COSTS OF ALTERNATIVE LOADING AND UNLOADING STRATEGIES IN A COOPERATIVE COTTON WAREHOUSE

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Abstract

Cotton warehouse cooperatives provide storage services to the cotton supply chain, a function that could benefit from reducing costs, which would be passed through to the farmer-owners of the marketing cooperative. This study conducts applied analysis using the program developed by (Richard 2020), and more specifically develops alternative logistical management strategies for cotton warehouses. Those strategies include different approaches for loading the cotton warehouses by organizing the inventory based on quality characteristics rather than the current practice of simply loading the warehouse in the order the bales are delivered from the gins. The research also examines different strategies for retrieving the specific bales requested in a shipment order. More specifically, the logistic advantage of working multiple orders simultaneously is examined under an assumed constraint on the maximum allowable time to fulfill any given order. Results suggest that working thirty orders simultaneously minimized the overall costs of warehouse logistics with a reduction from the current strategy of $356,828.20.

Introduction

Electronic trading systems have made considerable advancements in the cotton supply chain. TELCOT, a computer based trading system has given rise more recently to an Electronic Title System (ETS) and "The Seam." Kenkel and Kim, (2008) provide more detail as to how these technologies have impacted the industry. These among other supporting technologies have allowed the merchants to access individual bale characteristics and complete orders electronically. This new ability gives the downstream merchants more information, but the effects this has had on the warehouse operations are not fully understood.

Cotton warehouse cooperatives are an essential part of the overall cotton supply chain. They administer the beginning of the trading system by adhering the permanent bale identification, communicating with first merchants and organizing the first purchase of bales, facilitating the storage and beginning of the baled cotton shipping system. This stage in the supply chain is prone to coordination bottlenecks. The cotton warehouse charges a daily storage fee but does not control the storage date or shipping date, and thus the length of storage. All of the logistical costs of warehouse operation are passed on to the grower-owners. If warehouses logistics could be improved to reduce the overall bale movement during the annual cycle of bale delivery and order fulfillment, additional profits could be passed on to the grower-owners. This paper estimates the previously unknown potential cost savings from improved warehouse logistics.

This paper will focus on the total movement of bales during one operating cycle of a typical cotton warehouse. One cycle means the warehouse is completely full, in our example this turns over three times a year. The order fulfillment process is a particularly time consuming aspect of the overall warehouse operations. The task of picking an individual bale out of each respective row and section is commonly referred to as "break-out." During break-out, warehouse personnel must move non-targeted bales to reach a targeted bale; then replace the non-targeted bales in their previous position to maintain the inventory location index.

As mentioned, this paper examines two basic research questions. The first research question is whether organizing the warehouse inventory on the basis of quality attributes can reduce the number of times bales are handled and the associated costs relative to the current first-in loading strategy. If cotton merchants are attempting to assemble uniform lots of cotton as they select the bales in each order, then organizing the warehouse based on quality could place the ordered bales closer together and minimize the handling of non-targeted bales. On the other hand, if merchants or end users are striving for a composite quality by mixing bales with different quality attributes then quality based warehouse strategies may not reduce handling costs. In order to address the first research question, seven scenarios, each based on loading the warehouse based on a separate quality characteristic, are examined to determine the impact on the number of bale touches and resulting costs.

The second basic research question is whether changing the number of orders that are worked simultaneously can reduce the overall number of bale movements and the resulting costs. As the number of orders being worked simultaneously increases, the number of non-targeted bales among the total bales moved decreases. Cotton warehouses operate under the regulations of the Commodity Credit Corporation (CCC) and must provide a written report to CCC on a weekly basis. As part of that report, the warehouse must indicate whether the bales which were ordered and scheduled for shipment were either shipped or made available for shipment. The cotton warehouse regulatory environment therefore creates a constraint on the number of orders worked simultaneously. As the number of orders being worked increases it becomes more likely that one or more orders may not be positioned for the scheduled shipment date. This can also be a point of concern for the reason of keeping customers satisfied by timely service.

