TEXAS A&M UNIVERSITY
Biological and Agricultural Engineering

January 25, 2007

Dr. Ed M. Barnes
Cotton Incorporated
6399 Weston Parkway

Dear Ed:

Attached is the annual report of project 04-543 TX entitled, "**Engineered Systems for Seed Cotton Handling, Storage and Ginning**". I have sent you the summary report as an email attachment.

Sincerely,

Stephen W Searcy

Stephen W. Searcy, P.E.
Professor

Xc: Diane Gilliland

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Cotton Incorporated Cooperative Agreement No. 04-543TX
Texas Agricultural Experiment Station

Problem Statement and Justification: The number of gin facilities is on the decrease both in Texas and the US; however, cotton production remains steady. Therefore, gins are expected to handle more cotton, haul modules from farther distances, minimize cost and gin the seed cotton in the shortest period possible so the producer can market the cotton. Cotton ginning systems will change to remain operable. Seed cotton storage systems must allow for longer periods of storage while maintaining seed and lint quality. Seed cotton transportation systems must provide for larger volumes of seed cotton per trip over all roadways. Ginning systems must be optimized for increased ginning rates and increased length of the ginning season.

Accomplishments: Module cover testing continued with standardized testing of water impact penetration, hydrostatic resistance and outdoor weathering resistance. Module cover use data were compiled and a brochure and poster were developed, and distributed to all Texas gins for educational purposes. Instrumentation of a module builder was accomplished to monitor operator performance during field use. Laboratory testing of seed cotton distribution was performed using a module builder simulator. Prior laboratory tests examining the visco-elastic performance of seed cotton indicating that creation of a surface that will shed rainwater requires an increased mass of seed cotton along the centerline of the module.

The use of older, worn module covers and the building of poorly shaped modules resulted in lint quality losses valued at $400 and $200/module, on average, respectively. At the same time, gin turnout decreases over 8% and ginning rate is reduced 55%.

Cost of seed cotton transport was modeled for module truck and semi-tractor trailer (STT) systems. These transport cost equations were used with GIS programming to determine transport costs for example Texas gin locations. Mathematical equations were developed for fixed, variable and total ginning costs as a function of percent utilization (%U) using survey data and multi-year historical data. An initial decision support software Cotton Ginning Simulation Model (CGSM) was developed.

Ginning costs per bale varied with gin size. The results of the ginning costs versus %U for each gin size category suggest that there exists an optimum %U and that the optimum increased with ginning rate. The ginning rate categories and optimums are as follows:

- less than 15 bph - 170% utilization;
- from 15 to 25 bph - 180% utilization;
- from 25 to 40 bph - 180% utilization; and
- gins larger than 40 bph - 240% utilization.

Application: One goal of this study is to improve both the modules and covers used to transport and store seed cotton. The module formation aid will provide modules better able to shed rainwater without infiltration into the cotton. Module cover testing will result in better constructed covers for producers and gin owners. Recommendations on the useful cover life are anticipated from testing and research. Seed cotton damage due to water penetration is an unnecessary loss of profit that can be avoided with proper module construction and protection. A second goal of this project is to utilize a systems engineering approach to analyze scenarios that could help cotton producers and cotton ginners achieve an optimum system that would be economically attractive for the immediate and long-term future of the cotton industry.

Annual Report
Cotton, Inc. Cooperative Agreement No. 04-543TX
Texas Agricultural Experiment Station
Submitted by
Stephen W. Searcy, P.E.
Calvin B. Parnell, Jr., P.E.
January 25, 2007

Objectives

1. Develop tools and systems that will maintain cotton lint and seed quality during module building, transport and extended storage periods.
2. To develop user-friendly decision support software for cotton ginning and transport of seed cotton from the turn-row to the cotton gin storage site.

Introduction

The cotton industry, like many industries, has found more efficient production and processing approaches through the years. Several systems that help to improve ginning efficiencies worth noting are the gin universal density press, the module feeder, air quality control systems (while not a ginning efficiency, a requirement by federal, state and local governments), various seed cotton and lint cleaning machines, and gin stand improvements. These progressive yet expensive upgrades have caused some gins to go out of business.

In Texas alone, gin numbers since 1960 have plummeted from over 1,400 gins to less than 280 active gins in the 2003 ginning season (figure 1). Most gin numbers for cotton producing states in the U.S. have followed similar declining trends. The result of a regression analysis of gin numbers versus time (from 1983 to 2003) suggests that all gins in Texas will be out of business in 2018 (R^2 = 0.98). This will not occur but it suggests that significant changes in the production, harvesting, storage of seed cotton and ginning are likely in the near future. The goal of this research is to provide technology that will assist with the transition to new systems.

From figure 1 it is evident that Texas production numbers are remaining steady and even increasing slightly at around 5 million bales. The 2005 and 2006 seasons were successive record-breaking years for Texas production with approximately 8 million bales. These two years of heavy production have shown that the current gin infrastructure can handle significantly greater production, but with longer operating seasons. Data in the last few years show a slowing in the reduction of gin numbers. In 2007, it is estimated that the number of bales produced and ginned will decrease to approximately 5 million. Whether the continued reduction in number of gins and cotton production will level off at 5 million bales in the future is yet to be seen.

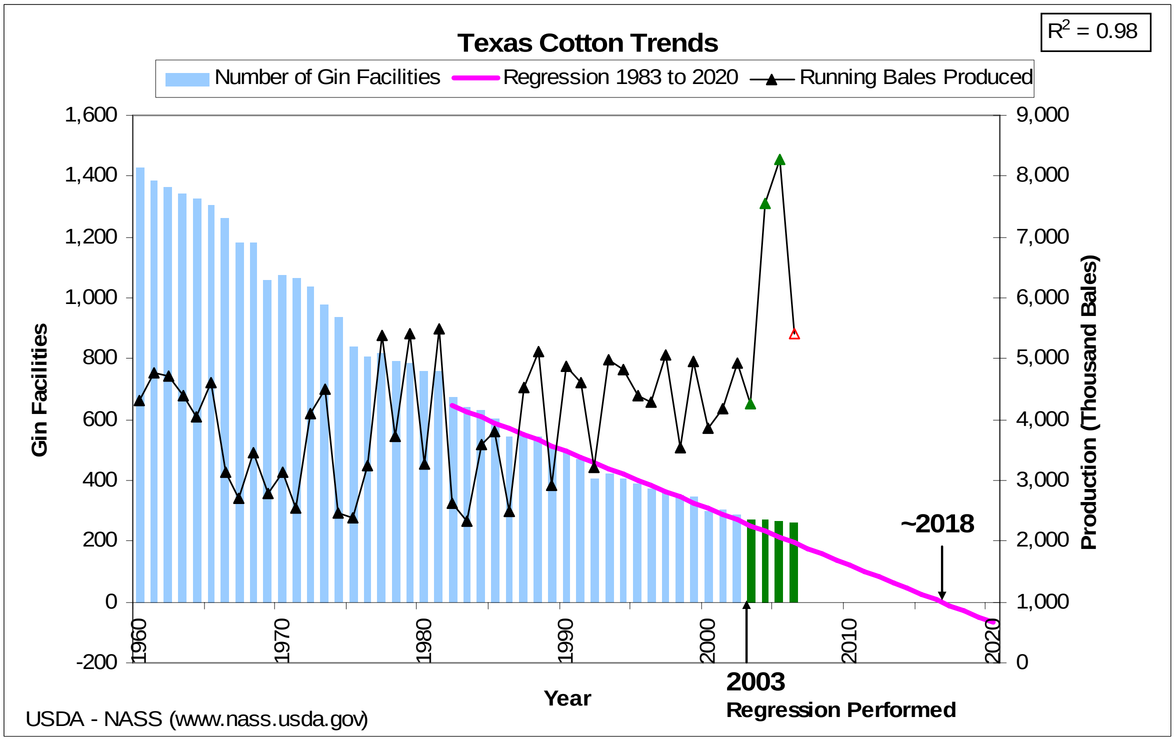


Figure 1: Gin facility numbers and production in thousand bales from 1961 through 2006, with regression of gin facilities, performed in 2003, from 1983 to 2020.

