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ENGINEERING AND GINNING

Improving Cotton Warehousing Efficiencies through Novel Bale Marketing Strategies: Aisle-Stacking and Block-Stacking

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ABSTRACT

The National Cotton Council's Vision 21 Cotton Flow Study sought to improve the flow of cotton from the gin to the warehouse. The primary objective of the study was to identify cotton flow strategies, systems, and practices that the United States (U.S.) cotton industry can employ to lower costs or improve returns while meeting the demands of exporting cotton and simultaneously servicing the domestic market. The goal of this study was to evaluate two different warehouse methods using three different marketing techniques at different sized facilities and levels of inventory. Typical aisle and block-stacking cotton warehouses were modeled with discrete event simulations. Time and motion data were collected from multiple warehouses as the basis for the simulation models. The principal output was the total time required to assemble an 88-bale order. Implementation of a four-bale marketing plan or use of Cotton Incorporated's MILLNet™ for Merchants software was evaluated against baseline marketing. In larger aisle-stacking warehouses, the use of MILLNet™ for Merchants software decreased the time required to assemble an 88-bale load of cotton for shipping; whereas, four-bale marketing did not reduce assembly times. In block-stacking warehouses, four-bale marketing and MILLNet™ for Merchants generated time savings for order assembly. Block-stacking in a cotton warehouse was the most efficient way to assemble and load one 88-bale order. The four-bale marketing method generated the shortest order assembly time in small warehouses; however, MILLNet™ for Merchant software provided shorter assembly times for medium to large warehouses. International shipments were the fastest to assemble and load regardless of the bale selection method.

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 United States (U.S.) cotton supply is held, most warehouses utilize an aisle-stacking organizational structure in which bales are typically stacked two high by two wide and about 60 deep with additional bales placed horizontally on top of the stacks. In the Mid-South and Southeast, most warehouses utilize a block-stacking organizational structure, in which bales are stacked in blocks of four wide and three high by eight deep. However, these dimensions can vary by warehouse.

Before bales arrive at the warehouse, the cotton is harvested into modules in the field. The modules are transported to a gin where the cotton lint is separated from the cotton seed and trash (sticks, leaves, and other debris from harvesting). After cleaning and separation, the cotton lint is compressed into bales and wrapped in a protective covering. 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 by a number of methods including in twenty-foot equivalent unit (TEU) containers, 53-foot box trucks, and tandem axle flatbed trailers. Two TEU containers hold 88 bales while a box truck or flatbed trailer may hold as many as 105 bales. A sample of each bale is shipped to the closest United States Department of Agriculture (USDA) quality office for grading based on fiber length, fiber strength, length uniformity, micronaire, color, trash, leaf, and extraneous matter (Cotton Incorporated, 2013). Cotton strength, length, length uniformity, and micronaire readings can be averaged for all bales from a given module and the averages assigned to those bales excluding outliers. This process is known as module averaging.

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When bales arrive from the gin, the first four bales from the truck are often checked for weight consistency. The 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 are placed on the bale at the gin and are scanned into the warehouse's electronic location system to record each bale and its storage location. This information is used to determine the locations of the bales when assembling orders. Cotton merchants develop distributions of multiple fiber quality parameters needed to fulfill an order from a given warehouse based on the production and quality goals of a textile mill. The warehouse receives this order in the form of a list of PBI numbers. For most domestic orders, merchants require that each truckload comprising an order have similar distributions of fiber quality parameters to ensure a consistent laydown at the textile mill. For most international shipments, each truckload must meet these specifications, but each bale does not have to be uniform as long as the average across the shipment meets specifications. Therefore, when aggregating bales for international customers, the merchant will have a larger selection of bales from which to choose. The warehouse's electronic location system matches the PBI number with the location of each bale in the warehouse and creates a pull-sheet for the warehouse personnel assembling the load.

