the trainee learns and the pace at which he or she learns, and it must incorporate these factors into training courseware [7].

The training shall be provided by a competent instructor for formal instruction of supervisors and employees who will be charged with operation of the system. The training program shall include at least the following topic:

- System Concepts
- Mail Processing Requirements
- Controlling Mail Flow as related to the conveyor system
- Understanding Operating Reports
- Understanding Maintenance Reports
- System Control Computer Activities
- Computer Commands

The instructor shall be totally dedicated to the training program and shall have no other duties during instruction. The objective of the training is to provide the appropriate personnel with knowledge and operating proficiency of the system. Therefore, the training shall consist of no less than 80 percent hands-on-equipment and the remainder being devoted to system related topics including "malfunction recognition" and "corrective action".

3.3 System Maintenance - Equipment Access

The following guidelines ensure that adequate access is incorporated in the final design. Since OSL defines the amount of space allocated for use in the processing of the mail, it was also deemed important at this level that the space required for maintainability is addressed. During the design of the location and length of conveyors, it will be important for the designers to consider the space required for motor platforms, walkways, gates, ladders, and others. This space requirement is defined in the MD-15 "Fixed Mechanization Guidelines" and is acceptable for deployment.

The proper size, positioning and elevation of the motor platform and the addition of walkways will make preventive maintenance a daily routine as opposed to a chore. Visual inspection during different work shifts allows the system to be check for any problem that may present a catastrophic failure. By providing the adequate space for maintenance, the system will have a better repair time and inspections can be easily accomplished.

3.4 Testing and Acceptance Guidelines

During the development of the design, it is important than the designers select the components that have met the required quality standards. If the component or subsystem has not been tested, it is incumbent upon the designer to ensure that the selection of this component will not cause any unwarranted delays or rejection of the system for failure to meet customers' standards.

The County AMC will undergo three phases of testing before systems acceptance. The test result should be acceptable to the USPS representatives both local and regional before acceptance. Tests shall be accomplished in three phases: 1) installation, 2) preliminary operating tests, followed by a 3) 45-day operational test.

During the test, the different components and system controls are tested to ensure proper installation and operation as described in the specifications and design drawings. Any workmanship problems are normally identified and a punch list of deficiencies is generated. The components for the conveyors are procured items and purchase often in lots. The conveyor itself has to be assembled or built in the contractors facility and brought in the site for installation. Knowing that there can be potential problems during transportation and handling, the first phase of testing enables the contractor to isolate these problems before the preliminary operating test.

Before any test, the contractor shall present an acceptance test procedure for both installation and operating tests. The plan shall be submitted for approval of the Contracting Officer sixty days before the anticipated time of test. The test plan must be approved before any test. The test plan should address the following areas:

- **Verification of critical mechanical dimensions**
- Verification of major mechanical and electrical components against the approved cut sheets and bills of materials.
- Verification of all safety related features
- Verification of all specified mechanical and electrical operational features
- Verification of compliance with noise level requirements
- Verification of compliance with specified throughput requirements

The test plan shall provide a matrix containing the components, dimensions, noise levels, and expected systems response. Space next to each criterion shall be provided for use of by the authorized person conducting the test. The testing personnel shall record the measured dimension, noise levels and observed response.

Critical components should be identified at an early stage. They should be included in the test configuration for "life testing". All components used in test configurations shall be identical to those which are to be used in actual installation. The contractor shall operate the test units for a continuous number of hours, as specified in the "life testing" requirements for each specific component at the specified operation rate, stopping only for adjustments or lubrication as permitted in the specific requirement of each device. An event recorder shall be used to collect the necessary information to complete the "life testing" of specific components.

In failure mode, effect and criticality analysis (FMECA), a product is examined at the system and/or lower levels for all the ways in which failure may occur [8]. This type of analysis is the framework for "life testing". It is important to identify the failure mode for it is the symptom of failure, as distinct from the cause of failure, which consists of the proved reasons for the existence of the symptoms. The analysis shall include and should not be limited to the following:

- Safety

  Injuries are the most serious of all failure effects and should be handled through a special program.

- Effect on downtime

  Designers must consider this issue when the system is being developed, such that subsystems maintenance requirements (preventive and corrective) are defined ahead of time to minimize downtime. Designers have to remember that the success of the project hinges on the on-time arrival and departure of the mail.

- Access

  What hardware items must be removed to get to the failed components? Is it easy to get to the conveyor with the failed components?

- Repair planning

What is the anticipated repair time? Are special tools required to bring the system on line again?

- Recommendations

What design changes should be made? Should there be additional tests? Are the instructions in the inspection, operations, and maintenance manual adequate?

To ensure uniform and reliable testing, the contractor shall request the test materials for use in testing six weeks in advance. The dummy mail shall be used for component and system debugging. The contractor shall be responsible for providing the instruments to be used for testing (i.e., tachometers, timer/displays, etc.). It is also imperative that the contractors have all the necessary materials, equipment, and experienced personnel to ensure safe and successful performance of each test.

Upon completion of the test, the contractor shall provide the Contracting Officer a report detailing the hours of the test, times and extent of maintenance, failure analysis and time to repair. It is also essential that all high-wear areas be identified during the in-house tests.

The installation test procedures shall be designed to assure that all components are functioning correctly and that the functional requirements specified are satisfied. As part of the installation test, maintenance manuals shall be reviewed and approved for their completeness and accuracy of the documents. All of the procedures covered in the manual shall be verified during the installation test. Results shall be forward to the contracting officer for his record of system performance under test.

The process control system installation shall be tested in accordance with an approved procedure for a period required to verify all system features and functions. The duration is nominally forty (40) machine operating hours. USPS shall furnish mail and provide the necessary postal operating personnel during this test period. Complete system operation must be demonstrated to the satisfaction of the Contracting Officer. The installation test period shall not be used by the contractor to accomplish debugging.

Once the installation test is completed and the deficiencies are corrected, the next phase of testing is conducted. The third phase of testing shall enable the facility to rigorously test the system to the specified requirements. Furthermore, the last phase shall allow the facility to use with the system, with contractors' personnel support on standby.

3.5 System Reliability Analysis

The system reliability analysis predicted that the both originating system and destinating system are within the accepted system reliability of 75%. The reliability calculations were based on the "Reliability Component Relationships" [9]. For a system that has a subsystem in series, such that subsystem A, subsystem B, and subsystem C are in series; the reliability of the system is expressed as:

$$R = (R_A)\,(R_B)\,(R_C)$$

For a system that has a subsystem in parallel, such that subsystem A being in parallel with subsystem B; the reliability of the system is expressed as:

$$R = R_A + R_B - (R_A)\,(R_B)$$

Using spreadsheets, the formula was encoded and each conveyor reliability was assumed to be .98. The reliability of both the bulk mail and tray mail system for both the originating and destinating system was calculated. See Figure 12 and 13 for conveyor designations.

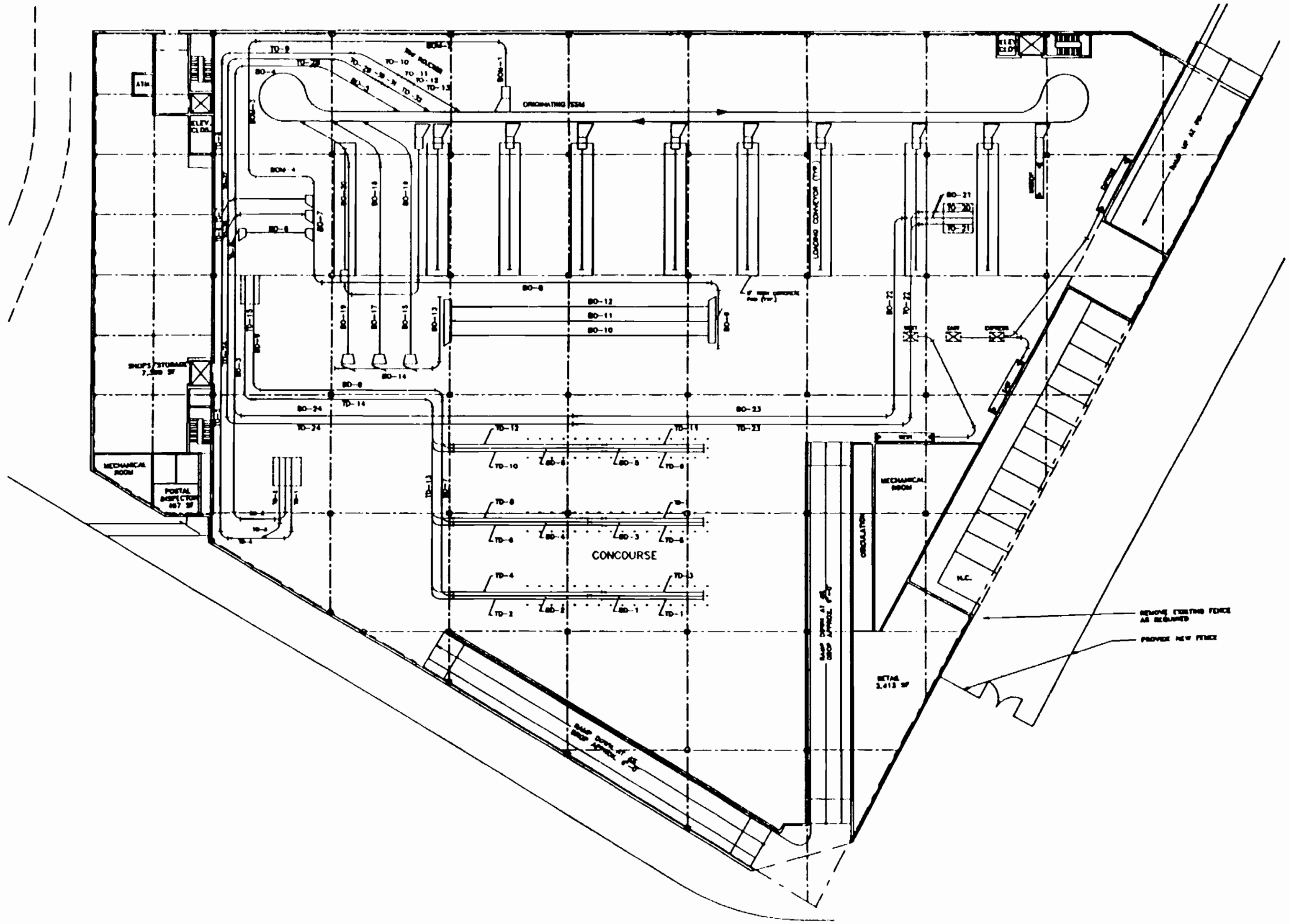


Figure 12. Operational Systems Layout First Floor Plan (Reliability Calculation)