Wu, Gunter, & Shurley (2007), Ethridge, Brown, Price, and Bragg (1992), and Brown and Ethridge (1995) provide examples for examining the impact of quality attributes on economic value, but do not relate this information to warehouse operations. Burinskiene (2011) and Burinskiene (2015) provide generic warehouse simulation examples, providing a conceptual starting point for modelling techniques and the application of Visual Basic for Applications. Hazelrigs et. al., (2017) provides an example specific to a cotton warehouse by examining alternative stacking and marketing techniques, but does not compare the bale movements across quality-determined alternative loading strategies or consider the shipment schedule is not under the warehouse operator's control. The research in this paper is unique because it focuses on cotton warehouse logistic strategies that have not been previously examined.

The remainder of the paper will first establish the conceptual framework, then describe the simulation, present the data, and then the results and proceeding discussion. This work will not only contribute to the field of knowledge of warehouse management but will also be readily extendable to cotton warehouse managers.

Conceptual Framework

Understanding high volume instruments provide accurate reading of cotton characteristics is critical to understanding how the warehouse eventually gets precision information about each bale. A sample of each bale is taken at the gin after ginning and is sent to a classification office managed by the Agriculture Marketing Services (AMS) branch of the USDA where a permanent bale identification tag is generated. This tag is associated with the quality of each individual bale and uploaded to various digital trading systems (Cotton Inc., 2018.) All cotton sold using futures contracts in addition to the Intercontinental Exchange is classified through these offices. In general, most cotton is classified, all classification services are charged fees and there are twelve classification offices throughout the cotton belt. This process is important because the warehouse cannot take advantage of the information until the permanent identification is known by the warehouse.

In the current protocol, warehouse operators are storing the cotton as it comes in, filling a warehouse before proceeding to the next. Although operators have no control over which bales are ordered when, they do have a reasonable amount of control over where the bales are initially stored. The loading strategy and number of orders worked are the two choice variables pertaining to the objective. By modelling the break-out of individual bales according to historic orders, each scenario of bale locations will be simulated, maintaining the same order history, providing means for comparing the costs of various strategies. This process will also be repeated across two alternative quantities of orders to be worked. The loading strategies and how they determine the shed, row, section and position are described in Table 1.

Table 1. Explanation of Alternative Loading Strategies

Attribute Determined	Description of Strategy
Current	Bales are placed in shed-rows from back to front, bottom to top within each section, as they arrive from the gins, strictly first-in.
Micronaire	Premium mic is placed in one set of shed-rows, then non-discounted mic in the next set, then discounted in the remaining.
Random	Ad hoc scenario where bales are purely randomly sorted into sheds, rows, sections, and positions.
Leaf grade	Grade 1 bales are placed in the first seven sheds, grade 2 bales are placed in the next seven, etc. until grade 8 is placed in the remaining seven sheds.
Reflectiveness	Lower percentage bales are placed in the first sheds and rows while higher percentage bales are placed in the last sheds and rows
PlusB	Each class group determines which sheds and rows the bales are placed in. Lower classes are placed in first sheds, higher classes are placed in last sheds.
Trash	Bales are assigned to sheds based on their percentage, where low trash content are sent to the first shed-rows and high trash bales are placed in the last shed-rows.
Gin code	Bales are placed in shed-rows from back to front, bottom to top within each section, as they arrive from the gins, keeping separate gins in separate sheds and rows.
Acct no. (Farmer)	Each farmer's bales are placed in different sheds and rows, keeping each farmers set of bales together.

[1] At the end of one subgroup, two groups may occupy the same shed but likely separate rows.

Data

This study utilizes information from one cooperatively-owned cotton warehouse in Altus, OK. The Plains Cotton Cooperative Association provided data for the entire 2016 cotton crop which is summarized in Table 2.