Aisle-stacking- shipping. Warehouse personnel collect bales and stage for loading using forklifts equipped with bale hooks and clamps. A forklift equipped with a hook is used to maneuver individual bales out of an aisle. A bale clamp can grab up to four bales at a time to move them as a group. The bales are stamped with a specific order number ("mark") and the PBIs are scanned to verify that the order is complete.

Block-stacking. Block stacked bales are warehoused in groups that are four bales wide by three bales high and eight bales deep although this may vary by warehouse. This 88-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 separated in order to find specific bales within the stack. Only forklifts with clamps are used to move bales in block-stacked warehouses. As many as three or four orders are sorted from one block at any given time. Once the selected bales are separated out of the block, they are grouped by order number or mark and unneeded bales are restacked into the block. The bales for a specific order are moved to a staging area and loaded into the truck.

MATERIALS AND METHODS

The factors evaluated in this project were warehouse organization, marketing method, facility size, facility utilization rate, and shipment method. Two types of warehouse organization were used: aisle-stacking and block-stacking; the marketing methods evaluated were baseline, four-bale marketing, and MILLNet™ for Merchants; the facility sizes were small (five 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 international (Figure 1). Although the number of bales per load depend on the particular shipping container, a truckload was assumed to be equal to two TEUs (88 bales). A baseline model simulation was created to evaluate the impact of the above factors on the time required to assemble an 88-bale load.

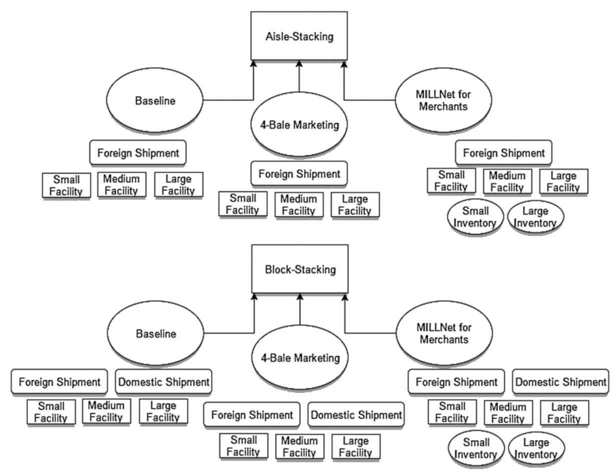

Figure 1: Schematic of factors in the scenarios evaluated. There were two types of warehouse organization (aisle-stacking and block-stacking), three marketing strategies (baseline, 4-bale CLOB, and MillNet™ for Merchants), three facility sizes (small – 5 sheds, medium – 20 sheds, and large – 40 sheds), two inventory levels (small – less than 60% capacity and large – greater than 60% capacity), and two types of shipping (international and domestic) for block-stacking warehouses.

In the four-bale marketing model, four successive ginned bales (a "clamp-load of bales" or CLOB) were module averaged and grouped together throughout the simulation. The bales were subsequently sold as a four-bale lot to merchants. Therefore, an 88-bale order in the four-bale marketing model consisted of 22 CLOBs rather than 88 separate bales.

MILLNet™ for Merchants is a software package created by Cotton Incorporated 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 resulting in more efficient load assembly than is currently realized in warehouse operations (Gus Schild, Director, Program Development, Cotton Incorporated, personal communication, 2014). Presently, merchants have no incentive to consider bale location when assembling an order; however, warehouses sometimes charge fees or offer discounts for certain services. Thus, utilizing a novel bale selection method was considered reasonable with the assumption that potential savings will incentivize merchants and warehouses to adopt the technology.

Baseline. A DES model was created for each aisle and block-stacking "baseline" warehouse operations (Figure 2 and 3). The steps shown might change slightly depending on the warehouse manager, but these process flows are the most common for warehouses.