Continued steady production levels of US cotton and decreasing ginning facility numbers will force gin management practices to change. Processing more cotton per gin facility, extending the operating season of the gin, and transporting seed cotton longer distances from the turn row to the gin facility are a few of the changes industry will be forced to consider. The possibility of longer ginning seasons gives rise to another concern – seed cotton quality in module storage. It is due to these impending changes that researchers in the Department of Biological and Agricultural Engineering at Texas A&M University are working to provide industry with alternative solutions. Research goals during the 2006 reporting period were to:

1. Develop tools and systems that will maintain cotton lint and seed quality during module building, transport and extended storage periods.
2. To develop user-friendly decision support software for cotton ginning and transport of seed cotton from the turn-row to the cotton gin storage site.

Lint and Seed Quality – Objective 1
Method of Research

Research involved with this objective has been on-going for four years. In the first year of reporting, module covers were tested in standardized test apparatus to determine their ability to protect seed cotton from damaging water due to rainfall and ponding after rainfall. Module shape improvement included the evaluation of modules on gin yards, instrumentation of a module builder to monitor operator performance and laboratory testing of seed cotton compression.

During the second year of reporting, module covers continued to be tested in outdoor weathering studies for cumulative solar radiation degradation. Miniature modules were formed in South Texas for initiating cover testing and impact on seed cotton during an extended storage period. The compressive properties of seed cotton were determined to be visco-elastic and were mathematically modeled. The operator feedback system was implemented on a module builder at the Texas A&M University IMPACT Center. The system recorded and displayed the compressed height of the seed cotton in the module and the position of the carriage when the compression was completed.

The third year of reporting continued with miniature module formation on the High Plains of Texas and outdoor weathering of covers. A study of module shape and cover condition at a Texas gin was conducted and quantified quality and monetary losses due to poor shape and poor condition. The operator feedback system was tested on a module builder at the Lubbock USDA Cotton Production and Processing Unit. A cotton distribution device was designed and built for testing.

Activities and results during the fourth year of work are described below.

<u>Module Shape Improvement</u>

Serious economic losses can result from moisture damage to seed cotton in modules. If a significant rainfall occurs, the degree of quality loss is determined by the condition of the module cover and the shape of the module. The economic loss due to a poorly formed module has been estimated at over $200/module, regardless of cover quality (Simpson and Searcy, 2005). Therefore, modules must be built with a shape that prevents the collection of rainwater.

Previously in our study of the physical properties of seed cotton (Hardin, et al., 2004) it was concluded that more cotton must be placed in the center of the module to produce a convex top surface. Additional tramping of high areas will not significantly affect the module shape. To properly construct a module, the operator must move cotton from areas with more mass into regions with less cotton. Several factors complicate this process. It is difficult to visually estimate the mass of cotton in a particular location in the module, as certain regions may not have been compressed. The module builder operator may also have difficulty seeing the far end of the module builder. Therefore, a system that provides information about module shape to the operator should result in modules that do not collect water and produce higher quality lint and seed.

The 2004 study by Hardin, et al. also demonstrated that with a constant force, the compressed height of seed cotton varies linearly with the mass of cotton compressed. This observation was used as the basis for the feedback system. The original design of the feedback system is detailed in a paper by Hardin and Searcy (2005). The motion of the carriage and tramper were tracked, and an algorithm developed to identify tramping strokes. The minimum height during the tramping stroke is used as the indicator of the mass of cotton at that location in the module.

Originally, the tramper and carriage locations were determined using ultrasonic sensors due to their low cost and adaptability. The tramper motion sensing was accurate; however, the carriage position could not be adequately sensed (Hardin and Searcy, 2006). The ultrasonic sensor was not accurate over the full range of carriage motion due to misalignment of the sensor and target area, wind, and dust. As a result, a different sensing technique was used for determining the carriage location.

Design Modifications

Two inductive proximity sensors were used to track carriage motion (figure 2). The sensors were mounted on the channel at the front of the module builder and detected a hub mounted on the carriage drive shaft. The sensing hub consisted of four steel teeth welded to each side of a split shaft collar. Each time a tooth passes the sensor, a pulse is produced. Counting the number of pulses indicates the distance the carriage has moved- 3.75” per pulse. The two sets of teeth are offset approximately 12° so that the direction can be determined by comparing the values from the two sensors. The sensor mount was adjustable so the distance between the sensors and the hub could be set precisely.

Figure 2. Carriage sensing apparatus.

In order to provide an absolute position reference, proximity sensors were also used to indicate when the carriage reached the front or rear of the module builder. The module builder the system was mounted on had an automatic tramping system, so these sensors were already installed. The feedback system hardware was also redesigned, with a smaller enclosure and user-adjustable LCD contrast. The new feedback system is shown mounted in the module builder cab in figure 3. The system is simple to operate with only an on/off switch, reset button, backlight switch, and LCD contrast adjustment.

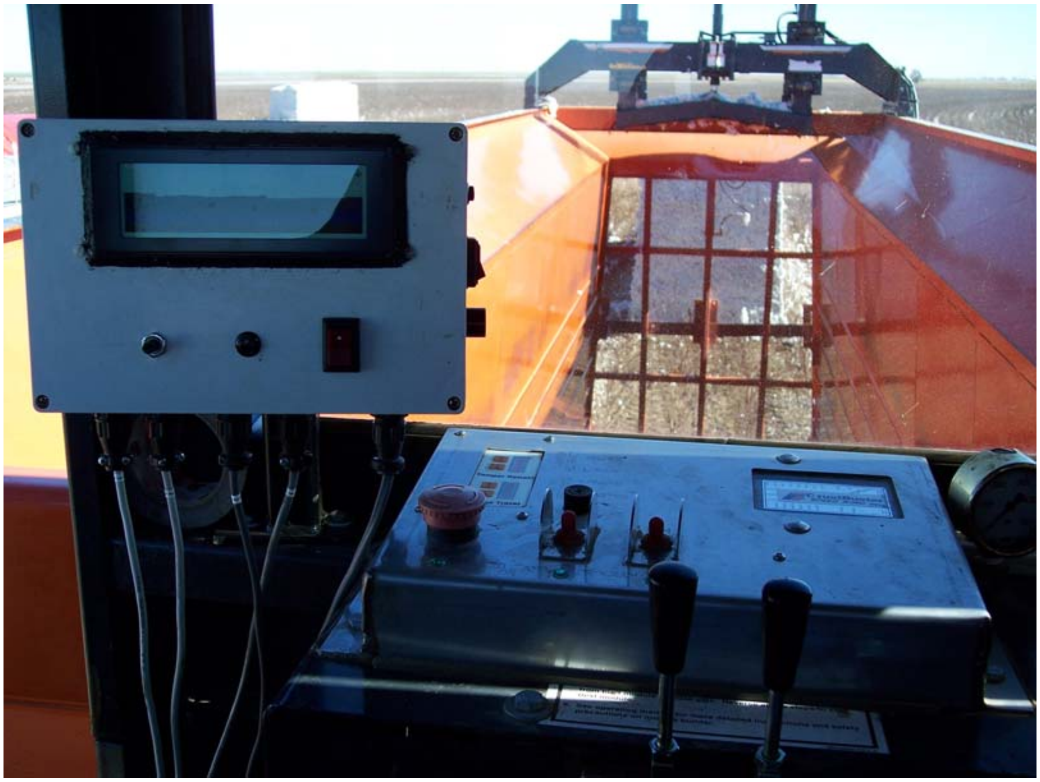


Figure 3. Feedback system.