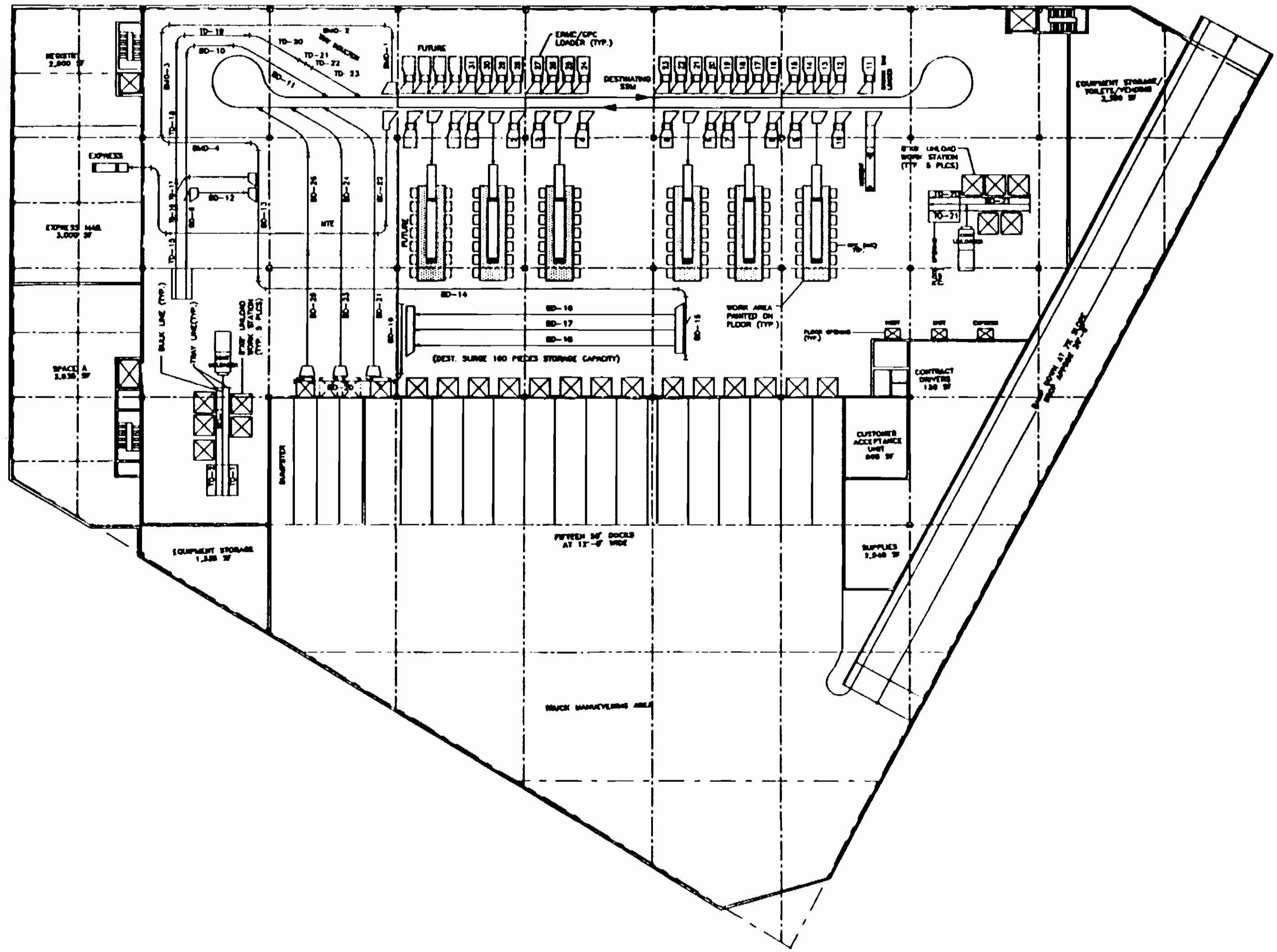


Figure 13. Operational Systems Layout Second Floor Plan (Reliability Calculation)

BULK CONVEYOR ORIGINATING SYSTEM

CONVEYOR NO.	RELIABILITY OF CONVEYOR	RELIABILITY CALCULATION	RELIABILITY AT CONVEYOR NO.
BO-1	0.98		
BO-2	0.98		
BO-3	0.98	BO-1 - BO-3	0.9412
BO-4	0.98		
BO-5	0.98	BO-3 - BO-5	0.9039
BO-6	0.98		
BO-7	0.98		
BO-8	0.98		
BO-9	0.98	BO-5 - BO-9	0.8337
BO-10	0.98		
BO-11	0.98		
BO-12	0.98	BO-10 - BO-12	1
BO-13	0.98		
BO-14	0.98	BO-13 - BO-14	0.9604
BO-15	0.98		
BO-16	0.98	BO-15 -BO-16	0.9604
BO-17	0.98		
BO-18	0.98	BO-17 - BO-18	0.9604
BO-19	0.98		
BO-20	0.98	BO-19 - BO-20	0.9604
		BO-9 - BO-20	0.8336
BO-21	0.98		
BO-22	0.98		
BO-23	0.98		
BO-24	0.98	BO-21 - BO-24	0.9224

		BO-21 - BO-24 - BO-3 - BO - 20	0.8171
BOM-1	0.98		
BOM-2	0.98		
BOM-3	0.98		
BOM-4	0.98	BOM-1 - BOM-4	0.9224
		BOM-1 - BOM-4, BO-3 - BO-20	0.7691

BULK CONVEYOR DESTINATING SYSTEM

CONVEYOR NO.	RELIABILITY OF CONVEYOR	RELIABILITY CALCULATION	RELIABILITY AT CONVEYOR NO.
BD-1	0.98		
BD-2	0.98	BD-1 - BD-2	0.9604
BD-3	0.98		
BD-4	0.98	BD-3 -BD-4	0.9604
BD-5	0.98		
BD-6	0.98	BD-5 - BD-6	0.9604
BD-7	0.98	BD-1 - BD-7	0.9799
BD-8	0.98	BD-7 - BD-8	0.9603
BD-9	0.98		
BD-10	0.98		
BD-11	0.98	BD-9 - BD-11	0.9038
BD-12	0.98		
BD-13	0.98		
BD-14	0.98		

BD-15	0.98	BD-9, BD-12 -BD-15	0.8858
BD-16	0.98		
BD-17	0.98		
BD-18	0.98	BD-15 - BD-18	0.8858
BD-19	0.98		
BD-20	0.98	BD-18 - BD-20	0.8507
BD-21	0.98		
BD-22	0.98	BD-21 - BD-22	0.9604
BD-23	0.98		
BD-24	0.98	BD-23 - BD-24	0.9604
BD-25	0.98		
BD-26	0.98		0.9604
		BD-1 - BD-9, BD-12 - BD-26	0.8506
BDM-1	0.98		
BDM-2	0.98		
BDM-3	0.98		
BDM-4	0.98		0.9224
		BDM-1 - BDM-3, BD-13 - BD-26	0.8337

TRAY CONVEYOR ORIGINATING SYSTEM

CONVEYOR NO.	RELIABILITY OF CONVEYOR	RELIABILITY CALCULATION	RELIABILITY AT CONVEYOR NO.
TO-1	0.98		
TO-2	0.98		

TO-3	**0.98**	**TO-1 - TO-3**	**0.9604**
TO-4	0.98		
TO-5	0.98		
TO-6	0.98		
TO-7	0.98		
TO-8	0.98		
TO-9	0.98		
TO-10	0.98		
TO-11	0.98		
TO-12	0.98		
TO-13	0.98	TO-1 - TO-13	0.7847
TO-20	0.98		
TO-21	0.98	TO-20 - TO-21	0.9996
TO-22	0.98		
TO-23	0.98		
TO-24	0.98		
TO-25	0.98		
TO-26	0.98		
TO-27	0.98		
TO-28	0.98		
TO-29	0.98		
TO-30	0.98		
TO-31	0.98		
TO-32	0.98	TO-20 - TO-32	0.8004

TRAY CONVEYOR DESTINATING SYSTEM

CONVEYOR NO.	RELIABILITY OF CONVEYOR	RELIABILITY CALCULATION	RELIABILITY AT CONVEYOR NO.
TD-1	0.98		
TD-2	0.98	TD-1 - TD-2	0.9604
TD-3	0.98		
TD-4	0.98	TD-3 -TD-4	0.9604
		TD-1 - TD-4	0.9984
TD-5	0.98		
TD-6	0.98	TD-5 - TD-6	0.9604
TD-7	0.98		
TD-8	0.98	TD-7 - TD-8	0.9604
		TD-5 - TD-8	0.9984
TD-9	0.98		
TD-10	0.98	TD-9 - TD-10	0.9604
TD-11	0.98		
TD-12	0.98	TD-11 - TD-12	0.9604
		TD-9 - TD-12	0.9984
TD-13	0.98	TD-1 - TD-13	0.98
TD-14	0.98		
TD-15	0.98		
TD-16	0.98		
TD-15	0.98		
TD-16	0.98		
TD-17	0.98		
TD-18	0.98		
TD-19	0.98		
TD-20	0.98		

TD-21	**0.98**		
TD-22	0.98		
TD-23	0.98	TD-1 - TD-23	0.769

Using the formula $R = e^{-t/MTBF}$ and the calculated reliability for each conveyor subsystems, mean time between failure MTBF can then be predicted. Since the system is expected to operate at a minimum of 5.5 processing days, MTBF's are as follows:

Originating System

Conveyor Subsystem	Reliability	MTBF(hrs)
Bulk Conveyor System (BO-1 - BO-24)	0.8171	653.5
Bulk Conveyor Missent (BOM-1 - BOM -4)	0.7691	502.8
Tray Conveyor System (TO-1 - TO -13)	0.7847	544.4
Tray Conveyor System (TO-20 - TO -32)	0.8004	592.9

Destinating System

Conveyor Subsystem	Reliability	MTBF(hrs)
Bulk Conveyor System (BD-1 - BO-26)	0.8506	815.8
Bulk Conveyor Missent (BDM-1 - BDM -4)	0.8337	715.7
Tray Conveyor System (TD-1 - TD -23)	0.769	502.5

If the number of processing days increased, MTBF should be recalculated to reflect the change. The above MTBF shall be used to define the minimum requirements for the systems reliability.