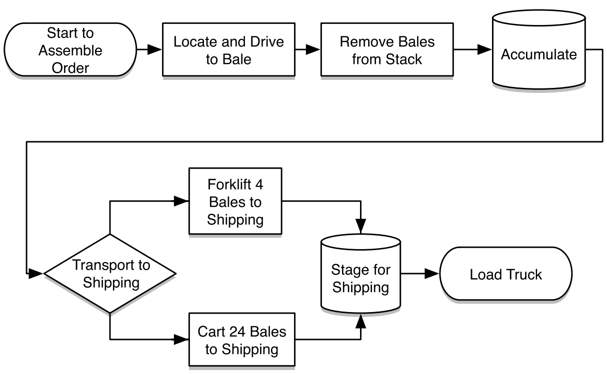

Figure 2: Block flow diagram for a typical aisle-stacking warehouse under baseline conditions.

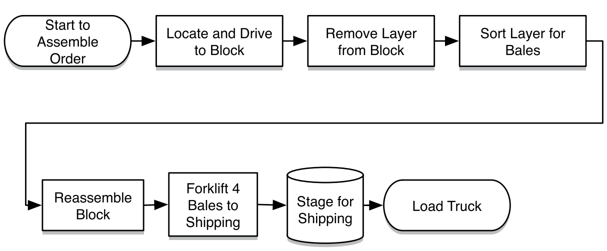

Figure 3: Block flow diagram for a typical block-stacking warehouse under baseline conditions.

Time and motion data were collected at three Texas warehouses and two North Carolina warehouses to quantify the time spent on each of the steps shown in Figures 2 and 3. 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 analyzed to determine significant factors that influenced observed load accumulation times. Candidate factors included:

- Location (warehouse 1 versus warehouse 2)
- Truck number (order of the trucks arriving in the day)
- Truck type (box versus flatbed)
- Shed number (warehouse shed in which the activity was observed)

Raw data were analyzed for outliers and normality and the significance of each variable on the time required to accumulate an 88-bale load was determined. Analysis of variance (Box et al., 2009, pg. 173-185) using computer software (JMP Pro 12, SAS Institute, Cary, NC) determined that the only factor to significantly impact load accumulation time was shed number ($p<0.001$). The shed number was correlated to the distance travelled between the storage sheds and staging area and is therefore an indicator of the time to travel between sheds.

StatFit2© (Geer Mountain Software Corp., South Kent, CT) was used to determine the distribution of time measurements for each observed activity. The baseline model was developed using ExtendSIM 9.2® (Imagine That Inc., San Jose, CA) and the time distributions were used to define the activities in the model (Hazelrigs, 2016).

Merchant bale ownership data were collected from two merchants with inventory in two of the warehouses studied. This data and the electronic bale location data were merged to determine where the location of the merchant's bales within the warehouse complex. MILLNet™ for Merchants was used to create representative orders of 88 bales with average micronaire between 3.2 and 4.9. This parameter was established based on the average micronaire of the inventory ±1 standard deviation. MILLNet™ for Merchants identified bales that fit this quality parameter without respect to bale location, simulating orders that are typically received in warehouses. Warehouse blueprints were used to determine 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 specified bale. The distance measurements were matched to the locations of bales specified in the simulated orders and the times required for warehouse personnel to drive those distances were calculated.

Three generic warehouse complexes, setup in a basic grid patterns, were modeled (Figure 4): a small facility (five sheds), a medium-sized facility (20 sheds), and a large facility (40 sheds) to assess the impact of facility size on the distribution of distances between storage sheds and the staging area. Each shed was assumed to contain 50,000 bales. The baseline model assumed 80% of the sheds available were used to aggregate an order. Bale selection was assumed to be 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).

