

A COMPUTER SIMULATION OF THE PALLETIZING SYSTEM
AT FRITO-LAY, INC. IN TOPEKA, KANSAS

by

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I. INTRODUCTION

There are five major steps involved in producing a product in a Frito-Lay, Inc. manufacturing plant. The first step involves receiving raw materials into a plant and feeding them into the production process. The next step is to transform these raw materials into an edible product. The third step is to package the edible product in the appropriate packages. The fourth step is to store the packaged product in a storage facility, such as a warehouse, and the fifth step is to ship the finished product to the various customers. This report researches the interface between two of these steps, the transfer of the finished packaged product to the warehouse facility for storage until shipping to the customer.

Originally, the Frito-Lay plant in Topeka, Kansas had transferred the finished packaged product from the packaging floor into the warehouse by employees pulling full skids of finished product from the packaging floor into the warehouse with hand jacks. In October of 1983, a conveyor system was installed to transfer the finished cases of product from the packaging floor into the warehouse, thus eliminating the manual transportation of product. With the new system, the packers, whose prior responsibilities included packing the bags of product into cardboard cases, stacking the cases onto pallet board, and accounting for the cases that were packed, are now only responsible for packing the bags of product into cases and placing the cases of finished product onto a conveyor. Their other responsibilities were transferred to

employees called palletizers. The palletizers are located at the end of the conveyor system at a continuous loop called a palletizing loop. Their responsibilities included stacking the cases of finished product onto pallet boards and accounting for the cases produced, for up to four different items. It is the activity of the palletizer that is the topic of this thesis.

This conveyor system was developed specifically for Frito-Lay, Inc. and has not been previously modeled using a computer simulation. Pertinent conveyor research reveals a moderate amount of consideration of conveyor theory and modeling. Kwo, 1958, was the first to quantify basic conveyor principles. His research, however, presented only a minimum amount of operating characteristics. From the literature, it appears that "there has been a fair amount of prior research concerned with non-recirculating conveyor supplied systems, [and that] there appears to be only a meager amount of work concerned with the recirculation system in which the conveyor is a continuous loop moving at a constant speed," Bussey, 1972. Bussey presents a model for analyzing closed loop conveyor systems with multiple workstations. His research, however, investigates a closed loop conveyor with discretely spaced loads. Another simulation model developed in this area is that of Buxey and Owen, 1981, dealing with the final assembly of a telephone. Bobillier, Kahan and Probst, 1976, also modeled a continuous loop conveyor with discretely spaced loads in their

simulation of an automatic warehouse.

The above models, although similiar to the model needed for this conveyor system, do not include the decision process for the palletizer at the palletizing loop. These considerations also do not deal with the continuous loop with randomly spaced loads. This loop has been referred to in past research but very few papers have dealt directly with this system. These aspects of the simulation model of this system make it a unique model applying specifically to the Frito-Lay conveyor system in Topeka, Kansas.

The purpose of this study was to develop a model to explore possible productivity improvements to the current palletizing system. The areas researched in this study were the current conditions of the system which provided the highest productivity levels. A simulation model written in GPSSH was the tool used to model the system and determine the productivity improvements.

II. DESCRIPTION OF THE SYSTEM OPERATION

There are four major aspects of the system operation: the infeed of the cases into the conveyor system; the programmable controller which controls the conveyor system; the conveyor and case accumulation capabilities of the conveyor; and the palletizing loop and palletizer. To model this system it was necessary to understand each of these components. A discussion of these aspects of the system will be given below.

Case Infeed

The cases of product are fed into the conveyor system and placed onto the infeed conveyor on the packaging floor by employees called packers. Bags of product are produced at the packaging machines and travel up a short conveyor to the packer. The packer then takes the bags of finished product and places them into a cardboard case with a pre-set bag configuration and case count. After the packer places the correct number of bags into the case, he or she closes the cardboard case and places a case label on it to identify the contents of the case. The packer then places the finished case onto a conveyor located directly in front of the packing station. This conveyor is the infeed of cases into the palletizing loop.

There are 8 to 10 packaging machines which supply one infeed conveyor and one palletizing loop. There are 39 packaging machines on the packaging floor. The 39 packaging machines are specifically used in one of the five major

departments of products produced in this manufacturing facility: potato chips; Doritos(R); extruded products; Tostitos(R); and universal corn products/Variety Pack(R). These departments supply one of the four existing palletizing loops.

The size and type of product run on the packaging machines shift is determined from the production schedule. The production schedule for each department is determined the prior day by a real time demand from the route salesmen. A salesman can submit an order for his route up to 78 hours before delivery and can change his submitted order by phone up to 24 hours beforehand. Because of the salesmen's ordering procedures, the production schedule is determined one day in advance.

The production schedules are a very important aspect of this computer simulation model. The items on the production schedule are not produced at the same case per hour rate and because of this, the different combinations of products being run in one department can greatly affect the amount of cases to be palletized in a given shift.

The Programmable Controller.

The entire conveyor, from case infeed to the palletizing loop is controlled through a programmable controller. Photo cells are placed on the conveyor in strategic places to monitor the flow attributes of the cases on the conveyor. When buildup conditions on the conveyor

exist, certain segments of the conveyor will shut off and accumulate cases as a temporary storage area. When these accumulation areas collect a pre-set number of cases, the photo cell will trigger the programmable controller to react to the condition in some other manner, i.e. turn on a segment of conveyor or shut off another segment of the conveyor.

The programmable controller with the aid of the photo cell also provides case spacing before the case enters the palletizing loop. An accumulation area prior to the decline conveyor entering the palletizing loop will store cases to allow adequate spacing. When a case passes by the photo cell at position A (see Figure 1), it stops the case at B for a pre-set time period. After that period elapses, the case in area B begins to move again, and the process continues. This spaces the cases before entering the loop to avoid any jams at the entrance to the palletizing loop.

The controller is programmed with ladder logic to perform certain actions under certain conditions. The broken or unbroken beams of the photo cell are the source that relays these conditions to the the programmable controller. The programmable controller, therefore, acts as the "traffic cop" to the conveyor system by controlling the case flow. The application of the programmable controller and the ladder logic to the simulation model is discussed later in this study.

Conveyor and Case Accumulation

The conveyor rollers throughout the length of the

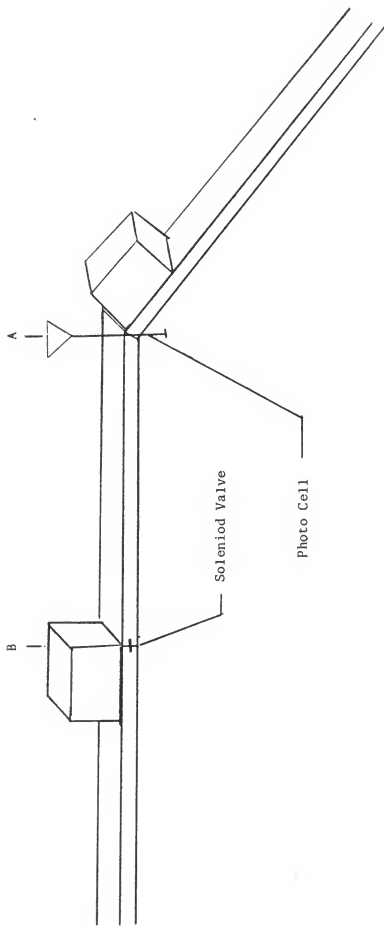


Figure 1: Case Spacing Before a Case Enters the Palletizing Loop

conveyor are chain driven live rollers with intersperced dead rollers. The live rollers are the mechanism that makes the cases move along the conveyor. In certain areas of the conveyor there exists the capability of zero pressure accumulation. Zero pressure accumulation is the process of stopping and storing cases on the conveyor without having the cases exert any pressure on each other. Zero pressure accumulation provides temporary storage for the cases on the conveyor. This zero pressure accumulation is controlled by pressure sensor rollers located at 30 inch intervals down the length of the conveyor. When a case rolls over a pressure roller, the clutch disengages the rollers in the near vicinity. When a case can continue to roll over the pressure roller, the clutch re-engages the rollers to continue the case movement process. When there is an accumulation situation and the case can not move off the pressure roller, the case sitting on the pressure roller temporarily disengages the clutch for the rollers in the vicinity and stops the case movement process. This is the process used to accumulate cases on the conveyor.

The entire accumulation and release process is started by the activation and deactivation of certain solenoid valves as determined by the programmable controller. The broken or unbroken beams of the photo cells are the signal to the programmable controller to begin the accumulation process. When cases are released from accumulation, they are released by reversing the accumulation condition of the

solinoid valve to allow the first case in the accumulation area to move. The remainder of the cases are released by the process of singulation. Releasing the cases by singulation allows spacing between the cases because they are released one by one.

There are certain areas of the conveyor where accumulation can occur. These areas are the long straight segments of the conveyor. The conveyor segments with bends do not have the capability of accumulating cases. This is to avoid unnecessary jams in the curved part of the conveyor.

The Palletizing Loop and the Palletizer

The palletizing loop contains three major functions: case infeed, case pickup and case recirculation (see Figure 2). Cases are fed into the loop by a belt driven conveyor which is controlled by the programmable controller. Cases are allowed to feed into the loop unless there is a backup in the recirculating-accumulation area. If there is a backup with the recirculating cases, control will be given to this conveyor section until those cases have been cleared. Photo cells are located at three points on the loop, the case infeed, the beginning of the recirculating-accumulation section and the end of the recirculating-accumulation segment on the loop to control the infeed and recirculation processes.

