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

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Abstract

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 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.

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 of interest for improving 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 time by reducing the number of locations within a warehouse from which bales must be pulled to assemble a load bale groups will be consolidated within a given aisle or block. Another option for improving the flow of cotton in the warehousing system could be use of Cotton Incorporated's MILLNet™ for Merchants software, 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 will help to 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 even out 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, largely depending 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.

Figure 1. Example of aisle 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 putting together 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 will then receive this electronic order in the form of a list of PBI numbers. In most cases, each truckload comprising an order should have nearly-identical distributions of fiber quality parameters to ensure a consistent laydown at the textile mill, although this is often less important in international orders than in domestic orders because the long lead-time in orders requires these mills to reorder bales for laydown at the time of use. The warehouse's electronic location system will match the PBI numbers with locations of each bale in the warehouse and create a pull-sheet for the warehouse personnel responsible for assembling a given load. Forklift drivers then collect these bales and stage them to be loaded using forklifts equipped with bale hooks and clamps. A forklift equipped with a hook (Figure 2a) is used to shimmy bales out of an aisle one at a time. A bale clamp (Figure 2b) can grab onto four bales at a time and is used to move them around as a group.

(a) (b)

Figure 2. Example of a (a) bale hook and (b) bale clamp.

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

<u>Operational Research</u>

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 test that uses a large number of sample repetitions in order to estimate the average mean and standard deviation of the population. This way of testing data can be easily incorporated into simulation models. 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 methods, warehouses utilizing 4-bale marketing, and warehouses utilizing MILLNet™ for Merchants bale selection software. Simulations considered facility size (small, medium, and large) and the relative inventory available to a given merchant during order development (small and large). These simulations model the time it takes to aggregate bales for an order in the warehouse today and what time savings might be realized with a 4-bale marketing or MILLNet™ for Merchants bale selection strategy. Data for baseline operations were gathered from two Texas warehouses that employ an “aisle stacking” organizational structure, and models were generalized in an effort to produce results that will be useful across the cotton belt.

<u>Methods</u>

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 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 individual 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 unheard of 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 3). The steps shown in Figure 4 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.

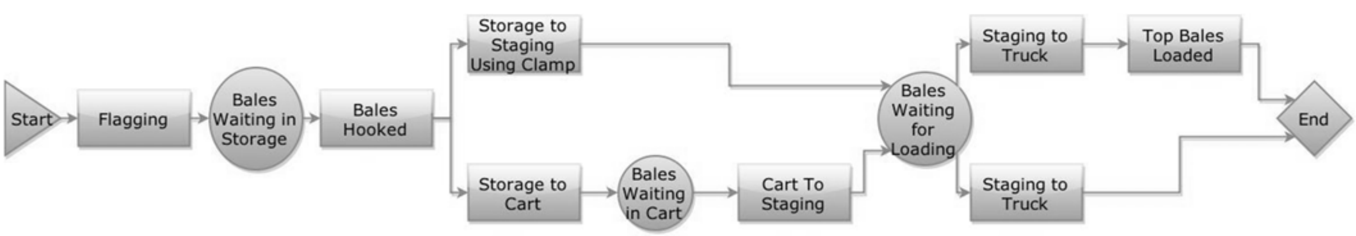

Figure 3. Baseline activity flowchart.

Time and motion data were collected at two Texas warehouses to quantify the time spent in each of the steps shown in Figure 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 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 1), 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 1. Observed factors affecting load accumulation time.

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. In order 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 today. 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 (5 sheds), a medium-sized facility (20 sheds), and a large facility (40 sheds). The "large" generic facility is shown in Figure 4; 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).

