IMPROVING COTTON WAREHOUSING EFFICIENCIES THROUGH NOVEL BALE MARKETING STRATEGIES: AISLE-STACKING AND BLOCK-STACKING

A Thesis

by

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ABSTRACT

The National Cotton Council's Vision 21 Cotton Flow Study sought to improve the flow of cotton through the gin and warehouse system. Time and motion data were collected from multiple warehouses as the basis for models, which simulate differences in the total time needed to assemble an order for three different bale selection techniques: the baseline method, a 4-bale marketing plan, or the use of MILLNet™ for Merchants software; and for two different methods of warehouse storage: aisle-stacking and block-stacking.

In larger warehousing facilities using aisle-stacking, the use of MILLNet™ for Merchants software significantly decreased the time required to assemble an 88-bale load of cotton for shipping. However, in warehouses utilizing aisle-stacking, 4-bale marketing did not reduce the time required to assemble a load for shipment in aisle-stacking arrangements.

Compared to baseline operations for block-stacking warehouses, 4-bale marketing and MILLNet™ for Merchants offered significant potential time savings in order assembly. The greatest time savings, 50%-75%, were realized using MILLNet™ for Merchants and pulling bales only from the fronts of the blocks. When MILLNet™ for Merchants was not an option, 4-bale marketing reduced total order assembly time by up to 56%.

Block-stacking in a cotton warehouse was the most efficient way to assemble and load one 88-bale order. If the facility was small then using the 4-bale marketing method generated the shortest order assembly time. If the facility was medium or large, then the MILLNet™ for Merchant software generated shorter order assembly times. Other factors that may impact order assembly time are the expertise and experience of the facility management personnel, the number of bales within the warehouse, and the shipping method. When considering foreign and domestic shipments from a block-stacking warehouse, foreign shipments were the fastest to assemble and load regardless of the bale selection method, baseline, 4-bale marketing, or MILLNet™ for Merchants.

DEDICATION

This thesis is dedicated to my family, friends, and colleagues for their never-ending support and, Dr. Faulkner for his patience, guidance, and trust in me. I could never have accomplished all this without them.

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There are many people that have guided me, shaped me, and helped to support me throughout my education and in life. Without them I would not be the person I am today, and for that I am forever grateful.

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CHAPTER I

INTRODUCTION AND BACKGROUND

The National Cotton Council's Vision 21 Cotton Flow Study "was a systems-wide assessment of the actions necessary to improve and reduce costs associated with the flow of U.S. cotton from cotton bale formation to the textile end user" (Wilbur Smith Associates, 2010). The primary objective of the study was to identify cotton flow strategies, systems, and practices the U.S. cotton industry may employ to lower costs or improve returns while meeting the demands of moving cotton into export markets and simultaneously servicing the domestic market. Among options considered to improve cotton flow are novel bale marketing strategies that could reduce the time required to aggregate shipping orders from U.S. warehouses. One option explored in the Vision 21 study was a 4-bale marketing option, in which a clamp-load-of-bales (CLOB) is marketed as a single unit (Robinson, 2014). This could help to reduce load accumulation and shipping time by reducing the number of locations within a warehouse from which bales must be pulled to assemble an 88-bale load. Groups of bales would be consolidated within a given aisle or block. Another option for improving the flow of cotton in the warehousing system is the use of MILLNet™ for Merchants software (Cotton Incorporated, 2000), which utilizes bale storage location data to assist in bale selection for order development in addition to the standard fiber quality metrics used by merchants to select bales. This would reduce the time required to gather all of the bales in a given order since the bales are more likely to be located within a few sheds of a given warehouse complex rather than spread over the whole facility.

Warehouse Operations

The cotton warehousing industry adds value to the cotton supply chain by centralizing cotton from multiple gins, holding cotton to stabilize the rate at which it enters the market, and serving as a liaison between the bale's owner and merchants wishing to purchase the bale. Cotton warehouses use different stacking patterns which are largely dependent on the region of the country in which the facility is located. In the Southwest and Far West, where approximately 40-50% of the US cotton supply is held, most warehouses utilize an aisle-stacking organizational structure in which bales are typically stacked two bales high by two bales wide and about 60 bales deep with additional bales placed horizontally on top of the stacks (Figure 1). In the Mid-South and Southeast, most warehouses utilize a block-stacking organizational structure, in which cotton is stacked in blocks four bales wide and three bales high by eight bales deep (Figure 2). However, these dimensions can vary by warehouse.

Figure 1: Example of aisle-stacking in a cotton warehouse.

Figure 2: Example of block-stacking in a cotton warehouse.

When bales arrive from the gin, the first four bales from the truck are often weighed to check for consistency in the order shipment that was received from the gin. The entire truckload is then stacked into the warehouse, usually without regard to bale ownership or fiber quality, which are often unknown to the warehouse. Permanent Bale Identification (PBI) tags placed on the bale packaging at the gin are scanned into the warehouse's electronic location system to record each bale and its storage location. This allows the workers to access the locations of the bales when assembling orders. Based on the production goals of a textile mill, cotton merchants develop distributions of multiple fiber quality parameters needed to fulfill an order from a given warehouse. The warehouse then receives this electronic order in the form of a list of PBI numbers. For most domestic orders, each truckload comprising an order should have nearly-identical distributions of fiber quality parameters to ensure a consistent laydown at the textile mill. For most international shipments, each individual load still has to meet these specifications, but each load doesn't have to be uniform as long as the total shipment meets conditions. Therefore, when aggregating bales for international customers, more bales may be made available to the merchant. The warehouse's electronic location system then matches the PBI numbers with locations of each bale in the warehouse and creates a pull-sheet for the warehouse personnel responsible for assembling a given load.

Aisle-stacking- Shipping

Forklift drivers collect bales and stage them to be loaded using forklifts equipped with bale hooks and clamps. A forklift equipped with a hook (Figure 3) is used to maneuver bales out of an aisle one at a time. A bale clamp (Figure 4) can grab onto four bales at a time and is used to move them around as a group.

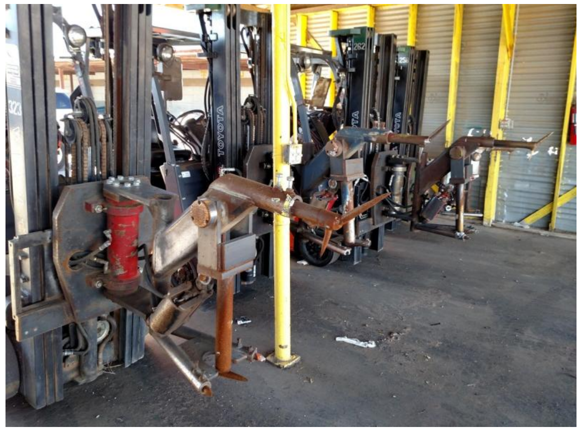

Figure 3: Example of a bale hook.

Figure 4: Example of a bale clamp.

The bales are stamped with a specific order number (“mark”) and the PBIs are scanned to check that the order is complete before they are shipped.

Block-stacking Background

In block-stacking the method of pulling the bales for an order is different although similar to aisle-stacking. Block stacked bales are stacked in groups that are four bales wide by three bales high and eight bales deep (dependent upon warehouse). This 96 bale block is typical of the number of bales that arrive on a single truck load. When assembling an order for shipping from the warehouse, the blocks are taken apart to find the specific bales needed within the stack. Clamp machines are used to move bales in block-stacked warehouses, there is no need for the forklift with a hook. Multiple orders, as many as three or four, are sorted from one block at any given time. Once the needed bales are separated out of the block, they are set into groups by order number or mark. Unneeded bales are then stacked back into the block. Once sorted, the bales for the particular order are staged together and loaded into the truck.

Operational Research

Operational logistics research has been done for many years. Time-in-motion studies, discrete event simulations, and Monte Carlo tests are all common tools to assess the efficiency of logistical operations. Discrete event simulations (DES) can be used to model real-world systems and allow analysis of "what-if" scenarios without interrupting normal operations (Diaz et al., 2012). These scenarios can be "useful in the analysis of the ability to meet the production norms, which include: completion date of production orders, resource utilization, and to ensure an acceptable quality of the production system functioning" in a quantifiable manner (Krenczyk, 2015). One of the main advantages of

DES modeling is it allows for “virtual experimentation,” in which experimental changes to operations can be modeled without interrupting day-to-day operations, which can result in cost savings (Diaz et. al., 2012).

A Monte Carlo simulation is a statistical method that uses a large number of sample repetitions to estimate the average mean and standard deviation of the population. Monte Carlo simulations give a more accurate measurement of process operations than just one test. It also follows the central limit theorem in which the sum of a large number of independent random variables having a finite mean and variance is normally distributed, enabling easier statistical analysis of a given process (Diaz et. al., 2012).

The objective of this research was to identify potential time and/or cost savings that could be realized in cotton warehouses by using novel bale selection techniques relative to “baseline” operations commonly in use today. To do this, DES models were developed to represent baseline operations in cotton warehouses using aisle-stacking and block-stacking methods, warehouses utilizing 4-bale marketing, and warehouses utilizing MILLNet™ for Merchants bale selection software (Cotton Incorporated, date). Simulation parameters were facility size (small, medium, and large) and the relative inventory available to a given merchant during order assembly (small and large). Simulations models of the operations were used to estimate the time to aggregate bales for an order in the warehouse. These values were used to estimate the time savings that might be realized by implementing either a 4-bale marketing or MILLNet™ for

Merchants bale selection strategy versus the baseline values. Data for baseline operations was gathered from two Texas warehouses that employ an aisle-stacking organizational structure, and two North Carolina warehouses that use “block-stacking” structure. Models were generalized in an effort to produce results that are useful across the cotton belt.

CHAPTER II

METHODOLOGY

Introduction

Before bales come into the warehouse, they are first harvested in modules in the field and pressed into bales at the gin. During the ginning process, the bales can be module averaged. Module averaging is a way to grade individual cotton bales based on the average grade of all bales in a module. HVI (high volume instrument) measurements for length, strength, uniformity, and micronaire are averaged, then these averages are assigned to all the bales within that module excluding the outlier bales (Earnest, 2012). Once the bales are pressed and wrapped, they are shipped to the warehouses for storage until they are bought by a merchant. The bales are shipped in box trucks, which hold 88 bales. A sample of each bale is shipped to the closest USDA quality office to grade the bales.

When the bales arrive at the warehouse, the only information available is the originating location for each bale. Bale grades will not arrive for three or four days. Because of this, the warehouses will attempt to consolidate the bales to minimize the time spent driving to sheds and pulling orders. Usually to do this, warehouses will stack the bales by the originating gin. Once the bales are stored within the warehouse, they will remain there until a merchant orders the bales.

The factors considered in this project were warehouse organization, marketing method, facility size, facility utilization rate, and shipment method. Two types of warehouse organization, aisle-stacking and block-stacking, were used; the marketing methods evaluated were baseline, 4-bale marketing, and MILLNet™ for Merchants; the facility sizes were small (5 sheds), medium (20 sheds), and large (40 sheds); the inventory size (facility utilization rate) was either small (greater than 60% of the shed capacity was used) or large (less than 60% of the shed capacity was used); and the shipment method was either domestic or foreign (Figure 5).

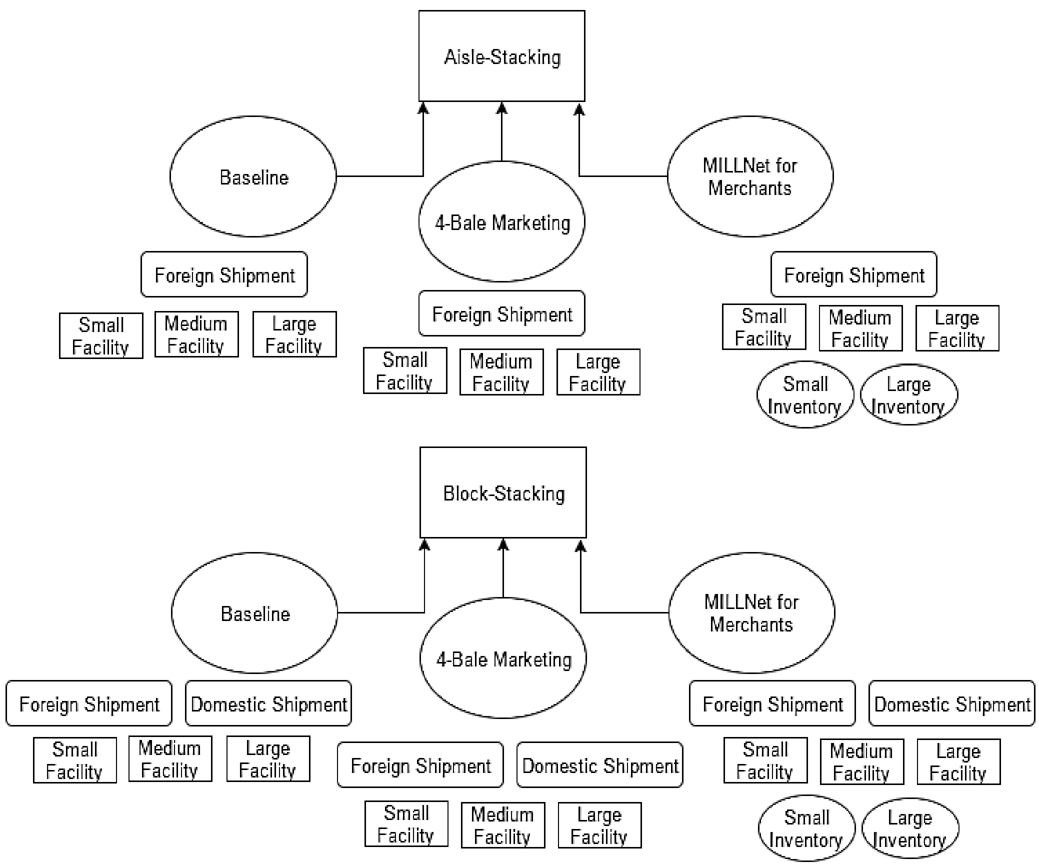

Figure 5: Aisle-stacking and block-stacking scenario levels.