3.6 System Supportability

The design for logistic support normally focused on the actual components/systems deployed. Restricting the use of nonstandard parts will ensure limited downtime due to unavailability of spares. Documentation of the system has to be complete and accurate in order for logistic support to be successful. Often, the customer will accept a system and a few months after will recognize that the design documentation does not reflect the systems as-built conditions. This is true in almost all systems development. The funds for design documentation are almost unlimited during the preconstruction or pre-installation phase of the project. Unfortunately, most management fails to recognize that is equally important to fund the documentation effort during post-installation phases.

One of the elements for fitness of use is availability [8]. Failure to provide accurate parts list and correct revision of the design can contribute to the downtime of the system. This will reflect on the contractors' ability to secure another project from the same organization.

To ensure that the design documentation effort will be complete to the satisfaction of the USPS, the organization normally hires another mechanization design team to provide design documentation reviews. The review will consist of installation monitoring, construction management, coordination of testing and training schedules. The engineering auditor with the assigned USPS representatives is responsible for ensuring that the proper test is done before acceptance of the system.

3.6.1 Documentation

The following shall be the criteria for preparation of shop drawings and associated design documents:

- Drawing scale shall not be less than 1/4" = 1'-0".
- Except for areas where two or more conveyors are in close proximity, each conveyor shall be submitted on a separate drawing.
- Plan and elevation views for each conveyor shall be contained on the same drawing. All related equipment such as drives, platforms, walkways, etc. shall be included.
- Each of the elevation and layout drawings shall contain a Bill of Materials. The bill of materials shall include but not be limited to drive configurations, reducers, clutches, brakes, and all components required to build the conveyor. All reference drawings shall contain the complete drawing reference number and data sheets where applicable.

Besides the drawings required the contractor shall provide a machinery schedule. It should list, by conveyor, the quantity of all major components provided. A summary line shall show the total quantity of each component required. Each drawing submittal requires an updated copy of the machinery schedule.

It is recommended that no more than 25 drawings shall be submitted within a week. This ensures that the contractor is not hurrying-up the design documentation package at the expense of quality of workmanship. Further, the above criteria ensure legibility, accuracy and uniformity of the documents. The training manuals also follow a similar review process, except that manual contents shall be verified for accuracy and conciseness by executing the steps required for inspection, operations and maintenance.

3.6.2 Standard Components

The selection of parts shall be kept to a minimum, the number of different types of components and components of different manufacturers. This allows the reduction of spares that the site and their logistics depot have to stock. The use of standard parts also ensures that parts can be acquired readily from any source and sole sourcing should be avoided to ensure availability of spares during operations. The system shall be designed to definite standard dimensions, tolerances, and clearances so that respective parts, assemblies are interchangeable.

The standardized parts allow for easy disposal/re-use and reduce the cost associated with spare parts stocking. The parts reserved will be significantly lower than if parts are not standardized. Though it may lead to a monopoly of a few manufacturers, however the quality of parts will not be an issue. The organization can have a better customer-vendor relationship that can lead into a better supplier relationship, reliable parts and reduce cost.

3.6.3 Spare Parts

Using the predicted reliability and MTBF, and the "Spare part requirement nomograph", the number of spares can be calculated for six months and one year [9]. These actual required spares can then be translated to a percentage of the parts that can be included in the design specifications, keeping the cost to a minimum.

Number of spares required for 6 months

(Probability of the required spare available is 98%)

Originating System

Conveyor Subsystem	No. of Parts	λ	KλT	No. of Spares
Bulk Conveyor System (BO-1 - BO-24)	24	0.00153	0.17	1
Bulk Conveyor Missent (BOM-1 - BOM -4)	4	0.00198	0.035	1
Tray Conveyor System (TO-1 - TO -13)	13	0.00184	0.11	1
Tray Conveyor System (TO-20 - TO -32)	33	0.00169	0.27	2

Destinating System

Conveyor Subsystem	No. of Parts	λ	KλT	No. of Spares
Bulk Conveyor System (BD-1 - BD-26)	26	0.00123	0.14	1
Bulk Conveyor Missent (BDM-1 - BDM -4)	4	0.00134	0.022	1
Tray Conveyor System (TD-1 - TD -23)	23	0.00199	0.19	1

The total number of bulk conveyors is 58 with their components being the same. The percent of spares is 7% of the total parts count. For the tray conveyors with the total number of conveyor being 69 the percent of spares are 6%.

Number of spares required for one year

(Probability of the required spare available is 98%)

Originating System

Conveyor Subsystem	No. of Parts	λ	KλT	No. of Spares
Bulk Conveyor System (BO-1 - BO-24)	24	0.00153	0.34	1

Bulk Conveyor Missent (BOM-1 - BOM -4)	**4**	**0.00198**	**0.07**	**1**
Tray Conveyor System (TO-1 - TO -13)	13	0.00184	0.22	2
Tray Conveyor System (TO-20 - TO -32)	33	0.00169	0.54	4

Destinating System

Conveyor Subsystem	No. of Parts	λ	KλT	No. of Spares
Bulk Conveyor System (BD-1 - BD-26)	26	0.00123	0.28	2
Bulk Conveyor Missent (BDM-1 - BDM -4)	4	0.00134	0.044	1
Tray Conveyor System (TD-1 - TD -23)	23	0.00199	0.28	2

The total number of bulk conveyors is 58 with their components being the same. The percent of spares is 9% of the total parts count. For the tray conveyors with the total number of conveyor being 69 the percent of spares are 12%.

3.7 System Upgrade and Disposability

The components to be specified for the new conveyor system will have been approved and undergone "life testing". New components specified have to be qualified by undergoing "life testing" to ensure that they can withstand various applications and environmental constraints. All components are standardized both in dimensions and functions. The primary intent in requiring standardized components is to ensure product availability and limit the number of spares that need to be stocked to keep the operation of different material handling system.

Second to the improvement of logistic support is the issue of disposal and upgrade. Often the projected use of the system is surpassed by the growth in the demand of mail processing. When these situations occur, the system design to support an operation for 5 years can be out dated in 2 years or less. If this situation exists, it becomes apparent the system needs an upgrade to continue the commitment of the organization to provide unparalleled quality in mail handling.

In the event that an upgrade is required, components can be reused and worn-out parts are part of the analysis and study for continuous process improvement. When a site is slated for renovation, the mechanization design team will present a plan to upgrade the material handling capability. Once the area has been identified, a technology assessment is prepared. This includes the part of the system that requires upgrade and demolition. In both situations, the contractor has the responsibility of identifying the components that are affected. Normally, the working drawing and as-built condition will show all the components used to build the system. Once the components are identified including their condition, the report is presented to the local USPS representative for his/her disposition. The lists of components and their conditions are then provided to the regional USPS logistic office. This will allow different sites that require the same parts to acquire the parts from within. Components that have not exceeded their projected life and are in good working condition are then identified and disassembled first. They are carefully repackaged and stored for further disposition.

This method of disposal allows the USPS also to conduct studies of badly worn-out parts and the situation that has led to the rapid deterioration of the parts. This information is related back to the technical managers in the headquarters office so as they can avoid the same design in their future projects. Oftentimes, components may fail because of poor maintenance. If this condition exists, the question of maintainability and suitability of design for maintainability is challenge. This organization is noted for their quest of quality and continuous improvement processes.

Lastly, in order for a system to be accepted by the facility, the system shall have components standardized in both dimension and function. The drawings shall reflect the actual components and comparable substitute if any. This makes the disposal of the components easy for it is reused and the rest that are not usable have to be disposed of in accordance with the local and federal regulations regarding disposal. Hazardous materials and questionable materials being removed have to be monitored by the safety inspector of the facilities.

3.8 Economic Justification

The objective of the Operational Systems Layout (OSL) is to provide the customer a realistic view of a solution and primarily a decision tool. The effectiveness of OSL cannot be underestimated. The arrangement of equipment determines the amount of material handling that is necessary. A layout determines to a large extent how efficiently operations are performed, because the layout generally influences the pace, motions, effort and safety with which the employees work [10]. Once the customer is satisfied with the OSL and the initial cost estimate provided, the next design level is pursued.

During the design of any facility, the priority is to capture the customer's need and present a design that will satisfy the need. An initial cost estimate is also provided to the customer for their review and comment. The cost estimate does not include the operations and support needed to ensure that the facility's missions are met. The only figures that the mechanization design engineers have, are the hard numbers associated with the cost of equipment and installation. Beyond such figures, it then becomes the responsibility of the organization to justify the continuance of the project. Most of the operational and support figures are proprietary. To have a realistic view of the total cost of the system over a period an estimated cost is provided below:

Estimated total cost of the system with capital recovery within ten years

Cost Category	Total Cost	Annual Cost (10 years period at 6% interest rate)
Cost of Research and Development		
Preparation of the OSL	$40,000.00	$5,436.00
Simulation and Analysis	$50,000.00	$6,795.00
Design Engineering Cost (from conceptual design to 100% design effort)	$110,000.00	$14,949.00
Cost of Installation and Construction (Includes all activities, i.e., engineering, documentation, procurement, program management, training, etc.)		
Bulk Mail System	$6,100,000.00	$828,990.00
Tray Mail System	$1,600,000.00	$217,440.00
Universal Sorting Machine	$3,000,000.00	$407,700.00
Building Construction	**$14,000,000.00**	**$1,902,600.00**
Cost of Operation		
Labor		$16,650,000.00
Lease of Property		$5,400,000.00
Utility and Other Expenditures		$750,000.00
Total		$26,183,910.00

For ten years, the system will need about $26.1 million per year in investment to operate. Beyond the ten-year period the capital investment has been recovered and the only required costs are the annual cost to operate.