As the cases are being fed onto the conveyor, they follow a guide that turns the case sideways so the case label can be easily read by the palletizer. The case then

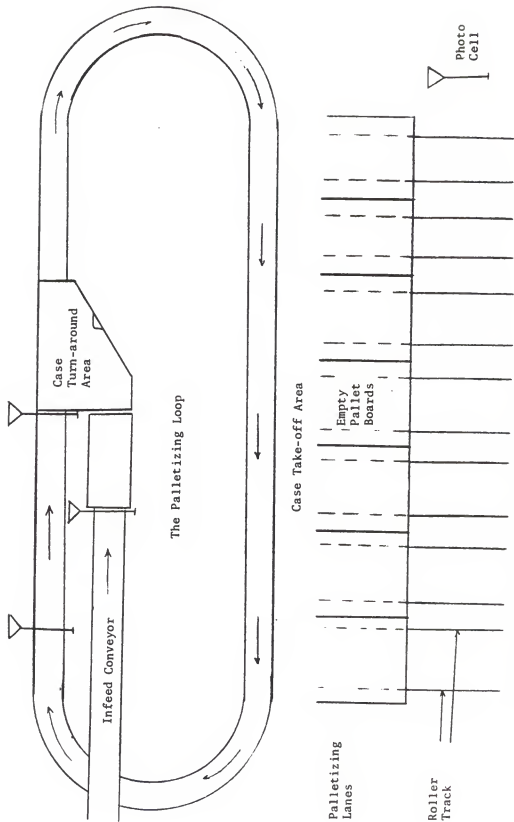


Figure 2: The Palletizing Loop and Palletizing Area

continues in this position the entire time it is on the loop. The cases follow the the conveyor until they reach the front side of the loop where the palletizer is standing (see Figure 2). If the palletizer misses a case, the case recirculates around the loop. The case follows around to the back side of the conveyor where it either accumulates or recirculates, according to the present conditions on the loop as determined by the photo cells.

The palletizer's workstation consists of the conveyor with cases circulating on it, the pallet stacking area, and a small desk used to facilitate counting the cases that have been produced (see Figure 2). The palletizer takes a case off of the conveyor and stacks it on a pallet board located behind him. There are seven to eleven lanes for empty and full pallet boards at each palletizing loop. Each of these lanes consists of roller track for easy movement of the pallet board, and a stacking guide for straight stacking of product. One of the lanes is used to store empty pallet boards.

Cases are stacked on the pallets according to product line and item. As the palletizer stacks the appropriate number of cases on the pallet as determined by product and line item, he or she must place an inventory ticket on the pallet and record the ticket on a line sheet. This is the accounting system for production and shipping to determine of the number of cases produced on a shift. The palletizer then pushes the pallet along the roller track into a position

where the shipping personnel can pick up the pallet with a fork lift and put it into inventory. The palletizer then puts down an empty pallet board on the roller track and begins stacking cases on the empty pallet board. Each palletizer is responsible for palletizing between one to five different items at a time, depending on the hourly production rate of these items.

III. DEVELOPMENT OF SYSTEM PARAMETERS

Before determining the criterion to be used in the final model of this system, there were several areas studied to determine the appropriate approach to the model. A brief discussion will be given below on the different aspects of the system that were evaluated for the simulation model.

A Study of the System's Ladder Logic as it Relates to Product Flow

Initially, the simulation model was to be based on the ladder logic of the programmable controller. Ladder logic is the computer language that tells a programmable controller how to react to certain conditions in the operating system. An example of the format is shown in Figure 3. Ladder logic functions much like boolean variables. If certain conditions are true a reaction will occur in the system. If the conditions are not true a different reaction will occur in the system. A study was performed to decode the ladder logic into actual boolean variables. After converting the ladder logic into boolean variables, the plan for the model was to utilize the various conditions set forth in the logic of the programmable controller to become the basis for action in the model. After modeling only a short segment of the conveyor with a large amount of code it was determined that this approach was much too complicated for the purpose of this study and that simplification of the model was necessary.

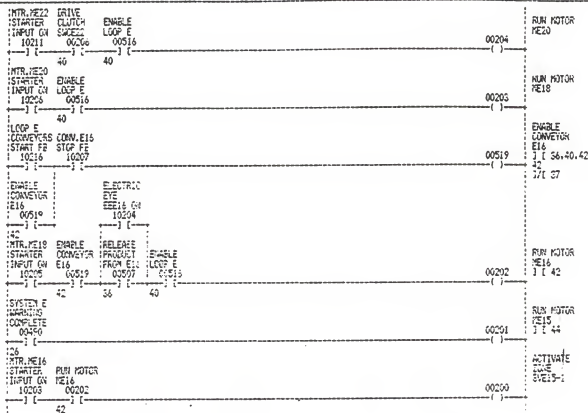


Figure 3: Ladder Logic of the Programmable Controller

An Occurance Sample of the Activities of the Palletizer

After abandoning the ladder logic approach, it was decided to gain more information about the activities of the palletizers on a daily basis. This led to an occurrence sample of the activities of the palletizers. The activities of the palletizers were divided into sixteen categories as shown in Table 1.

An initial assumption of the management at Frito-Lay, Inc. was that the palletizers spend a large quantity of their time in idle activities, i.e. walking and standing. The occurrence sample was based on the idle time of the palletizers as shown by the calculations in Table 1. An initial sample of 78 observations was taken to determine the activities and the initial percentage breakdown for the sample. An idle time percentage of 25% and a relative accuracy of 12% was used to determine the number of observations needed to provide a statistical confidence interval about 25% idle time between 22% and 28%. The final idle time activity percentage was 28% using 563 observations.

The occurrence sample provided a breakdown of the activities of the palletizer. It also confirmed the assumption that the palletizer did spend a fair amount of his time walking for the most part to pick up a case and standing idly or waiting for a case to come to him. Due to the complexity of incorporating each of the activities into the simulation model, the occurrence sample was used to gain a knowledge of the hourly functions of the palletizer.

Table 1. Occurance Sample Description

Activity	Observations	Percent
1. Filling out line sheets	8	1.3%
2. Throw case on skid	70	11.7%
3. Place case on skid	42	7.0%
4. Place ticket on skid	12	2.0%
5. Walking	97	16.1%
6. Standing	71	11.9%
7. Putting down pallet board	19	3.2%
8. Walking with case	41	6.8%
9. Placing two cases on skid	8	1.3%
10. Re-arranging skid	17	2.8%
11. Writing on line sheet	61	10.2%
12. Re-arranging case on loop	6	1.0%
13. Pushing back skid	13	2.2%
14. Picking up case	97	16.2%
15. Pushing back case	12	2.0%
16. No one on loop	25	4.2%
Total Observations	599	

Actual case pickup and placement on skid = 34.9%

Time spent walking or standing = 28.0%

Time spent doing other palletizing activities = 37.1%

Calculations:

$$A = sp = z(p(1-p)/n)^{1/2}$$

$$s = .12$$

$$p = .25$$

$$z = 1.645 \text{ @ } 90\% \text{ C.I.}$$

$$n = 563 \text{ observations according to percent idle time}$$

where n = no. of observations
 p = mean percent occurrence
 z = no. of std deviations
 for confidence interval
 A = desired absolute accuracy
 s = relative accuracy

Determining the Operating Speed and Length of the Conveyor

The dimensions of the palletizing loop were determined from a blue print of the palletizing area. The conveyor speed is rated at 90 feet per minute. Although there may be some case slippage from the rollers due to friction, the simulation model uses this conveyor running rate. Both the length of the conveyor and the the conveyor running rate are used in the model to simulate the amount of time it takes for a case to travel around the length of the conveyor.

A Study of Production Schedules

Approximately six weeks of production schedules at three shifts per day were reviewed to determine some typical production schedules. As was previously discussed, the production schedule is determined by a real time demand by the route salesmen and is variable on a day-to-day basis. The production schedules were studied by department, being categorized by the item and bag size being run i.e. \$1.49 Lays(R) Potato Chips. From the breakdown of line items, the schedules were further refined by determining the actual cases produced with a schedule by applying the standard machine speeds to the schedule. This was done in attempt to find some typical production schedules for each department. The study showed that there was a wide variety in the number of cases per hour run in a given production schedule. It was determined at this point to utilize the high and low points in the range of cases generated per hour to determine how the palletizer would react in productivity to the various

conditions. The range of case per man hour inputs were 260 cases per hour to 521 cases per hour. The study of production schedules was performed for each of the five departments. However, the actual simulation model only represents potato chip production so the study of production schedules proved to be more detailed than necessary. The exact rates used in the model will be discussed in Section IV.

IV. MODELING THE SYSTEM

After attempting to model the system through the ladder logic of the programmable controller, it was evident that a simpler modeling approach was necessary. One assumption that was made in the model was that the cases arrive at the palletizing loop in a random pattern. It was also determined from the production schedules that the quantity of the different items to be generated could be assigned a probability distribution. The probability was based on the individual case per hour output of the item on a given production schedule. These assumptions gave the model a basis for the case infeed into the system. The flow of the cases around the palletizing loop was also known, as well as the basic pattern used by a palletizer to pick up a case of product. The final model was determined from the knowledge of these characteristics of the system.

Case Infeed and Product Flow

Figure 4 shows an example of a production schedule. The schedule lists the items to be produced on the shift as well as the quantity of each item. Each item is scheduled at 90% of the standard machine speed for that package size. In the area of potato chip palletizing, there are limitations on the pounds of potato chips that can be produced in an hour. Because of this, a package may not be able to be run at the 90% of standard machine speed. The input probability distribution for the case type generation in the model was



DAILY PRODUCTION SCHEDULE

DATE	1	2	3	4	5	6	7
7/10/14 Tue			1st				PC
CP SC ON PC 211				650 min	800 max		
1.39 SC ON PC 716				950 min	1050 max		
Vend SC ON PC 190				200 min	300 max		
CP SC ON PC 211							
8PK PC 65				900 min	1000 max		
8PK PC 105							
8-PK PC 105							
1.39 PC 850				1600 min	1500 max		
1.99 PC 911				1100 min	1300 max		
2.49 PC 102				1000 min	1300 max		
				CP PC 211	400 min	600 max	
							CP PC 190
Vend BBQ PC 190				160 min	240 max		
							CP BBQ PC 190
CP BBQ PC 211				650 min	800 max		
1.39 BBQ PC 43				600 min	750 max		

Figure 4: Daily Production Schedule

developed with this in mind. Table 2 shows the number of items run in each of the simulation runs of the model. The first column lists how many palletizers were used in the model which, is either one or two palletizers. The second column lists the total number of cases per hour that were run into the system. The third column lists the probability distribution of the different case types run into the system, and the fourth column shows the total number of different items run into the system. The different case types are identified by a number of one through six instead of by the name used on the production floor, such as \$1.49 Lays(R) Potato Chips, etc. Again, case type probability distributions are taken from actual production schedules, and the number of palletizers assigned to the palletizing loop is that number which would have been assigned for crewing on the production floor.