The marketing options include 4-bale marketing, in which a clamp-load-of-bales (CLOB) is marketed as a single unit (Robinson, 2014). This could help to reduce load accumulation and shipping time by reducing the number of locations within a warehouse from which bales must be pulled to assemble an 88-bale load. Groups of bales would be consolidated within a given aisle or block. Another option for improving the flow of cotton in the warehousing system is the use of MILLNet™ for Merchants software (Cotton Incorporated, 2000), which utilizes bale storage location data to assist in bale selection for order development in addition to the standard fiber quality metrics used by merchants to select bales. This would reduce the time required to gather all of the bales in a given order since the bales are more likely to be located within a few sheds of a given warehouse complex rather than spread over the whole facility.

Time-and-Motion Analysis

Time and motion data were collected at two aisle-stacking warehouses in Texas (one large and one medium size) and two block-stacking warehouses in North Carolina (one small and one large) to quantify the duration for each of the activities involved in filling an order for cotton from the warehouse. Data were collected for date, location, shed number, row number, activity, time required for a given activity, forklift speed, and distance the forklift traveled. At the aisle-stacking warehouses the activities recorded included:

- Flagging (17 data points)
- Bales Hooked (208 data points)

- Time in Aisle (56 data points)
- Drive to Staging (114 data points)
- Storage to Cart (110 data points)
- Staging to Truck (398 data points)
- Top Bales Loaded (for Flatbed Trucks) (42 data points)

At the block-stacking warehouses the activities recorded included:

- Drive to Shed (modeled from aisle stacking)
- Drive to Block (modeled from aisle stacking)
- Take Off Layer (75 data points)
- Reassemble Unused Bales (63 data points)
- Storage to Sorting (32 data points)
- Sorting (32 data points)
- Sorting to Staging (36 data points)
- Loading Truck (35 data points)

Statistical Analysis

Collected data from aisle-stacking and block-stacking were analyzed separately within Design Expert (StatEase, Inc., Minneapolis, MN) using analysis of variance (ANOVA) to determine the factors that were significant to load accumulation times. Candidate factors for aisle-stacking included:

- Location (Warehouse 1 v. Warehouse 2)
- Truck number (Order of the trucks arriving in the day)

- Truck type (Box v. flatbed)
- Shed number (Warehouse shed in which the activity was observed)

Outliers in the data were determined by locating the points more than 1.5 interquartile ranges (IQRs) below the second quartile or above the third quartile, and then these points were excluded from the analysis. Following the ANOVA, the residuals were plotted to determine if the data met the assumption of normality and a Box-Cox transform was used to determine if the variances satisfied the assumption of equality. Both assumptions were valid and the ANOVA results were accepted. Independent variables were considered to significantly impact the time allocated to a given operation when the p-value was <0.05. The only variable found to significantly impact load accumulation time was shed number (Table 1), which was determined to correlate with the distance travelled between the storage sheds and staging area when aggregating individual bales into order loads.

Table 1: Observed factors affecting load accumulation time for aisle-stacking.

Factor	**p-value**
Location	0.458
Truck Number	0.059
Truck Type	0.265
Shed Number	<0.001*

*indicates statistical significance

Probability Distribution Analysis

StatFit2© (Geer Mountain Software Corp., South Kent, CT) was used to determine the distribution of time measurements for each observed activity. All times for each activity, excluding outliers, were input into StatFit. The data were auto-fit to a family of continuous distributions that were assigned a lower bound of the smallest number in the data. The distributions were ranked by goodness of fit. The highest ranked distributions were chosen for use in the simulation. This program gives the distributions of the data and the specific parameters used are shown in

Table 2 and Table 3. These distributions were exported to the respective simulation model activity.

Table 2: Aisle-stacking warehouse activity distributions.

Activity	Distribution	α	β	Mean	Standard Deviation	Min	Max	Most Likely	p	q
Flagging	Log-Logistic	-	4.75	-	-	2	-	-	1.24	-
Bales hooked	Weibull	24.8	1.73	-	-	8	-	-	-	
Time in aisle	Inverse Weibull	1.79	0.162	-	-	6	-	-	-	
Drive to staging	Gamma	13.2	2.29	-	-	9	-	-	-	
Storage to cart	Normal	-	-	29.91	3.98	-	-	-	-	
Staging to truck	Pearson Type VI	-	607	-	-	13	-	-	1.42	26
Top bales loaded	Triangular	-	-	-	-	7	60.2	27.4	-	-

Table 3: Block-stacking warehouse activity distributions.

Activity	Distribution	α	β	Mean	Standard Deviation	Min	Max	Most Likely	p	q
Drive to Block	Weibull	1.53	51.8	-	-	4	-	-	-	-
Take Off Layer	Lognormal	-	-	28.6	33.5	16	-	-	-	-
Reassemble Unused Bales	Log-Logistic	-	8.48	-	-	15	-	-	2.88	-
Storage to Sorting	Lognormal	-	-	38.3	34.2	5	-	-	-	-
Sorting	Weibull	2.2	57.3	-	-	10	-	-	-	-
Sorting to Staging	Exponential	-	-	46.1	-	24	-	-	-	-
Loading Truck	Weibull	23	1.65	-	-	55	-	-	-	-

The baseline, 4-bale, and MILLNet™ scenarios were each modified to better represent the given scenario being represented in the simulation. Baseline (aisle and block) changes can be seen below in Table 4 and Table 5. Block-stacking was based on the aisle-stacking distributions for drive to shed times.

Table 4: Aisle-stacking baseline distribution changes.

Activity	Distribution	Size Facility	α	β	Minimum
Drive to Shed	Weibull	Small	2.09	3.4	23
		Medium	2.62	6.73	42
		Large	10.1	36.5	49
Shed door to aisle	Weibull	-	2.45	4.68	3
Aisle to bale	Weibull	-	5.03	5.38	10

Table 5: Block-stacking baseline distribution changes.

Activity	Distribution	Size Facility	α	β	Minimum
Drive to Shed	Weibull	Small	2.09	3.4	23
		Medium	2.62	6.73	42
		Large	10.1	36.5	49

When simulating the 4-bale marketing distribution, time changes were made for aisle-stacking (Table 6) and block-stacking (Table 7).

Table 6: Aisle-stacking 4-bale marketing distribution changes.

Activity	Distribution	α	β	Minimum	p
Aisle to bale	Log-Logistic	3.53	4.86	7	-

Table 7: Block-stacking 4-bale marketing distribution changes.

Activity	Distribution	α	β	Mean	Standard Deviation	Minimum
Take Off Layer	Lognormal	-	-	7.15	8.37	4
Sorting	Weibull	1.1	28.65	-	-	5

MILLNet™ for Merchants also changed between aisle and block stacking methods, as seen in Table 8 and Table 9.

Table 8: Aisle-stacking MILLNet™ for Merchants distribution changes.

Activity	Distribution	α	β	Minimum	p
Door to aisle	Log-Logistic	-	4.77	3	3.71
Aisle to bale	Weibull	2.49	3.83	6	-

Table 9: Block-stacking MILLNet™ for Merchants distribution changes.

Activity	Distribution	α	β	Minimum	Maximum
Drive to Block	Weibull	1.53	51.8	4	-
Drive to Block (After 1st)	Uniform Real	-	-	3	10

Inventory size was measured within this simulation so that small merchant inventory (~ 2% owned) indicated the number of sheds pulled from to assemble a given order was greater than 60% of those available, and a large merchant inventory (~ 20% owned) signified the number sheds pulled from to assemble a given order was less than 60% of those available. The table values represent the distribution of time spent driving to each shed based on the inventory and facility size (Table 10). Both aisle and block stacking used the same inventory distributions.

Table 10: Aisle-stacking and block-stacking MILLNet™ for Merchants inventory size distributions.

Inventory Percentage	Facility Size	Distribution	p	q	Minimum	Maximum
20%	S	Beta	5.15	4.68	24	28
-	M	Beta	2.54	3.73	38	55
-	L	Beta	1.72	1.83	68	90
2%	S	Beta	3.55	3.83	23	28
-	M	Beta	6.64	41.5	32	112
-	L	Beta	3.14	3.27	52	87

MILLNet™ for Merchants

The MILLNet™ for Merchants data were created from bale quality information from two merchants and warehouse inventory data from the four observed warehouses. Data from the merchants were merged with data from the warehouses to get grade and location data for the bales.

After the data were combined, they were entered into the MILLNet™ for Merchants software categorized by merchant. Each merchant was sorted into warehouse location number. Each MILLNet™ test was done as follows: one merchant was selected, one warehouse was selected, bales were checked to see the distribution of micronaire grade values, the first standard deviation to and from the mean was used as a max and min guideline to only pull bales within that range, the bales were pulled randomly from all warehouses available and by location (i.e. only pulled from two or three warehouses that are located close together). A random order sheet and location specific order sheet was created. This was done for all warehouses under both merchants. Each warehouse/merchant combination order sheet had 5 random and location specific order pulls of 88 bales each. This allowed for as much data as possible within the confines of the model.

The data were input into a spreadsheet and the distance and time traveled was calculated. According to the warehouse managers, the average speed for the forklifts was between 10 and 12 mph. The distances between the warehouse and the staging area were found using Google Earth path distance measurements. The distances inside the warehouses from the door to the aisle, and the aisle to the bale were dependent on location and were calculated using building blueprints provided from the warehouse managers. The spreadsheet was used to calculate mean and standard deviation times from shed to staging area, time from the door to the aisle, and time in aisle to bale and back. All times were expressed in seconds. Means and standard deviations were combined and one mean of means and one standard deviation for each measurement was calculated, which was represented in the model by the times noted as: “drive to shed”, “drive to aisle”, and “drive to staging.” The data were combined into one order selected randomly and one location specific order (MILLNet™ for Merchants) to create a generic warehouse model.

Discrete Modeling Analysis

ExtendSIM 9.2® (Imagine That Inc., San Jose, CA) was used to create simulations to represent aisle-stacking and block-stacking warehouses. The simulation scenarios included a baseline, 4-bale marketing, and MILLNet™ for Merchants simulation. Time data was analyzed from the simulations to determine the time to accumulate one 88-bale order. The baseline scenario was created using the time and motion data collected at the warehouses (Table 2, Table 3, Table 4, and Table 5). All activities, such as hooking or storage to staging, that were included in the warehouse studies were modeled by an activity block in ExtendSIM (Figure 6).