A closer view of the display is shown in figure 4. The left side of the display is the front of the module, and the arrow indicates the carriage position. The column height is proportional to the mass of cotton at that location in the module.

Figure 4. Feedback system display.

Testing

The feedback system was installed in early November on a module builder in the High Plains of Texas. The harvesting crew that used the feedback system had almost no experience building modules. Originally, the system was installed in a location where the operators could not see the display. Data was collected and the quality of the modules built without the system was evaluated. The system was then mounted inside the cab (figure 3) where it could be used by the operator. The original testing plan involved each operator using the module builder with the system installed where it was not visible and later with the system in the cab. Due to weather and mechanical problems with the module builder, this plan was not fully implemented. A total of 12 modules were built using the system, under the conditions described in table 1. The data collected using the feedback system was analyzed to determine if the system accurately displayed compression strokes.

Table 1. Module test conditions.

Module #	Operator	Display Visible?
1	A	No
2	A	No
3	A	No
4	A	No
5	A	No
6	B	Yes
7	B	Yes
8	B	Yes
9	B	Yes
10	B	Yes
11	A	Yes
12	A	Yes

The actual module height was measured for the 12 modules in table 1. Height measurements were taken at the front of the module, every 3 ft from the front of the module, and at the rear of the module, resulting in 12 height measurements. The height measurements were taken by placing a measuring tape over the top of the module and recording the distance from the ground on one side of the module to the ground on the other side. The actual height was estimated by subtracting 7 ft from the measurement (for the top width of the module) and dividing by 2. This method was used because it was faster and more accurate than measuring the actual height and two people could make the measurements from the ground. The estimated actual height was compared to the displayed column height to determine the system accuracy in predicting module height.

Five additional modules built by operator B before he used the feedback system were also measured. These modules were compared to the 5 he built using the system to determine if the feedback system had any effect on module shape. To provide an objective assessment of module shape, the size of the areas in the module profile where water could collect was calculated. Figure 5 provides an example of this calculation. The areas covered by the diagonal black lines represent where water could collect.

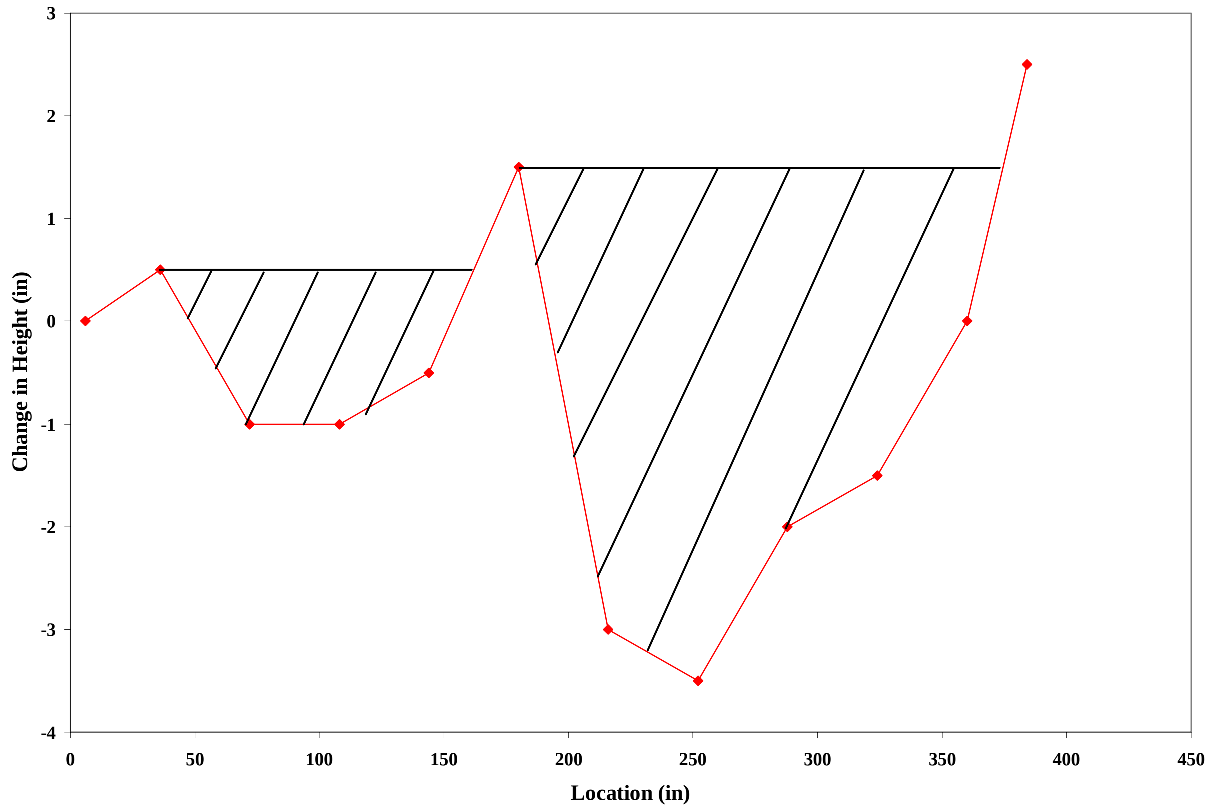


Figure 5. Potential water collection areas- module 7.

The system was left installed on the module builder after the initial testing. The harvesting crew continued to use the system, and modules built with the system were marked. On December 12, the heights of 18 modules built by the same harvesting crew were measured. The modules were at the gin and covered at that time. Half of the modules had been built using the feedback system, but the operator was unknown. All the module builders were the same model. Again, the potential water collection areas were compared for the modules built with the system and without. 13 of these modules were subjectively classified as having a good, average, or poor shape.

Results and Discussion

Display Accuracy

The feedback system identified approximately 80% of the compression strokes correctly. The accuracy of the system was not affected by the carriage location, as the earlier design had been (Hardin and Searcy, 2006). The primary cause of compression strokes not displaying was that the distance the tramper retracted before the carriage moved was less than the threshold necessary to consider an operator action a tramping stroke. This value can easily be changed in the system software and should not adversely affect system performance since no leveling actions were classified as tramping strokes. A tramper retraction threshold of 9 in may be more appropriate, especially as the module in the builder is finished.

Height Prediction

The estimated actual heights of the 12 modules with feedback system data were plotted against the display heights and the regression line is shown in black (figure 6). The R^2 value was 0.48, which is lower than desired. However, a great deal of uncertainty exists in determining the estimated actual height. The measuring tape may not be completely straight across the top or sides of the module and an uneven top surface of the module can result in additional error. The location at which the compression stroke occurs may differ slightly from where the measurement was made. For these reasons, a height measurement error bound of ±3 in was considered reasonable. Approximately 70% of the data points fall within these error bounds, which are displayed in blue on the graph.