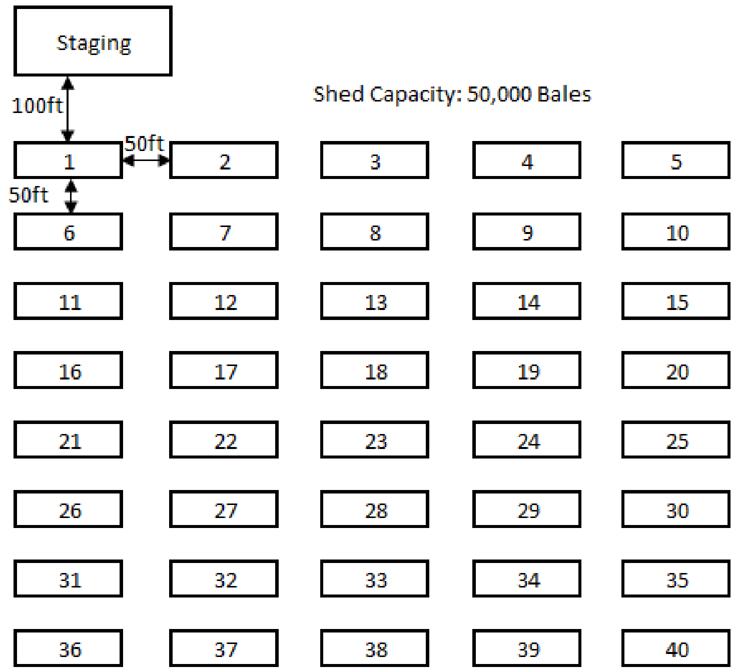

Figure 4. Generalized warehouse blueprint. Small facilities included sheds 1-5, medium-sized facilities included sheds 1-20, and large facilities included sheds 1-40.

The model was set-up to simulate accumulation of a mock order of 88 bales at the staging area in order 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 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 8 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 8 second search time and the next three bales would take 2 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, but analysis of block-stacking warehouses is beyond the scope of the present manuscript.)

In order 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 10 replications were modeled for each facility size. In order 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 is 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 5 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. This distribution was found using the actual distributions of sheds determined from the given 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 over 60% of those available, and a large merchant inventory (~20% owned) signified the number sheds pulled from to assemble a given order was under 60% of those available.

Time distributions were again assessed using the warehouse model shown in figure 4. The model assigned the 88 bales randomly to each shed using the exponential distribution of sheds available (except the small facility, where all 5 sheds were utilized). The bale selection process was randomized and replicated 10 times for each size and inventory measure. In total, 12 scenarios were analyzed using ten model replications of each scenario (Table 2).

Table 2. Modeled scenarios.

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 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

Results of the data analysis indicate the total time required to aggregate bales for one 88-bale truck load using the different bale selection methods.

Baseline
Baseline modeling results indicate that load assembly time increases with increasing facility size (Table 3). These results are logical given that the further from the staging area the driver has to travel to get the bales, the longer the required total assembly time. If bales are transported from the storage shed to the staging area in 4-bale loads, over 60% of the load accumulation time is spent driving from the shed to the staging area (Figure 5). For example, the

percentage time spent in transport decreases drastically for smaller warehouses from 63% when using the clamp, to 28% when using the cart, but time spent in transportation is unaffected for medium and large facilities. In medium-sized and large facilities, the number of bales pulled from each shed is lower, so more time is spent driving to the multiple sheds needed to fulfill the order.

Table 3. Time required to assemble an 88-bale load using standard bale selection (baseline) techniques[b]

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
[b] Clamp times only

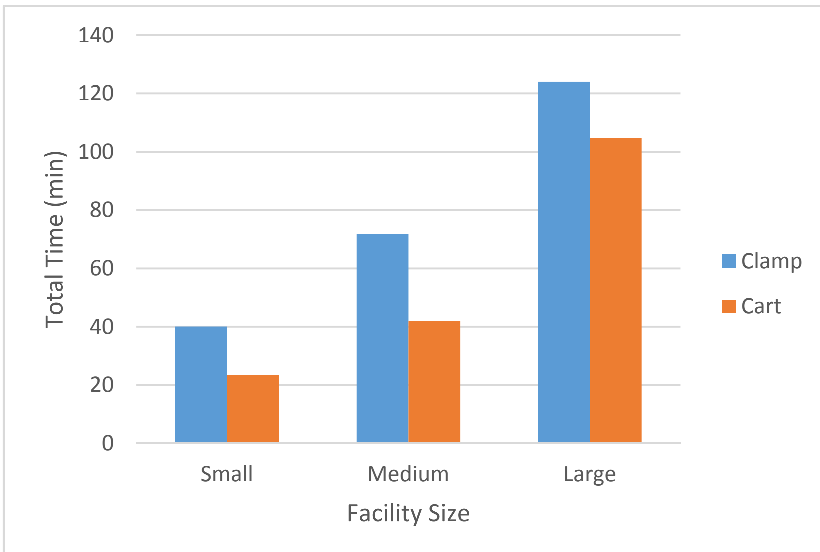

Figure 5. Baseline clamp vs cart total accumulation time (min).