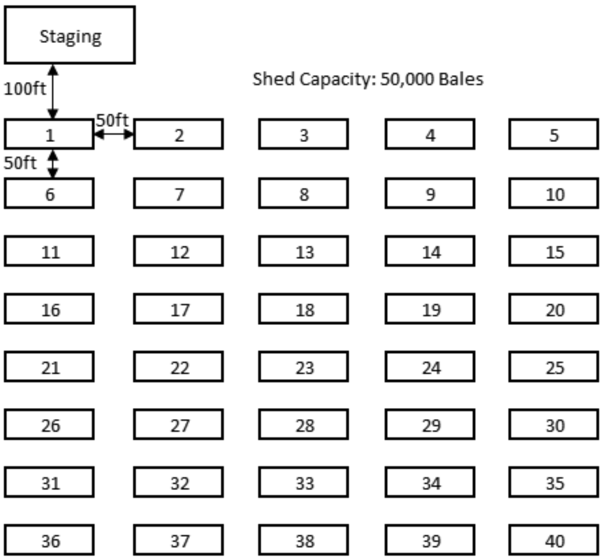

Figure 4: Hypothetical warehouse site plan. Small facilities included sheds 1-5, medium-sized facilities included sheds 1-20, and large facilities included sheds 1-40.

The model was programmed to simulate accumulation and shipment of an order of 88 bales at the staging area. The primary metric was the total time required to complete order assembly. Orders of 88 bales were assigned randomly to 80% of the sheds available, except for the small facility where all five sheds were utilized. The number of trips needed to carry four bales at a time to the staging location was calculated. When carts were used in load assembly, the model assumed that 24 bales were transported to staging per trip. Travel distances were divided by average forklift speeds (ten MPH for aisle-stacking, six MPH for block-stacking) to determine the total forklift driving time required to assemble one 88-bale load. The speed difference was based on observed data and are a consequence of forklifts in an aisle-stacking arrangement handling one bale at a time, while in the block-stacking they are handling four bales at a time. The bales within each order were randomized and replicated ten times for each facility size. Simulation data were compared to observed load aggregation times to validate the modeled results.

Four-Bale Marketing. When using four-bale marketing, load accumulation and shipping time would be reduced since bales were already in four-bale groups, thereby reducing the number of bales handled from 88 individual bales to 22 CLOBs. Time spent searching for bales in the aisle was decreased because the bales were grouped together, as opposed to scattered throughout the warehouse. However, in an aisle-stacking warehouse, all four bales in a CLOB were pulled for shipping as individual bales using a bale hook. Therefore, the only difference between four-bale marketing and the baseline scenario for an aisle-stacking warehouse was the time the operator spent searching for the second, third, and fourth bales in a given CLOB.

The same time distributions from the baseline model were used to model load aggregation using a four-bale marketing strategy, except the aisle-to-bale time was adjusted to account for the shorter search time required for 75% of the bales. The baseline model assumption was an eight second search time for each bale in the aisle based on observations made at the warehouses. The four-bale marketing model assumed that the first bale required an eight second search time and the remaining three bales took two seconds each to identify since the remaining bales were adjacent to the initial bale. The number of sheds used were 80% of sheds available. The bales included in each order were randomized and ten replications were modeled for each facility size.

MILLNet™ for Merchants. Bale selection utilizing MILLNet™ for Merchants was analyzed in the same way as in four-bale marketing except that inventory size was considered. Bale locations were assumed to be consolidated so that more bales were pulled from a given shed reducing the distance driven to obtain a load. A larger inventory increased the probability that bales located in close proximity to each other would meet the quality specifications of the merchant order. A smaller inventory did not have as many bale options and it was less likely that bales meeting the quality criteria were located in the same shed. The small facility used all five sheds for both inventory size considerations, while medium and large facilities used an exponential distribution determined from merchant-warehouse order data to establish the number of sheds accessed to create an 88-bale order. A small merchant inventory (~ 2% owned) used greater than 60% of available sheds and a large merchant inventory (~ 20% owned) used less than 60% of available sheds.

Time distributions were assessed using the warehouse model shown in Figure 4. The 88 bales were randomly assigned to sheds using an exponential distribution of sheds available except for a small facility where all five sheds were used. The bale selection process was randomized and replicated ten times for each size and inventory measure.