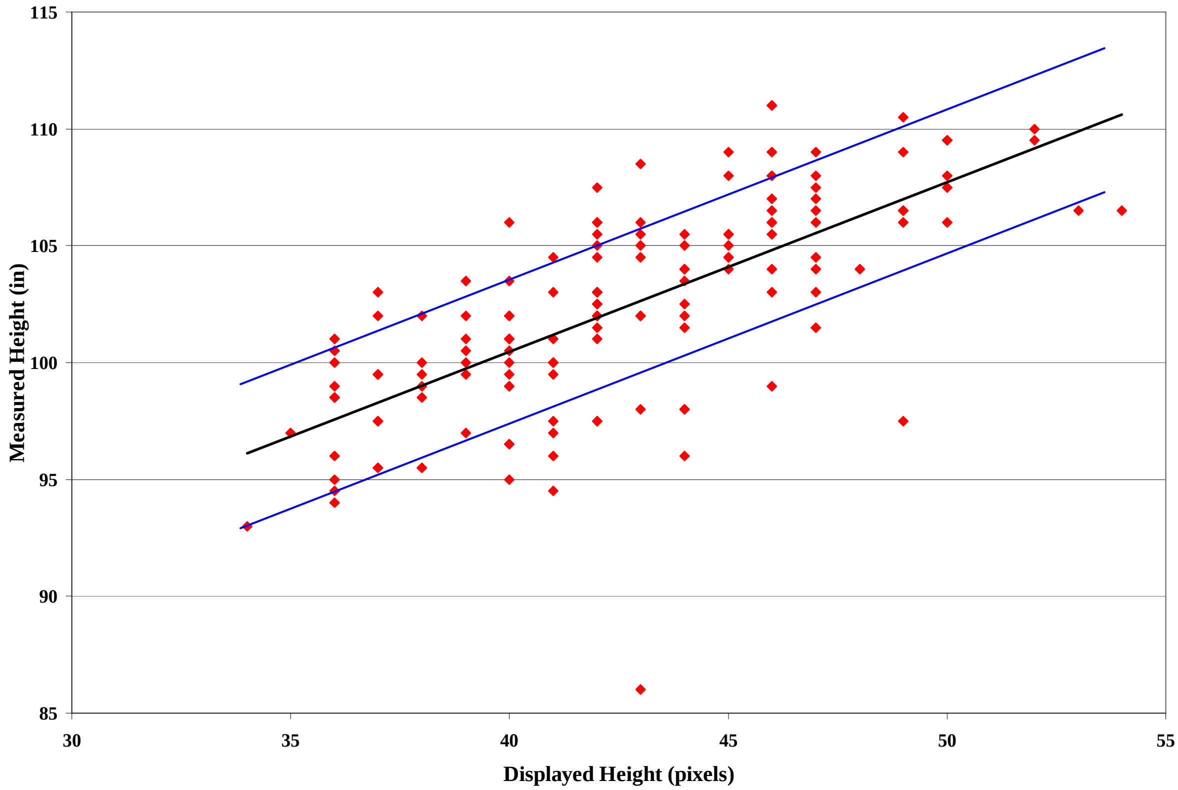


Figure 6. Measured and displayed height for all modules.

A more in-depth analysis of the data reveals that all of the data points in module 2 lie outside of almost all other data points (figure 7). The actual height is significantly less than what would be predicted using the regression equation. One possible explanation is this module was built at night before wet weather moved into the region. The increased humidity could have caused the module to expand less after the module builder was pulled off, resulting in lower measured heights. The regression line with the module 2 data excluded is shown in figure 8. The R^2 value is now 0.65 and approximately 80% of the data points fall within ±3 in of the regression line.

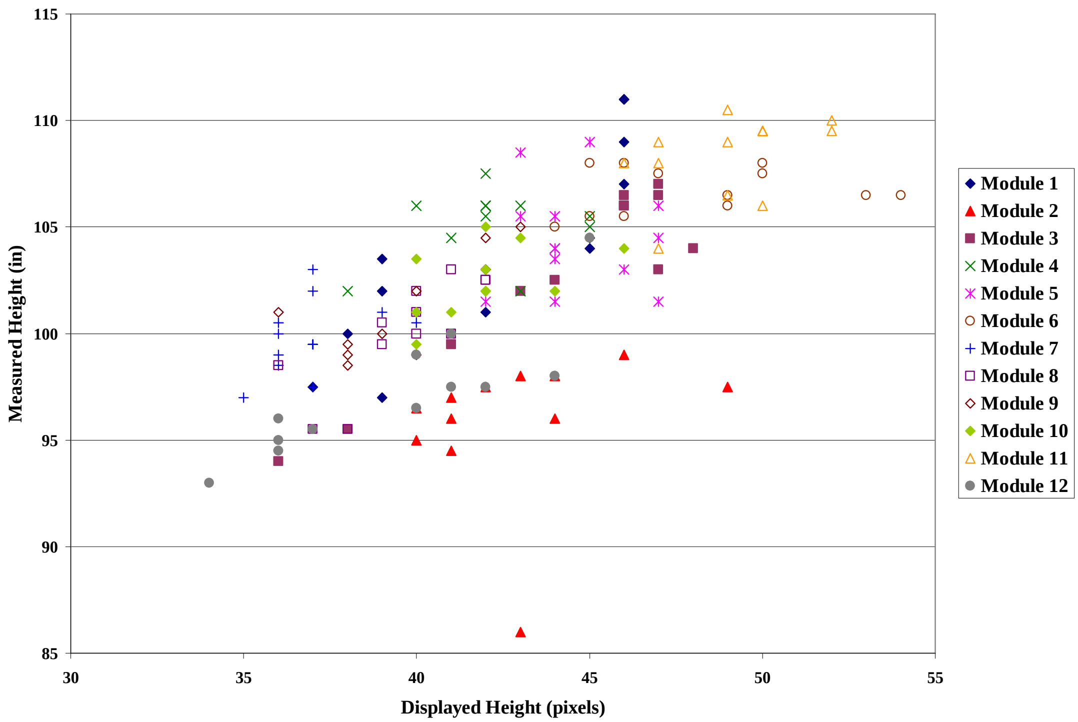


Figure 7. Measured and displayed height by module.