Estimated total cost of the system with capital recovery within five years

Cost Category	Total Cost	Annual Cost (5 years period at 6% interest rate)
Cost of Research and Development		
Preparation of the OSL	$40,000.00	$9,496.00
Simulation and Analysis	$50,000.00	$11,870.00
Design Engineering Cost (from conceptual design to 100% design effort)	$110,000.00	$26,114.00
Cost of Installation and Construction (Includes all activities, i.e., engineering, documentation, procurement, program management, training, etc.)		
Bulk Mail System	$6,100,000.00	$1,448,140.00
Tray Mail System	$1,600,000.00	$379,840.00
Universal Sorting Machine	$3,000,000.00	$712,200.00
Building Construction	$14,000,000.00	$3,323,600.00
Cost of Operation		
Labor		$16,650,000.00
Lease of Property		$5,400,000.00
Utility and Other Expenditures		$750,000.00
Total		$28,711,260.00

For five years, the system will need about $28.7 million per year in investment to operate. Beyond the five-year period the capital investment has been recovered and the only required costs are the annual cost to operate. The difference in capital recovery between the ten-year period and five-year period is

$2.6 million per year. The site processes enough mail per year to pay for the system in five years. The combined piece count of mail processed in a given day is approximately 39,600 pieces daily. Using the multiplier 5.5, which is the processing days per week at 52 weeks, the total piece count is 11,325,600 pieces annually. Since the data acquired in the survey only show the piece count and do not include the weight per piece, the total revenue can be estimated by assigning a dollar value per piece count. Each piece may weigh from 1 lb. to 70 lbs. If the site receives at a minimum $3 per piece average for processing, the annual revenue will be about $34 million. The project revenue exceeded the total annual cost by approximately $ 5 million, justifying the continuance of this design to the next level.

4.0 Summary of the Conceptual Design

A summary of the conceptual design for the County AMC is shown on Figures 14 and 15. In completing the conceptual design the following specific design characteristics were developed:

- Areas with constant human interaction met human engineering requirements as demonstrated in the design characteristics of the loading area at the concourse and the keyer induction station.
- The training guidelines specified the type and length of the training including the contractor's responsibility in conducting such training.
- The equipment access for both preventive and corrective maintenance were considered by allocating the proper motor platform size and elevation, and adding walkways for easy access and inspection.
- The design characteristics also dictated the criteria to be used in the selection of parts and the guidelines for testing prior to system acceptance.
- The subsystem reliability can be predicted by assigning a desired value for each conveyor. Using each conveyor's reliability, the system engineer can define the reliability allocation of each component. This will be valuable information in the selection of conveyors' components.

- After defining the subsystems reliability, the spare parts required to keep the system running can also be derived. This technique will ensure that there are adequate spares during operation. Using both scenarios of 6 months and one year, spare requirements are presented. This allows the organization to determine the cost of spares associated with the project.
- Since one of the criteria in continuance of the design is the proof of capital recovery, both calculation for the ten-year and five-year return on investment is provided and compared. The justification can be linked with the amount of volume processed in a given day and calculated annually for the comparison of the total systems cost annually and the annual revenue earned for processing the amount of mail.

Lastly, the development of the design characteristics leading to the completion of the conceptual design was facilitated by the use of the established OSL as the baseline where the second phase of the design activity began. Also, equally important is the XYZ Company's effort in capturing the system requirements of the County AMC as highlighted in the early portion of this report. The two distinct activities which are parts of systems engineering have made the design effort produce a system that will meet customers requirements.

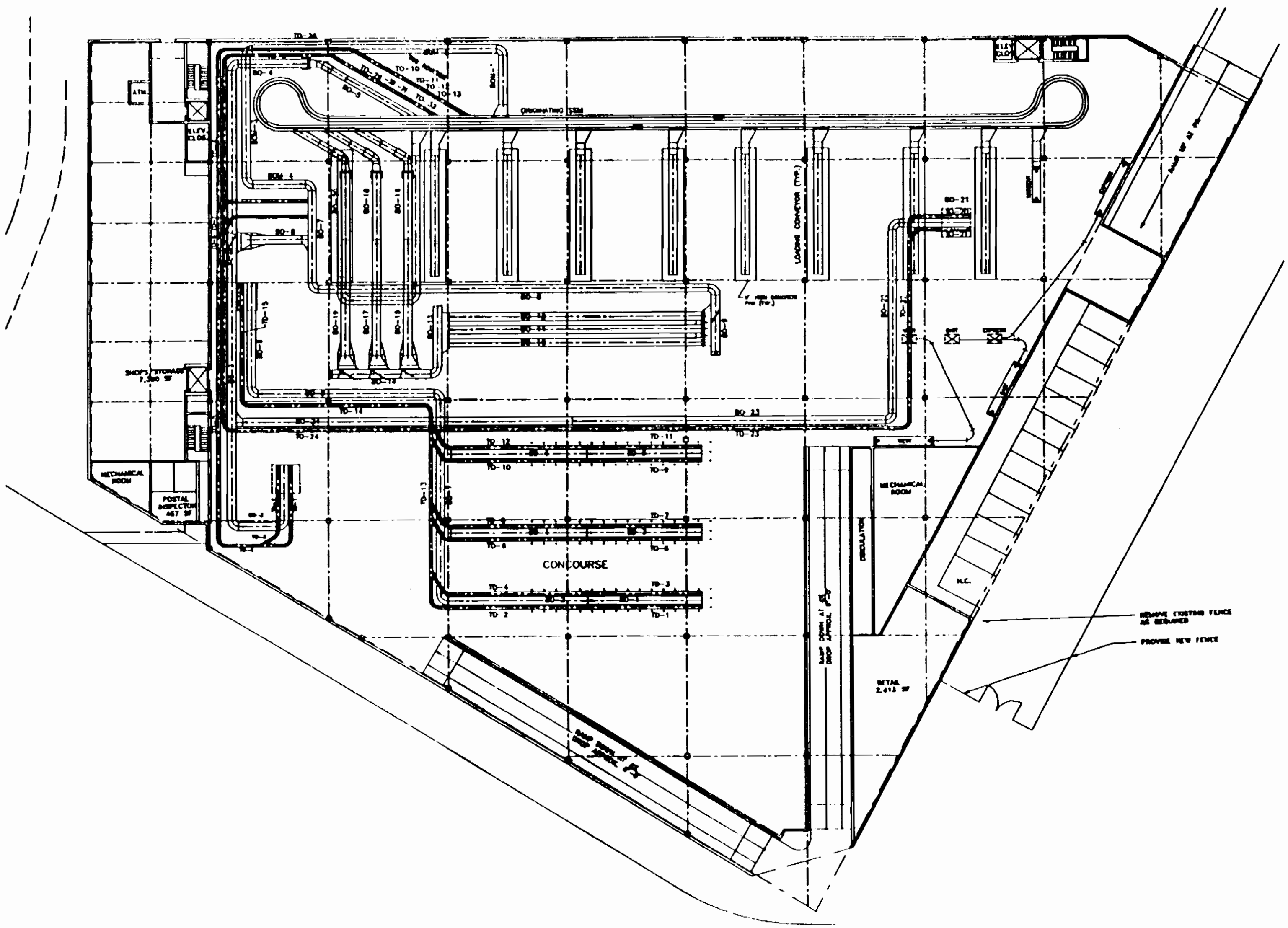


Figure 14. Conceptual Design First Floor Plan

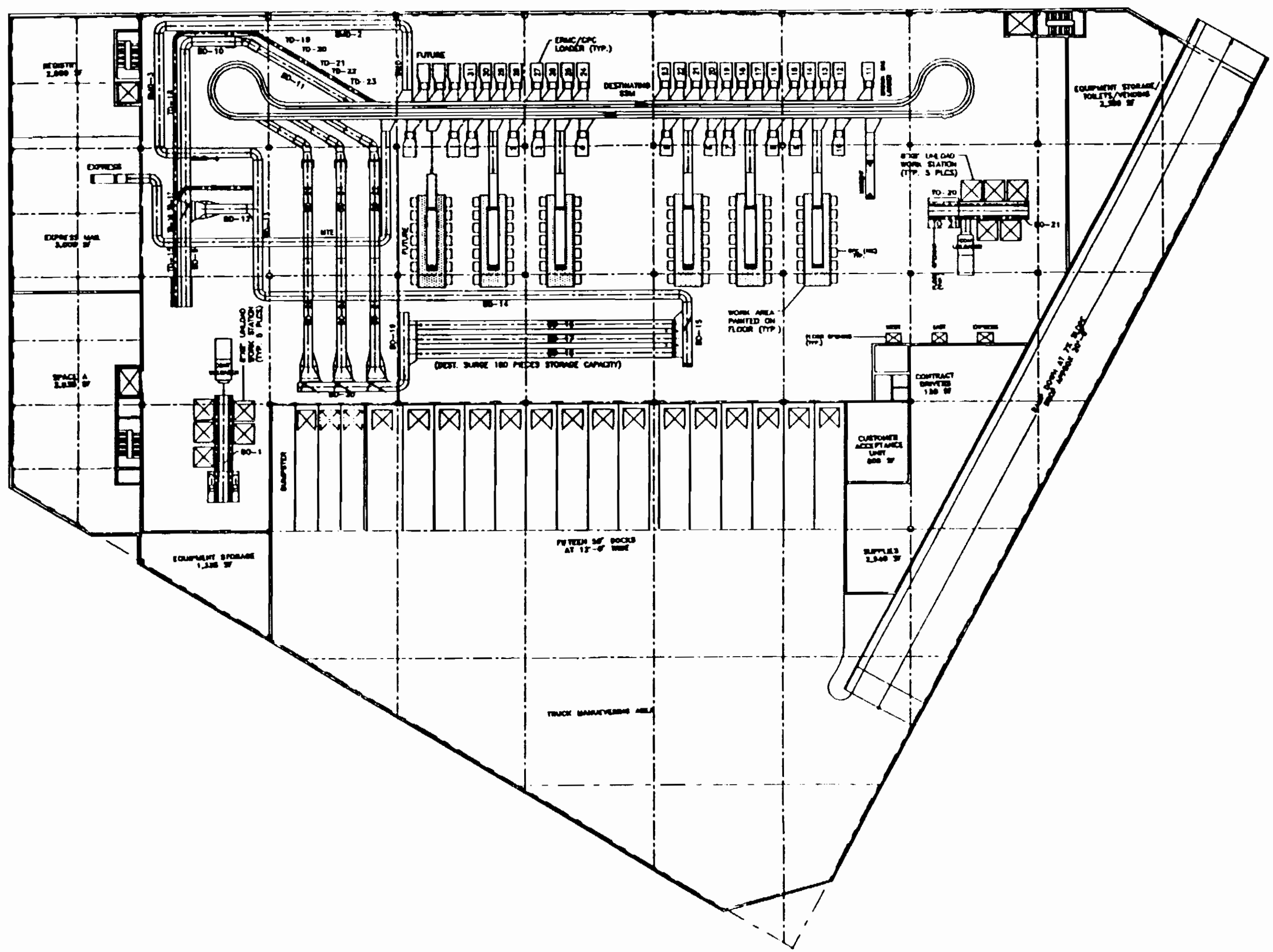


Figure 15. Conceptual Design Second Floor Plan

5.0 Guidelines for Future Systems Development Projects

Design engineering is a complex activity. Lacking organization and structure offered by systems engineering, it becomes nearly impossible to produce a design that will meet the customer's need within budgetary constraints. Designers should realize that their activity is not limited to the design document they produced. The documents are means of communicating ideas. It is always important that these ideas can be transformed to reality [13].