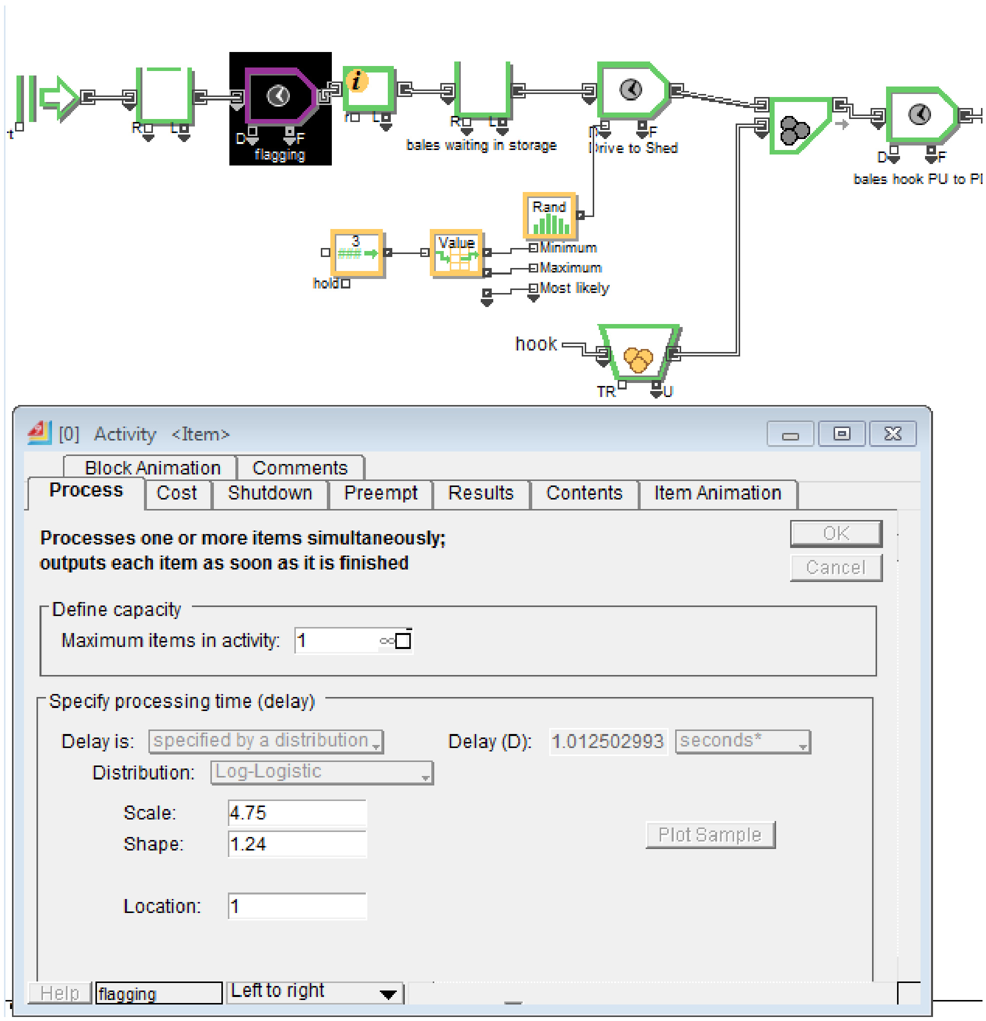

Figure 6: Example of the activity block with distribution for flagging the bale for an order.

Statistical distribution were fit to the collected data using StatFit 2 as noted previously. Other blocks included in the model simulation are resource, batching and un-batching, information, and queue blocks. The item flow tracked through the simulation was the individual bales of cotton.

Resource blocks represent the forklifts within the warehouse, as seen in Figure 7. These were equipped either as clamp or hook machines. The resource block tracks the number of forklifts available based on an initial inventory and allots them activities during the simulation. Each resource is removed from the pool during use and returned once they are no longer needed, duplicating real life operations.

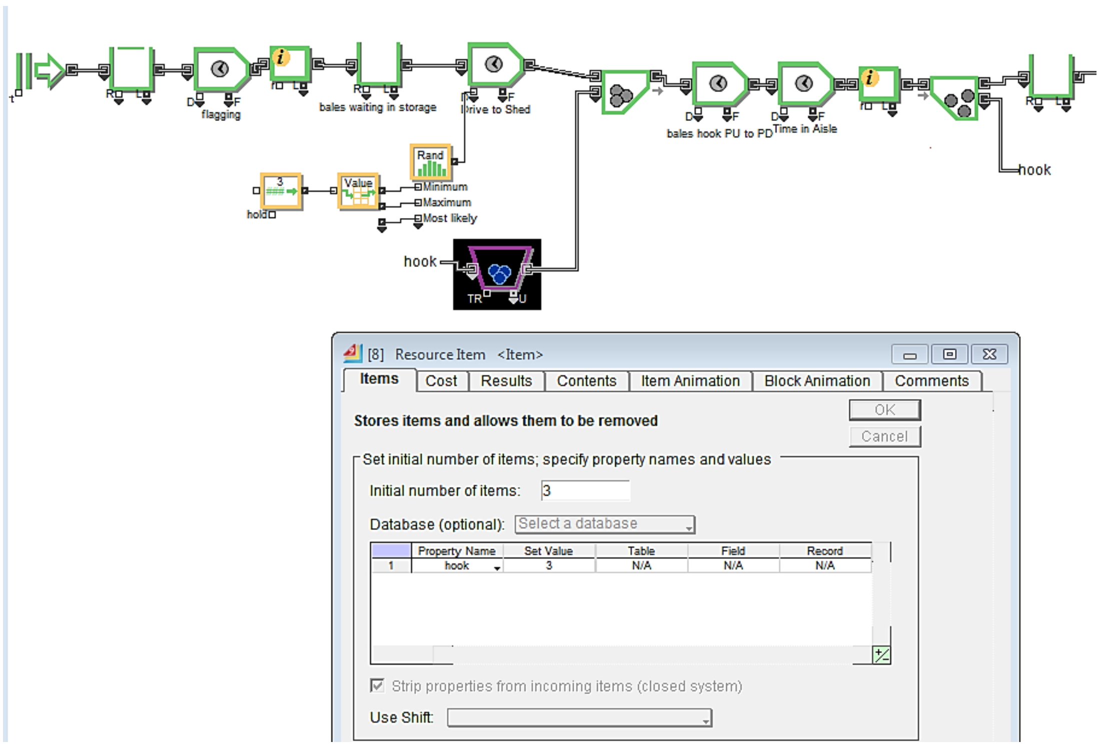

Figure 7: Example of the resource block with distribution.

Batching blocks were used to combine the bales with the forklifts during the simulation (Figure 8). This allowed the user to set the number of bales handled per machine to the number of forklifts used. For example, a forklift with a clamp could handle four bales but a forklift with a hook could only handle a single bale. Batching keeps the forklift and bale(s) together as they progress through the model until separated at a later activity.

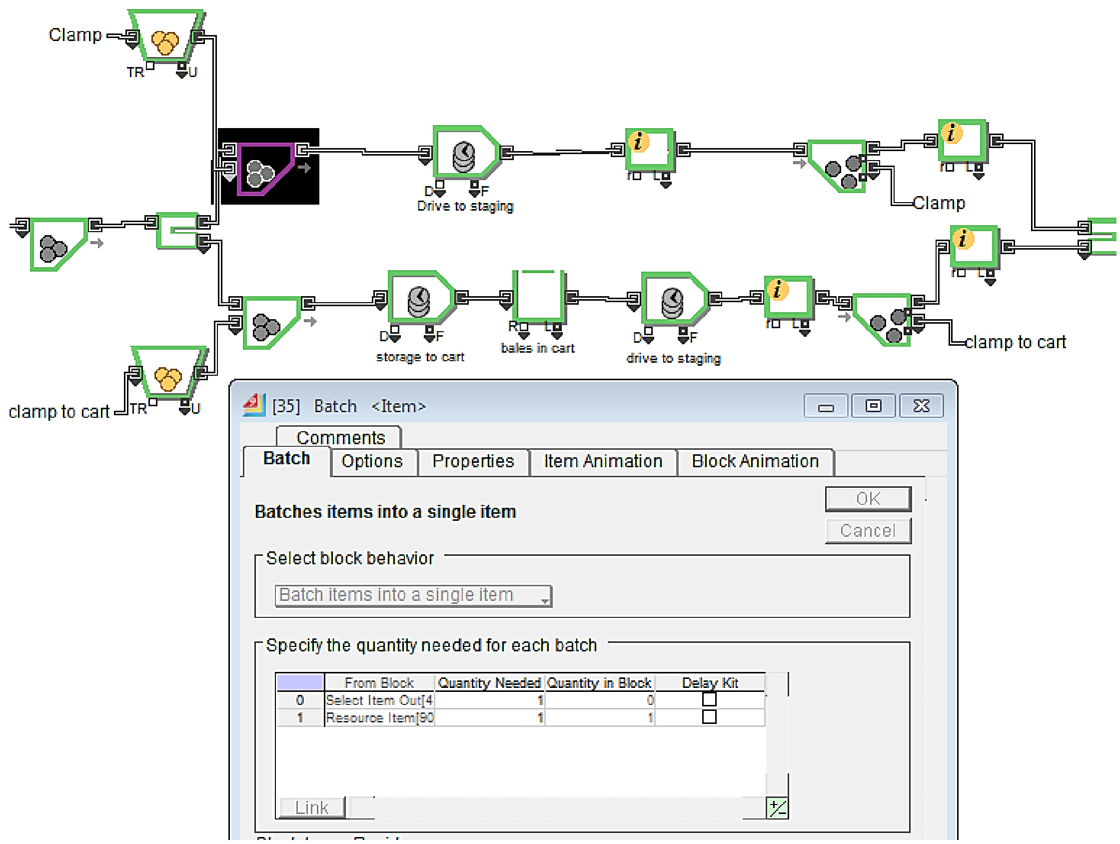

Figure 8: Example of clamp batching blocks with quantity needed.

Once a batch passes through the necessary activities, it was un-batched. The un-batching block separated the resources (forklifts) from the items (bales) (Figure 9) and allowed the bales to progress individually, instead of in groups of four. Un-batching also released the forklift to return to the pool and be available for the next group of bales.

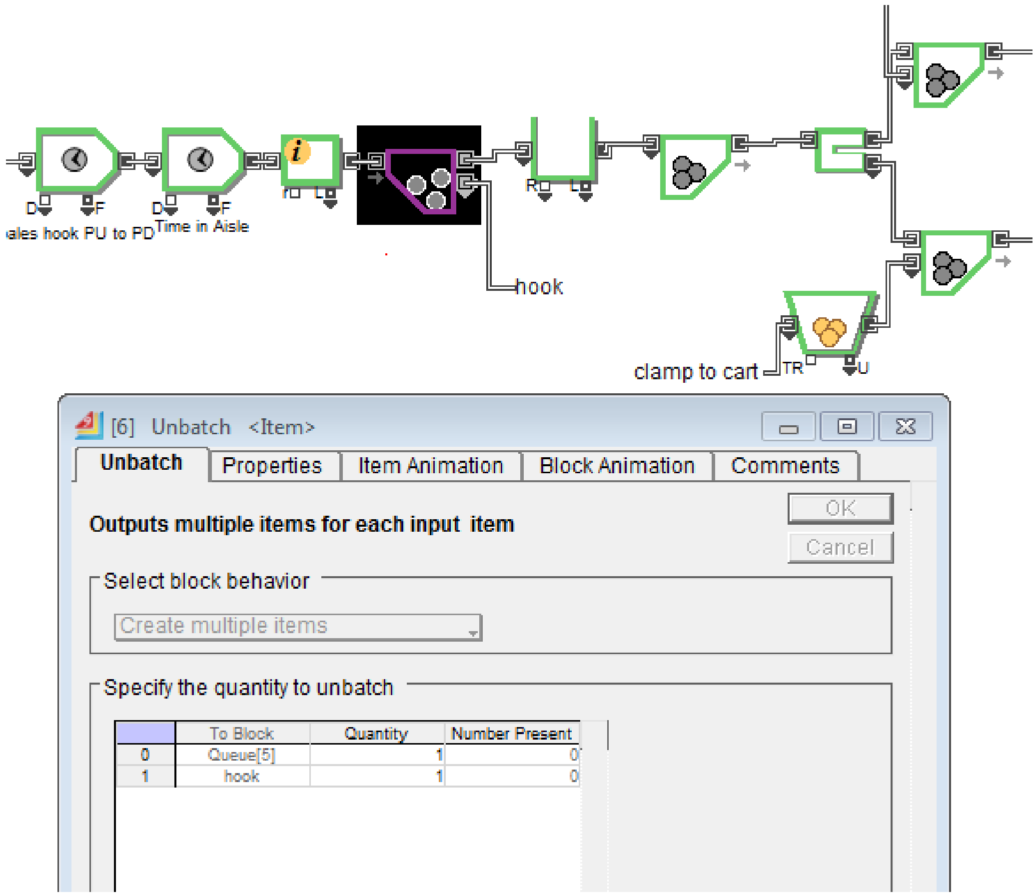

Figure 9: Example of hook un-batching block with quantity needed.

Information blocks were used to check the state of the simulation at various points in the item flow. Multiple information blocks were used to display results from different activity sections within the system. An information block at the end of the simulation reported the overall simulation data. Information blocks primarily reported time between items, the number of items that entered, and the number of items exiting the section being monitored. This was helpful in model validation and troubleshooting. A history block was included at the end of the simulation to show the final time for each bale to move through the whole simulation.

Queue blocks served as the waiting areas, e.g. a truck waiting to be unloaded or loaded or bales waiting for a forklift. Queues followed the first-in first-out (FIFO) rule.