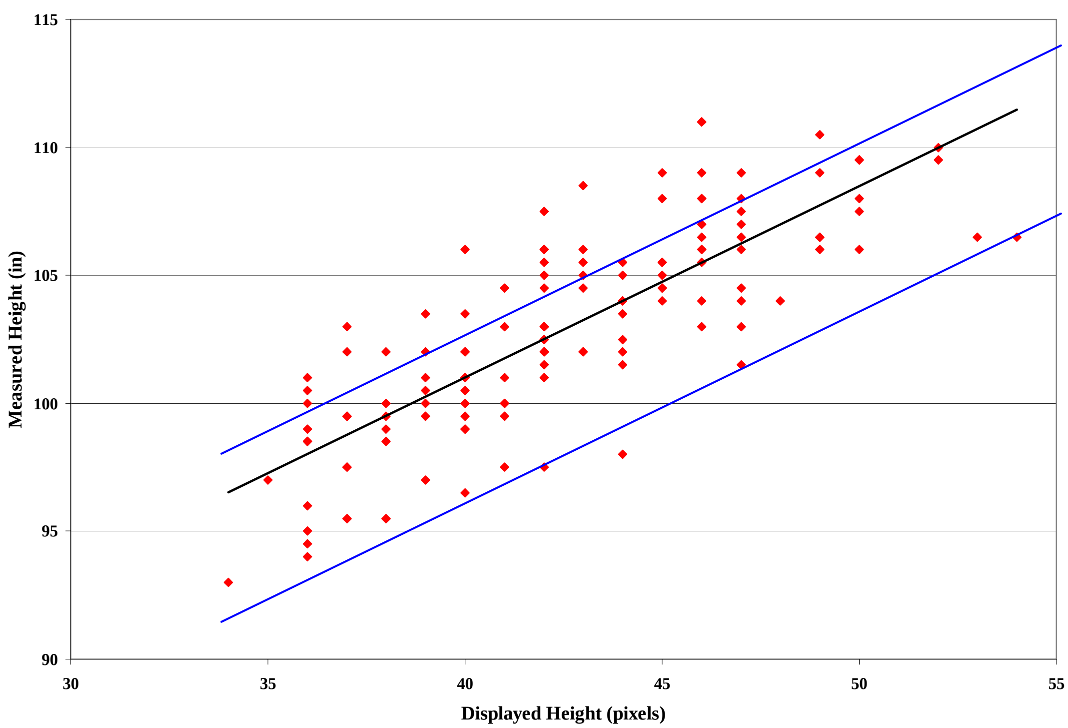


Figure 8. Measured and displayed height with module 2 excluded.

Effect of System on Module Shape

The calculated potential water collection areas for modules built by operator B before and while using the feedback system are shown in table 2. The modules built with the feedback system are modules 6-10 in table 1. A t-test was performed to determine if the means were significantly different. The resulting *P*-value was 0.052, indicating that using the feedback system immediately improved module quality. Visual observation of the modules supported this result.

Table 2. Potential water collection areas (in^2) from initial testing.

	Before System	With System
Module A	999.67	408.00
Module B	1734.50	748.80
Module C	299.25	247.20
Module D	979.20	215.59
Module E	540.00	432.30
Mean	910.52	410.38

Table 3 shows a comparison of the potential water collection areas of the modules measured on 12/12/2006. The means of the potential water collection areas are not significantly different (*P*-value = 0.252). Generally, all the modules observed on this date were well constructed. The feedback system may have served as a useful training tool for the operators, enabling them to build well-constructed modules without the system.

Table 3. Potential water collection areas and subjective evaluation of modules on 12/12/2006.

	Without System		With System	
	Area (in^2)	Subjective	Area (in^2)	Subjective
Module 1	14.40		113.14	Good
Module 2	108.00	Good	864.00	Good
Module 3	0.00	Good	605.70	Good
Module 4	21.60	Good	684.00	Good
Module 5	273.24	Good	675.00	
Module 6	56.70	Good	246.24	
Module 7	453.60		165.24	
Module 8	834.30	Average	151.20	Average
Module 9	77.76	Average	89.10	Good
Mean	204.40		399.29	

Acceptability of System to Operators and Supervisor

The module builder operators both stated that the feedback system definitely helped them shape the module. They used the display to direct the boll buggy to unload cotton in regions that had a lower height on the display and found that the feedback system was most useful when finishing a module. Both operators agreed that the shape of the module was accurately represented by the feedback system display. When asked how frequently they used the display, both operators replied, “all the time”, which confirmed observations made during testing. The module builder operators found the feedback system particularly useful in low visibility situations, such as at night and at the far end of the module builder. The feedback system was simple to use, as both operators were successfully trained on the first module each built with the system.

The supervisor’s comments echoed the response of the operators. He believed that the feedback system would definitely help his crew. He also thought the display was an accurate representation of the module shape. The supervisor stated that the system lets you know where to tramp more. One of the module builder operators made the same comment, but our research and observations have indicated that tramping more in a particular location has little effect. Cotton needs to be moved to regions of the module with a lower height. Module builder operators need to be aware of this in order to build high quality modules.

Conclusions

The feedback system provided an accurate representation of module shape, as demonstrated by the relationship between the measured and displayed height and the statements of the harvesting crew. The feedback system was also useful in constructing properly shaped modules. Using the system significantly improved the quality of modules built, and later observations showed that the harvesting crew was building consistently good modules. The feedback system is simple to use and was easily accepted by the module builder operators.

Using the feedback system provides several advantages over building modules conventionally. Primarily, the system gives the operator an image of the module shape. While an experienced operator may make a good assessment of the shape of the module he is building, the system still provides several advantages. The feedback system provides a constant reminder of the importance of module shape. Also, the system provides information even when visibility is poor, such as at the far end of the module or at night. Finally, the system is inexpensive and will have a rapid payback due to improved lint quality. The feedback system will likely cost less than $500, and the possible loss in lint value due to a poorly constructed module is $200.

Future Work

Future work with the feedback system will involve analyzing ginning data from the 2006 harvest to determine the effects of using the system on lint quality. Module weight will also be compared to the displayed heights to determine if the system can accurately predict module weight and density. Knowledge of these values would be quite useful to producers. Further testing of the system will be done with the beginning of the 2007 harvest and efforts will be made to commercialize the system.

<u>Cotton Redistribution Device</u>

In addition to forming a module with a feedback system, distribution of seed cotton along the width of the module is important for creating a well crowned shape. As cotton is dumped into a module builder, there is no control over the distribution of mass laterally within the builder. Previous work has shown that greater mass is needed along the center-line of the module to give the crown desired for rapidly shedding water. Two preliminary ideas for accomplishing this distribution were developed, designed and tested. One design employed a raking theory and was tested last year. Results were detailed in the 2004-05 annual report. The second design reported below operates with a belt conveyance system.

Introduction to Experiment

During research of the belt drive design, a belt with 0.5 inch cleats and a belt with 1 inch cleats were tested. The speed of the belts was varied from low to high speed at predetermined intervals. Since a cotton picker dumps a large amount of cotton against the opposite side of the module builder, several different scenarios of cotton buildup were examined. The three scenarios of cotton buildup in this experiment were varied from an even distribution to buildup on the outside and middle of the cotton module builder. The time of operation was recorded for each speed and with every cotton scenario. A SolidWorks model of the belt drive system is shown in the appendix in Figure 9.