When Frito-Lay, Inc. installed the palletizing loops into their Topeka, Kansas facility, a standard was established for the cases per man-hour output, which was four hundred cases per man-hour. The eight simulation runs made of the model vary around that standard cases per man-hour output. This procedure was used to establish the characteristics of the overload and underload points of the palletizer. A Generate statement was used to input cases into the palletizing loop at the various inter-arrival times, which would provide the system with the given cases per hour input. After a case had been generated into the system, it would be assigned a case-type, according to the various probability distributions.

Table 2. Probability distributions for Simulation Runs

No. of Palletizers	Total Cases per Hour	Item Distribution	Total Items
1	280	.5,1/1,2	2
1	394	.678,1/1,2	2
1	460	.580,1/.710,2/1,3	3
1	521	.457,1/,578,2/1,3	3
2	673	.218,1/.500,2/.698,4/1,5	4
2	812	.180,1/.500,2/.836,4/1,5	4
2	882	.461,1/.530,2/.708,4/ .874,5/1,6	5
2	969	.289,1/.441,2/.510,3/ .675,4/.716,5/1,6	6

This provided the model a case type assignment and a case rate input into the system.

To simplify the model of the palletizing system, only the palletizing loop and its characteristics were used. Therefore, when the cases were generated into the system, they were generated directly onto the palletizing loop. As was previously mentioned, the palletizing loop is a recirculating continuous loop conveyor.

The palletizing loop can be divided into three sections. The first section is the case entry section where the cases are fed onto the loop; the next section is case take-off, where the palletizers remove the cases from the loop and place them on pallet boards for storage in the warehouse; and the last section is recirculation, where there is no normal case removal or case infeed. This model was developed such that the cases were fed onto the conveyor after the case take-off section. Therefore, the cases enter onto the conveyor, travel into the recirculation section, and then travel through the case take-off section. Actually, the cases come onto the conveyor in the middle of the recirculating area, then through the case take-off section to a portion of the recirculating conveyor back to the case infeed section. For simplicity, the cases in the model are fed into beginning of the recirculating conveyor.

The product flow around the palletizing loop is developed through the a series of Advance statements to model the case travel at 90 feet per minute. The recirculating section of the conveyor is a Storage facility which can

contain a maximum of 35 cases. The cases reside in the Storage for the duration of the recirculating period and leave the Storage on a first-in first-out basis. The case take-off segment is sub-divided into two Storage facilities, one for each palletizer, and it contains a total of 15 cases. Each of the two palletizer's take-off sections are subdivided into five Storage areas, which can contain a total of three cases. The reason for this, is to control the logic used for the case pickup, which will be explained under the next sub heading and to maintain a truer product flow in the area where the palletization occurs.

Palletization of Cases

The palletization logic is based on two GPSSH programming concepts. The first of those is the use of a Group in conjunction with the Scan and Alter blocks. In this simulation model, a group is used to mark a case in each of the two palletizing areas when it has been identified as a case to be picked up. The Scan and the Alter blocks are the mechanisms which enable the logic to mark the next case on the palletizing loop to be palletized. The second basic GPSSH concept used in the simulation model is a series of Test blocks which determine the status of the case as it travels on the loop in respect to the current location of the palletizer, the case type, and the current location of the case on the loop. These basic concepts are the crux of the simulation model and will be explained in detail in this

section.

When a case enters one of the two palletizing take off areas it joins a Group. As previously stated, the maximum content of one of these palletizing areas is 15 cases. Therefore, the maximum content of each of the two Groups is also 15 cases. Therefore, when a case enters or leaves a palletizing take off area it also enters or leaves the same group. As the case enters the case take off area and the group, it is given a number from 1 to 15 to represent its position in that group. These case number assignments are important in the simulation model because they are used in the process of determining the next case to be picked up off the loop. This enables the model to look at case take off candidates in a first-in first-out basis so to avoid favoring case number one in the case takeoff procedure. The case number is basically a position marker of the case based on the length of time the case has spent in the group.

Each of the two palletizer take off areas are divided into 5 storage areas of three case widths (see Figure 5). Each of these storage areas represents the location of a particular case on the loop, i.e. if the case is in the first storage area it is at location 1 on the loop; or, if the case is in the second storage area it is at location 2 on the loop, etc. These storage area give the model a marker of case location. These markers provide one of the three testing criteria to determine if the case can potentially be taken off of the loop.

There are two other criteria used to determine if a case

can be potentially taken off of the loop. Those criterion are the case type, that is, type of product and the location of the palletizer at that time. The case type of the product is determined when the case is generated into the system by the different probability distributions. The current location of the palletizer is represented by the last case to be palletized. The last case to be palletized represents the current location of the palletizer because the palletizer takes the case off of the loop and places the case onto a pallet board and waits at that location until he or she decides on the next case to be picked up.

After the case travels one case width in the case take-off area it is tested according to current case location on the loop, case type and current location of the palletizer. If the case meets all of the above criteria, a one is placed into a matrix to denote that that specific case in the group can be a candidate for case takeoff. The matrix is a 2 column by 15 row matrix. The two columns represent the two independent case take-off areas. The 15 rows represent the 15 potential cases in the case take-off areas. It is this matrix which stores the status of the 15 cases in the case take-off group. The one is placed into the matrix according to the given case number of the case in that group. This is a status record of a particular case in one of the two groups and is the basis from which the scan is made to determine which case is the next case to be taken off of the loop. If a case travels through one location marker (one of

the five locations in a case take off area) to the next location marker and has met the criterion in the previous location marker, the matrix value is reset to zero to allow testing without retaining the status of the case at the previous location marker. It is this testing and recording procedure occurring throughout the length of the case take-off section that provides the model with the knowledge of which cases are in the proper position for case take-off.

The above procedure explains how a potential candidate for case pick up is determined. It does not, however, explain how the case actually leaves the loop and consequentially leaves the system. There are four points in the simulation model that determine next case to be palletized. These points are before a case enters each of the two case take-off areas and immediately after a case is palletized by one of the two palletizers. The cases flowing through the system at these points trigger the procedure used to determine the next case to be taken off of the loop. The first two testing areas are immediately after a case is palletized at the palletizers. The testing is done at this point to model the real-world situation. It is not until after a palletizer palletized a case, that he then looks for the next case to be palletized. The second two testing areas just prior to each of the case take-off areas are triggered by any case traveling through that area. This is done to insure that there is an ongoing test being made to determine the next case to be palletized. If the test procedure were not made at this point, an initial case would never be

designated to be palletized. The second two testing areas provide a backup to the testing done after the case is palletized.

The basic procedure used to determine the next case to be palletized is by scanning the matrix to determine if any of the cases meet criteria to be palletized. The scan is performed on the case that had been in the group the longest, second longest, etc. which is determined from the last case number assigned in one of the two groups. If, for example, the last case number assigned in the group for palletizer 1 was number 10, the model will scan column 1 row 11 in the matrix to determine if the case has met the necessary criteria to be palletized. If, the case has met the criteria (it has a 1 in that position in the matrix), the case will be marked in one of its parameters with a 1. The 1 marked in the parameter shows the system that this is the next case to be taken off of the palletizing loop to be palletized. If column 1 row 11 has not met the criteria to be palletized, the model will check column 1 row 12 through column 1 row 10 until it finds a case that meets the criteria for palletization or until it ends the scan because no case in the group meets the necessary criteria.

The actual marking of the cases is done through the use of the Alter block in conjunction with use of the Group. Using the Alter block and the Group enables the system to place a 1 in the designated parameter without necessitating the case to travel through an assign block to mark the

parameter.

Before a the testing procedure begins to determine the next case to be palletized, it must first be determined whether or not a case in the group is currently marked for pickup. This is done to insure that two cases are not marked at the same time for pick up. This again is where the Group is useful because it can enable the system to scan all the cases in the group to test for pick-up marking without needing the cases to travel through a block for the testing.

The cases are tested at every case width to determine whether the case has been marked for pickup. If the case has been marked and the palletizer is not busy, the case is transfered off of the loop to the palletizer. At the palletizer, the case is palletized for eight seconds which is based on the pre-set standard of 400 cases per manhour. After being palletized, the case is used to determine the next case to be palletized and tabulates some statistics about its travel on the palletizing loop.

A complete documentation of the computer program used to model the system is shown in Appendix A.

V. RESULTS

This section shows the results tabulated from the statistics generated from the different simulation runs made of the model. The overall plan of the simulation was to run the model at the various case per hour generation rates for an eight hour shift to determine the effects on the palletizers when operating under the current system. The most important statistics gathered were the utilization of the first and second palletizers. Other statistics gathered were the interarrival times of the the cases as they go through the system and the mean number of times a case traveled around the palletizing loop before it was picked up to be palletized. The following tables show the information derived from the simulation runs and uses a reference point of the number of cases generated per hour into the system. Also shown are the number of cases palletized according to the number of cases generated into the systems.

Figures 6a, 6b and 6c, along with Table 3, show the results of the simulation runs with respect to the palletizer utilization or busy time, and the number of cases generated to each of the palletizers. The graph illustrates the break point, the point at which generating more cases into the palletizing loop does not increase the number of cases palletized by the palletizer. This point is at a case generation rate of approximately 435 cases per hour. Any case generation rate higher than 435 cases per hour will decrease the utilization of the the palletizer.