Twelve scenarios were simulated using ten replications for each scenario. Load accumulation and shipping time were calculated for each simulation. Results were analyzed for outliers and average results were compared to baseline results using a two-sample t-test assuming unequal variances ($\alpha = 0.05$) (Box et al., 2009, pg. 67-80).

RESULTS AND DISCUSSION

Baseline. The results of the baseline simulations are shown in Figure 5. In the baseline model, block-stacking was differentiated by either international or domestic shipping while aisle-stacking was modeled as only international shipments. Aisle-stacking was the most efficient for aggregating loads from a small facility (five sheds); however, in larger facilities, block-stacking with international shipments took the least amount of time to accumulate and ship one 88-bale order. In aisle-stacking warehouses, the operator will have to access more sheds and spend more time driving to assemble an order. In block-stacking, most of the bales were pulled from five sheds and the majority of transportation time was between blocks instead of between sheds. Assembling loads for domestic shipping took longer because less variance was allowed in the quality parameters for each truck load versus international shipping where a broader distribution was permitted. With domestic shipping, 15% of the bales were available to be aggregated as blocks as compared to 40% for international shipments (Gus Schild, Director, Program Development, Cotton Incorporated, personal communication, 2014).

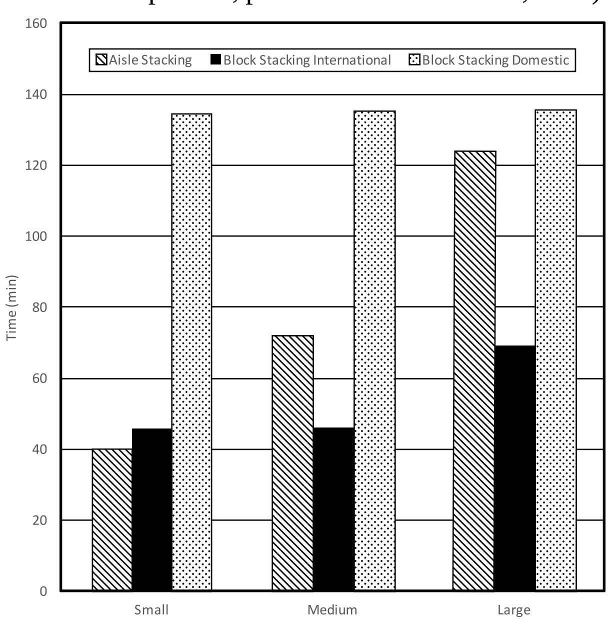

Figure 5: Baseline times to assemble an 88-bale order for aisle-stacking and block-stacking warehouses with three different facility sizes (small, medium, and large) and domestic or international shipping in block-stacking warehouses.

Four-Bale Marketing. Figure 6 shows the results of the four-bale marketing simulations. In theory, four-bale marketing will reduce the total time spent aggregating an order since bales will be in groups of four, as opposed to scattered individually. Block-stacking included the shipping method (international or domestic) while aisle-stacking had only international shipments. Block-stacking with international shipment was the most efficient overall except for large facilities. Within the large facility, block-stacking with domestic shipping was about two minutes faster. In general, block-stacking was faster compared to aisle-stacking because the bales were already in groups of four. Domestic shipment times were greater than international shipment times because fewer bales were available from each block.