The "drive to shed" activity block had different distributions for each of the three sizes of facility (5, 20, and 40 sheds). A lookup table was used to select the appropriate distribution and provide it to the activity block through the D connector, as seen in Figure 10.

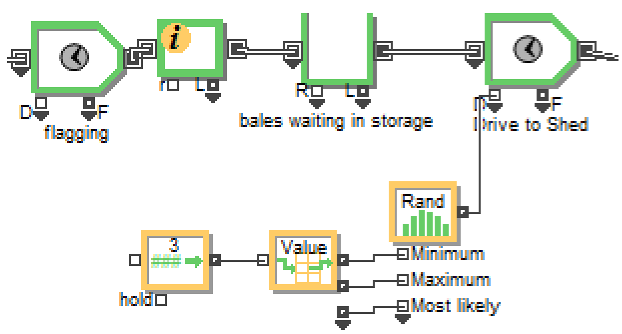

Figure 10: Example of the facility size connection blocks within the simulation model.

The initial constant block was set prior to the simulation at 1, 2, or 3 to represent a small, medium, or large facility using the Scenario Manager. The Scenario Manager block controlled the input variables and collected the output data (Figure 11) based on an experimental plan. The simulation results were written to a spreadsheet at the end of the simulation.

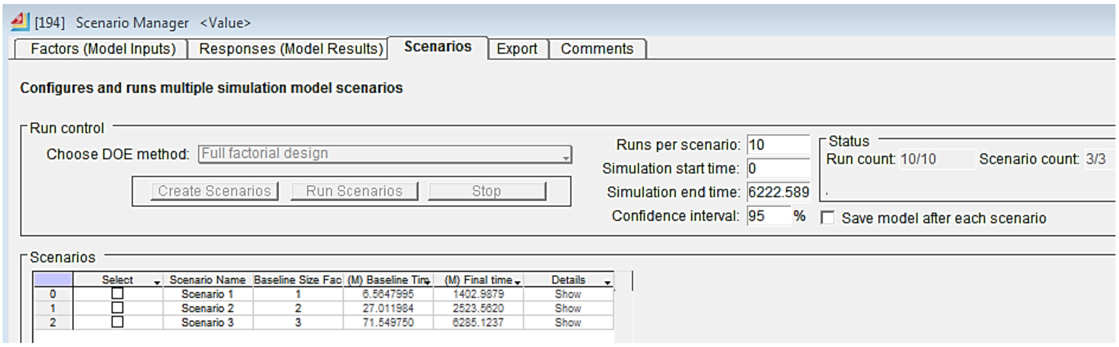

Figure 11: Example of the scenario manager within the simulation.

The experimental plan consisted of two warehouse scenarios (aisle stacking and block stacking), three marketing scenarios (baseline, 4-bale at a time, and MILLNet™ for Merchants), three facility sizes (5, 20, and 40 sheds), two inventory levels (small and large inventory), and two shipping methods (domestic and international). Simulations were run in a full factorial design and there were 10 runs for each scenario. Each run was the assembly of an 88-bale load, which is the size that fits on a standard box truck commonly used in the industry. Some combinations of factors were excluded from the factorial design as they did not represent actual applications or were theoretically impossible. These will be noted in the following chapters. The output of the simulation was the total time needed to assemble one 88-bale load, expressed in seconds.

Validation

A validation test was performed to establish that the simulation model represented actual outcomes observed at cotton warehouses based on the total times observed during data collection. These times included, total truck load time, total time to hook a bale, total bale repair time, and the total number of layers to get a specific number of bales. Table 11and Table 12 show the measured times.

Table 11: Aisle-stacking total average times.

Total Hook	Loading Total	
Per Bale	Box	Flatbed
(sec)	(min)	(min)
56±.01	17.69±1.5	21.36±8.0

Table 12: Block-stacking total average times.

All Bales Out of Block	Bale Repair	Total Truck Load
(min)	(min)	(min)
10.17±8.4	5.75±1.8	14.0±2.83

Aisle-stacking and block-stacking simulated times were reviewed with the warehouse managers, who opined that the model results were realistic.

CHAPTER III

AISLE-STACKING

Overview

The National Cotton Council's Vision 21 Cotton Flow Study sought to improve the flow of cotton through the system. Discrete event simulations were used to model the operations of a typical aisle-stacking cotton warehouse and evaluate potential improvements that may be realized by implementing a 4-bale marketing plan or incentivizing use of Cotton Incorporated's MILLNet™ for Merchants software. Time and motion data were collected from multiple warehouses to support the simulations, which address differences in time of implementing innovative bale selection techniques. For larger warehousing facilities, use of MILLNet™ for Merchants can significantly decrease the time required to accumulate a load of cotton for shipping. However, in warehouses utilizing aisle-stacking, 4-bale marketing did not reduce the time required to assemble a load for shipment.

Methods

To evaluate the potential impact of novel bale selection techniques, a baseline model simulation with a variety of inputs was created. In a 4-bale marketing model, four successive bales (a "clamp-load of bales" or "CLOB") produced at a gin where they were "module averaged" will be grouped together throughout the remainder of the cotton supply chain. Module averaging is a way to grade individual cotton bales based on the average grade of all bales in a module. Each bale's HVI (high volume instrument) measurements for length, strength, uniformity, and micronaire are averaged, then these averages are assigned to all the bales within that module, excluding the outlier bales (Earnest, 2012). The bales will then be handled and sold as a 4-bale lot to merchants. In theory, 4-bale marketing will reduce the total time spent aggregating an order since bales will be in groups of four, as opposed to scattered individually. Therefore, an 88-bale order would consist of 22 CLOBs rather than 88 separate bales. MILLNet™ for Merchants is a software package created by Cotton Inc. for merchants to use in bale selection. In addition to fiber quality parameters, the software utilizes bale location data within a warehouse to select bales for a given shipment (Gus Schild, Cotton Inc., personal communication, 2014), resulting in more efficient load assembly than is currently realized in warehouse operations. Presently, merchants have no incentive to consider bale location when putting together an order. However, it's not uncommon for warehouses to offer fees or discounts for certain services, like expedited shipping, so inclusion of an incentive for utilizing a novel bale selection method was considered reasonable.

Discrete Event Simulation (DES)

Baseline

A DES model was created for "baseline" warehouse operations (Figure 12). The steps shown in Figure 12 might change depending on the warehouse manager, but within most warehouses this process is the most common. First, the bales listed in the order are flagged or pre-marked to distinguish the bales within an order from the rest of the bales within an aisle. The hook truck then pulls each bale individually out of the aisle and aggregates them in the main aisle of the warehouse where a clamp truck gathers the bales in groups of four and carries them to the staging area from which orders leave the warehouse complex. Bales are moved from the storage warehouse to the staging area by the clamp driving to the staging warehouse with four bales at a time or by using a cart. The cart is a trailer that holds 24 bales and is towed by the forklift. Carts are used when the staging area is relatively far away to reduce travel time between the storage warehouses and staging area. Once the bales are transported to the staging area they are stacked in groups by order number. When the truck assigned to that order arrives, the bales are then loaded into the truck.

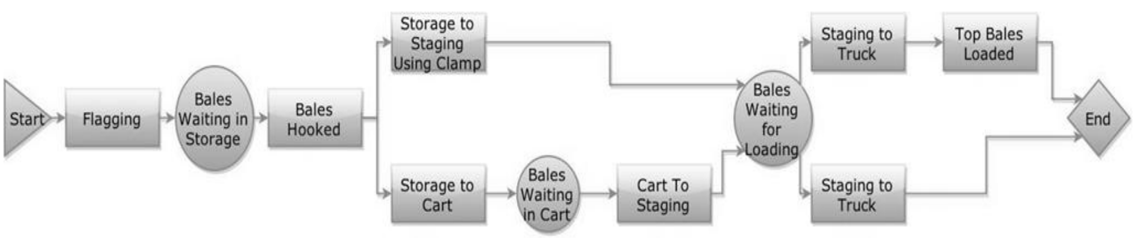

Figure 12: Aisle-stacking baseline activity flowchart.

Time and motion data were collected at two Texas warehouses to quantify the time spent in each of the steps shown in Figure 12. Data collected at the warehouses included: date, location, shed number, row number, activity, time required for a given activity, forklift speed, and distance the forklift traveled. Collected data were then analyzed using

Analysis of Variance (ANOVA) to determine significant factors that influenced observed load accumulation times. Candidate factors included:

- Location (Warehouse 1 v. Warehouse 2)
- Truck number (Order of the trucks arriving in the day)
- Truck type (Box v. flatbed)
- Shed number (Warehouse shed in which the activity was observed)

Raw data were analyzed for outliers and normality and the impact of each variable on the time required to accumulate an 88-bale load was determined. Independent variables were considered to significantly impact the time allocated to a given operation when the p-value was <0.05. The only variable found to significantly impact load accumulation time was shed number (Table 13), which was essentially a method of distinguishing the distance travelled by forklifts between the storage sheds and staging area when aggregating individual bales into order loads.

Table 13: Observed factors affecting load accumulation time for aisle-stacking.

Factor	**p-value**
Location	0.458
Truck Number	0.059
Truck Type	0.265
Shed Number	<0.001*

*indicates statistical significance

Once “shed number” was determined to be the only significant variable, StatFit2© (Geer Mountain Software Corp., South Kent, CT) was used to determine the distribution of time measurements for each observed activity to enable representative modeling. These distributions were entered into the baseline model developed using ExtendSIM 9.2® (Imagine That Inc., San Jose, CA).

Once the baseline ExtendSIM model was developed, mock baseline orders were created using MILLNet™ for Merchants to develop realistic fiber quality distributions for a given order but ignoring bale location data. To run the mock orders, merchant bale ownership data were collected from two merchants that had inventory in the two warehouses studied. These data and the warehouses’ electronic bale location data were merged to determine where a given merchant’s bales were located within the warehouse complex. MILLNet™ for Merchants was then be used to create orders of 88 bales with average micronaire between 3.2 and 4.9; the parameter was decided based on the average micronaire of the inventory ±1 standard deviation. The program then selected bales that fit this quality parameter (without respect to bale location), simulating orders that are commonly received in warehouses. Warehouse blueprints were used to find the distance from the door of each shed to the aisle in which each bale was located and the distance down the aisle to the given bale. These distance measurements were then matched to the locations of bales specified in the simulation orders, and the times required for warehouse personnel to drive those distances were calculated.

To assess the impact of facility size on the distribution of distances between storage sheds and the staging area, three generic warehouse complexes, setup in basic grid patterns, were modeled: a small facility (five sheds), a medium-sized facility (20 sheds), and a large facility (40 sheds). The "large" generic facility is shown in Figure 13Figure 13: Generalized warehouse blueprint. Small facilities included sheds 1-5, medium-sized facilities included sheds 1-20, and large facilities included sheds 1-40.; small and medium-sized facilities were modeled using similar distances between sheds. Each shed was assumed to contain 50,000 bales. The baseline model assumed 80% of sheds available were used to aggregate an order. Bale selection was assumed to be completely random within the quality parameters specified, therefore selection would be unaffected by relative inventory size (i.e., the percentage of a given warehouse's inventory available to the merchant developing the order).

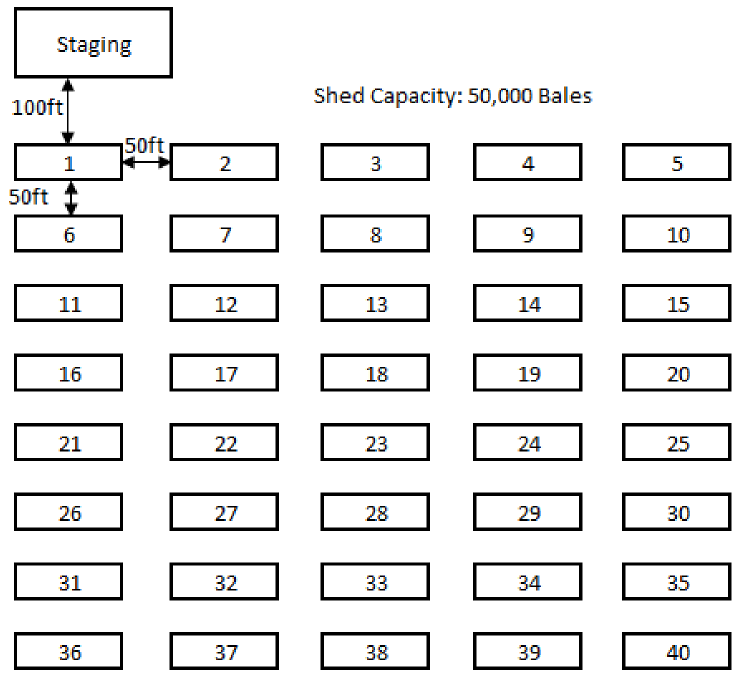

Figure 13: Generalized warehouse blueprint. Small facilities included sheds 1-5, medium-sized facilities included sheds 1-20, and large facilities included sheds 1-40.