4- Bale Marketing

Times required to assemble a load using a 4-bale marketing bale selection method are shown in Table 4. None of the CLOB results were statistically different than baseline values. The lack of time savings is due to the bales still being pulled out one at a time with the hook in an aisle stacking warehouse. Only six seconds are saved for each of the last three bales being pulled out of the CLOB to account for a reduction in the driver's search time. However, the time required to travel down the aisle and the time required to move bales between storage and the staging area are unaffected by grouping bales as CLOBs. A larger time savings may be realized in block-stacking warehouses, where all four bales in a CLOB may be removed from storage at once using a clamp, but an analysis of block stacking warehouses is beyond the scope of the present manuscript. Based on these results the 4-bale marketing technique will not provide any measurable time savings compared to baseline operations in aisle-stacking warehouses.

Table 4. Time required to assemble an 88-bale load using 4-bale marketing

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

Results of MILLNet™ for Merchants simulations are shown in Table 5. Significant time savings were realized using this bale selection technique for some scenarios. The larger the inventory and the larger the facility, the more time that can be saved in load aggregation relative to baseline bale selection because the amount of time traveling between various sheds is 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 pulled from leads to more significant time savings. When using the clamp to transport bales, although the total accumulation time increases as the facility gets larger, the time it takes to transport the bales from shed to staging stays near 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 is drive time rather than pulling bales.

However, when looking at the time traveled with the carts, the percentage time spent driving at the small facility drops to 35%, with a total average time driving of 65±4% for medium and large facilities (Figure. 6). This figure shows a clear picture of how load accumulation time is drastically reduced when the number of sheds from which bales are pulled is reduced. In Table 5, 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, the time savings for a large facility increases to 27%.

Table 5. Time required to assemble an 88-bale load using MILLNet™ for Merchants

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

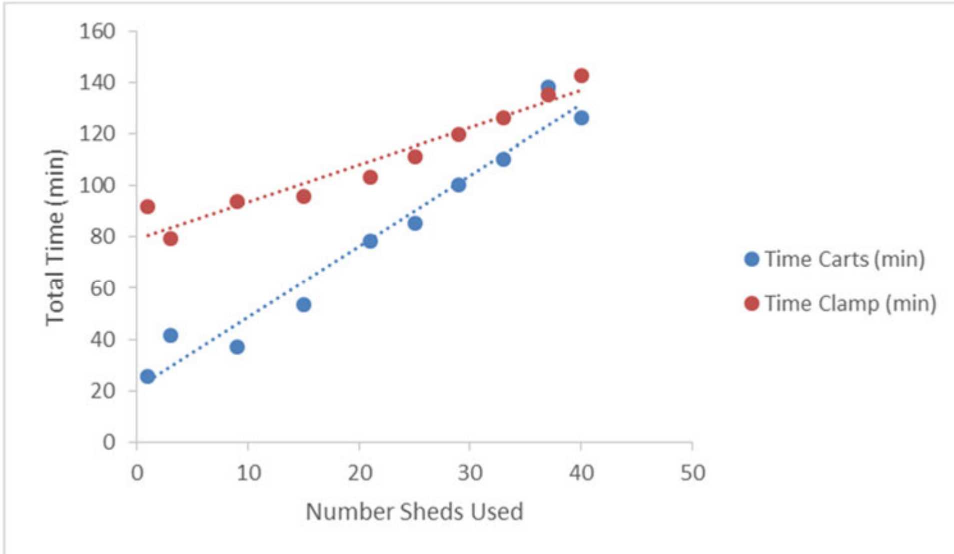

Figure 6. MILLNet™ for Merchants load aggregation time vs number of sheds pulled from for clamps and carts.

Results shown are logical because the larger the inventory available to a merchant from which to pull bales, the more bales that will meet the required quality specifications are likely to be available in a given shed. Because there are more bales available in a given shed, the bales are 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 time and increasing the efficiency of warehouse operations. The potential time savings realized could be much greater if the number of sheds is further reduced, as demonstrated by figure 6. When all bales were pulled from only one shed, the average total load accumulation time for carts and clamps was 25 and 90 minutes, respectively. This is a time savings of ~27% to ~2% when compared to average loading time under the baseline scenario.

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, or CLOB, marketing offers no real time savings. However, use of MILLNet™ for Merchants software can lead to significant time savings, depending on the size of the warehouse facility and the inventory to which the merchant has 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 can be 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 27%, translating to a savings of up to 54 minutes per load. The higher time savings (27%) were realized when only one or two sheds were used to pull the bale orders. Financial savings associated with use of MILLNet™ for Merchants could help warehouses to incentivize the use of such software to merchants who currently have limited or no motivation to consider bale location in their order development. Overall, with use of the MILLNet™ for Merchants software, a cotton warehouse can realize significant time savings with very little effort on the part of the merchant.

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