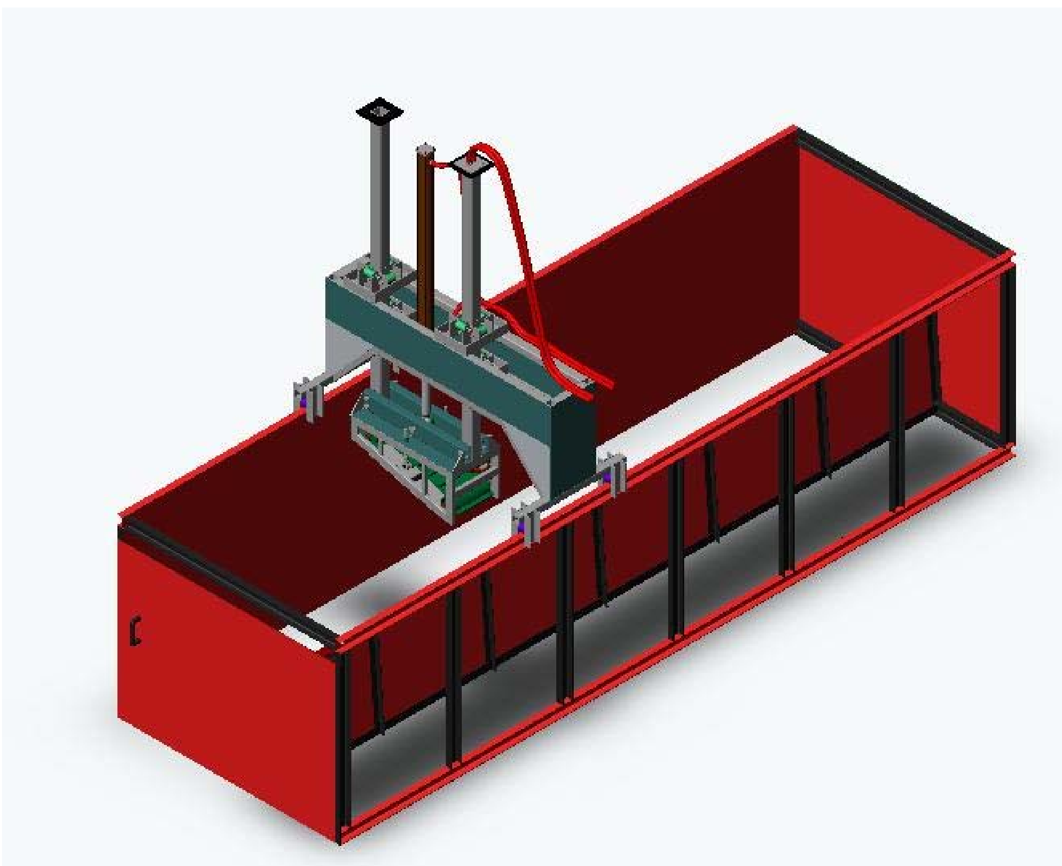


Figure 9: SolidWorks Belt Drive Experimental Design

Experimental Results

Belt with 1 inch cleats

The belt with longer cleats proved to clog quicker than the belt with shorter cleats in general. According to Table 4, it can be seen that the belt performed poorly with moderate and high belt speeds. At low speed however, the belt showed some promising performance until the cotton was moved toward the middle. When the belt moved the cotton as it should, clogging soon occurred after one or two passes because the cotton had no place to go. The cotton therefore increased in density and clogged at a support point for the frame of the belt drive system.

Table 4: Experimental Data for Belt Driven System Using 1" Cleats

Belt with 1" Cleats						
Cotton Scenario						
	Even Distribution		Middle Buildup		Outside Buildup	
	Time	*Comments/Quality*	Time	*Comments/Quality*	Time	*Comments/Quality*
Speed						
Low	2:04	Clog: b/w roller and belt 2 passes/Quality:7	0:28	Clog: Pinch Point 0.5 pass/Quality:4	4:13	Clog: Pinch Point 4 passes/Quality:5
	1:01	Clog: b/w roller and belt; and Pinch Point 1 pass/Quality:5	0:24	Clog: Pinch Point 0.5 pass/Quality:4	3:47	Clog: Pinch Point 4 passes/Quality:5
	1:54	Clog: Pinch Point 2 passes/Quality:6	0:11	Clog: Pinch Point First Tramp/Quality:1	4:48	Clog: Pinch Point 4.5 passes/Quality:5
Moderate	0:17	Clog: Pinch Point 0.5 pass/Quality:3	0:08	Clog: Pinch Point First Tramp/Quality:1	0:09	Clog: Pinch Point First Tramp/Quality:1
	0:33	Clog: Pinch Point 0.5 pass/Quality:4	0:10	Clog: Pinch Point Second Tramp/Quality:1	0:09	Clog: Pinch Point Second Tramp/Quality:1
	0:22	Clog: Pinch Point 0.5 pass/Quality:4	0:10	Clog: Pinch Point Second Tramp/Quality:1	0:26	Clog: Pinch Point 0.5 pass/Quality:2
High	0:24	Clog: Pinch Point 0.5 pass/Quality:3	0:08	Clog: Pinch Point First Tramp/Quality:1	0:07	Clog: Pinch Point First Tramp/Quality:1
	0:07	Clog: Pinch Point First Tramp/Quality:4	0:14	Clog: Pinch Point Third Tramp/Quality:1	0:12	Clog: Pinch Point Second Tramp/Quality:1
	0:48	Clog: Pinch Point 1 pass/Quality:7	0:09	Clog: Pinch Point First Tramp/Quality:1	0:27	Clog: Pinch Point Fourth Tramp/Quality:2

The cotton scenario had some impact on the experimental results also. At low speed, the even distribution scenario proved to be the best situation. Although this scenario did not have the longest operation times, the average quality of 6 on a scale of 1-10 was found. Therefore, the end result of each run proved to create a better slope on the cotton module. The reason that the longest times were recorded for the outside buildup is that at low belt speeds, the cotton moved very slowly. Therefore, by the time cotton built up in the middle to clog, several minutes had already passed. If the cotton was already built up in the middle of the module, the belt drive would clog very quickly at the structural support using the 1" belt.

Belt with 0.5 inch cleats

The belt with shorter cleats proved to be more useful for moving cotton since it did not clog the system as often. Table 5 shows the highest quality of cotton movement for an even distribution with a moderate speed and for an outside buildup with a high speed. The moderate belt speed was very dependant on the cotton buildup inside the module builder. The belt system clogged very quickly with a middle buildup scenario. However, with an even distribution of cotton in the module builder, the belt system operated for an average of 1 minute and 45 seconds with very good cotton movement. The high belt speed performed satisfactorily with an even distribution or outside buildup, but for the middle buildup scenario, the belt system clogged very quickly on the first or second tramp as expected.

Table 5: Experimental Data for Belt Driven System Using 0.5" Cleats

Belt with 0.5" Cleats						
Cotton Scenario						
	Even Distribution		Middle Buildup		Outside Buildup	
	Time	*Comments/Quality*	Time	*Comments/Quality*	Time	*Comments/Quality*
Speed						
Low	1:46	No clog: not much movement 2 passes/Quality:3	1:35	Clog: Pinch Point not much movement 1.5 passes/Quality:5	3:46	No clog: Clumps w/ not much movement 4 passes/Quality:3
	1:33	No clog: not much movement 2 passes/Quality:3	3:36	No clog: not much movement 4 passes/Quality:7	4:04	No clog: Clumps w/ not much movement 4 passes/Quality:3
	1:25	No clog: not much movement 2 passes/Quality:3	3:09	No clog: not much movement 4 passes/Quality:7	3:55	No clog: Clumps w/ not much movement 4 passes/Quality:3
Moderate	1:19	Clog: Pinch Point good movement 2 passes/Quality:8	0:30	Clog: Pinch Point fair movement 0.5 pass/Quality:6	3:13	Clog: Pinch Point fair movement 4.5 passes/Quality:8
	2:28	Clog: Pinch Point good movement 2.5 passes/Quality:8	0:24	Clog: Pinch Point fair movement 0.5 pass/Quality:6	2:48	Clog: Pinch Point fair movement 3.5 passes/Quality:8
	1:28	Clog: Pinch Point good movement 2 passes/Quality:8	0:14	Clog: Pinch Point fair movement 2nd Tramp/Quality:4	1:43	Clog: Pinch Point fair movement 2 passes/Quality:8
High	1:32	Clog: Pinch Point good movement 1.5 passes/Quality:9	0:33	Clog: Pinch Point fair movement 0.5 pass/Quality:7	3:27	Clog: Pinch Point good movement 4 passes/Quality:9
	0:38	Clog: Pinch Point good movement 0.5 pass/Quality:7	0:10	Clog: Pinch Point 1st Tramp/Quality:1	3:01	Clog: Pinch Point good movement 3.5 passes/Quality:9
	0:45	Clog: Pinch Point good movement 1 pass/Quality:8	0:17	Clog: Pinch Point 2nd Tramp/Quality:3	0:28	Clog: Pinch Point good movement 0.5 passes/Quality:5

The lowest qualities were found to be associated with a low belt speed. The reason for this is that the 0.5” cleats on a slow moving belt do not move the cotton very well. Since the belt is set to stop moving after a given hydraulic pressure is reached, many times the low belt speed proved to be not useful for this belt even though the system did not clog.