The model was set-up to simulate accumulation and shipment of a mock order of 88 bales at the staging area to calculate the total time required to complete order assembly. It assigned the 88 bales randomly to 80% of the sheds available (except for the small facility, where all 5 sheds were utilized), then the number of trips needed to carry 4 bales at a time to the staging location was calculated. To account for use of carts in load assembly, models were re-run assuming 24 bales were carried to staging at one time. This reduces the number of trips needed to move the bales. Calculated travel distances were divided by average forklift speeds (10 MPH) to determine the total forklift driving time required to assemble one 88-bale load. The bales within each order were randomized and replicated 10 times for each facility size. Simulation data were then compared to observed load aggregation times to ensure the reasonableness of modeled results.

4-Bale Marketing

When utilizing 4-bale marketing, the hypothesis was made that load accumulation and shipping time will be reduced since bales are already staged in 4-bale groups, reducing the number of "sales units" from 88 individual bales to 22 CLOBs. Time spent searching for bales in the aisle will be shorter because the bales will be grouped together, as opposed to scattered throughout the warehouse. However, when using aisle-stacking, all four bales in a CLOB must still be pulled for shipping as individual bales using a bale hook, so the only substantive difference between 4-bale marketing and the baseline scenario for an aisle-stacking warehouse was the time the hook spent searching for the second, third, and fourth bales in a given CLOB in the aisle. Instead of the baseline assumption of an eight second search time for each bale in the aisle (based on observations made at the warehouses), it was assumed that the first bale would require an eight second search time and the next three bales would take two seconds each to identify. This time change was assumed because, when trying to find a bale within a marked section of aisle there are about 15 bales to look through to find one. When four bales are grouped together, there would be only three additional bales to look through. (Additional time savings may be realized in block-stacking warehouses, where clamps could be used to pull bales four at a time,. Results from the block-stack analysis are reported in section 4.)

To model load aggregation using a 4-bale marketing strategy, the same time distributions from the baseline model were used, except the aisle-to-bale time was adjusted as described to account for the shorter search time required for 75% of the bales. The number of sheds used were kept at the same (i.e., 80% of sheds available), and inventory size was not considered because the 4-bale CLOBs will still be randomly placed throughout the warehouse complex, only in groups of four. Again, the bales included in each order were randomized, and ten replications were modeled for each facility size. To calculate the shed-to-staging-area time using carts, the number of bales carried per trip was changed from four to 24, thereby reducing the number of trips needed.

MILLNet™ for Merchants

Bale selection utilizing MILLNet™ for Merchants was analyzed in much the same way except that inventory size was also considered. The analysis for this technique assumed that the bale locations would be more consolidated so more bales are pulled from a given shed, reducing the distance driven to obtain a load. Inventory was considered because a larger inventory increases the probability that bales located in close proximity to each other will be capable of meeting the quality specifications of the merchant order. With a smaller inventory there are not as many bale options, so it less likely that bales capable of meeting specified quality criteria will be located in the same shed. The small facility used all of the five sheds available for both inventory size considerations, while medium and large facilities used an exponential distribution to determine the percentage of sheds pulled from to create the 88-bale order. The distribution of sheds was determined from merchant-warehouse order data. Based on inventory data received from two different merchants at the two warehouses where time and motion data were collected, the inventory percentage was defined so that small merchant inventory (~ 2% owned) indicated the number of sheds pulled from to assemble a given order was greater than 60% of those available, and a large merchant inventory (~ 20% owned) signified the number sheds pulled from to assemble a given order was less than 60% of those available.

Time distributions were again assessed using the warehouse model shown in Figure 13. The model assigned the 88 bales randomly to each shed using the exponential distribution of sheds available (except the small facility, where all five sheds were utilized). The bale selection process was randomized and replicated ten times for each size and inventory measure. In total, twelve scenarios were analyzed using ten model replications of each scenario (Table 14).

Table 14: Modeled scenarios aisle-stacking.

Bale Selection Method	Scenarios		
Baseline	Small Facility	Medium Facility	Large Facility
4-Bale Marketing	Small Facility	Medium Facility	Large Facility
MILLNet™ for Merchants	Small Facility – Small Inv. Small Facility – Large Inv.	Medium Facility – Small Inv. Medium Facility – Large Inv.	Large Facility – Small Inv. Large Facility – Large Inv.

For each model run, the load accumulation and shipping time was calculated. Model results were analyzed for outliers and average results using novel base selection methods were compared to baseline results using a two-sample t-test assuming unequal variances ($\alpha = 0.05$).

Results and Discussion

Baseline

Baseline modeling results indicate that load assembly time increased with increasing facility size (Table 15). These results are logical given that the further from the staging area the driver had to travel to get the bales, the longer the required total assembly time. If bales were transported from the storage shed to the staging area in 4-bale loads, over 60% of the load accumulation time was spent driving from the shed to the staging area (Figure 14). The percentage of time spent in transport decreased from 63% for smaller warehouses when using the clamp to 28% when using the cart, but time spent in transportation was unaffected for medium and large facilities. In medium-sized and large facilities, the number of bales pulled from each shed was lower, so more time was spent driving to the multiple sheds needed to fulfill the order.

Table 15: Time required to assemble an 88-bale load using standard bale selection (baseline) techniques in an aisle-stacking arrangement using only clamps.[a]

Facility Size	Time (min)[a]
Small	40.1 ± 2.0
Medium	71.8 ± 1.7
Large	124.0 ± 1.0

[a] Mean ± one standard deviation

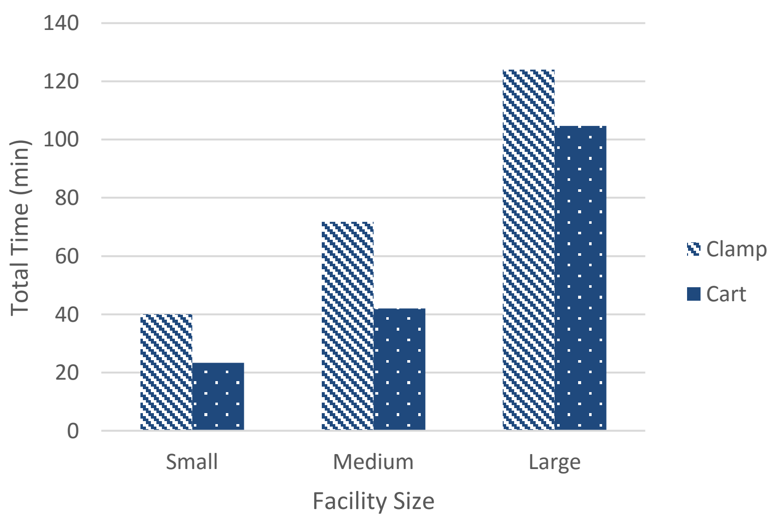

Figure 14: Baseline clamp vs cart total accumulation and loading time (min) in an aisle-stacking arrangement.

4- Bale Marketing

Times required to assemble a load using a 4-bale marketing bale selection method are shown in Table 16. None of the CLOB results were statistically different than baseline values. The lack of time savings was due to the bales still being pulled out one at a time with the hook in an aisle-stacking warehouse. Only six seconds were saved for each of the last three bales pulled out of the CLOB to account for a reduction in the driver's search time. However, the times required to travel down the aisle and to move bales between storage and the staging area were unaffected by grouping bales as CLOBs. The 4-bale marketing technique did not provide any significant time savings compared to baseline operations in aisle-stacking warehouses, as seen by the >.05 p-value. The percent change time column is a direct comparison between 4-bale total accumulation time and baseline total accumulation time.

Table 16: Time required to assemble an 88-bale load using 4-bale marketing in an aisle-stacking arrangement using only clamps.[a]

Baseline		**Four Bale CLOB**		
Facility Size	Time (min) [a]	Time (min)[a]	% change	P-Value
Small	40.1 ± 2.0	39.1 ± 2.2	-2%	0.783
Medium	71.8 ± 1.7	71.3 ± 0.6	-1%	0.250
Large	124.0 ± 1.0	124.2 ± 1.4	0%	0.744

[a] Mean ± one standard deviation

MILLNet™ for Merchants

Simulation results for the MILLNet™ for Merchants are shown in Table 17. Significant time savings were realized using this bale selection technique for some scenarios. Larger inventory and larger facilities resulted in more time saved in load aggregation relative to baseline because the amount of time traveling between sheds was reduced. However, for the small facility with small inventory, no time savings was realized between baseline methods and using MILLNet™ for Merchants because the number of sheds from which bales were pulled was not markedly reduced. Ultimately, reducing the number of sheds needed to fill an order led to greater time savings. When using the clamp to transport bales, although the total accumulation time increases as the facility got larger, the time it took to transport the bales from shed to staging remained constant at 66±1% of the total time for each facility. This means a little more than half the total time spent accumulating a load was time spent driving rather than time spent pulling bales.

When looking at the time traveled with the carts, the percentage time spent driving at the small facility dropped to 35%, with a total average time driving of 65±4% for medium and large facilities. Figure 15 shows a clear picture of how load accumulation time was reduced when the number of sheds from which bales are pulled was reduced. In Table 17, the largest percent change between MILLNet™ and baseline was found to be 17% (large facility/large inventory). This percentage was based on use of <60% of sheds available for a large inventory and >60% sheds available for a small inventory. When bales are all pulled from a single shed using carts, the time savings for a large facility increased to 27%.

Table 17: Time required to assemble an 88-bale load using MILLNet™ for Merchants in an aisle-stacking arrangement using only clamps.[a]

	Baseline	**MILLNet™ for Merchants**					
		Small Inv.			Large Inv.		
Facility Size	Time (min)[a]	Time (min)[a]	% change	P-Value	Time (min)[a]	% change	P-Value
Small	40.1 ± 2	41.0 ± 5.9	2%	0.986	39.2 ± 5.8	-2%	0.031
Medium	71.8 ± 1.7	66.5 ± 0.9	-7%	0.007	64.7 ± 2.3	-10%	<0.0005
Large	124.0 ± 1	116.7 ± 8.0	-6%	0.006	102.8 ± 1.7	-17%	<0.0005

[a] Mean ± one standard deviation

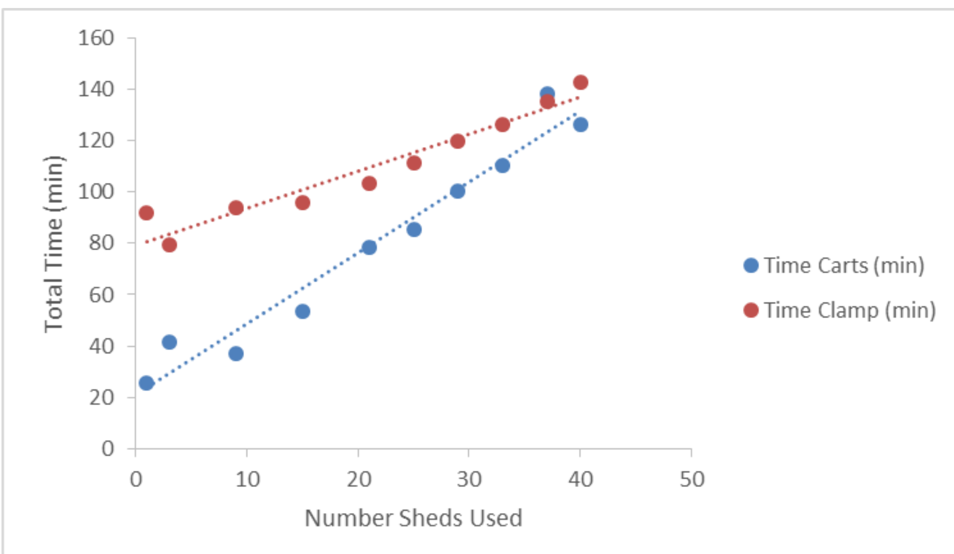

Figure 15: MILLNet™ for Merchants load aggregation time vs number of sheds pulled from for clamps and carts in an aisle-stacking arrangement.

Results shown are expected because when a larger inventory was available to a merchant from which to pull bales, more bales that met the required quality specifications were likely to be available in a given shed. Because there were more bales available in a given shed, the bales were more likely to be closer together, decreasing the number of sheds that must be accessed to put together a load having the desired distribution of quality parameters, thereby reducing the total accumulation and loading time and increasing the efficiency of warehouse operations. The potential time savings realized could be greater if the number of sheds is further reduced as demonstrated by Figure 15. When all bales were pulled from only one shed, the average total load accumulation and shipment time for carts and clamps was 25 and 90 minutes, respectively. This is a time savings of ~ 2% to ~ 17% when compared to average loading time under the baseline scenario using only the cart.