Table 2. Characteristics of Plains Cotton Cooperative Association Cotton in 2016

Variable	Mean	Minimum	Maximum	Units
Warehouse Tag	8307291.89	5004033.00	9688372.00	integer
Gin Code	51289.05	50251.00	70158.00	integer
Account Number	1080.87	1.00	9999.00	integer
Staple	36.31	28.00	42.00	millimeters
Micronaire	43.59	23.00	59.00	unitless
Leaf Grade	2.96	1.00	8.00	class
Uniformity	81.19	73.50	88.80	percentage
Strength	30.23	20.20	38.80	grams per tex
Reflectiveness	77.29	45.80	85.70	percentage
Color (PlusB)	83.96	51.00	160.00	class
Trash	3.68	0.00	32.00	percentage

Each observation provides the individual bale's ID, location (shed, row, and section), the quality attributes, the day it was stored, the day it was moved to the staging area (clearance date for final order), what gin it came from, what farmer produced it, and what merchant bought it. These data are incomplete with respect to the exact position of each bale, which was assigned by a number one through twelve or sixteen depending on how many bales are in that section. Another step to prepare the data for the simulation was to generate an order number by examining the unique combinations of clearance dates and first merchants. After sorting by these two variables, as either changes, this signals the bale belongs to the next order, and every bale throughout the dataset is labeled with an order number by this method. There are 1,091 orders of 88 bales or less in the 2016 crop. Finally, to prepare the data for the program, it is first sorted by order number, then shed, row, section, and descending by position. This is done so the program can effectively identify the last targeted bale in a shed-row. The data is then ready for the simulation program.

One limitation in our data set was that the warehouse sometimes positioned bales that were delivered late in the ginning season into vacant position in existing rows. That resulted in more than one bale occupying a given location. To simplify the modeling, the bales which were placed into previously occupied warehouse positions, were deleted from the data set. Some of the data was lost to this simplification, but programming advantages were significant. Future research could extend our modeling to consider in season re-filling of bale locations.

Procedures

First, the possible bale locations from the original data set were sorted by shed, row, descending section, and ascending position, so as to mimic the order in which the positions would be filled as bales arrive. Each shed was "filled" or locations were assigned with bales sorted by the selected data characteristic for each loading strategy. For example, the micronaire scenario would be sorted such that all the premium micronaire appeared first, then non-discounted, then discounted. Premium cotton might fill the first fifteen sheds, then non-discounted might fill twenty sheds, and the discounted may fill the rest, for instance. Bales were located in each row, from the back section to the front section, and the bottom positions to the top positions, before moving on to filling the next row until the shed was full and then moving on to the next shed. This procedure was repeated for each of the loading strategies in order to create multiple data sets on which to perform the applied analysis.

After the warehouse bale locations were determined for each loading strategy, the total number of bale movements was determined. This was performed by the model developed in (Richard, 2019). Each of the loading strategies was analyzed by working all orders (entire shed-rows) for a sample of shed-rows. After the total bale movements for each loading strategy were determined under the assumption that the warehouse worked a single order at a time, the analysis was expanded to compare unloading strategies of working just 20 orders simultaneously with working 30 orders simultaneously. This was done by calculating bale movements across all shed-rows for just a sample of 5 orders. The unloading strategies were analyzed for the current loading strategy as well as the gin code loading strategy.

The previously described methods for determining the total bale movements were converted into a cost basis using economic engineering-based estimates of forklift operations. Table 3 provides a detailed step by step calculation of the costs associated with a bale movement. The per-bale costs were multiplied by the number of bale movements to develop resulting cost savings from implementing loading and unloading strategies.

Table 3. Determination of Cost-per-bale-movement

Calculation of Distance			Calculation of Time			Calculation of Cost per Bale Movement		
Most number of Sections Back		35	Average Forklift Distance		30.625 ft.	Total Time		.0074 hrs.
(to get to middle of stack)	÷	2	Average Forklift Speed	÷	3.66 ft./sec[a]	Labor with Benefits	×	$25.00/hr.
Average number of Sections Back		17.5			8.36			$0.19
Bale Width	×	1.75 ft.		×	2	Total Time		.0074 hrs.
Average Forklift Distance		30.63 ft.	Time to middle of stack and back		16.73 sec	Forklift Fuel and Maintenance	×	$2.28/hr.
			(Time to Pick-up/Put-down)	+	10 sec.			$0.01
			Total Time		26.73 sec.	**Cost per Bale Movement**		**$0.20/bale movement**

[a]Singh et al (2009) utilizes average speed of forklift operations. Here, we average between the minimum and the average speed to account for acceleration and deceleration.