Conclusion
Overall, the 0.5” belt cleats proved to be more useful for cotton movement and produced more desirable results. As the size of the belt cleats decrease, the speed of the belt should increase to produce the desired results. The best qualities of cotton movement were found with the belt with 0.5” cleats with moderate to high belt speeds, but were very dependant upon the distribution of cotton inside the module builder. This experiment proved that belt system would inevitably clog under extended use, but the experimental results are still very useful to determine seed cotton behavior inside a module builder for future designs and analysis. This study showed that the prototype system with the cleated belt was not workable because of the likelihood of plugging. An alternative design is needed that eliminates pinch points that can result in plugging.

Future Work
Efforts will continue with design alternatives. One potential concept is the use of an auger, but this will require additional testing to evaluate the quality of compression that can be obtained using an auger instead of the tramper. Tests will be conducted to analyze the compression of seed cotton with various portions of auger flighting and flat surface, as a preliminary study for a redistribution design that uses augers.

<u>Module Cover Performance</u>
The protection of seed cotton in the module form is a two-part system beginning with proper formation of the module, and continuing with the adequate coverage of the module. The module cover must protect lint and seed against rainfall, water and snow standing on top of the cover, also wind, sunlight and other environmental conditions. Assuming that the cover will be tied to the module effectively, the materials and manufacturing processes of the cover are important aspects to evaluate. Evaluation of 35 new and 50 used module covers began in January 2003 at the Department of Biological and Agricultural Engineering at Texas A&M University.

Procedures
Testing continued in 2005-06 on module covers with standardized test methods. Standardized tests included water impact penetration (AATCC TM 42-2000), hydrostatic resistance (ASTM D 751 – 98), and weathering resistance (ASTM D 1435-99), all described in the 2002-2003 annual TFFC report. Cover samples new in the first year of testing have now been tested for four years on outdoor weathering resistance racks. Samples were placed in the Brazos Valley all four years as well as in Lubbock for two years.

Results
Outdoor weathering was evaluated for summer 2005 and comparisons were made for Brazos Valley and Lubbock locations. Rainfall and ponding water testing (table 6) indicate that a higher level of damage occurred to cover samples in the Brazos Valley despite the lower level of solar radiation compared to samples placed in Lubbock. Additional "forces" besides solar radiation

may be affecting the cover samples. These "forces" could include rainfall impact, humidity, and temperature.

Table 6. Water penetration through module cover samples in ponding tests after weathering

	Test Location/ Solar Radiation, MJ/m^2	Brazos Valley 2,000		Lubbock 2,097	
Test Method	Cover Model	Average, g	Std Dev, g	Average, g	Std Dev, g
Rainfall	G	0.013	0.017	0.003	0.004
	I	0.006	0.008	0.004	0.004
	K	11.7	2.0	0.013	0.018
Ponding	G	0.208	0.355	2.787	4.588
	I	67.4	127.2	0.266	0.330
	K	451.9	205.3	-	-

The latest testing performed in summer 2006 was analyzed with standardized water test methods. Meteorological data were collected including solar radiation. Samples of four cover models tested in the forth summer period accumulated 2,050 MJ/m^2 of solar radiation (table 7).

Table 7. Water penetration through module cover samples in ponding tests after weathering

Outdoor Test	Material	Construction	Ponding Test Results				
			Summer 1	Winter 1	Summer 2	Summer 3	Summer 4
Solar Radiation, (MJ/m^2)			2,200	1,030	2,120	2,100	2,050
Accumulated Solar Radiation, (MJ/m^2)			2,200	3,230	5,350	7,450	9,500

Future Work

Accelerated UV-light testing adhering to standard ASTM G 155, Cycle 7A (except with continuous light), would provide faster testing of cover samples. This would require quartz jacketed xenon arc lamps with Daylight filters (Table 1 in the standard describes performance), irradiance at 0.55 W/m2 nm at wavelength 340 nm, 50% RH, black panel temperature 70°C, and air temperature 42°C. Comparison of accelerated UV-light testing and outdoor weathering should be performed to indicate any differences in performance during water resistance testing. Laboratories with appropriate instruments for performing ASTM G 155 have been contacted and are cooperating to determine our application requirements.

The focus on testing of module cover performance will shift from UV-light degradation to the examination of wind damage. Wind damage is an important degradation source in both Coastal bend and High Plains regions and little information is available on cover failure modes due to wind. Forces covers experience due to wind will be evaluated and the impact of such forces sought to be minimized. Mechanical damage due to flexing will continue to be evaluated by standardized test methods identified. In addition, sections of covers or scale models of modules and covers will be tested in a wind tunnel. The USDA-ARS Areawide Pest Management Research Unit in College Station operates a wind tunnel with a 6’ x 6’ flow field, and has agreed to allow its use in these studies.

Development of a tool for quick and reliable inspection of module covers at the gin will continue in 2007. Cameras and sensing techniques identified in 2006 research will be evaluated for designs that can be easily implemented. Building a better module is important. Refinement of the shape feedback system will continue. In addition to this tool for improving the shape of the module along the length, mechanical modifications of the module builder carriage are being designed in the current year's activities. The purpose of these modifications is to move cotton from the outer edges to the center line of the module. A design that can provide a consistant crown to the module will aid in resisting ponding. Completion of this modification is not expected in 2006 and will be continued in 2007.

Knowledge gained in this project will be used to support the development of a performance standard for cotton module covers. The Cotton Engineering committee of ASABE has charged a committee with developing such a standard, with Steve Searcy and Shay Simpson serving in leadership roles. While difficult to anticipate exactly what additional data will be required by the committee, this project will try to serve as a source of unbiased data and perform needed studies as time and resources allow.

<u>Module Cover Inspection</u>

Quick and accurate assessments of module cover quality are needed to allow ginners to manage their cover inventory and to ensure that only good quality covers are placed on modules for storage. A study was initiated in the fall semester to determine if image processing techniques can be used to estimate the amount of water that would penetrate a cover. While the study is still in the preliminary stages, results to date are positive.

Procedures

Analysis was initiated using the samples of module covers with varying quality that were previously extracted for the moisture penetration studies. For each of the samples, a subjective assessment was made of the quality (light, moderate, heavy or abused), and previously measured moisture penetration mass data were available. The selected samples represented all of the quality levels. Samples were place on a light box with back lighting and images created with a digital color camera. The images were analyzed using the Image Analysis toolbox of the Matlab software package. The processing method developed selects the optimum color band for analysis, performs adaptive thresholding and measures the number and size of pinholes in the image.

Results

To date, the best performance in predicting moisture penetration has occurred when comparing the logarithmic transformation of the number of pinholes to the mass of moisture penetrating during the rainfall test, with an R^2 value of about 0.65. Testing continues in an effort to improve this predictive relationship, but these results are sufficient to justify further testing and development.

Future Work

The machine vision approach to cover inspection will be extended to assessing pinhole density while the cover is being pulled beneath the camera. Initial tests will be performed with the existing light box and long strips of cover taken from used module covers. Techniques will be developed for real time assessment and judgment of cover quality. If these results are satisfactory, a full scale system suitable for assessment of intact covers under gin conditions will be developed and tested.