The design of material handling system or mail handling system is similar with any product development activity, and the following steps are highlights required to complete a successful design effort:

1) Define the goals and objectives of the organization that needs the design. The goals and objectives of the project have to be clearly identified. The organization must be committed to these goals and objectives. Some design efforts have failed due to the lack of support from the management. A successful project has the total support of the entire organization.

2) Define the needs of the mail processing facility under consideration. Needs of the facility should be defined completely. This shall include not only

the description of the problem and scope of work, but also the data must reaffirm the needs and describes the problem that the facility encounters.

Designers must be good listeners. During the needs analysis process, the representatives of the facility and technical managers should provide the majority of the input. Designers should restrain themselves from formulating any opinion and suggesting any solution before all the necessary information is acquired. This might have a negative influence to the need's analysis.

Analysis should be performed on the most current data available. After the kickoff meeting, it is important to verify all the data collected for its appropriateness, accuracy and currency. This can be achieved by conducting site visits and field verification. Often, the designers rely on as-built drawings supplied by the customers. As-built drawings are not always accurate and updated. Designers should use the as-built drawings as a guide and must conduct site surveys to ensure its accuracy. Site surveys should be conducted before starting any design activity.

3) Prepare a baseline layout of the design. In preparing a preliminary design layout, the locations of docks for loading and unloading mail should be identified. In addition, locations of the major operations and their associated

activities should be drawn first (i.e., number of inductions and run-outs, and their locations). A layout determines to a large extent how efficiently operations are performed, because the layout generally influences the pace, motion, effort and safety with which the employees work [10].

When all the equipment is in place, use a single line design layout to trace the flow of the mail/material in the system. Whenever, single line layouts are used to convey different design options, ensure that the single line layout can be carried through 100% design level. Proper space allocation and height requirements have to be defined, though elevations are not required. The designer should think about 100% design level activity while presenting an initial design layout. Do not present a single line drawing that can never be carried through 100% design activity.

4) <u>Conduct a design review.</u> It is important that at least a formal design review be conducted every time a significant portion of the design is completed. This is a process of verifying that all the requirements are met. Design review allows all stakeholders to comment concurrently on a particular aspect of the design or the entire design itself. The baseline layouts are used for discussion and verifications of the assessment of the needs. Often, design review becomes a coordination meeting also. After each design review, all the comments

generated in the meeting should be incorporated and drawings are revised.

5) Perform analysis. Once the revised baseline is completed, then the system can be analyzed "for fitness of use". In material handling, the requirements are defined by timeliness of material processing that is, similar to the Just -In-Time concept. The mail should arrive at the appropriate run-outs in time for dispatch.

Simulation should be used to ensure that the system designed will have the adequate capability to process the anticipated mail. This can be achieved by creating an event for every piece of mail introduced and tracking their movement in the system. Using the baseline parameters and standards, the designer can analyze the system for adequacy. Different design options shall be validated using simulation. It is also equally important that a monetary amount be assigned to each different option. The different design options including the cost estimates then can be presented during the next design review.

6) Prepare design specifications. During the early stages of the design process, it is important to address the "ilities" of the critical areas of concern only. Time is a luxury that designers don't have during the design and development of products. By addressing the critical areas of concern, then the

design can move smoothly and customer's concerns are immediately resolved. The operational system description can now be completed after all the "ilities" considerations are incorporated. This is important so as the electrical and controls engineers can accomplish their task.

7) If the project has to be carried to the final design stage, ensure that there are formal design reviews and all the comments are incorporated for every review. This process should be done at least once every significant design milestone.

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Appendix A

Tables of Simulation Data and Results

TABLE A-1
DESTINATING ARRIVAL PROFILE
NORMAL VOLUME

Time (Hours)	Outsides	Priority	Sacks	Trays	Tubs	Total (Pieces)
700	530	429	4	78	10	1051
800	31	90	20	203	48	392
900	155	130	38	569	144	1036
1000	28	19	45	320	129	541
1100	61	102	54	406	172	795
1200	76	193	82	787	138	1276
1300	24	115	42	359	50	590
1400	86	151	113	483	368	1201
1500	90	215	164	692	291	1452
1600	26	149	109	319	142	745
1700	59	145	142	937	381	1664
1800	20	178	75	551	206	1030
1900	65	198	112	568	150	1093
2000	88	210	176	534	302	1310
2100	37	50	142	628	233	1090
2200	17	74	28	314	36	469
2300	0	0	0	0	0	0
0	0	0	0	0	0	0
100	0	0	0	0	0	0
200	0	0	0	0	0	0
300	0	0	0	0	0	0
400	0	0	0	0	0	0
500	0	0	0	0	0	0
600	0	0	0	0	0	0

TABLE A-1 (cont'd)
DESTINATING ARRIVAL PROFILE
PEAK VOLUME

Time (Hours)	Outsides	Priority	Sacks	Trays	Tubs	Total (Pieces)
700	663	537	6	98	13	1317
800	39	113	26	254	61	493
900	194	163	48	712	181	1298
1000	36	24	57	401	162	680
1100	77	128	68	508	216	997
1200	96	242	103	984	173	1598
1300	31	144	53	449	63	740
1400	108	189	142	604	461	1504
1500	113	269	206	866	364	1818
1600	33	187	137	399	178	934
1700	74	182	178	1172	477	2083
1800	26	223	94	689	258	1290
1900	82	248	141	711	188	1370
2000	111	263	221	668	378	1641
2100	47	63	178	786	292	1366
2200	22	93	36	393	46	590
2300	0	0	0	0	0	0
0	0	0	0	0	0	0
100	0	0	0	0	0	0
200	0	0	0	0	0	0
300	0	0	0	0	0	0
400	0	0	0	0	0	0
500	0	0	0	0	0	0
600	0	0	0	0	0	0

TABLE A-2
ORIGINATING ARRIVAL PROFILE
NORMAL VOLUME

first class pieces were split 60% trays, 24% tubs, 16%sacks
priority were split 32% parcels, 68% sacks

TIME	FIRST CLASS PIECES	PRIORITY PIECES	FIRST CLASS GPMCS	PRIORITY GPMCS
1400	6	2	1	1
1500	81	18	4	1
1545	7	0	1	0
1600	64	0	3	0
1650	21	0	1	0
1700	40	2	2	1
1745	17	0	1	0
1745	0	157	0	8
1800	207	23	8	2
1815	0	14	0	1
1830	6	18	1	1
1845	67	0	3	0
1900	41	6	2	1
1900	47	72	2	4
1915	153	0	6	0
1935	0	711	0	36
1945	42	0	2	0
1945	0	150	0	8
2000	102	4	4	1
2000	0	9	0	1
2040	78	209	4	1
2000	0	9	0	1
2040	78	209	4	11
2045	68	0	3	0
2100	0	52	0	3
2100	0	399	0	20
2100	305	0	12	0
2100	6	175	1	9
2100	25	44	1	3
2115	66	0	3	0
2115	0	184	0	10
2115	0	85	0	5
2135	0	96	0	5
2145	156	0	7	0
2200	130	102	6	6
2245	97	0	4	0
2300	332	103	13	6
2300	438	219	17	11
2330	371	0	15	0
2330	0	117	0	6
2335	0	237	0	14
2355	474	187	19	8

TABLE A-2 (cont'd)
ORIGINATING ARRIVAL PROFILE
NORMAL VOLUME

first class pieces were split 60% trays, 24% tubs, 16%sacks
priority were split 32% parcels, 68% sacks

TIME HOURS	FIRST CLASS PIECES	PRIORITY PIECES	FIRST CLASS GPMCS	PRIORITY PIECES
0	29	10	2	1
15	520	0	21	0
20	371	176	15	9
25	949	587	37	30
45	429	0	17	0
100	784	109	31	6
110	0	87	0	5
130	67	0	3	0
145	293	0	12	0
145	693	591	27	30
145	692	155	27	8
155	275	0	11	0
200	51	0	2	0
200	131	128	6	7
230	1874	0	73	0
245	471	0	19	0
250	0	59	0	3
300	87	40	4	3
300	1099	58	43	3
310	67	0	3	0
345	320	0	13	0
345	246	37	10	2
345	21	0	1	0
400	3	6	1	1
400	979	7	38	1
400	651	6	26	1
415	152	0	6	0
415	240	11	10	1
440	8	0	1	0
445	299	0	12	0
455	948	0	37	0
500	85	7	4	1
500	11	0	1	0
545	301	0	12	0
600	35	0	2	0
600	89	1	4	1
630	20	0	1	0
645	220	0	9	0
700	3	0	1	0
800	72	5	3	1
900	194	12	8	1

TABLE A-2 (cont'd)
ORIGINATING ARRIVAL PROFILE
PEAK VOLUME

first class pieces were split 60% trays, 24% tubs, 16%sacks
priority were split 32% parcels, 68% sacks