Conclusions

Reducing the time required to accumulate bales for shipment from warehouses can improve the flow of cotton through the US supply chain and has the potential to improve warehouse profitability. Compared to baseline operations for aisle-stacking warehouses, 4-bale marketing offered little to no time savings. However, use of MILLNet™ for Merchants software led to significant time savings, depending on the size of the warehouse facility and the inventory level which the merchant could access within a given warehouse. Shipping cotton overseas generally requires less consideration of load uniformity and may allow for greater flexibility when choosing bales for shipments, thereby enabling greater time savings by reducing the number of sheds from which bales are pulled. The greatest time savings were realized with MILLNet™ by limiting the number of sheds from which bales are pulled.

Compared to baseline operations, use of MILLNet™ for Merchants resulted in time savings of between 2 and 17%, translating to a reduction of up to 54 minutes per load. The higher time reduction (27%) was realized when clamps were used and only one or two sheds were selected to pull the bale orders. Financial savings associated with use of MILLNet™ for Merchants could help aisle-stacking warehouses to incentivize the use of such software to merchants who currently have limited motivation to consider bale location in their order development. Overall, with use of the MILLNet™ for Merchants software, a cotton warehouse could realize significant time savings with minimal effort on the part of the merchant.

CHAPTER IV

BLOCK-STACKING

Overview

The National Cotton Council's Vision 21 Cotton Flow Study sought to improve the flow of cotton through the system. Discrete event simulations were used to model the operations of a typical block-stacking cotton warehouse and evaluate potential improvements that may be realized by implementing a 4-bale marketing plan or incentivizing use of Cotton Incorporated's MILLNet™ for Merchants software. Time and motion data were collected from multiple warehouses as input parameters for discrete event simulation models, which were used to estimate the time to assembly an 88-bale order for current operations and for two innovative bale selection techniques. Compared to baseline operations for block-stacking warehouses, 4-bale marketing and MILLNet™ for Merchants were estimated to significantly reduce order assembly time. The greatest time savings, 50%-75% reduction, was realized by using MILLNet™ for Merchants and pulling bales only from the fronts of the blocks. However, this may not be a viable option in all warehouses depending on the situation. The 4-bale marketing strategy also reduced order assembly time by up to 56% and has the advantage of easier implementation as it is more similar to current baseline operations.

Methods

To evaluate the potential impact of novel bale selection techniques, a baseline discrete event model with a variety of input parameters was developed. The baseline process flow is shown in Figure 16. In the 4-bale marketing method (also known as a "clamp-load of bales" or "CLOB"), four successive bales are produced at a gin where the quality parameters are "module averaged," that is, the quality for all bales ginned from a harvested module is assumed to be equal to the quality based on samples from a sample of bales. Each bale's HVI measurements for length, strength, uniformity, and micronaire are averaged, then these averages were assigned to all the bales within that module, excluding outlier bales (Earnest, 2012). The CLOB remains grouped together throughout the cotton supply chain and sold as a 4-bale lot to merchants. In theory, 4-bale marketing will reduce the total time spent aggregating an order since the bales are in groups of four, as opposed to individually selecting bales in the block to assemble an order.

MILLNet™ for Merchants (Cotton Incorporated, date) created for merchants to use in bale selection. The software utilizes bale location data within a warehouse and fiber quality parameters, to select bales for a given shipment (Gus Schild, Cotton Inc., personal communication, 2014). The assumed advantage is that this would result in more efficient load assembly than currently realized in warehouse operations. The software can specifically select by block or layers of bales within the blocks to further reduce search times. Presently, merchants have no incentive to consider bale location when assembling an order; however, warehouses often offer fees or discounts for extra services, like expedited shipping. The addition of an incentive or fee for utilizing/not utilizing a preferred bale selection method may be considered reasonable.

Discrete Event Simulation (DES)

Baseline

A DES model was created for "baseline" shipping warehouse operations (Figure 16). The steps shown may change slightly for a specific warehouse, but the general flow of cotton is widely applicable throughout the US cotton belt. The bales start in storage in the warehouse and are stacked in blocks of 4 bales wide, 3 bales tall, and up to 8 bales deep; stacked lengthwise or vertically top to bottom versus horizontal. After the warehouse receives orders, they will often pull three to four orders at a time out of the blocks to increase efficiency instead of going into the block multiple times per day. The clamp machine pulls groups of four bales at a time off the block. The operator checks those bales to see if the PBI numbers match the order sheet. Matching bales will be set aside according to their respective order. Once the operator is finished searching the block and retrieving the needed bales, the unused bales are stacked back into the same block formation as before. The bales needed to fulfill an order then go to sorting. The sorting area is divided into sections where the different orders are being assembled. The bales are taken to their order group and collected in clamp loads of four bales at a time. Once enough bales are assembled for the order, a forklift with a clamp will take them to the staging area to be shipped. The bales within the staging area are also stacked in block formation with the same dimensions as the storage warehouse. When the box or flatbed truck comes to pick up the order, the bales are loaded and shipped.

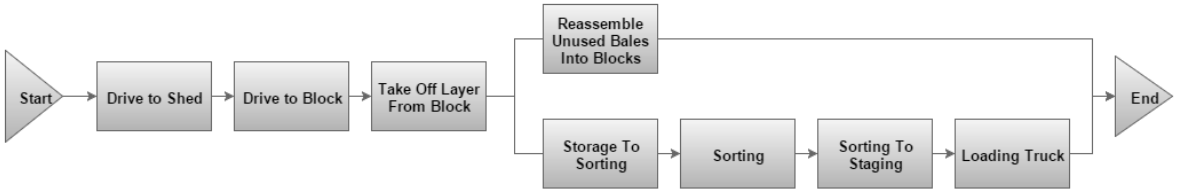

Figure 16: Block-stacking baseline activity flowchart.

Time and motion data were collected at two North Carolina block-stacking warehouses (one small and one large) to quantify the time spent in each of the steps shown in Figure 16. Data collected at the warehouses included: date, warehouse location, shed number, row number, activity being performed, time in seconds, forklift speed, and distance traveled. The raw data were analyzed for outliers and normality. Once outliers were removed, StatFit2© (Geer Mountain Software Corp., South Kent, CT) was used to determine the distribution of time measurements for each observed activity to enable representative modeling. These distributions were entered into the baseline model developed using ExtendSIM 9.2® (Imagine That Inc., San Jose, CA).

Two baseline models were created, one representing foreign shipments and the other domestic shipments. For domestic orders, each truckload comprising an order should have nearly-identical distributions of fiber quality parameters to ensure a consistent laydown at the textile mill. For most foreign shipments, each individual load still has to meet these specifications, but each load does not have to be uniform as long as the total shipment meets specified contract conditions. Both models included pulling four orders at a time, using five, sixteen, and 32 random warehouse sheds, and a forklift speed of

6mph. The shed amounts were calculated by taking 80% of the sheds available for small, medium, and large warehouses. This is similar to what was done in the aisle-stacking process described in section 3. The small warehouse used all five sheds available. The aisle-stacking generic warehouse blueprint in Figure 17 (Hazelrigs, 2016) was used to represent the drive time between the staging warehouses to the random shed locations.

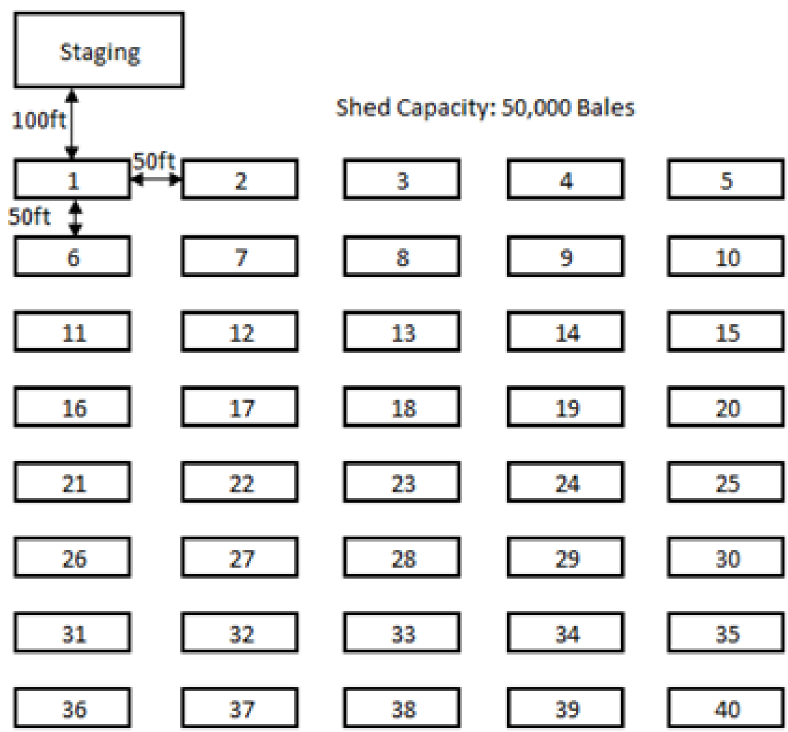

Figure 17: Generalized warehouse blueprint. Small facilities included sheds 1-5, medium-sized facilities included sheds 1-20, and large facilities included sheds 1-40.

A uniform shed capacity of 50,000 bales was used. Figure 18 shows the layout of one block-stacking shed used to determine the drive time from the shed entrance to any given block and a distribution was created to represent "drive to block" time in the simulation. This distribution was assigned randomly to each block of 96 bales passing through the warehouse.

The number of bales needed per each block for the four orders varied between foreign and domestic orders at 40% and 15%, respectively (Gus Schild, Cotton Inc., personal communication, 25 January 2016). To compensate for the percentages and still get a total of four orders at the end of the simulation, the starting number of bales available also had to be different between shipment methods. The initial inventory in the simulation was 960 bales for foreign shipments and 2,880 bales for domestic shipments. Domestic shipping will take longer, but that was already assumed due to having to sort through more bales. The simulation was run 30 times for each facility size to determine the average total forklift driving time. The results of each run were divided by the 4 orders to get the time to assemble one 88-bale load. Simulation results were compared to observed load aggregation times to validate the model.

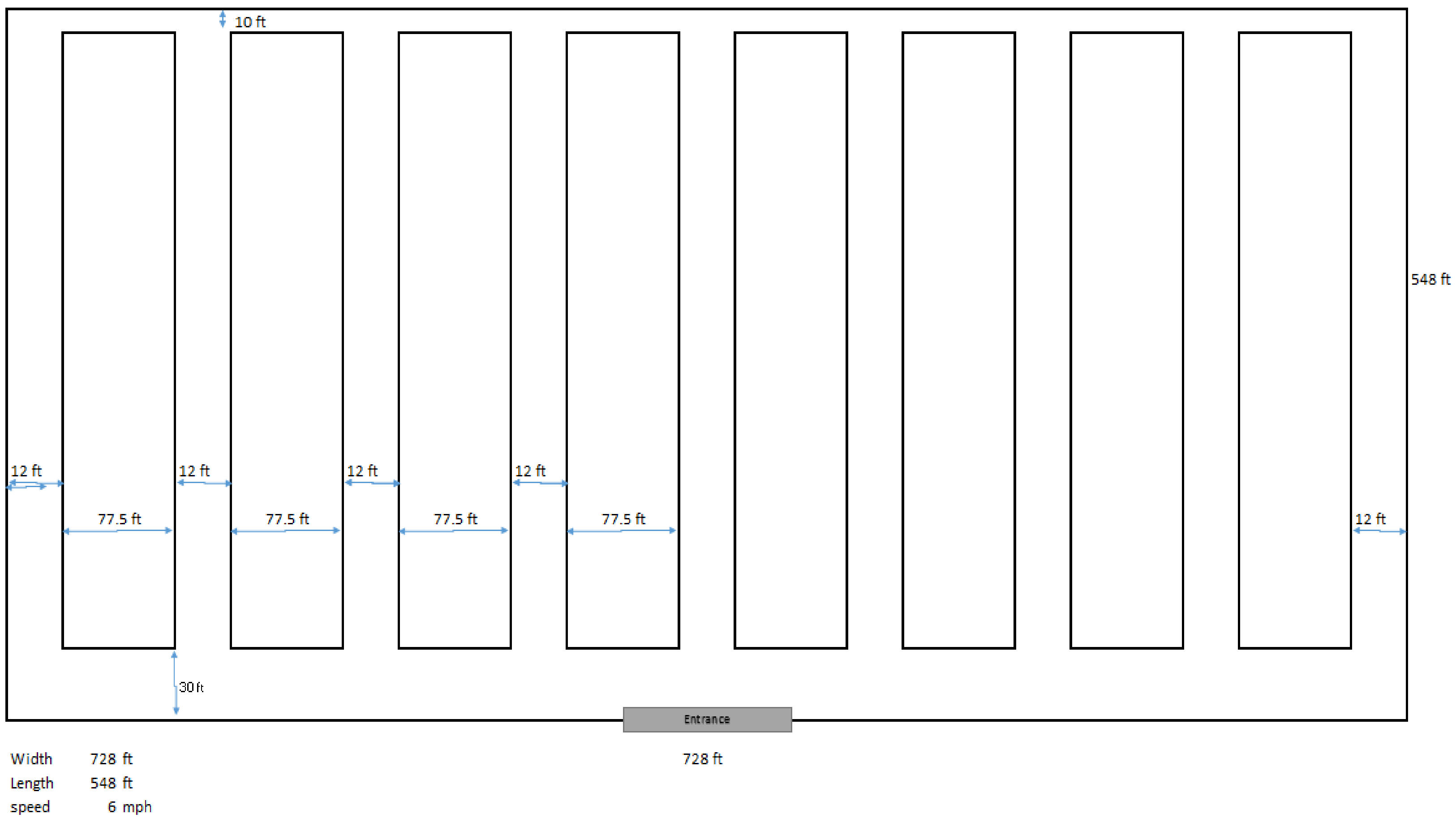

Figure 18: Generic block-stacking warehouse blueprint.