The overall utilization of the palletizers in the different scenarios, i.e. palletizer 1 utilization when run with palletizer 2, palletizer 2 utilization when run with palletizer 1 and palletizer 1 run alone show that running the palletizing loop with only palletizer 1 being fed is the most efficient use of a palletizer. The efficiency of palletizer 1 being run alone is 1.4% higher than that of the other two palletizer scenarios, the highest utilization factor being 95.8%. This seems to be intuitively correct that running with one palletizer is more efficient because the case flow to the palletizer is more consistent since all of the cases passing by the palletizer are palletizer specific. The overall efficiency of palletizer 2 being run with palletizer 1 is lower than that of palletizer 1 being run with palletizer 2 and that of palletizer 1 being run alone. This could be due to a higher wait time for palletizer 2 because the cases have to travel farther to reach the palletizer, and because of the gaps created by palletizer 1. The conclusion at this point is that palletizer 1 running alone has the greatest efficiency.

TABLE 3. UTILIZATION OF PALLETIZERS

CASES/HOUR =====	PALLETIZER 1 =====	PALLETIZER 2 =====
800	90.2%	86.4%
812	92.0%	88.6%
882	94.4%	85.0%
969	93.6%	90.0%
673	76.8%	73.2%
394	87.5%	----
280	61.7%	----
460	95.8%	----
521	95.7%	----

PALLETIZER UTILIZATION

PALLETIZER 1 WITH PALLETIZER 2

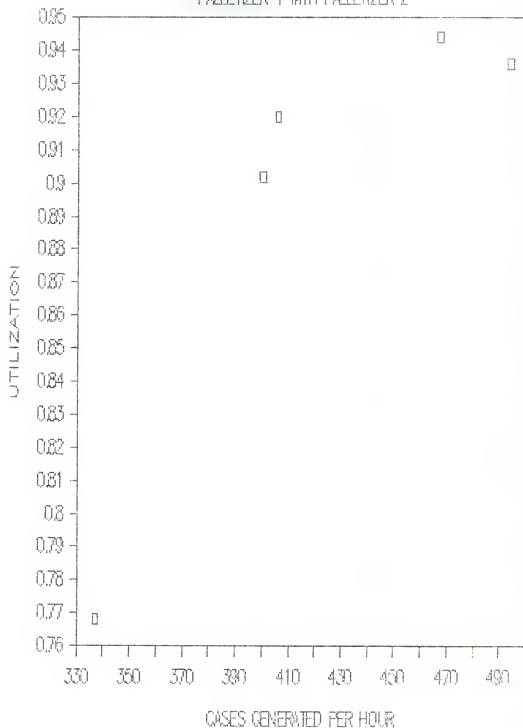


Figure 6a: Palletizer Utilization - Palletizer 1 with Palletizer 2

PALLETIZER UTILIZATION

PALLETIZER 2 WITH PALLETIZER 1

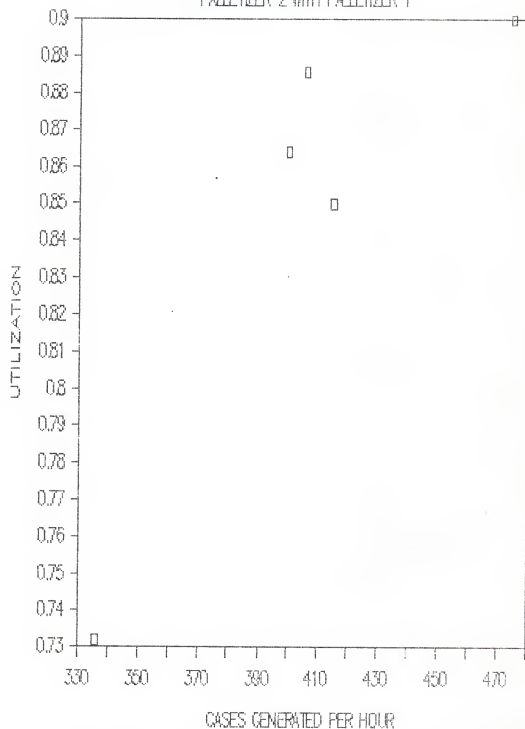


Figure 6b: Palletizer Utilization - Palletizer 2 with Palletizer 1

PALLETIZER UTILIZATION

PALLETIZER 1 ONLY

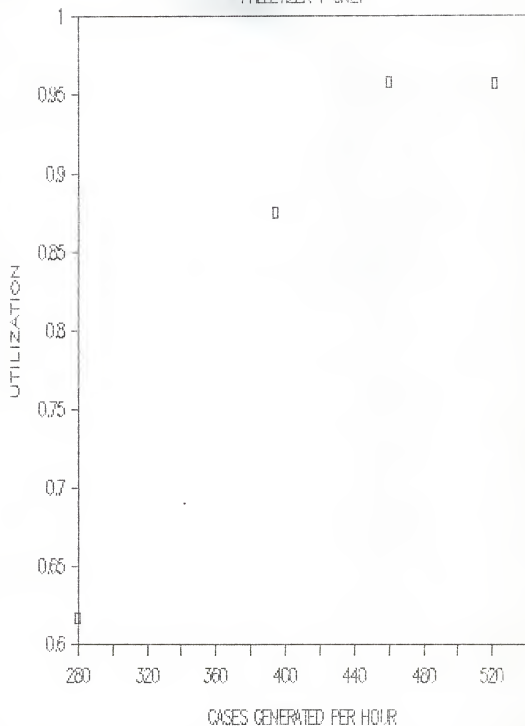


Figure 6c: Palletizer Utilization - Palletizer 1 Only

Figures 7a, 7b and 7c and Table 4 show the effects of the number of cases generated on the interarrival times of the cases as they go through the palletizing loop. The interarrival time is the time between two cases being palletized. The Figures show that the break point for the shortest interarrival times through is at approximately 435 cases per hour. At 435 cases per hour, the cases have the shortest interarrival times. At any higher case generation rates, the interarrival times increases. Again the graph shows that palletizer 1 has the shortest interarrival times and palletizer 2 with palletizer 1 has the overall longest interarrival times. The shortest average interarrival time for any of the simulation runs was palletizer 1 alone at 83.4 time units or 8.36 seconds. The results of interarrival times of the different simulation runs are consistent with that of the results of the efficiencies of the palletizers. The palletizer with the highest utilization is going to process more cases through the system per time interval.

TABLE 4. INTERARRIVAL TIMES OF CASES GOING THROUGH SYSTEM

CASES/HR =====	PALLETIZER 1		PALLETIZER 2	
	MEAN ====	STD. DEV. =====	MEAN ====	STD. DEV. =====
800	88.6	19.2	92.3	29.8
812	87.0	17.0	90.1	28.2
882	84.4	11.4	93.8	34.2
969	85.2	12.6	88.6	22.2
673	103.7	50.9	108.7	62.7
394	91.1	24.6	----	----
280	129.1	92.5	----	----
460	83.4	8.1	----	----
521	83.6	8.5	----	----