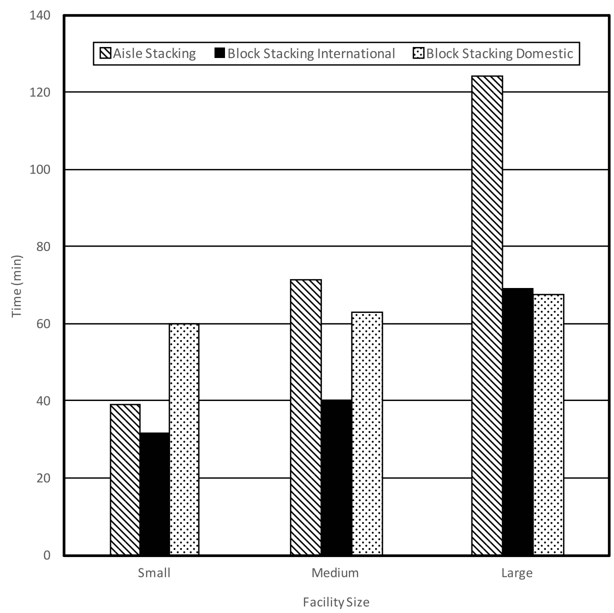

Figure 6: Time to assemble an 88-bale order for the 4-bale CLOB marketing strategy in aisle-stacking and block-stacking warehouses with three different warehouse sizes (small, medium, and large) and domestic or international shipping in block-stacking warehouses.

MILLNet™ for Merchants. Block-stacking produced the smallest order assembly times for all sizes of warehouses. Figure 7 shows the simulation results for the MILLNet™ for Merchant's scenario. The block-stacking warehouse model included the shipping method, international or domestic, while the aisle-stacking warehouse model considered only international shipments. Block-stacking was modeled where only the front bales were pulled from the block. This reduced the number of bales available for selection to 12 and the operator did not have to separate the block to assemble the order. The aisle-stacking warehouse model with MILLNet™ for Merchants assumed reduced order assembly time for transportation and searching because the bales were closer together. This method may be limited because not every warehouse will be able to pull orders only from the front of the blocks. This would require real time tracking of bale locations to determine the bale identification at the outside of the stack as bales are removed.

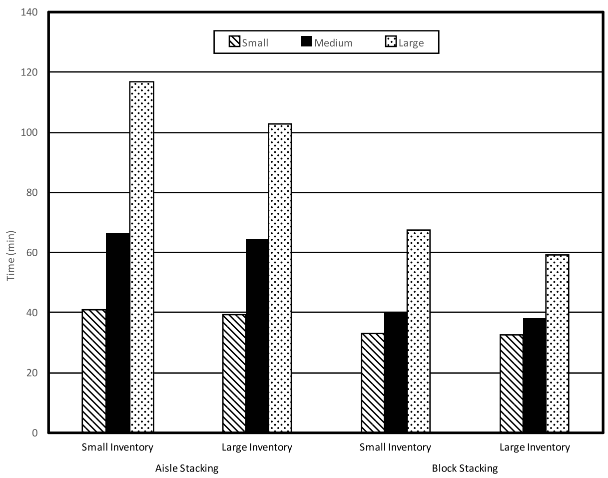

Figure 7: Time to assemble an 88-bale order for the MILL-Net™ for Merchants marketing strategy in aisle-stacking and block-stacking warehouses with three different warehouse sizes (small, medium, and large) and two different inventory sizes (small and large).

The financial analysis shown in Tables 1, 2, and 3 was created by Clayton Roots of the Texas A&M Agricultural Economics Department using the results from this study. These calculations were based on the assumption that reduced order assembly time would generate savings from reduced labor and improved machine efficiency. Hourly wage workers account for 20% of the total workforce expenditures. Employee savings were calculated based on the time saved under each scenario and the total spent on hourly wages adjusted accordingly. Equipment savings were based on reduced repairs, fuel, and lease terms proportional to the time saved. In general, the equipment savings account for approximately two-thirds of the total amount saved (Clayton Roots, Graduate Research Assistant, Department of Agricultural Economics, Texas A&M University, personal communication, 29 February 2016).