4- Bale Marketing

In 4-bale marketing, the hypothesis is that load accumulation and shipping time will be reduced since bales are already staged in 4- bale groups, reducing the number of "sales units" from 96 individual bales to 24 CLOBs. Instead sorting through each layer of four bales, the entire group of four bales is moved directly to their respective order or back into the block. This should reduce the time needed to take off each layer by 75% as compared to the baseline. Sorting time should also be impacted and reduced by half compared to baseline since the bales do not have to be individually moved and grouped into CLOBs.

The 4-bale marketing simulation was set up much the same as the baseline, in which there were two different shipping simulations: foreign and domestic. Within these two, the same number of starting bales (960 and 2,880, respectively) and percentages of bales needed from one block (40% and 15%, respectively) were used. Five, sixteen, and 32 random warehouse sheds were used as the facility size. Time distributions for each activity shown in Figure 16 (other than “take off layer” and “sorting”) were the same as the baseline model. The simulation was run 30 times for each facility size to determine the average total aggregation time. Results were divided by the 4 orders to get the time to assemble one 88-bale load. Simulation data were compared to observed load aggregation times to validate the modeled results.

MILLNet™ for Merchants

MILLNet™ for Merchants was represented by pulling bales off only the front face of the block. Instead of moving multiple layers in a block to get assemble an order, only the front twelve bales were available from which to pull. This reduced the time used to rebuild the block. Within the 12 bales, 75% of them were assigned to orders and 25% were stacked back onto the block (Gus Schild, Cotton Inc., personal communication, 25 January 2016). An initial inventory of 576 bales from 45 blocks was used to produce four 88-bale orders at the end of the simulation.

To model the driving between blocks, two pathways were used in the simulation. The first path was the drive time from the entrance of the shed to the first block using the distances shown in Figure 18 Figure 17: Generalized warehouse blueprint. Small facilities included sheds 1-5, medium-sized facilities included sheds 1-20, and large facilities included sheds 1-40.(Hazelrigs, 2016). Drive times between all blocks after that were determined by a uniform real distribution between three to ten seconds. This time was based on observations at the warehouses visited. The forklifts did not travel randomly through the blocks, but went block to block in an orderly fashion. Five, sixteen, and 32 random warehouse sheds were pulled from and the simulation was run 30 times for each facility size to determine the average total forklift driving time. The results were divided by the 4 orders to get the time to assemble one 88-bale load. Simulation data were then compared to observed load aggregation times to ensure the reasonableness of modeled results.

Results and Discussion

Baseline

Simulation model results for the baseline indicated that load assembly would increase with domestic shipping and with a larger facility (Table 18). Facility size was a factor due to longer drive times. The difference is small between the times because the longer drive times was offset by the reduced time needed in the larger sheds to assemble an order. The small facility had 576 bales within each of five sheds to pull, the medium facility had 180 bales to pull distributed within each of sixteen sheds, and the large facility had 90 bales spread throughout each of 32 sheds.

The shipping method had a large impact on assembly time because there were 25% more bales available to be pulled by the driver for orders with foreign shipments. Foreign orders needed fewer blocks to create the orders; therefore, the driver was able to gather more bales per block and less time was spent traveling from block to block, disassembling blocks, sorting, and restacking blocks. The operator in the small facility spends about 1% of the total time in driving to the sheds, in the medium facility they spend 2.5% of the total time driving, and in the large facility they spend 8.2% of the total time driving.

Table 18: Time required to assemble an 88-bale load using standard bale selection (baseline) techniques in a block-stacking arrangement.[a]

	Shipping Method	
	Foreign	**Domestic**
Facility Size	**Time (min)**	**Time (min)**
Small	45.8 ± 2.1	134.5 ± 3.6
Medium	45.9 ± 1.7	135.2 ± 4.3
Large	69.2 ± 2.1	135.4 ± 3.8

[a] Mean ± one standard deviation.

4- Bale Marketing

Times required to assemble a load using a 4-bale marketing bale selection method are shown in Table 19. In all cases but one (large/foreign), the time reduction was significant when comparing the baseline to the 4-bale marketing method. Organizing the bales in groups of four in block-stacking resulted in a time savings of between 12% and 56% when assembling an order in groups of four bales. The greatest percentage of time savings (over 50%) was realized at the small facility in conjunction with domestic shipping ($p < 0.0001$). This time savings is mostly due to the 75% reduced "time needed to take off each layer" as compared to baseline and by sorting time being reduced by half since the bales did not have to be individually moved. Facility size was a greater factor in the CLOB method since drive time was a greater percentage of total time. Drive time took approximately 2%, 9%, and 16% of total foreign shipment time, respectively. For domestic shipments, drive time was approximately 1%, 6%, and 17% of the total time to accumulate the orders, respectively.

Table 19: Time required to assemble an 88-bale load using 4-bale marketing in a block-stacking arrangement.

	Baseline		Four Bale CLOB					
	Foreign	Domestic	Foreign			Domestic		
Facility Size	Time (min)[a]	Time (min)[a]	Time (min)[a]	% change	P-Value	Time (min)[a]	% change	P-Value
Small	45.8 ± 2.1	134.5 ± 3.6	31.9 ± 2.5	-30%	<0.0001	59.7 ± 1.0	-56%	<0.0001
Medium	45.9 ± 1.7	135.2 ± 4.3	40.3 ± 2.8	-12%	<0.0001	62.8 ± 0.9	-54%	<0.0001
Large	69.2 ± 2.1	135.4 ± 3.8	69.2 ± 5.5	0%	0.7016	67.5 ± 0.8	-50%	<0.0001

[a] Mean ± one standard deviation

MILLNet™ for Merchants

Results of MILLNet™ for Merchants simulations are shown in Table 20. Significant time savings of 50% to 76% were realized using this bale selection technique, primarily as a result of bales being pulled off the front of the blocks within the warehouse. This saved time when repairing the block, since fewer bales have to be moved. The use of MILLNet™ for Merchants resulted in significant time savings when compared to the baseline technique. This study can only be compared to the baseline values for domestic shipping. Warehouses that operate by accessing only the end bales are typically only able to so for a short amount of time (~ 25%) or under certain conditions. For example when shipments from the gin are just starting to arrive to the warehouse or if the warehouse is only shipping to one merchant, the distribution of bales remains mostly undisturbed. When more bales are mixed coming into the warehouse from the gin, the more intermixed the bales will become.

The percentage of drive time relative to the total order assembly time yielded results very similar to 4-bale marketing with 2%, 9%, and 17% drive times for a small inventory in the small, medium, and large facilities, respectively. Warehouses with a large inventory showed 2%, 9%, and 19% drive times for the small, medium, and large facilities, respectively. Compared to baseline, MILLNet™ for Merchants proved to be a successful method of assembling an 88-bale load and dramatically saved time in a warehouse with the stipulation that the warehouse will have to track the grade of the front bales. Along with using USDA EFS data to track bale storage, the warehouse may need more specific storage tracking to keep the "front of the block" updated.

Table 20: Time required to assemble an 88-bale load using MILLNet™ for Merchants in a block-stacking arrangement.

	Baseline	MILLNet™ for Merchants					
	Domestic	Small Inventory			Large Inventory		
Facility Size	Time (min)[a]	Time (min)[a]	% change	P-Value	Time (min)[a]	% change	P-Value
Small	134.5 ± 3.6	33.2 ± 0.9	-75%	<0.0001	32.8 ± 1.0	-76%	<0.0001
Medium	135.2 ± 4.3	40.0 ± 0.9	-71%	<0.0001	38.2 ± 1.0	-72%	<0.0001
Large	135.4 ± 3.8	67.5 ± 1.6	-50%	<0.0001	59.3 ± 1.4	-56%	<0.0001

[a] Mean ± one standard deviation

Conclusions

Reducing the time required to accumulate bales for shipment from warehouses can improve the flow of cotton through the US supply chain and has the potential to improve warehouse profitability. Compared to baseline operations for block-stacking warehouses, 4-bale marketing and MILLNet™ for Merchants offered potential time savings. Depending on the size of the warehouse facility and the destination of shipping, the time to accumulate and load an 88-bale order can be greatly reduced compared to baseline operations. Shipping cotton overseas to the foreign market generally required less consideration of load uniformity and allowed for greater flexibility when choosing bales for shipments, which enabled greater time savings by reducing the number of sheds and blocks from which bales are pulled.

The greatest time savings (50%-75%) was realized by using MILLNet™ for Merchants and pulling bales only from the front faces of the blocks, but this marketing method will not be applicable for long amounts of time. This driver had only 12 bales to move and rearrange instead of digging deeper into the block. The greatest time savings (~ 75%) was realized with the smallest facility and inventory did not make a difference to the times.

When the use of MILLNet™ for Merchants is not applicable, 4-bale marketing will also result in a significant reduction in the amount of time needed to accumulate a load. Because the extra storage specifications are not needed for 4-bale marketing method, the bales in the facility will be easier to track and store. This is also the easiest method to start, since little change has to occur within the warehouse. However, module averaged cotton will need to have leaf grade included into the properties or the merchants will have to exclude it from the ordering constraints. This was demonstrated in the simulations when the test failed due to the leaf grade requiring separation of the 4-bale CLOBS. Potential financial savings associated with use of MILLNet™ for Merchants and 4-bale marketing could incentivize merchants to consider bale location in their order development. Overall, the use of MILLNet™ for Merchants software or 4- bale marketing could generate a significant time savings with little effort on the part of the merchant.

CHAPTER VI

AISLE-STACK VERSUS BLOCK-STACK COMPARISONS

Introduction

Many differences can be seen between warehouses utilizing aisle-stacking and block-stacking patterns in the warehouse layout, the machinery used to transport the bales, and the effect the bale marketing strategies have on the total order accumulation and loading time. The previous chapters describe the individual stacking patterns in detail and how different marketing strategies have an effect on order processing. Those results are used to form the basis of the comparisons.

Comparison

Both aisle-stacking and block-stacking are commonplace in U.S. cotton warehouses. Stacking method is dependent on the manager, how much cotton they need to store, and the location of the warehouse. Any warehouse can essentially do either; it is up to the discretion of the manager. Aisle-stacking uses cotton stacked in rows two wide by two high and around 80 bales deep. These rows form aisles within the warehouse for hooks access and remove individual bales for an order. Block-stacking is comprised of groups of four bales arranged four wide by three high and about 8 deep. Block-stacking does not allow the operator to reach all the bales from the outside; they must disassemble each block to access the bales needed for an order and then restack unused bales. The machines used to handle and transport bales also differ; aisle-stacking warehouses use both bale hooks and bale clamps mounted on forklifts to pull and transport bales. Block-stacked warehouses use only bale clamps, which do less damage to bale packaging materials and are less likely to result in bale contamination from the packaging material (Figure 19).

Figure 19: Bale packaging damage by hooks.

In aisle-stacking warehouses, bales are moved out of the stacks and set into the center aisle prior to be moved to the staging area. In block-stacking this also occurs, but before the bales go to staging they must be sorted by order number. This can account for additional time when considering the baseline scenario. These differences were accounted for in the models and the results were used to compare the two methods. Additionally, two marketing methods were compared.