CASE INTERARRIVAL TIMES

PALLETIZER 1 WITH PALLETIZER 2

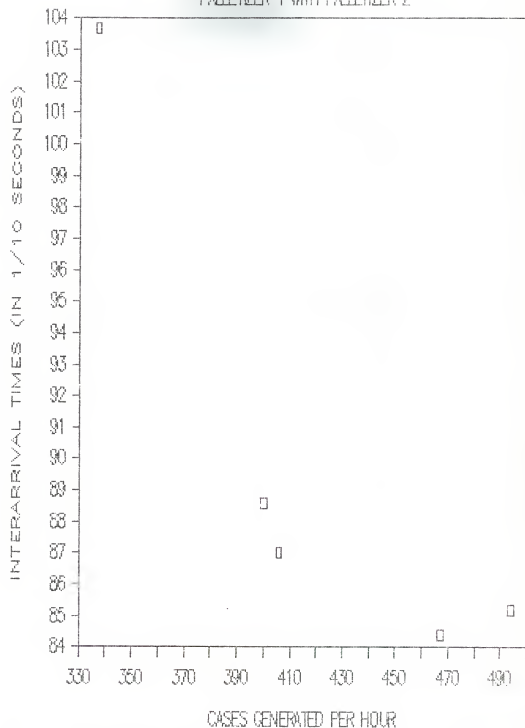


Figure 7a: Case Interarrival Times - Palletizer 1 with Palletizer 2

CASE INTERARRIVAL TIMES

PALLETIZER 2 WITH PALLETIZER 1

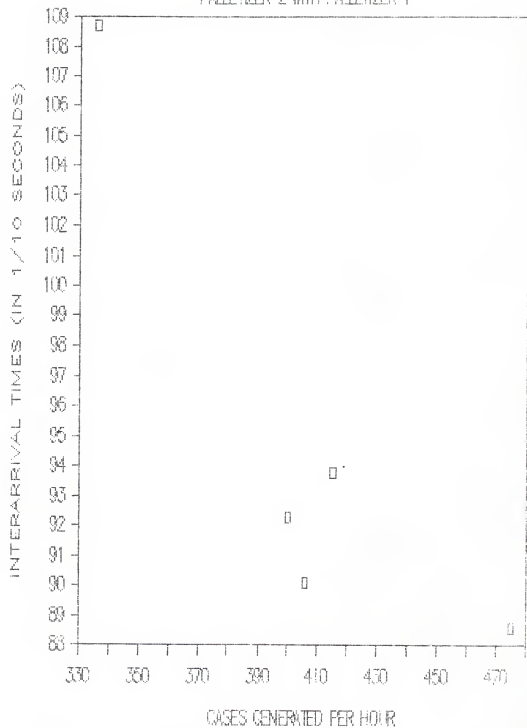


Figure 7b: Case Interarrival Times - Palletizer 2 with Palletizer 1

CASE INTERARRIVAL TIMES

PALLETIZER 1 ONLY

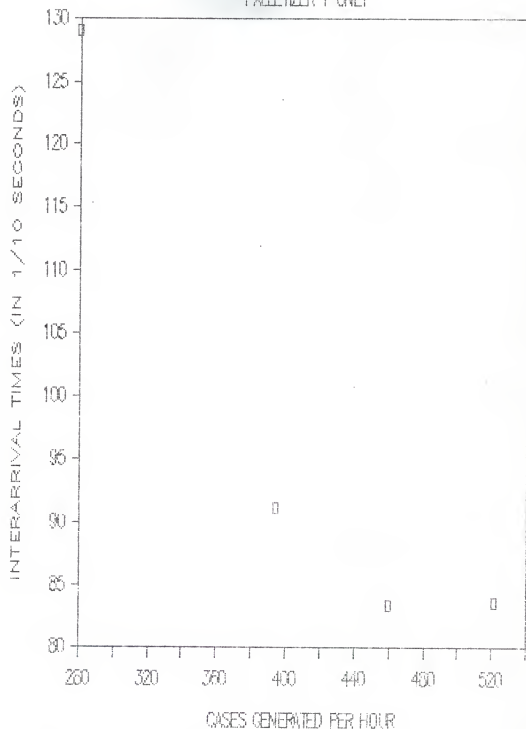


Figure 7c: Case Interarrival Times - Palletizer 1 Only

Figures 8a,8b and 8c and Table 5 show the results of the number of times a case travels around the palletizing loop versus the number of cases generated per hour. For the three model scenarios, the graph does not show a definite trend. What the graph does show is an upward trend in the number of times a case travels around the loop versus a greater number of cases generated into the loop. This is an intuitive conclusion; the more cases on the loop, the less chance of a case being picked up the first time around the loop. The Figures show that palletizer 2 run with palletizer 1 has the curve with the fewest average number of trips around the loop. Palletizer 1 alone has the greatest number of trips around the loop. This is consistent with the utilization factors of the palletizers in the different cases.

Because palletizer 2 run with palletizer 1 has the lowest utilization factor, it is capable of picking up more of the cases when they go by the first time. This graph also shows that with palletizer 1 alone, there is a faster increase in the number of times a case travels around the loop, as the number of cases per hour generated increases. This then shows a trade-off between the palletizer utilization and the number of times a case travels around the palletizing loop. The most important of these two characteristics is palletizer utilization; the conveyor carrying the cases is already running for the system so there is no loss for having a case travel around the loop a few extra times. This is a concern, however, when the excess number of cases causes a backup in the palletizing system.

TIMES TRAVELED AROUND LOOP

PALLETIZER 1 WITH PALLETIZER 2

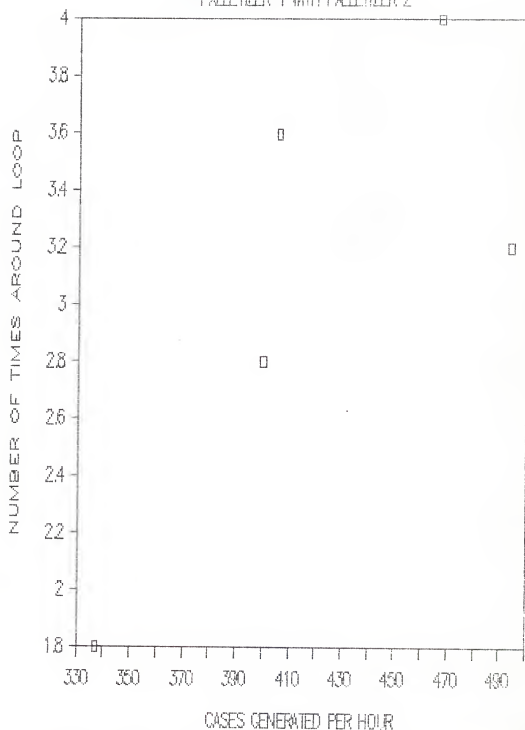


Figure 8a: Times Traveled Around Loop - Palletizer 1 with Palletizer 2

TIMES TRAVELED AROUND LOOP

PALLETIZER 2 WITH PALLETIZER 1

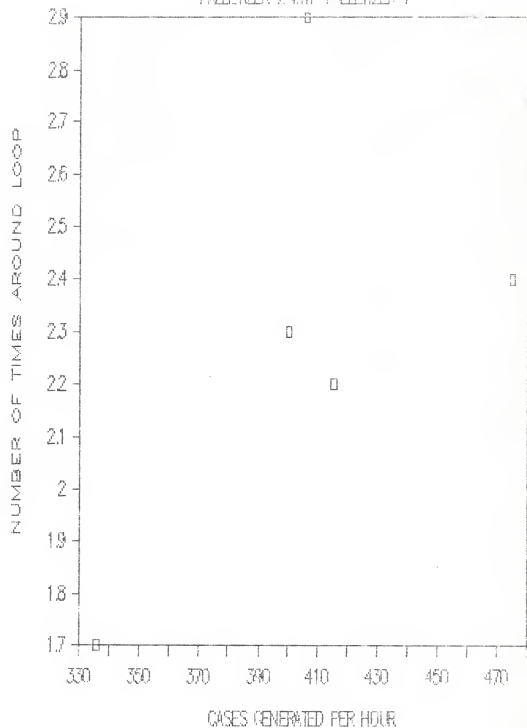


Figure 8b: Times Traveled Around Loop - Palletizer 2 with Palletizer 1

TIMES TRAVELED AROUND LOOP

PALLETIZER 1 ONLY

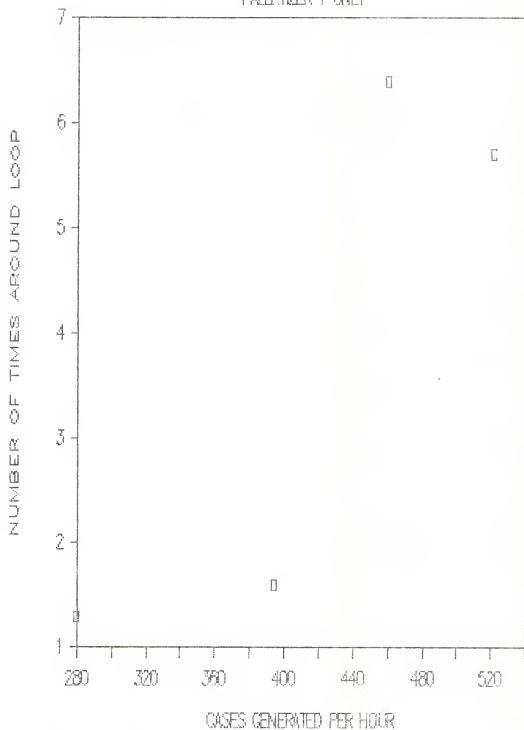


Figure 8c: Times Traveled Around Loop - Palletizer 1 Only

TABLE 5. NUMBER OF TIMES A CASE TRAVELED AROUND LOOP

CASES/HR =====	PALLETIZER 1		PALLETIZER 2	
	MEAN =====	STD. DEV. =====	MEAN =====	STD. DEV. =====
800	2.8	4.1	2.3	3.7
812	3.6	5.5	2.9	4.1
882	4.0	4.8	2.2	3.5
969	3.2	4.3	2.4	3.5
673	1.8	2.8	1.7	2.6
394	1.6	2.6	---	---
280	1.3	2.0	---	---
460	6.4	8.8	---	---
521	5.7	8.3	---	---

Table 6 shows the relationship between the number of cases generated per hour versus the number of cases palletized per hour. The impact on the system shown by this table is two-fold. It shows that nearly all of the cases generated below an approximate 450 cases per palletizer per hour rate are palletized. Above that rate, there are excess cases in the system which are not being palletized. It should be mentioned that the palletizing time was a constant in this model which would not account for any speed up or slow down by a palletizer.

This table also shows a relative number of overflow cases in the system. The implication of this figure is that if too many cases are generated into the system, the system may back up because it is unable to handle all of the cases. The worst case of an overflow onto the loop is running the system with two palletizers where 973 cases are being generated per hour, and only 85% or 827 cases per hour are being palletized. This means that an average of 146 extra

cases are on the loop per hour.

The computer model was not developed with a shut off mechanism for an overflow of cases on a palletizing loop, but was developed with a maximum capacity of 95 cases on the loop at any one time. Although this simulation with 973 cases per hour being generated may appear to show a backup condition on the palletizing loop, in actuality the loop is controlled by photocells. These photo cells control the number of cases allowed on the palletizing loop thus for the most part control any backup on the palletizing loop.

Table 6. Number of Cases Palletized

Cases/Hour Generated =====	Cases/Hour Palletized =====	Percent Cases Palletized of Generated Cases =====
800	794.8	99.3%
812	811.9	99.9%
882	808.5	92.1%
969	827.3	85.0%
673	669.1	99.5%
394	393.4	99.5%
280	277.5	99.5%
460	430.5	93.2%
521	429.9	83.1%

The above results are based on the input production schedules generated into the model. The schedule itself, or the number of cases generated by the production schedule, are the basis of the results tabulated. Therefore, it is the production schedule which determines the overall productivity of the palletizer. If the palletizers are scheduled a sub-optimal number of cases per hour, their overall utilization will also be sub-optimal.

VI. CONCLUSIONS

Overall, the results of the simulation runs have proven to be a realistic model of the actual palletizing system in the Frito-Lay plant. The model has shown a maximum number of cases per hour to be approximately 435 cases per man hour, which is very close to the predetermined standard of 400 cases per manhour. This fact, as well as the other results described in the previous section, support the model as being a realistic representation of the palletizing system.

There are five main conclusions that can be made from this simulation model of the palletizing system. First, there is a break point in generating cases onto the palletizing loop where there is a diminishing return in generating additional cases onto the loop. This break point is approximately 435 cases per hour per palletizer. Any case generation rate above this, according to a constant palletizing rate, will not increase the number of cases palletized per hour. And, in fact, may decrease the number of cases that can be palletized per hour by a palletizer.