TIME HOURS	FIRST CLASS PIECES	PRIORITY PIECES	FIRST CLASS GPMCS	PRIORITY GPMCS
1400	8	3	1	1
1500	102	23	4	2
1545	9	0	1	0
1600	81	0	4	0
1650	27	0	2	0
1700	51	3	2	1
1745	22	0	1	0
1745	0	197	0	10
1800	259	29	10	2
1815	0	18	0	1
1830	8	23	1	2
1845	84	0	4	0
1900	52	8	3	1
1900	59	91	3	5
1915	192	0	8	0
1935	0	889	0	45
1945	53	0	3	0
1945	0	188	0	10
2000	128	6	5	1
2000	0	12	0	1
2040	98	262	4	14
2045	86	0	4	0
2100	0	66	0	4
2100	0	499	0	25
2100	382	0	15	0
2100	8	219	1	11
2100	32	56	2	3
2115	83	0	4	0
2115	0	231	0	12
2115	0	107	0	6
2135	0	121	0	7
2145	196	0	8	0
2200	163	128	7	7
2245	122	0	5	0
2300	416	129	17	7
2300	548	274	22	14
2330	464	0	18	0
2330	0	147	0	8
2335	0	342	0	18
2355	593	234	23	12

TABLE A-2 (cont'd)
ORIGINATING ARRIVAL PROFILE
PEAK VOLUME

first class pieces were split 60% trays, 24% tubs, 16%sacks
priority were split 32% parcels, 68% sacks

TIME HOURS	FIRST CLASS PIECES	PRIORITY PIECES	FIRST CLASS PIECES	PRIORITY GPMCS
0	37	13	2	1
15	651	0	26	0
20	464	221	18	12
25	1187	734	46	37
45	537	0	21	0
100	981	137	38	7
110	0	109	0	6
130	84	0	4	0
145	367	0	15	0
145	867	739	34	37
145	866	194	34	10
155	344	0	14	0
200	64	0	3	0
200	164	161	7	9
230	2343	0	91	0
245	589	0	23	0
250	0	74	0	4
300	109	51	5	3
300	1374	73	53	4
310	84	0	4	0
345	401	0	16	0
345	308	47	12	3
345	27	0	2	0
400	4	8	1	1
400	1224	9	48	1
400	814	8	32	1
415	191	0	8	0
415	301	14	12	1
440	11	0	1	0
445	374	0	15	0
455	1186	0	46	0
500	107	9	5	1
500	14	0	1	0
545	377	0	15	0
600	44	0	2	0
600	112	2	5	1
630	26	0	2	0
645	276	0	11	0
700	4	0	1	0
800	91	7	4	1
900	243	16	10	1

TABLE A-3
TIME IN SYSTEM - TRAYS AND TUBS (ORIGINATING)
NORMAL VOLUME

Time (Hours)	Trays and Tubs (Keyed Pieces)	Trays and Tubs Automatic Induction (Pieces)	Avg. Time in System Keyed (Minutes)	Max. Time in System Automatic Induction (Minutes)	Max. Time in System (Keyed Minutes)	Max. Time in System Automatic (Induction Minutes)
1500	1	21	6.5	6.1	6.5	8.7
1600	7	103	5	5.7	6.6	8.7
1700	4	81	6	5.8	8.1	8.7
1800	3	69	6.7	5.7	8.6	8.7
1900	13	242	6.1	5.9	9	10.2
2000	20	242	6.3	5.6	10.4	8.8
2100	12	226	9.6	5.6	15	8.8
2200	23	490	9.3	7.9	17.6	17.9
2300	10	212	6.8	5.8	9.3	10
0	36	998	12.4	9.8	22.3	20.7
100	104	2244	15.2	12.6	34.5	33.8
200	77	1234	25.5	9.9	41.9	19.1
300	140	2920	26	19.4	43.7	33.6
400	113	1787	19	13	35.1	31.5
500	103	2010	12.9	12.8	28.6	29.5
600	53	1039	10.7	9.8	19.6	20.9
700	18	332	5.8	5.7	9.6	10.2
800	2	19	5.3	6.2	6.1	8.7
900	3	68	4.9	5.8	6.2	8.7
1000	9	169	6.6	5.8	9.6	10.2
1100	0	0	0	0	0	0
1200	0	0	0	0	0	0
1300	0	0	0	0	0	0
1400	0	0	0	0	0	0

TABLE A-3 (cont'd)
TIME IN SYSTEM - TRAYS AND TUBS (ORIGINATING)
PEAK VOLUME

Time Hours	Trays and Tubs (Keyed Pieces)	Trays and Tubs Automatic Induction (Pieces)	Avg. Time in System Keyed (Minutes)	Max. Time in System Automatic Induction (Minutes)	Max. Time in System (Keyed Minutes)	Max. Time in System Automatic (Induction Minutes)
1500	2	18	3.2	4.8	3.8	6.9
1600	3	109	5.7	5.6	7.3	8.8
1700	8	122	5.5	5.5	7.5	8.8
1800	2	61	6.5	5.9	8.3	8.7
1900	17	316	5.6	5.9	8.3	10.3
2000	17	346	6.5	6.1	12.1	12.3
2100	14	267	10.8	5.6	21.7	8.8
2200	17	627	14.6	8.3	24.8	17.9
2300	23	232	11.3	6	19.6	10.2
0	68	1213	15.9	11.6	29.4	24.3
100	96	2376	15.2	15.5	34.3	35
200	128	1922	32.8	14.3	59.3	38.4
300	104	3069	38.3	23.9	58.9	46.6
400	229	2828	41.3	24.5	57.3	46.5
500	147	2515	15.8	16	30.6	35.2
600	73	1315	10.4	11.4	20.8	24.7
700	22	401	6.2	5.7	10	10.3
800	0	23	0	6.3	0	8.7
900	9	80	5.4	5.5	7.1	8.7
1000	18	208	6.2	6.1	10.5	10.2
1100	0	0	0	0	0	0
1200	0	0	0	0	0	0
1300	0	0	0	0	0	0
1400	0	0	0	0	0	0

TABLE A-4
TIME IN SYSTEM - SACKS AND PARCELS (ORIGINATING)
NORMAL VOLUME

Time (Hours)	Sacks and Parcels (Pieces)	Avg. Time in System (Minutes)	Max. Time in System (Minutes)
1500	24	5.4	8.7
1600	40	6.5	9.5
1700	19	6.9	9.5
1800	186	6.2	9.4
1900	137	6	9.5
2000	740	12.2	25
2100	598	17.6	36
2200	1211	18.4	40.6
2300	158	6.5	11
0	953	10.7	22.4
100	1151	15.8	35
200	919	20.4	47.5
300	1189	30.8	55.4
400	681	17.1	35.3
500	511	13	29.8
600	232	10.1	20.8
700	86	6.4	9.3
800	5	7.7	8.7
900	27	5.3	9.5
1000	50	6.1	9.4
1100	0	0	0
1200	0	0	0
1300	0	0	0
1400	0	0	0

TABLE A-4 (cont'd)
TIME IN SYSTEM - SACKS AND PARCELS (ORIGINATING)
PEAK VOLUME

Time (Hours)	Sacks and Parcels (Pieces)	Avg. Time in System (Minutes)	Max. Time in System (Minutes)
1500	26	6.3	8.3
1600	58	6	9.5
1700	26	6.4	8.9
1800	235	6.9	11.3
1900	157	6.2	9.6
2000	776	11.8	25
2100	900	23.9	47
2200	1402	24	48.9
2300	291	12.8	27.9
0	1210	13.4	29.5
100	1217	16.9	34.9
200	1178	32.5	59.9
300	1294	40.5	62.6
400	1070	37.1	34.8
500	647	15.5	34.8
600	273	11.2	25.2
700	117	6.8	10.8
800	3	6.3	8.3
900	35	6.5	9.5
1000	54	6.2	9.6
1100	0	0	0
1200	0	0	0
1300	0	0	0
1400	0	0	0

TABLE A-5
TIME IN SYSTEM - TRAYS AND TUBS (DESTINATING)
NORMAL VOLUME

Time (Hours)	Trays and Tubs (Keyed Pieces)	Trays and Tubs (Automatic Induction Pieces)	Avg. Time in System Keyed	Avg. Time in System Automatic Induction (Minutes)	Max. Time in System Keyed (Minutes)	Max. Time in System Automatic Induction (Minutes)
700	6	82	3.1	1.9	4.5	3.3
800	14	237	4.6	3.3	6.4	6.2
900	33	680	9.3	7.1	14.1	14
1000	17	432	4.9	4.8	8.2	8.9
1100	35	543	6.7	6.1	11.8	11.8
1200	40	885	9.6	9	17.5	17.5
1300	14	395	4	4.8	8.4	8.9
1400	41	810	10.7	8.4	16.5	16.7
1500	47	936	11.5	9.5	18.2	19.1
1600	29	432	6.1	5.2	10.6	10.2
1700	68	1250	11.4	12.1	23.1	23.2
1800	35	722	8.5	7.6	17.8	14.7
1900	33	685	8.5	7.4	14.5	14.8
2000	42	794	9.5	8.5	16.8	17
2100	47	814	8.9	8.3	15.4	15.9
2200	20	330	5	4.1	7.7	7.7
2300	0	0	0	0	0	0
0	0	0	0	0	0	0
100	0	0	0	0	0	0
200	0	0	0	0	0	0
300	0	0	0	0	0	0
400	0	0	0	0	0	0
500	0	0	0	0	0	0
600	0	0	0	0	0	0

TABLE A-5 (cont'd)
TIME IN SYSTEM - TRAYS AND TUBS (DESTINATING)
PEAK VOLUME

Time (Hours)	Trays and Tubs (Keyed Pieces)	Trays and Tubs (Automatic Induction Pieces)	Avg. Time in System Keyed	Avg. Time in System Automatic Induction (Minutes)	Max. Time in System Keyed (Minutes)	Max. Time in System Automatic Induction (Minutes)
700	6	105	2.5	2.1	4.4	3.7
800	17	298	4.8	3.9	7.5	7.5
900	50	843	11.4	8.7	18.2	17.2
1000	23	540	6.4	5.7	9.5	10.9
1100	33	691	7.9	7.4	14.4	14.5
1200	53	1104	11.6	11.2	21.1	21.9
1300	29	483	6.7	5.6	10.3	10.8
1400	51	1014	12.1	10.3	20.4	20.4
1500	60	1170	13.1	11.9	22.9	23.7
1600	37	540	7.7	6.2	13.2	12.3
1700	85	1564	14.4	14.8	28.2	28.5
1800	49	898	9.5	9.3	16	18
1900	55	844	10.6	9.1	18.2	18.1
2000	52	994	12.1	10.4	22	21
2100	50	1028	11.9	10	19.1	19.5
2200	28	411	5.5	4.9	9.4	9.3
2300	0	0	0	0	0	0
0	0	0	0	0	0	0
100	0	0	0	0	0	0
200	0	0	0	0	0	0
300	0	0	0	0	0	0
400	0	0	0	0	0	0
500	0	0	0	0	0	0
600	0	0	0	0	0	0