Table 1: Financial analysis of an aisle-stacking warehouse using either MILLNet™ for Merchants or a 4-bale CLOB marketing strategy. Change from baseline is the reduction in time needed to assemble 88-bale loads from the warehouse. Savings are annual cost reductions in operating costs

	Millnet				Four Bale CLOB	
	Large Inventory		Small Inventory			
Number of Bales Shipped Annually	Change from Baseline (%)	Savings ($ per year)	Change from Baseline (%)	Savings ($ per year)	Change from Baseline (%)	Savings ($ per year)
250,000	-2.2	12,288	2.2	-12,288	-2.5	113,654
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 2: Financial analysis of a block-stacking warehouse using the 4-bale CLOB marketing strategy for international and domestic shipping. Change from baseline is the reduction in time needed to assemble 88-bale loads from the warehouse. Savings are annual cost reductions in operating costs

	Four Bale CLOB			
	International Shipping		Domestic Shipping	
Number of Bales Shipped Annually	Change from Baseline (%)	Savings ($ per year)	Change from Baseline (%)	Savings ($ per year)
250,000	-30.2	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 3: Financial analysis of a block-stacking warehouse using the MILLNet™ for Merchants marketing strategy for warehouses with small and large inventories. Change from Baseline is the reduction in time needed to assemble 88-bale loads from the warehouse. Savings are annual cost reductions in operating costs

	MillNet™ for Merchants			
	Large Inventory		Small Inventory	
Number of Bales Shipped Annually	Change from Baseline (%)	Savings ($ per year)	Change from Baseline (%)	Savings ($ per year)
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

CONCLUSIONS AND RECOMMENDATIONS

Baseline simulations were compared against simulations for two types of warehouse management (aisle stacking and block stacking) using two different marketing approaches (four-bale marketing and MILLNet™ for Merchants) at two levels of inventory (2% and 20%) and three different sized facilities (5, 20, and 40 sheds). The total time to assemble an 88-bale order was the key metric in evaluating the different configurations. Other factors that were held constant in the simulations may influence these results when applied to specific warehouses. They would include the warehouse layout, the capability and experience of manager running the facility, and the total number of bales within the warehouse.

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, four-bale marketing was preferred if the facility was small and MILLNet™ for Merchants was preferred if the facility was medium or large. In a block-stacking warehouse, international shipments had the shortest order accumulation times regardless of the marketing method; baseline, four-bale marketing, or MILLNet™ for Merchants. The greatest time savings (50%-75%) were realized by using MILLNet™ for Merchants and pulling bales only from the front faces of the blocks. The greatest time savings (~ 75%) was realized with the smallest facility. However, implementation of MILLNet™ for Merchants will be limited by the capability of the warehouse to perform real-time tracking on the stack composition including identification of the outer bales. In general, four-bale marketing offered less savings but would be easier to implement in a block-stacked warehouse.

In aisle-stacked warehouses, four-bale marketing offered no time savings over baseline operations. However, use of MILLNet™ for Merchants software did lead to 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 were pulled.

Reducing the time required to accumulate bales in a cotton warehouse for shipment can improve the flow of cotton through the U.S. supply chain and has the potential to improve warehouse profitability. This work showed that in almost all cases the application of either of the two marketing methods to the order assembly process reduced order assembly times. Block-stacking in a cotton warehouse was the most efficient way to accumulate and load one 88-bale order and is recommended. For the two marketing methods tested, the shortest order assembly times were estimated when using the four-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 international shipments has shorter times for baseline, four-bale marketing, and MILLNet™ for Merchants methods. Shipping cotton overseas required less consideration of bale uniformity and allowed for greater flexibility when choosing bales for shipments, which subsequently generated greater time savings by reducing the number of sheds from which bales were pulled. Financial savings associated with the use of MILLNet™ for Merchants and four-bale marketing could incentivize warehouses to adopt a method that considers bale location as part of their order development. Overall, through the use of MILLNet™ for Merchants software or four-bale marketing a cotton warehouse can realize significant time savings with little effort on the part of the merchant.

ACKNOWLEDGEMENT

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DISCLAIMER

Mention of trade names or commercial products in this manuscript is solely for the purpose of providing specific information and does not imply recommendation or endorsement by Texas A&M University.

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