Results

Each loading strategy has a total that counts the number of bale movements required for all of 2016's cotton bales to be removed from the warehouse, given that 20 orders are worked at a given time. An associated reduction in cost per bale accompanies each loading strategy. This count is for all 575,800 bales and is summarized by Table 4.

Table 4. Total Bale Movements Required to Unload the Warehouse

Scenario	Average # of Bale Movements per Bale	Reduction of Cost per Bale
Baseline	9.22	
Micronaire	8.58*	($0.13)
Leaf Grade	6.08*	($0.63)
Reflectiveness	21.63	$2.48
Trash	8.71*	($0.10)
PlusB	12.31	$0.62
Gin Code	4.96**	($0.85)
Account Number	5.85*	($0.67)

*Denotes a reduction **Denotes the greatest reduction in movements per bale.

The findings indicate the current strategy of loading the warehouse has a fairly low touch count and was actually superior to some quality related loading strategies. However, sorting the bales by leaf grade, micronaire, trash, gin code, or account number (farmer id), result in a lower count of bale movements than the current loading strategy. Specifically, loading the warehouse by gin code reduced the number of bale movements the most, with a reduction of 4.26 bale movements per bale, and therefore an associated $0.85 cost savings per bale. This suggests alternatively choosing and implementing one of those loading strategies will reduce costs, and therefore increase profits. This benefit of the alternative sorting mechanism would be passed through to the farmer owners. Now that we know gin code is the optimal loading strategy, we performed the unloading strategy analysis and found the results in Table 5.

Table 5. Reduction in Costs from Touch-Reducing Loading Strategies

Scenario	Working 20 Orders at a Time		Working 30 Orders at a Time	
	Average # of Bale Movements per Bale	Average Days to Complete Order	Average # of Bale Movements per Bale	Average Days to Complete Order
Baseline	10.30	0.56	7.26	0.39
Gin Code	9.15	0.50	9.02	0.49

Noticing for the current (baseline) loading strategy that the average number of bale movements goes down when switching from working 20 orders at a time to working 30 orders at a time (on the table from left to right), we conclude that working more orders at a time makes warehouse operations more efficient. In this sample, working 30 orders at a time resulted in an average time-to-completion of 0.39 days per order, leaving plenty of time to have each order meet its respective deadline. This tells us that future work should determine not just the average days-to-complete-orders, but calculate the length of time to complete order fulfillment processes for every order in the sample so as to avoid missing fulfillment deadlines. We can also tell from this table, that under the gin code loading strategy, we also see savings from moving up to working 30 orders at a time, but the efficiency gains are less drastic. The resulting cost-per-bale-movement, $0.20, is utilized to develop the figures found in Table 6 which summarizes the value of the potential touch count reduction.

Table 6. Reduction in Costs from Bale-Movement-Reducing Loading and Unloading Strategies

$1,209,531.05	Baseline Scenario Cost
	Cost Reduction From:
($135,326.31)	Loading by Gin Code
($356,828.20)	Working 30 Orders at a time
($150,668.53)	Loading by Gin Code & Working 30 Orders at a time

Loading the warehouse based on gin code generated the greatest reduction in costs from the baseline first-in loading strategy. However, under the current loading strategy, only implementing the new unloading strategy of working 30 orders at a time lead to a greater reduction in the cost of bale handling. The combination of both the optimal loading and unloading strategy had a reduction greater than the loading strategy alone, but less than that of implementing the unloading strategy alone.

Summary and Conclusions

This analysis simulated the activity of a cooperative cotton warehouse, and analyzed alternative loading and order fulfillment strategies. The results determined that unloading the warehouse by working 30 orders at a time resulted in the largest cost reduction relative to the baseline of current warehouse practice. This was a $356,828.20 reduction in bale handling costs for one turn of this cooperative warehouse. Loading strategies based on account number, micronaire, trash or leaf grade yielded cost reductions relative to the current baseline but were inferior to gin code. We should note that this research only considered loading strategies based on a single quality factor. It is possible that cotton merchants consider a combination of quality variables when they decide which bales to order and more complex quality related loading strategies might yield higher cost reductions.