Second, using two palletizers on a palletizing loop is not as efficient as one palletizer working alone. This was shown in the results of the palletizer utilization (See Table 3 and Figures 6a through 6c) for different model scenarios. If each of two palletizers is assigned specific cases to palletize, the setup of the loop determines that there will be cases passing each palletizer that are not their responsibility to palletize. This mixing of cases that are

assigned for palletizing to specific palletizers makes it such that there are inherent delays in a two palletizer per loop setup.

Third, that palletizer 2 is not as efficient as palletizer one in any scenarios. Palletizer 2 has an overall longer waiting time for cases to come to him or her in relation to the position of palletizer 1. Also, palletizer 2 is farther away from the case infeed area onto the loop, thus supplementing the cases recirculating with newly produced or generated cases takes longer than it does for palletizer 1.

Fourth, that there are inherent delays in product flow built into the current palletizing system. Even running the model with only one palletier, the maximum utilization of palletizer 1 was 95.8%. This maximum utilization can be attributed to start up time or the time to bring the system into a state of equilibrium. This maximum utilization limit can also be attributed to the manner in which the product is fed to the palletizer. Even with a maximum number of cases on a palletizing loop, there is some waiting involved in picking a case off of the palletizing loop. There are also gaps or delays in the product flow on the palletizing loop.

The final conclusion that can be made from the model is that the production schedule is the most important input into the productivity of an individual palletizer. If the production schedule starves the palletizer, he or she will have a low utilization for the shift. Conversely, if the production schedule floods the palletizer, the he or she will

not be capable of palletizing the cases on the loop, and the loop may experience a backup condition.

VII. RECOMMENDATIONS

The results from the study show two recommendations to the current palletizing system. The first of those recommendations is running a single palletizer on a palletizing loop whenever possible for a higher palletizer productivity. The second recommendation is to schedule the palletizer workload at at least 435 cases per hour to fully utilize the palletizer. This optimally scheduled workload is achieved by combining the scheduled package case per hour output for the different products flowing onto the palletizing loop to achieve the 435 cases per hour output and assigning these packages to an individual palletizer. The ability to optimally schedule the workload of the palletizer is dependent on the production schedule assigned to be run for the day. Therefore, the productivity of the palletizers basically lies in the control of the production schedule and should be an accountability of the production scheduler.

With the recommendation of utilizing one palletizer per loop, one would expect that the current palletizing loop sizes would be too large. Further study could determine what an optimal loop size for a single palletizer would be.

Also, in trying to optimally schedule the workload of a palletizer, if more flexibility existed in what packages could be fed onto what loop, there may be an opportunity for increased overall palletizer utilization. Further study would need to be conducted to determine the opportunity in this recommendation.

The final question to be answered in reference to this palletizing system is whether or not this system is the most optimal system for a case flow process. It would be possible to have a laser scanner sort the cases as they come onto the palletizing loop into case storage lanes, and the palletizer could walk from lane to lane emptying the cases onto the pallet boards. Taking this idea one step further, instead of having the palletizer empty the cases in the lanes onto the pallet boards, have automatic palletizers performing this function. Finally, in a product flow situation such as that at Frito-Lay, Inc., would it be necessary to have the cases, which are coming from different packaging machines running different products, be mixed together onto one conveyor and then sorted at the end of the same conveyor? This study does not have the scope to answer questions such as these, but future study of these concepts may provide some interesting results to these questions.

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APPENDIX A

DC	BLOCK#	*LCC	OPERATION	A,B,C,D,E,F,G	COMMENT
	6		TEST L	PH1,4,TRV1	TESTS FOR CASE TYPE
	7		ENTER	DECAR	LETTERS PALT. DECISION AREA
	8		TEST L	XB1,15,ZZZ	LAST PKG NC < 15
	9		SAVEVALUE	1+,1,XB	LAST PKG + 1 ASSIGNED
	10		TRANSFER	,YYY	GOES TO STOP PKG NO
	11	ZZZ	SAVEVALUE	1,1,XB	ASSIGNS PKG NC TO 1
	12	YYY	ASSIGN	2,XB1,PF	ASSIGNS PKG NC TO TRANS
	13		JOIN	1	JOINS DECISION GROUP 1
	14		SCAN E	1,1PB,1,,OFTM	SCANS THE DEC GROUP TO
	15		TRANSFER	,ADV1	GO TO DECISION AREA ONE
	16	DETRM	ASSIGN	1,15,PF	LOOPING PARAMETER
	17		TEST L	XB1,15,OK1	IF POINTER=15, BACK TO 1
	18		TRANSFER	,ASXB3	TRANS TO XB3 ASSIGNMENT
	19	BK1	SAVEVALUE	3+,1,XB	GIVES XB3 VAL OF 1 FROM 15
	20		TRANSFER	,GOG	TRANSFERES TO LOOP TEST
	21	ASXB3	SAVEVALUE	3,XB1,XB	ASSIGNS XB1=XB3
	22		SAVEVALUE	3+,1,XB	INCREMENTS XB3 BY 1
	23	GIG	TEST G	PF1,0,NXT	HAS TRANS LOOPED 15 TIMES
	24		TEST E	MX1(XB3,1),0,101	TESTS FOR VAL OF 1 IN MX1
	25		TEST L	XB3,15,HCH	TESTS FOR XB3=15
	26		SAVEVALUE	3+,1,XB	INCREMENTS XB3 FOR TEST
	27		ASSIGN	1-,1,PF	DEC. LOOPING PARAMETER
	28		TRANSFER	,GOG	TRANSFERS BK TO TEST
	29	HOH	SAVEVALUE	3+,1,XB	ASSIGNS XB3=1 IF PREV=15
	30		ASSIGN	1-,1,PF	DEC. LOOPING PARAMETER
	31		TRANSFER	,GOG	TRANSFERS BK TO TEST
	32	IOI	ALTER E	1,1,1PB,1,2PF,XB3,NXT	MARKS IF PKG NO=XB2
	33	NXT	BUFFER		RELEASE PALT
					* AS THE CASE ENTERS A DECISION AREA IT TRAVELS A TOTAL OF 3.5 FEET.
					* THE AREA IS DIVIDED INTO THREE AREAS TO ALLOW FOR THE TESTING
					* PROCEDURE. THE TOTAL TRAVEL TIME IS 5.3 SECONDS.
	34	ADV1	ENTER	DEC1	
	35		ASSIGN	2+,1,PB	
	36		ADVANCE	XH2	
	37		TEST GL	PB2, FN*V1,XXX	
	38		TEST LE	PB2, FN*V2,XXX	
	39		MSAVEVALUE	1,PF2,1,1, MX	
	40		TEST E	BV1,0,PALTP	
	41	XXX	ADVANCE	XH2	
	42		TEST GE	PB2, FN*V1,WWW	
	43		TEST LE	PB2, FN*V2,WWW	
	44		MSAVEVALUE	1,PF2,1,1, MX	
	45		TEST E	BV1,0,PALTP	
	46	WWW	ADVANCE	XH2	
	47		TEST GE	PB2, FN*V1,VVV	
	48		TEST LE	PB2, FN*V2,VVV	
	49		MSAVEVALUE	1,PF2,1,1, MX	
	50	VVV	ENTER	DEC2	
	51		ASSIGN	2+,1,PB	
	52		LEAVE	DEC1	ENTERS DECISION AREA TWO
	53		TEST E	BV1,0,PALTP	
	54		MSAVEVALUE	1,PF2,1,0, MX	
	55		ADVANCE	XH2	
	56		TEST GE	PB2, FN*V1,UUU	
	57		TEST LE	PB2, FN*V2,UUU	
	58		MSAVEVALUE	1,PF2,1,1, MX	

NO	BLOCK#	*LOC	OPERATION	A,B,C,D,E,F,G	COMMENTS
		59	TEST E	BV1,0,PALTR	
		60	UUU ADVANCE	XH2	
		61	TEST GE	PB2, FN*V1, TTT	
		62	TEST LE	PB2, FN*V2, TTT	
		63	MSAVEVALUE	1, PF2, 1, 1, MX	
		64	TEST E	BV1,0,PALTR	
		65	TTT ADVANCE	XH2	
		66	TEST GE	PB2, FN*V1, SSS	
		67	TEST LE	PB2, FN*V2, SSS	
		68	MSAVEVALUE	1, PF2, 1, 1, MX	
		69	SSS ENTER	DEC3	
		70	ASSIGN	2+, 1, PB	ENTERS DECISION AREA THREE
		71	LEAVE	DEC2	
		72	TEST E	BV1,0,PALTR	
		73	MSAVEVALUE	1, PF2, 1, 0, MX	
		74	ADVANCE	XH2	
		75	TEST GE	PB2, FN*V1, RRR	
		76	TEST LE	PB2, FN*V2, PPP	
		77	MSAVEVALUE	1, PF2, 1, 1, MX	
		78	TEST E	BV1,0,PALTR	
		79	RPR ADVANCE	XH2	
		80	TEST GE	PB2, FN*V1, QQQ	
		81	TEST LE	PB2, FN*V2, QQQ	
		82	MSAVEVALUE	1, PF2, 1, 1, MX	
		83	TEST E	BV1,0,PALTR	
		84	QQQ ADVANCE	XH2	
		85	TEST GE	PB2, FN*V1, PPP	
		86	TEST LE	PB2, FN*V2, PPP	
		87	MSAVEVALUE	1, PF2, 1, 1, MX	
		88	PPP ENTER	DEC4	
		89	ASSIGN	2+, 1, PB	ENTERS DECISION AREA 4
		90	LEAVE	DEC3	
		91	TEST E	BV1,0,PALTR	
		92	MSAVEVALUE	1, PF2, 1, 0, MX	
		93	ADVANCE	XH2	
		94	TEST GE	PB2, FN*V1, UDD	
		95	TEST LE	PB2, FN*V2, ODD	
		96	MSAVEVALUE	1, PF2, 1, 1, MX	
		97	TEST E	BV1,0,PALTR	
		98	CUU ADVANCE	XH2	
		99	TEST GE	PB2, FN*V1, NNN	
		100	TEST LE	PB2, FN*V2, NNN	
		101	MSAVEVALUE	1, PF2, 1, 1, MX	
		102	TEST E	BV1,0,PALTR	
		103	NNN ADVANCE	XH2	
		104	TEST GE	PB2, FN*V1, MMM	
		105	TEST LE	PB2, FN*V2, MMM	
		106	MSAVEVALUE	1, PF2, 1, 1, MX	
		107	MMM ENTER	DEC5	
		108	ASSIGN	2+, 1, PB	ENTERS DECISION AREA FIVE
		109	LEAVE	DEC4	
		110	TEST E	BV1,0,PALTR	
		111	MSAVEVALUE	1, PF2, 1, 0, MX	
		112	ADVANCE	XH2	
		113	TEST GE	PB2, FN*V1, LLL	
		114	TEST LE	PB2, FN*V2, LLL	