TABLE A-6
TIME IN SYSTEM - SACKS AND PARCELS (DESTINATING)
NORMAL VOLUME

Time (Hours)	Sacks and Parcels (Pieces)	Avg. Time in System (Minutes)	Max. Time in System (Minutes)
700	963	18.7	38
800	141	3.5	6.3
900	323	6.9	13.8
1000	92	2.9	4.9
1100	217	4.8	9.1
1200	351	7	14
1300	181	3.9	6.9
1400	350	6.9	14.2
1500	469	8.6	17.5
1600	284	5.7	11
1700	346	6.9	13.9
1800	273	5.3	9.7
1900	375	6.9	13.3
2000	474	8.4	16.6
2100	229	4.8	8.9
2200	119	3.1	5.4
2300	0	0	0
0	0	0	0
100	0	0	0
200	0	0	0
300	0	0	0
400	0	0	0
500	0	0	0
600	0	0	0

TABLE A-6 (cont'd)
TIME IN SYSTEM - SACKS AND PARCELS (DESTINATING)
PEAK VOLUME

Time (Hours)	Sacks and Parcels (Pieces)	Avg. Time in System (Minutes)	Max. Time in System (Minutes)
700	1206	23.4	47.4
800	178	4.1	7.4
900	405	8.7	17.8
1000	117	3.2	5.6
1100	273	5.6	10.7
1200	441	8.1	16.6
1300	228	4.8	9
1400	439	8	15.8
1500	588	10.4	21.5
1600	357	6.8	13.2
1700	434	8	16
1800	343	6.3	11.9
1900	471	8.6	17.7
2000	595	10.5	21.7
2100	288	5.5	10.4
2200	151	3.6	6.2
2300	0	0	0
0	0	0	0
100	0	0	0
200	0	0	0
300	0	0	0
400	0	0	0
500	0	0	0
600	0	0	0

TABLE A-7
PLATFORM STAGING, SURGE AND SORTER UTILIZATION (ORIGINATING)
NORMAL VOLUME

Time (Hours)	Maximum GPMCs in Staging (Conveyor 1)	Maximum GPMCs in Staging (Conveyor 2)	Maximum Number of Pieces in Surge	Sorter Utilization	
				Pieces	Percent of Capacity
1500	1	1	1	46	1.00%
1600	2	3	1	150	3.00%
1700	1	2	1	104	2.00%
1800	4	5	24	258	4.00%
1900	4	4	7	392	7.00%
2000	5	5	155	1002	17.00%
2100	4	4	183	836	14.00%
2200	16	17	269	1724	29.00%
2300	4	4	19	380	6.00%
0	13	14	130	1987	33.00%
100	17	18	344	3499	58.00%
200	35	35	280	2230	37.00%
300	33	33	319	4249	71.00%
400	13	14	166	2581	43.00%
500	21	22	18	2624	44.00%
600	11	11	5	1324	22.00%
700	4	4	2	436	7.00%
800	0	1	1	26	0.00%
900	2	2	1	98	2.00%
1000	4	4	1	228	4.00%
1100	0	0	0	0	0.00%
1200	0	0	0	0	0.00%
1300	0	0	0	0	0.00%
1400	0	0	0	0	0.00%

TABLE A-8
SURGE REQUIREMENT AND SORTER UTILIZATION (DESTINATING)
NORMAL VOLUME

Time (Hours)	Maximum Number of Pieces in Surge	Sorter Utilization	
		Pieces	Percent
700	185	1051	18.00%
800	19	392	7.00%
900	66	1036	17.00%
1000	19	541	9.00%
1100	33	795	13.00%
1200	53	1276	21.00%
1300	9	590	10.00%
1400	57	1201	20.00%
1500	58	1452	24.00%
1600	33	745	12.00%
1700	55	1664	28.00%
1800	14	1030	17.00%
1900	27	1093	18.00%
2000	36	1310	22.00%
2100	23	1090	18.00%
2200	14	469	8.00%
2300	0	0	0.00%
0	0	0	0.00%
100	0	0	0.00%
200	0	0	0.00%
300	0	0	0.00%
400	0	0	0.00%
500	0	0	0.00%
600	0	0	0.00%

TABLE A-8 (cont'd)
SURGE REQUIREMENT AND SORTER UTILIZATION (DESTINATING)
PEAK VOLUME

Time (Hours)	Maximum Number of Pieces in Surge	Sorter Utilization	
		Pieces	Percent
700	233	1317	22.00%
800	22	493	8.00%
900	100	1298	22.00%
1000	19	680	11.00%
1100	34	997	17.00%
1200	55	1598	27.00%
1300	24	740	12.00%
1400	40	1504	25.00%
1500	69	1818	30.00%
1600	34	934	16.00%
1700	46	2083	35.00%
1800	17	1290	22.00%
1900	60	1370	23.00%
2000	70	1641	27.00%
2100	17	1366	23.00%
2200	13	590	10.00%
2300	0	0	0.00%
0	0	0	0.00%
100	0	0	0.00%
200	0	0	0.00%
300	0	0	0.00%
400	0	0	0.00%
500	0	0	0.00%
600	0	0	0.00%

TABLE A-9
KEYING STATION AND AUTOMATIC READER UTILIZATION (ORIGINATING)
NORMAL VOLUME

Time (Hours)	Keying Station #1		Keying Station #2		Keying Station #3		Sacks and Parcels Reader		Trays and Tubs Reader # 1		Trays and Tubs Reader # 2	
	Pieces	Percent	Pieces	Percent	Pieces	Percent	Pieces	Percent	Pieces	Percent	Pieces	Percent
1500	7	2.00%	7	2.00%	7	2.00%	4	0.00%	0	0.00%	21	1.00%
1600	14	4.00%	14	4.00%	15	4.00%	4	0.00%	42	2.00%	61	3.00%
1700	8	2.00%	8	2.00%	7	2.00%	0	0.00%	19	1.00%	62	3.00%
1800	47	12.00%	47	12.00%	47	12.00%	48	2.00%	24	1.00%	45	2.00%
1900	45	11.00%	44	11.00%	45	11.00%	16	1.00%	105	5.00%	137	7.00%
2000	190	48.00%	191	48.00%	190	48.00%	190	9.00%	127	6.00%	115	5.00%
2100	178	45.00%	178	45.00%	178	45.00%	75	4.00%	103	5.00%	123	6.00%
2200	334	84.00%	333	83.00%	334	84.00%	233	11.00%	196	9.00%	294	14.00%
2300	47	12.00%	47	12.00%	47	12.00%	27	1.00%	125	6.00%	87	4.00%
0	273	68.00%	274	69.00%	273	68.00%	171	8.00%	502	24.00%	496	24.00%
100	353	88.00%	353	88.00%	353	88.00%	194	9.00%	989	47.00%	1255	60.00%
200	293	73.00%	293	73.00%	293	73.00%	117	6.00%	624	30.00%	611	29.00%
300	400	100.00%	399	100.00%	400	100.00%	131	6.00%	1475	70.00%	1445	69.00%
400	239	60.00%	239	60.00%	239	60.00%	76	4.00%	874	42.00%	912	43.00%
500	190	48.00%	191	48.00%	190	48.00%	43	2.00%	1013	48.00%	999	48.00%
600	91	23.00%	91	23.00%	91	23.00%	12	1.00%	481	23.00%	556	26.00%
700	32	8.00%	32	8.00%	31	8.00%	9	0.00%	142	7.00%	190	9.00%
800	2	1.00%	2	1.00%	3	1.00%	0	0.00%	0	0.00%	19	1.00%
900	10	3.00%	9	2.00%	9	2.00%	2	0.00%	22	1.00%	46	2.00%
1000	18	5.00%	18	5.00%	18	5.00%	5	0.00%	83	4.00%	86	4.00%
1100	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
1200	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
1300	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
1400	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%

TABLE A-9 (cont'd)
KEYING STATION AND AUTOMATIC READER UTILIZATION (ORIGINATING)
PEAK VOLUME

Time (Hours)	Keying Station #1		Keying Station #2		Keying Station #3		Sacks and Parcels Reader		Trays and Tubs Reader # 1		Trays and Tubs Reader # 2	
	Pieces	Percent	Pieces	Percent	Pieces	Percent	Pieces	Percent	Pieces	Percent	Pieces	Percent
1500	9	2.00%	8	2.00%	8	2.00%	3	0.00%	18	1.00%	0	0.00%
1600	18	5.00%	18	5.00%	18	5.00%	7	0.00%	45	2.00%	64	3.00%
1700	9	2.00%	10	3.00%	10	3.00%	5	0.00%	61	3.00%	61	3.00%
1800	63	16.00%	62	16.00%	62	16.00%	50	2.00%	20	1.00%	41	2.00%
1900	52	13.00%	52	13.00%	52	13.00%	18	1.00%	168	8.00%	148	7.00%
2000	203	51.00%	204	51.00%	204	51.00%	184	9.00%	138	7.00%	208	10.00%
2100	265	66.00%	264	66.00%	264	66.00%	119	6.00%	147	7.00%	120	6.00%
2200	379	95.00%	379	95.00%	379	95.00%	282	13.00%	314	15.00%	313	15.00%
2300	96	24.00%	97	24.00%	97	24.00%	24	1.00%	131	6.00%	101	5.00%
0	357	89.00%	356	89.00%	357	89.00%	208	10.00%	585	28.00%	629	30.00%
100	363	91.00%	362	91.00%	362	91.00%	228	11.00%	1159	55.00%	1217	58.00%
200	399	100.00%	399	100.00%	398	100.00%	110	5.00%	972	46.00%	950	45.00%
300	399	100.00%	400	100.00%	398	100.00%	200	10.00%	1585	75.00%	1484	71.00%
400	400	100.00%	400	100.00%	400	100.00%	99	5.00%	1358	65.00%	1469	70.00%
500	250	63.00%	249	62.00%	250	63.00%	44	2.00%	1252	60.00%	1265	60.00%
600	109	27.00%	110	28.00%	109	27.00%	18	1.00%	618	29.00%	695	33.00%
700	43	11.00%	43	11.00%	44	11.00%	9	0.00%	209	10.00%	192	9.00%
800	1	0.00%	1	0.00%	1	0.00%	0	0.00%	0	0.00%	23	1.00%
900	13	3.00%	13	3.00%	13	3.00%	5	0.00%	38	2.00%	42	2.00%
1000	23	6.00%	22	6.00%	22	6.00%	5	0.00%	86	4.00%	122	6.00%
1100	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
1200	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
1300	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
1400	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%