While our results did not indicate that loading by any of the quality attributes resulted in the largest cost savings, we should point out the challenges in implementing any quality based warehouse loading strategies. As mentioned earlier, the classification information is not known at the time the warehouse is being loaded. The time delay in receiving quality information varies across the ginning season and also likely varies across warehouses. Additional research is needed to consider the additional costs and warehouse space needed to stage cotton while waiting for grade information. This study's findings do provide motivation however for the time delay in providing quality information to the warehouse. Loading warehouses according to quality information should be considered as a future opportunity for cotton warehouse management. Another practical issue with quality based warehouse loading is determining the warehouse area to assign to each quality level. The distribution of bales across quality factors is not known until all bales are delivered making it difficult for warehouse managers to allocate warehouse space across the quality levels. Additional research on the historic distribution of quality characteristics in bales delivered to cotton warehouses could help to address that issue.

Unloading strategies was found to be more economically impactful than loading strategies, that is, increasing the number of orders being worked simultaneously decreased bale handling costs the most. The results suggest that warehouse operators should work on as many orders at a time as possible, up to the point where order fulfillment times become unacceptable. Future work on this models results summary will determine the number of days to complete each order, as opposed to calculating an average days-to-completion for a sample of orders. This means future work will be able to say exactly how many orders can be worked at a time after a sensitivity analysis, as opposed to this initial guess of 30 orders at a time.

Recommendations to warehouse operators from this research include focusing on unloading strategies. Managers should plan to work on as many orders at a time, given that deadlines are not pushed back due to lack of complete fulfillment. It is interesting to note that, within the loading strategies considered, the optimal strategies involved gin code and farmer ID which is information available at the time of bale delivery to the warehouse. Warehouse managers should be able to implement either of those strategies with little additional costs since bales could be placed directly into position as they are delivered. There would be minor issues in allocating warehouse space but those could likely be addressed with available information on anticipated production from gins and producers.

References

Brown, J. E., and Ethridge, D. E. 1995. "Functional form model specification: an application to hedonic pricing." *Agricultural and Resource Economics Review*, 24:166–173.

Burinskiene, A. 2011. "The travelling of forklifts in warehouses." *International Journal of Simulation Modelling*, 10(4):204–212. https://doi.org/10.2507/IJSIMM10(4)4.191

Burinskiene, A. 2015. "Optimising forklift activities in wide-aisle reference warehouse." *International Journal of Simulation Modelling*, 14(4): 621–632. https://doi.org/10.2507/IJSIMM14(4)5.312

Cotton Inc. 2018. "Classification of Cotton." Retrieved from https://www.cottoninc.com/cotton-production/quality/classification-of-cotton/

Ethridge, D., Brown, J., Price, J., and Bragg, C. K. 1992. "An Econometric Approach for Estimating Daily Market Prices." In *Proceedings of the Beltwide Cotton Conference* (pp. 399–402).

Hazelrigs, L., Faulkner, W. B., Lacey, R. E., Robinson, J., and Parnell, C. B. 2017. "Improving Cotton Warehousing Efficiencies through Novel Bale Marketing Strategies: Aisle-Stacking and Block-Stacking." *Journal of Cotton Science*, (21), 167–174. Retrieved from http://journal.cotton.org

Kenkel, P., & Kim, T. 2008. "Investigation of the Costs of an Increased Shipping Standard for Cotton Warehouses." Paper presented at SAEA Meeting, Dallas TX, 2-5 February.

Richard, J., DeVuyst, E., and Kenkel, P. 2019 "Cotton Warehouse Modelling, A Visual Basic for Applications Program" *Work in Progress*

Wu, Y., Gunter, L. F., and Shurley, W. D. 2007. "Impacts of Quality Characteristics on U.S. Cotton Prices and Value." Paper presented at AAEA Meeting, Portland OR, 29-1 July-August.