NO	BLOCK#	*LHL	OPERATION	A,B,C,D,E,F,G	COMMENTS
115			MSAVEVALUE	1,PF2,I,1,MX	
116			TEST E	BV1,0,PALTP	
117	LLL		ADVANCE	XH2	
118			TEST GE	PB2, FN*V1, KKK	
119			TEST LE	PB2, FN*V2, KKK	
120			MSAVEVALUE	1,PF2,1,1,MX	
121			TEST E	BV1,0,PALTP	
122	KKK		ADVANCE	XH2	
123			TEST GE	PB2, FN*V1, JJJ	
124			TEST LE	PB2, FN*V2, JJJ	
125			MSAVEVALUE	1,PF2,1,1,MX	
126	JJJ		TEST E	BV1,0,PALTR	
127			MSAVEVALUE	1,PF2,1,0,MX	
128			LEAVE	DEC5	
129			REMOVE	1	REMOVES ALL TRANS FROM GROUP
130			LEAVE	DECAR	LEAVES THE DECISION AREA
131			ASSIGN	2,0,PB	ASSIGNS DECISION AREA TO 0
132			ASSIGN	3*,1,PB	COUNTS THE NO OF TIMES LOJPE
133			TRANSFER	,CONT	TRANSFERS TO BEG OF LOOP
134	TRV1		SAVEVALUE	1*,1,XB	
135			ENTER	TRT1	
136			ADVANCE	120	
137			LEAVE	TRT1	
138			TRANSFER	,CONT	
<p>* THIS SECTION IS REPRESENTS THE PALLETIZER. THERE ARE TWO ASSUMPTIONS * MADE FOR THE OPERATION OF THE PALLETIZER. THE ASSUMPTIONS ARE THAT * THE PALLETIZER WILL ALWAYS BE ABLE TO PICK UP A CASE IF HE DECIDES TO * TO DO SO AND THAT THERE WILL BE AN AVERAGE PALLETIZING TIME ASSUME) * WITH A DISTRIBUTION. THIS WILL BE MADE BECAUSE THE DECISION AREAS * OF THE SAME LENGTH. *</p>					
139	PALTR	SEIZE	PALTR		ACCORDING TO CASE TYPE
140		SAVEVALUE	1,PH1,XH		CASE SEIZES PALTR
141		LEAVE	DECAR		ASSIGNS PALLETIZER LOC
142		LEAVE	FNB		LEAVES DECAR
143		ADVANCE	80,10		LEAVES CURRENT DECI=5
144		MSAVEVALUE	1,PF2,1,0,MX		ADVANCES FOR PALLETIZING
145		REMOVE	1		SETS MATRIX TO 0
146		SCAN E	1,1PB,0,,NEXT		TAKES CASE FROM GROUP
147		ASSIGN	1,15,PF		SCANS TO SEE IF TRANS MKD
148		TEST L	XB1,15,BKTU1		LOOPING PARAMETER
149		TRANSFER	,ASXB2		IF POINTER=15, BACK TO 1
150	BKTU1	SAVEVALUE	2,1,XB		TRANS TO XB2 ASSIGNMENT
151		TRANSFER	,GGG		GIVES XB2 VAL OF 1 FROM 15
152	ASXB2	SAVEVALUE	2, XB1, XB		TRANSFERS TO LOOP TEST
153		SAVEVALUE	2*,1,XB		ASSIGNS XB1=XB2
154	GGG	TEST G	PF1,0,NEXT		INCREMENTS XB2 BY 1
155		TEST E	MX1(XB2,1),0,III		HAS TRANS LOOPLD 15 TIMES
156		TEST L	XB2,15,HHH		TESTS FOR VAL OF 1 IN *X1
157		SAVEVALUE	2*,1,XB		TESTS FOR *XB2=15
158		ASSIGN	1-,1,PF		INCREMENTS XB2 FOR TEST
159		TRANSFER	,GGG		DEC. LOOPING PARAMETER
160	HHH	SAVEVALUE	2,1,XB		TRANSFERS BK TO TEST
161		ASSIGN	1-,1,PF		ASSIGNS XB2=1 IF PREV=15
162		TRANSFER	,GGG		DEC. LOOPING PARAMETER
163	III	ALTER E	1,1,1PB,1,2PF,XB2,NEXT		TRANSFERS PK TO TEST
					MARKS IF PKG NO=XB2

DD BLOCK# *LOC OPERATION A,B,C,D,E,F,G COMMENTS

164		TRANSFER	,NEXT	
165	NEXT	RELEASE	PALT	RELEASE PALTR
166		TABULATE	1	CASE TYPE
167		TABULATE	2	INTERAPPRIVAL TIME
168		TABULATE	3	SAVEVALUE XH1
169		TABULATE	4	RECIRCULATING TIMES
170		TABULATE	5	CASE MARKED WHEN P-U
171		TERMINATE		

*
 * ENTERING THE SECOND DECISION AREA. THIS DECISION AREA OPERATES
 * THE SAME AS DECISION AREA 1
 *

172	CUNT	TEST G	PH1,3,TRV2	
173		ENTER	CECA2	ENTEPS PALT. DECISION AREA
174		TEST L	XB4,15,ZZZ2	LAST PKG NO < 15
175		SAVEVALUE	4+,1,XB	LAST PYG + 1 ASSIGNED
176		TRANSFER	,YYY2	GOES TO STORE PKG NO
177	ZZZ2	SAVEVALUE	4,1,XB	ASSIGNS PKG NO TO I
178	YYY2	ASSIGN	2,XB4,PF	ASSIGNS PKG NO TO TRANS
179		JOIN	2	JOINS DECISION GROUP 1
180		SCAN E	2,1PB,1,,DLTR2	SCANS THE DEC GROUP TO
181		TRANSFER	,ADV12	GO TO DECISION AREA ONE
182	DETR2	ASSIGN	1,15,PF	LOOPING PARAMETER
183		TEST L	XB4,15,BK12	IF POINTER=15, BACK TO I
184		TRANSFER	,ASXB6	TRANS TO XB3 ASSIGNMENT
185	BK12	SAVEVALUE	6,1,XB	GIVES XB3 VAL OF I FROM 15
186		TRANSFER	,GOG2	TRANSFERS TO LOOP TEST
187	ASXB6	SAVEVALUE	6,XB4,XB	ASSIGNS XB1=XB3
188		SAVEVALUE	6+,1,XB	INCREMENTS XB3 BY 1
189	GOG2	TEST G	PF1,0,NXT2	HAS TRANS LOOPED 15 TIMES
190		TEST E	MX1(XB6,2),0,IC12	TESTS FOR VAL OF I IN MX1
191		TEST L	XB6,15,HH2	TESTS FOR XB3=15
192		SAVEVALUE	6+,1,XB	INCREMENTS XB3 FOR TEST
193		ASSIGN	1-,1,PF	DEC. LOOPING PARAMETER
194		TRANSFER	,GOG2	TRANSFERS BK TO TEST
195	HH12	SAVEVALUE	6,1,XB	ASSIGNS XB3=1 IF PREV=15
196		ASSIGN	1-,1,PF	DEC. LOOPING PARAMETER
197		TRANSFER	,GOG2	TRANSFERS BK TO TEST
198	IC12	ALTER E	2,1,1PB,1,2PF,YB,4XT2	MARKS IF PKG NO=XB2
199	NXT2	BUFFER		RELEASE PALTR

* AS THE CASE ENTERS A DECISION AREA IT TRAVELS A TOTAL OF 3.5 FEET.
 * THE AREA IS DIVIDED INTO THREE AREAS TO ALLOW FOR THE TESTING
 * PROCEDURE. THE TOTAL TRAVEL TIME IS 5.3 SECONDS.