TABLE A-10
KEYING STATION AND AUTOMATIC READER UTILIZATION (DESTINATING)
NORMAL VOLUME

Time (Hours)	Keying Station #1		Keying Station #2		Keying Station #3		Sacks and Parcels Reader		Trays and Tubs Reader # 1		Trays and Tubs Reader # 2	
	Pieces	Percent	Pieces	Percent	Pieces	Percent	Pieces	Percent	Pieces	Percent	Pieces	Percent
700	244	41.00%	244	41.00%	243	41.00%	238	11.00%	41	2.00%	41	2.00%
800	33	6.00%	33	6.00%	33	6.00%	56	3.00%	120	6.00%	117	6.00%
900	86	14.00%	86	14.00%	86	14.00%	98	5.00%	344	16.00%	336	16.00%
1000	27	5.00%	27	5.00%	27	5.00%	28	1.00%	216	10.00%	216	10.00%
1100	55	9.00%	54	9.00%	54	9.00%	89	4.00%	270	13.00%	273	13.00%
1200	88	15.00%	88	15.00%	87	15.00%	128	6.00%	439	21.00%	446	21.00%
1300	35	6.00%	36	6.00%	35	6.00%	89	4.00%	197	9.00%	198	9.00%
1400	89	15.00%	88	15.00%	89	15.00%	125	6.00%	407	19.00%	403	19.00%
1500	112	19.00%	112	19.00%	111	19.00%	181	9.00%	470	22.00%	466	22.00%
1600	63	11.00%	63	11.00%	64	11.00%	123	6.00%	216	10.00%	216	10.00%
1700	90	15.00%	91	15.00%	90	15.00%	143	7.00%	627	30.00%	623	30.00%
1800	60	10.00%	60	10.00%	60	10.00%	128	6.00%	362	17.00%	360	17.00%
1900	78	13.00%	78	13.00%	78	13.00%	174	8.00%	341	16.00%	344	16.00%
2000	102	17.00%	102	17.00%	101	17.00%	211	10.00%	400	19.00%	394	19.00%
2100	59	10.00%	59	10.00%	59	10.00%	99	5.00%	404	19.00%	410	20.00%
2200	29	5.00%	29	5.00%	29	5.00%	52	2.00%	170	8.00%	160	8.00%
2300	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
0	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
100	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
200	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
300	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
400	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
500	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
600	0	0.00%	0	0.00%	0	0.00%	0	0.00%				

TABLE A-11
AIRLINE PURGE SCHEDULE
NUMBER OF PURGES (4 CONTAINERS) PER HOUR
NORMAL VOLUME

Time	Airline						
(Hour)	American	USAir	Delta	Northwest	United	Continental	Transworld
1500	0	0	0	0	0	0	0
1600	0	1	0	0	0	0	0
1700	1	0	0	1	0	1	1
1800	0	0	1	0	1	0	0
1900	2	1	1	1	1	1	0
2000	1	1	0	1	1	0	0
2100	2	2	2	2	1	1	1
2200	1	1	0	0	0	0	0
2300	3	2	2	2	2	1	1
0	5	4	4	4	4	2	2
100	4	2	2	2	2	2	1
200	7	5	5	4	4	2	2
300	4	3	2	3	3	2	1
400	4	4	3	3	3	1	2
500	2	1	1	1	1	1	0
600	1	1	1	1	1	1	1
700	0	0	0	0	0	0	0
800	0	0	0	0	0	0	0
900	1	0	0	0	0	0	0
1000	0	0	0	0	0	0	0
1100	0	0	0	0	0	0	0
1200	0	0	0	0	0	0	0
1300	0	0	0	0	0	0	0
1400	0	0	0	0	0	0	0

TABLE A-11 (cont'd)
AIRLINE PURGE SCHEDULE
NUMBER OF PURGES (4 CONTAINERS) PER HOUR
PEAK VOLUME

Time (Hour)	Airline						
	American	USAir	Delta	Northwest	United	Continental	Transworld
1500	0	1	0	0	0	0	0
1600	0	0	0	1	0	0	0
1700	1	0	1	0	0	1	0
1800	0	1	0	0	1	0	1
1900	2	1	1	2	1	1	0
2000	2	1	1	1	1	1	1
2100	3	2	2	2	1	1	1
2200	1	1	1	0	1	1	0
2300	3	3	2	3	2	3	1
0	6	4	4	3	4	2	2
100	5	4	4	3	3	2	2
200	7	5	4	5	5	3	2
300	7	5	4	4	4	2	2
400	5	4	4	4	3	1	1
500	3	2	1	2	2	0	1
600	1	1	1	1	0	0	0
700	0	0	0	0	0	0	0
800	0	0	0	0	0	0	1
900	0	0	1	0	1	0	0
1000	0	0	0	0	0	0	0
1100	0	0	0	0	0	0	0
1200	0	0	0	0	0	0	0
1300	0	0	0	0	0	0	0
1400	0	0	0	0	0	0	0

TABLE A-12
UNLOADING TIMES FOR ARRIVING PIECES
NORMAL VOLUME

Truck Arrival Time	First GPMC Arrives at Unloading	Unloading Completed	Time to Unload Minutes
1400	1402	1407	7
1500	1502	1507	7
1545	1547	1552	7
1600	1602	1607	7
1650	1652	1657	7
1700	1702	1707	7
1745	1747	1752	7
1745	1747	1752	7
1800	1802	1808	8
1815	1817	1822	7
1830	1832	1837	7
1845	1847	1852	7
1900	1902	1907	7
1900	1902	1907	7
1915	1917	1922	7
1935	1937	1949	14
1945	1947	1952	7
1945	1947	1952	7
2000	2002	2007	7
2000	2002	2007	7
2040	2042	2048	8
2045	2047	2052	7
2100	2102	2107	7
2100	2107	2112	12
2100	2102	2114	14
2100	2102	2116	16
2100	2105	2118	18
2115	2117	2122	7
2115	2117	2122	7
2115	2117	2125	10
2135	2137	2142	7
2145	2147	2152	7
2200	2202	2208	8
2245	2247	2252	7
2300	2302	2316	16
2300	2302	2317	17
2330	2332	2337	7
2330	2332	2340	10
2335	2337	2345	10
2355	2357	2408	13

TABLE A-12 (cont'd)
UNLOADING TIMES FOR ARRIVING PIECES
NORMAL VOLUME

Truck Arrival Time	First GPMC Arrives at Unloading	Unloading Completed	Time to Unload Minutes
0	2	8	8
15	17	27	12
20	22	33	13
25	28	55	30
45	48	58	13
100	102	117	17
110	112	117	7
130	132	137	7
145	150	201	16
145	147	212	27
145	147	223	38
155	215	223	28
200	222	227	27
200	219	228	28
230	232	258	28
250	259	304	14
245	254	304	19
300	303	309	9
300	303	323	23
310	318	323	13
345	347	352	7
345	347	357	12
345	347	357	12
400	405	412	12
400	402	422	22
400	402	427	27
415	423	428	13
415	423	432	17
440	442	447	7
445	447	453	8
500	507	512	12
500	507	512	12
455	457	513	18
545	547	553	8
600	602	607	7
600	602	607	7
630	632	637	7
645	647	653	8
700	702	707	7
800	802	807	7
900	902	908	8

TABLE A-12 (cont'd)
UNLOADING TIMES FOR ARRIVING PIECES
PEAK VOLUME

Truck Arrival Time	First GPMC Arrives at Unloading	Unloading Completed	Time to Unload Minutes
1400	1402	1407	7
1500	1502	1507	7
1545	1547	1552	7
1600	1602	1607	7
1650	1652	1657	7
1700	1702	1707	7
1745	1747	1752	7
1745	1747	1753	8
1800	1802	1808	8
1815	1817	1822	7
1830	1832	1837	7
1845	1847	1852	7
1900	1902	1907	7
1900	1902	1907	7
1915	1917	1922	7
1935	1937	1951	16
1945	1947	1955	10
1945	1948	1955	10
2000	2002	2007	7
2000	2002	2007	7
2040	2042	2050	10
2045	2047	2052	7
2100	2102	2107	14
2100	2102	2116	16
2100	2102	2116	16
2100	2105	2121	21
2115	2117	2122	7
2115	2117	2124	9
2115	2119	2128	13
2135	2137	2142	7
2145	2147	2152	7
2200	2202	2208	8
2245	2247	2252	7
2300	2302	2317	17
2300	2302	2322	22
2330	2332	2337	7
2330	2332	2342	12
2335	2337	2346	11
2355	2357	12	17

TABLE A-12 (cont'd)
UNLOADING TIMES FOR ARRIVING PIECES
PEAK VOLUME

Truck Arrival Time	First GPMC Arrives at Unloading	Unloading Completed	Time to Unload Minutes
0	3	9	9
15	17	28	13
20	23	37	17
25	32	101	36
45	57	107	22
100	103	122	22
110	117	125	15
130	132	137	7
145	150	202	17
145	147	219	34
155	219	231	36
200	227	232	32
145	147	232	47
200	228	237	37
230	234	314	44
245	301	317	32
250	313	318	28
300	314	322	22
300	303	338	38
310	318	340	30
345	347	352	7
345	347	357	12
345	347	401	16
400	402	407	7
400	402	423	23
400	402	433	33
415	427	433	18
415	429	439	24
440	442	447	7
445	447	453	8
500	507	512	12
500	507	512	12
455	457	517	22
545	547	553	8
600	602	607	7
600	602	607	7
630	632	637	7
645	647	653	8
700	702	707	7
800	802	807	7
900	902	908	8