Baseline

When evaluating the baseline stacking methods, block-stacking was differentiated by the shipping method (foreign or domestic) while aisle-stacking was modeled as all foreign shipments. Figure 20 shows the results of the baseline simulations. Aisle-stacking was the most efficient for aggregating loads from a small facility (5 sheds); however, in larger facilities, block-stacking with foreign shipments took the least amount of time to accumulate and ship one 88-bale order. For aisle-stacking warehouses, the operator will have to visit more sheds and spend more time driving back and forth to assembly an order. In block-stacking, most of the bales will be pulled from only 5 sheds and the transportation time was mostly between blocks instead of sheds. Assembling loads for domestic shipping took longer in all cases because the distribution of quality parameters for each truck load must be more similar than for foreign shipment. Because of this, fewer bales were available to pull from blocks at one time (15% compared to 40% for foreign) (Gus Schild, Cotton Inc., personal communication, 2014).

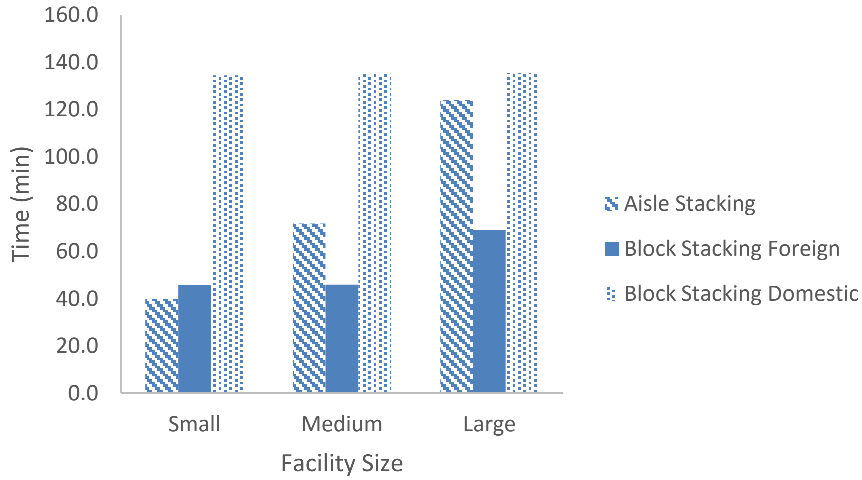

Figure 20: Baseline aisle-stacking vs block-stacking.

4-Bale Marketing

When considering the 4-bale marketing method, block-stacking included the shipping method (foreign or domestic) while aisle-stacking did not require that differentiation, and was represented by all foreign shipments. Figure 21 shows the results of the 4-bale marketing simulations. Block-stacking with foreign shipment was the most efficient overall until the large facility. Within the large facility block-stacking with domestic shipping was about two minutes faster, which was insignificant. These times represent the total accumulation and shipping time of one 88-bale order. Block-stacking methods were faster compared to aisle-stacking because the bales are already in groups of four. In aisle-stacking, the bales are still have to be pulled out individually. Domestic shipment times are greater than foreign shipment times, because fewer bales are available from each block.

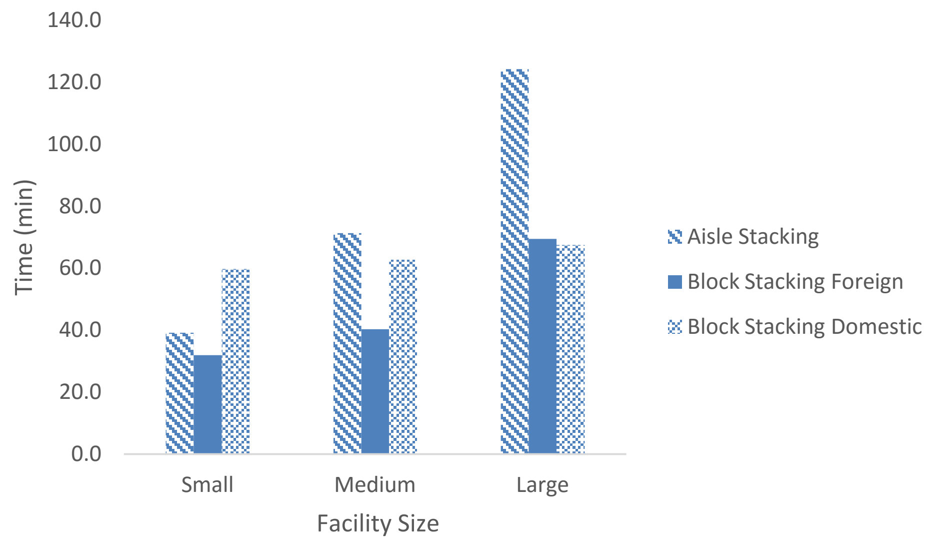

Figure 21: 4-bale marketing aisle vs block-stacking.

MILLNet™ for Merchants

In evaluating MILLNet™ for Merchants, block-stacking included the shipping method (foreign or domestic) while aisle-stacking did not require that differentiation. Figure 22 shows the simulation results for the MILLNet™ for Merchants scenario. Block-stacking produced the smallest order assembly times for all sizes of warehouses. Block-stacking was modeled where only the front bales were pulled from the block. This reduced the number of eligible bales to 12 and the operator did not have to separate the block to assemble the order. The aisle-stacking method using MILLNet™ reduced order assembly time on transportation and searching because the bales were closer together. Overall, block-stacking generated the shortest order assembly times when using MILLNet™ for Merchants. However, this method may be limited because not every warehouse will be able to pull their orders only from the fronts of the blocks. This would require a database of bale locations and software to keep track of what is the "front" of the stack in real time.

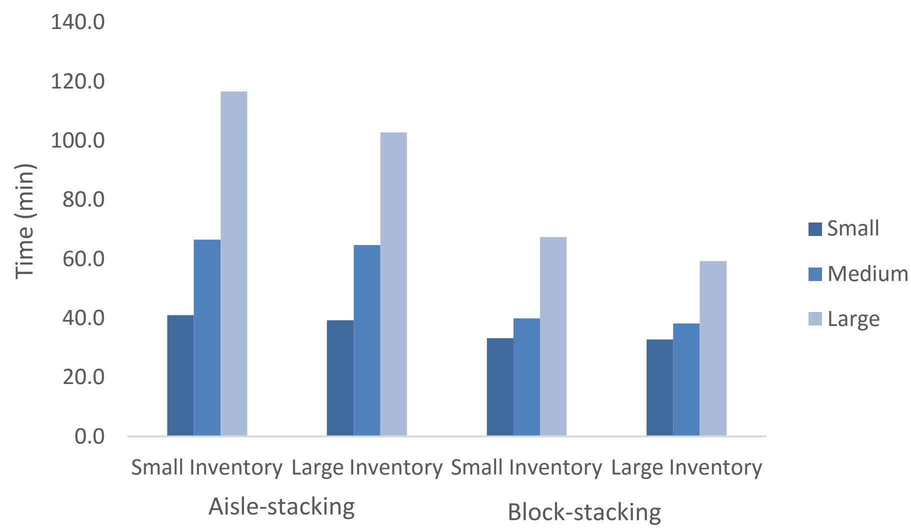

Figure 22: MILLNet™ for Merchants aisle-stacking vs block-stacking.

Application

The simulation models used real world time-and-motion study data collected at various warehouses within the Cotton Belt as input parameters and baseline results were validated against these data. Block-stacking in a cotton warehouse was the most efficient method to assemble and load one 88-bale order. For the two marketing methods considered, the 4-bale marketing method was preferred if the facility was small and MILLNet™ method was preferred if the facility was medium or large. Other factors that may influence these results would include the specific warehouse layout, the manager running the facility, and the number of bales within the warehouse. The differences between shipping to domestic and foreign markets impacted the times as well. In a block-stacking warehouse, foreign shipments had the shortest order accumulation times regardless of the marketing method; baseline, 4-bale marketing, or MILLNet™ for Merchants.

The following financial analysis (Table 21, Table 22, and Table 23) was created by Clayton Roots of the Texas A&M Agricultural Economics Department using the total time accumulation results from this study. "These calculations were based on the assumption that improved bale flow through a warehouse would generate savings from employing less man hours and improved machine efficiency. The employee savings are from hourly wage workers. Hourly employees tend to account for 20% of the total workforce expenditures. Therefore, the employee savings are based on the percentage of time saved from each scenario. Then the total spent on hourly wages is adjusted accordingly. The salary employees are left unchanged as these adjustments should not affect them. The equipment savings are based on equipment repairs, fuel, and equipment leases. Each category is reduced by the amount of time saved, as the equipment will be operated less. In general, the equipment savings account for around two-thirds of the total amount saved" (Clayton Roots, TAMU AGEC, personal communication, 29 February 2016).

Table 21: Financial analysis of aisle-stacking MILLNet™ and 4-bale marketing.

	MillNet				Four Bale CLOB	
	Large Inventory		Small Inventory			
Bales	% change	$/savings	% Change	$/Savings	% change	$/Savings
250,000	-2.2%	12,288	2.2%	(12,288)	-2.5%	13,654
800,000	-9.9%	173,251	-7.4%	129,328	-0.7%	12,201
1,600,000	-17.1%	599,081	-5.9%	206,287	0.2%	(5,652)

Table 22: Financial analysis of block-stacking 4-bale marketing.

	Four Bale CLOB			
	Foreign		Domestic	
Bales	% change	$/savings	% change	$/savings
250,000	-30.3%	166,165	-55.6%	304,488
800,000	-12.2%	213,755	-53.6%	938,217
1,600,000	0.0%	0	-50.1%	1,757,205

Table 23: Financial analysis of block-stacking MILLNet™ for Merchants.

	MillNet			
Domestic	Large Inventory		Small Inventory	
Bales	% change	$/savings	% change	$/savings
250,000	-75.6%	413,990	-75.3%	412,362
800,000	-71.7%	1,257,003	-70.4%	1,233,677
1,600,000	-56.2%	1,969,415	-50.1%	1,757,205

As seen above, this project has the potential to save up to $2 million. This could be used to increase the facility size, update the older sheds, or update equipment. This could be extremely useful in older shed buildings where columns in the building may interfere with the forklift operations. A new building would combat this problem and increase efficiency.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Reducing the time required to accumulate bales in a cotton warehouse for shipment can improve the flow of cotton through the US supply chain and has the potential to improve warehouse profitability. This work showed that in almost all cases the application of either of two marketing methods to the order assembly process reduced order assembly times. Additionally, shipping cotton overseas required less consideration of load uniformity and allowed for greater flexibility when choosing bales for shipments, which enabled greater time savings by reducing the number of sheds from which bales were pulled. Financial savings associated with use of MILLNet™ for Merchants and 4-bale marketing could incentivize warehouses to adopt a method that considers bale location as part their order development. Overall, with use of the MILLNet™ for Merchants software or 4- bale marketing a cotton warehouse can realize significant time savings with very little effort on the part of the merchant.

In aisle-stacking warehouses, 4-bale marketing offered no real time savings over baseline operations. However, use of MILLNet™ for Merchants software did lead to significant time savings, depending on the size of the warehouse facility and the inventory to which the merchant had access. Within aisle-stacking, the use of MILLNet™ for Merchants resulted in time savings of between 2 and 17%, which equated to a savings of up to 54 minutes per load. Greater time savings (27%) were realized when only one or two sheds were used to pull the orders. The greatest time savings was realized with MILLNet™ by limiting the number of sheds from which bales are pulled.

In block-stacking warehouses, 4-bale marketing and MILLNet™ for Merchants offered time savings compared to baseline operations. Depending on the size of the warehouse facility and the type of shipping the merchant is doing, the time to accumulate and load an 88-bale order can be greatly reduced compared to baseline operations. The greatest time savings (50%-75%) were realized by using MILLNet™ for Merchants and pulling bales only from the front faces of the blocks. This marketing method will not be applicable for long amounts of time due to the challenge in maintaining an accurate, real-time record of bale locations as blocks are depleted and restocked. The greatest time savings (~ 75%) was realized with the smallest facility. Inventory did not make a difference to the times. If the use of MILLNet™ for Merchants is not selected, the 4-bale marketing method will also result in a significant reduction in the amount of time needed to assemble a load. This method will also likely be easier to implement and keep running smoothly.

Block-stacking in a cotton warehouse was the most efficient way to accumulate and load one 88-bale order and is recommended. Within the two marketing methods tested the shortest order assembly times were determined when using the 4-bale marketing method if the facility was small and the MILLNet™ method if the facility was medium or large. The shipping method used impacted order assembly times in block-stacking warehouses, where foreign shipments has shorter times for baseline, 4-bale marketing, and MILLNet™ for Merchants methods.

Additional study is also recommended for block-stacking due to time and data limitations within this study. More data could be used for taking off layers, sorting, and truck loading times. Also if possible, more information on how many warehouses use MILLNet™ for Merchants already would be helpful to the study. A complete analysis of the data, as done with aisle-stacking, needs to also be completed. This project allows for many more factors to be input into the simulations. Looking at other major time factors in a cotton warehouse might prove beneficial, such as, implementing RFID. Much more can be added to this and used to determine efficiencies.

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