200	ADV12	ENTER	DECL2	
201		ASSIGN	2+,1,PB	
202		ADVANCE	XH2	
203		TEST GE	PB2,FM*V3,XXX2	
204		TEST LE	PB2,FM*V4,XXX2	
205		MSAVEVALUE	1,PF2,2,1,MX	
206		TEST E	BV2,0,PLTP2	
207	XXX2	ADVANCE	XH2	
208		TEST GE	PB2,FM*V3,WWW2	
209		TEST LE	PB2,FM*V4,WWW2	
210		MSAVEVALUE	1,PF2,2,1,MX	
211		TEST E	BV2,0,PLTP2	
212	WWW2	ADVANCE	XH2	

LOC	BLOCK#	*LOC	OPERATION	A,B,C,D,E,F,G	COMMENTS
	213		TEST GE	PB2, FN*V3, VVV2	
	214		TEST LE	PB2, FN*V4, VVV2	
	215		MSAVEVALUE	1, PF2, 2, 1, MX	
	216	VVV2	ENTER	DEC22	
	217		ASSIGN	2+, 1, PB	ENTERS DECISION AREA TWO
	218		LEAVE	DEC12	
	219		TEST E	BV2, 0, PLTR2	
	220		MSAVEVALUE	1, PF2, 2, 0, MX	
	221		ADVANCE	XH2	
	222		TEST GE	PB2, FN*V3, UUU2	
	223		TEST LE	PB2, FN*V4, UUU2	
	224		MSAVEVALUE	1, PF2, 2, 1, MX	
	225		TEST E	BV2, 0, PLTR2	
	226	UUU2	ADVANCE	XH2	
	227		TEST GE	PB2, FN*V3, TTT2	
	228		TEST LE	PB2, FN*V4, TTT2	
	229		MSAVEVALUE	1, PF2, 2, 1, MX	
	230		TEST E	BV2, 0, PLTR2	
	231	TTT2	ADVANCE	XH2	
	232		TEST GE	PB2, FN*V3, SSS2	
	233		TEST LE	PB2, FN*V4, SSS2	
	234		MSAVEVALUE	1, PF2, 2, 1, MX	
	235	SSS2	ENTER	DEC32	
	236		ASSIGN	2+, 1, PB	ENTERS DECISION AREA THREE
	237		LEAVE	DEC22	
	238		TEST E	BV2, 0, PLTR2	
	239		MSAVEVALUE	1, PF2, 2, 0, MX	
	240		ADVANCE	XH2	
	241		TEST GE	PB2, FN*V3, RPP2	
	242		TEST LE	PB2, FN*V4, RPP2	
	243		MSAVEVALUE	1, PF2, 2, 1, MX	
	244		TEST E	BV2, 0, PLTR2	
	245	RPP2	ADVANCE	XH2	
	246		TEST GE	PB2, FN*V3, CQQ2	
	247		TEST LE	PB2, FN*V4, CQQ2	
	248		MSAVEVALUE	1, PF2, 2, 1, MX	
	249		TEST E	BV2, 0, PLTR2	
	250	QQQ2	ADVANCE	XH2	
	251		TEST GE	PB2, FN*V3, PPP2	
	252		TEST LE	PB2, FN*V4, PPP2	
	253		MSAVEVALUE	1, PF2, 2, 1, MX	
	254	PPP2	ENTER	DEC42	
	255		ASSIGN	2+, 1, PB	ENTERS DECISION AREA 4
	256		LEAVE	DEC32	
	257		TEST E	BV2, 0, PLTR2	
	258		MSAVEVALUE	1, PF2, 2, 0, MX	
	259		ADVANCE	XH2	
	260		TEST GE	PB2, FN*V3, CQQ2	
	261		TEST LE	PB2, FN*V4, CQQ2	
	262		MSAVEVALUE	1, PF2, 2, 1, MX	
	263		TEST E	BV2, 0, PLTR2	
	264	CCQ2	ADVANCE	XH2	
	265		TEST GE	PB2, FN*V3, NNN2	
	266		TEST LE	PB2, FN*V4, NNN2	
	267		MSAVEVALUE	1, PF2, 2, 1, MX	
	268		TEST E	BV2, 0, PLTR2	

JO	BLOCK#	*LOC	OPERATION	A,B,C,D,L,F,G	COMMENTS
	269	MIM2	ADVANCE	XH2	
	270		TEST GE	PB2, FN*V3, MIM2	
	271		TEST LE	PB2, FN*V4, MIM2	
	272		MSAVEVALUE	1, PF2, 2, 1, MX	
	273	MIM2	ENTER	DECS2	ENTERS DECISION AREA FIVE
	274		ASSIGN	2+, 1, PB	
	275		LEAVE	DECA2	
	276		TEST E	BV2, 0, PLTR2	
	277		MSAVEVALUE	1, PF2, 2, 0, MX	
	278		ADVANCE	XH2	
	279		TEST GE	PB2, FN*V3, LLL2	
	280		TEST LE	PB2, FN*V4, LLL2	
	281		MSAVEVALUE	1, PF2, 2, 1, MX	
	282		TEST E	BV2, 0, PLTR2	
	283	LLL2	ADVANCE	YH2	
	284		TEST GE	PB2, FN*V3, KKK2	
	285		TEST LE	PB2, FN*V4, KKK2	
	286		MSAVEVALUE	1, PF2, 2, 1, MX	
	287		TEST E	BV2, 0, PLTR2	
	288	KKK2	ADVANCE	XH2	
	289		TEST GE	PB2, FN*V3, JJJ2	
	290		TEST LE	PB2, FN*V4, JJJ2	
	291		MSAVEVALUE	1, PF2, 2, 1, MX	
	292	JJJ2	TEST E	BV2, 0, PLTR2	
	293		MSAVEVALUE	1, PF2, 2, 0, MX	
	294		LEAVE	DECS2	
	295		REMOVE	2	REMOVES ALL TRANS FROM GROUP
	296		LEAVE	DECA2	LEAVES THE DECISION AREA
	297		ASSIGN	2, 0, PB	ASSIGNS DECISION AREA TO 0
	298		ASSIGN	3+, 1, PB	COUNTS THE NO OF TIMES LOOP
	299		TRANSFER	, AGAIN	TRANSFERS TO BEG OF LOOP
	300	TRV2	SAVEVALUE	4+, 1, XB	
	301		ENTER	TRT2	
	302		ADVANCE	120	
	303		LEAVE	TRT2	
	304		TRANSFER	, AGAIN	
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					* THE PALLETIZER WILL ALWAYS BE ABLE TO PICK UP A CASE IF HE DECIDES TO
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					* WITH A DISTRIBUTION. THIS WILL BE MADE BECAUSE THE DECISION AREAS
					* OF THE SAME LENGTH.
					*
					ACCORDING TO CASE TYPE
	305	PLTR2	SEIZE	PALT2	CASE SEIZES PALTR
	306		SAVEVALUE	3, PHL, XH	ASSIGNS PALLETIZER LOC
	307		LEAVE	DECA2	LEAVES DECAP
	308		LEAVE	FN9	LEAVES CURRENT DEC1-5
	309		ADVANCE	80, 10	ADVANCES FOR PALLETIZING
	310		MSAVEVALUE	1, PF2, 2, 0, MX	SETS MATHX TO 0
	311		REMOVE	2	TAKES CASE FROM GROUP
	312		SCAN E	2, 1PB, 0, ,, *EXT2	SCANS TO SEE IF TRANS MKJ
	313		ASSIGN	1, 15, PF	LOOPING PARAMETER
	314		TEST L	XB4, 15, BKT2	IF POINTER=15, BACK TO 1
	315		TRANSFER	, ASXB5	TRANS TO XB2 ASSIGNMENT
	316	BKTQ2	SAVEVALUE	5, 1, XH	GIVES XB2 VAL OF 1 FROM 15
	317		TRANSFER	, GGG2	TRANSFERS TO LOOP TEST

RI	BLOCK#	*LOC	OPERATION	A,B,C,D,E,F,G	COMMENTS
	318	ASX15	SAVEVALUE	5,XB4,XB	ASSIGNS XB1=XJ2
	319		SAVEVALUE	5*,1,XB	INCREMENTS XB2 BY 1
	320	GGG?	TEST G	PF1,0,NEXT2	HAS TRANS LOCKED 15 TIME;
	321		TEST L	MX1(XB5,2),0,1112	TESTS FOR VAL OF 1 IN MX1
	322		TEST L	XB5,15,HH2	TESTS FOR XB2=15
	323		SAVEVALUE	5*,1,XB	INCREMENTS XB2 FOR TEST
	324		ASSIGN	1-,1,PF	DEC. LOCKING PARAMETER
	325		TRANSFER	,GGG2	TRANSFERS BK TO TEST
	326	1112	SAVEVALUE	5,1,XB	ASSIGNS XB2=1 IF PPEV=15
	327		ASSIGN	1-,1,PF	DEC. LOCKING PARAMETER
	328		TRANSFER	,GGG2	TRANSFERS BK TO TEST
	329	1112	ALTER E	2,1,1PB,1,2PF,XB5,NEXT2	MARKS IF PKG NO=XB2
	330		TRANSFER	,NEXT?	
	331	NEXT2	RELEASE	PALT2	RELEASE PALTR
	332		TABULATE	6	CASE TYPE
	333		TABULATE	7	INTERARRIVAL TIME
	334		TABULATE	8	SAVEVALUE XH1
	335		TABULATE	9	RECIRCULATING TIMES
	336		TABULATE	10	CASE MARKED WHEN P-U
	337		TERMINATE		
	338		GENERATE	288000	ONE HOURS TIME
	339		TERMINATE	1	TERMINATE SIMULATION
	1		TABLE	PH1,1,1,4	
	2		TABLE	IA,10,10,15	
	3		TABLE	XH1,1,1,4	
	4		TABLE	PB3,0,1,8	
	5		TABLE	PB1,0,1,3	
	6		TABLE	PH1,4,1,4	
	7		TABLE	IA,10,10,15	
	8		TABLE	XH3,4,1,4	
	9		TABLE	PB3,0,1,8	
	10		TABLE	PB1,0,1,3	
			START	1	
			END		

A COMPUTER SIMULATION OF THE PALLETIZING SYSTEM
AT FRITO-LAY, INC. IN TOPEKA, KANSAS

by

DEANDRA TILLMAN CASSONE

B.S., Kansas State University, 1982

AN ABSTRACT OF A MASTER'S THESIS

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MASTERS OF SCIENCE

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ABSTRACT

At Frito-Lay, Inc. in Topeka, Kansas a conveyORIZED palletizing system was installed to transfer product from the packaging floor to the shipping warehouse. The purpose of this study was to optimize the current operation of this system. Data was gathered on the operating characteristics of this system and a simulation model was developed using the programming language GPSSH. The results of the simulation model showed the following conclusions. The model was a realistic representation of the current system. Based on a 8 second per case palletizing time, the maximum number of cases per hour to be generated to one palletizer was approximately 435 cases per manhour and that there is a diminishing return beyond this point. One palletizer working alone is more efficient than two palletizers working together. Palletizer 2 is not as efficient as palletizer 1 in any case. There are inherent delays in product flow built into the system. And, that the production schedule is the most important input into the system. The recommendations to the current system were to run only one palletizer per loop whenever possible, to schedule at least 435 cases per manhour to each of the palletizers through optimally scheduling product on the production schedules and to look at capital improvements to increase the efficiency of the system.