Interaction Between Module Shape & Cover Performance

Project Discussion

Past cooperation with a Texas High Plains gin during the 2004 ginning season was reported over the last two years. Unusual sustained rain afflicted the area and caused decreased quality and seed cotton loses. Additional data were extracted from gin data sets and loses were quantified for both producers and gin owners. Information was compiled into a brochure and poster (figures 10 and 11) and distributed to all Texas gins for the 2006 season.

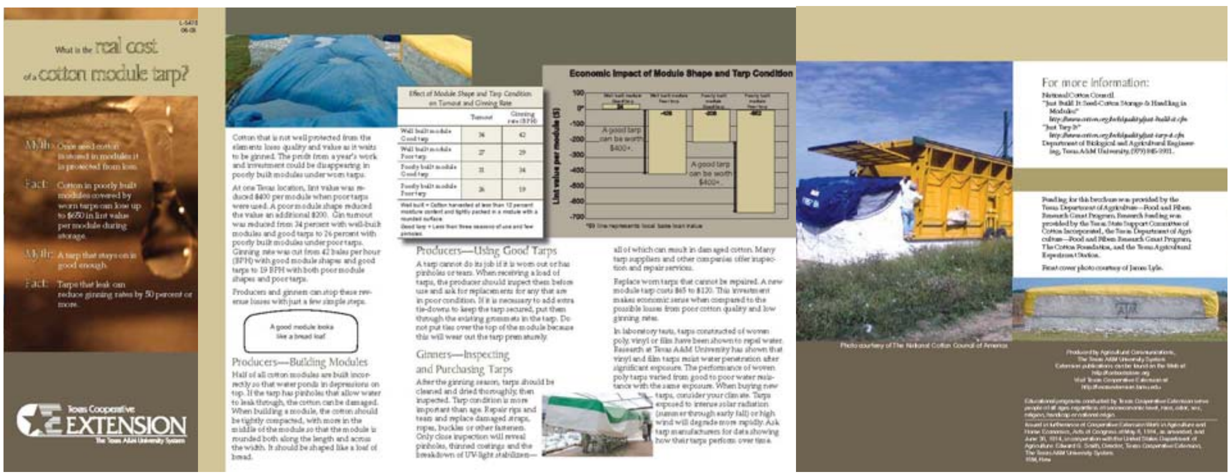


Figure 10. Tri-fold brochure developed for distribution to Texas gin locations.

The brochure is available by going on-line to http://tcebookstore.org and searching for document L-5478. The poster is available by contacting Shay Simpson at shay-simpson@tamu.edu.

Figure 11. Poster distributed for advertisement of the brochure.

Critical Findings

Some key points determined through the cooperative study indicate the advantages to keeping module covers in good condition and building modules with proper techniques. Monetary loses can be minimized due to lint quality loses; lint weight or turnout at the gin can be decreased; and ginning rate can remain at a maximum, therefore, energy costs remain low. Figure 12 illustrates that a good tarp can be worth and average of $400 or more compared to a poor tarp during a storage period experiencing rainfall.

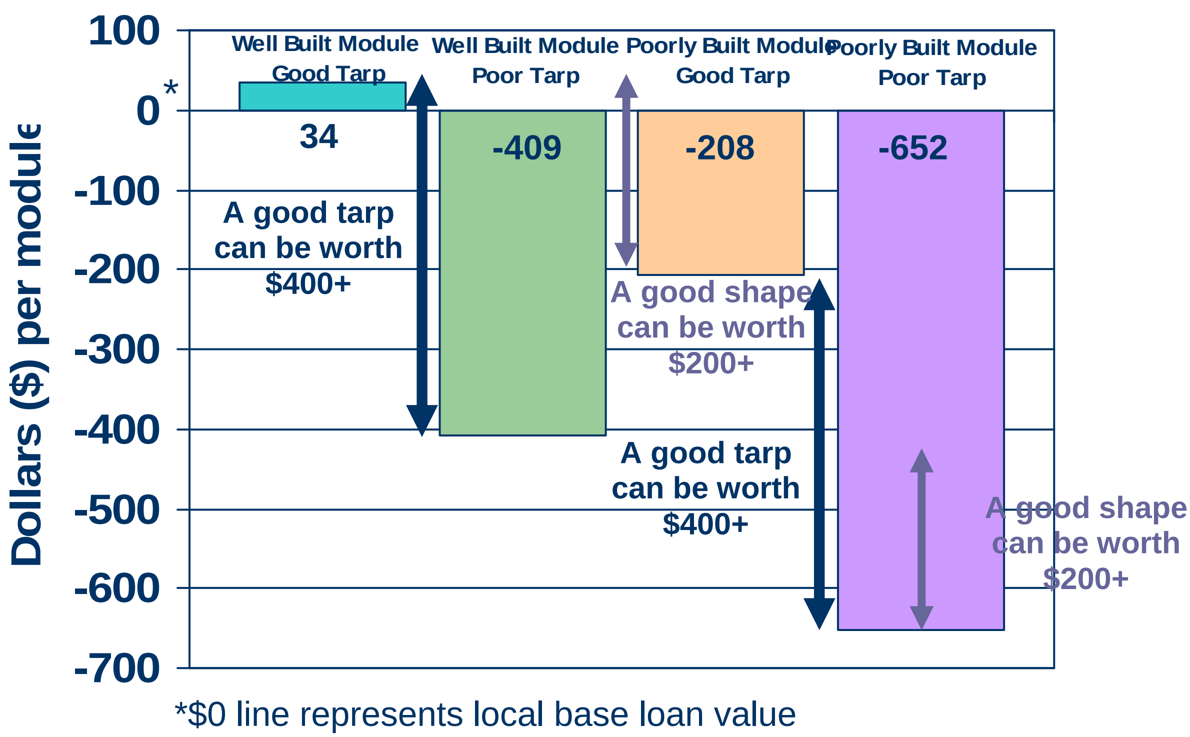


Figure 12. Lint value impact of module shape and tarp condition.

Poor tarps are described as having pin holes not always visible from the top surface or other damage that allows water to penetrate the cover. The same figure indicates that a well built module alone, can provide additional savings on average of $200 or more compared to a poorly built module. A well built module is described as being tightly compacted, with more cotton in the middle so that the module is shaped like a loaf of bread and the cotton is harvested at a moisture content no higher than 12 percent.

Not only can producer's returns be affected by loss of lint value, but also by turnout and ginning rate loss. Table 8 shows how the well built module and good tarp together as a "system" of module storage can prevent up to 8% turnout losses. Eight percent of a 500 pound bale equates to 40 pounds lost. Ginning rate is reduced by 55% when a module storage "system" is poorly built and poorly tarped. Ginning rate in bales per hour (BPH) dropped from 42 to 19 at the gin location studied. With a decrease in ginning rate of 55%, it is estimated that electrical expense AND seasonal labor expense to gin the same amount of cotton will increase two-fold.

Table 8. Cotton ginning parameters that are influenced by module storage conditions.

Effect of Module Shape and Tarp Condition on Turnout and Ginning Rate		
	Turnout (%)	Ginning rate (BPH)
Well built module Good tarp	34	42
Well built module Poor tarp	27	29
Poorly built module Good tarp	31	34
Poorly built module Poor tarp	26	19

Future Work

No further educational publications are planned at this time. Additional data may be available to us from the cooperating gin data base. More incidents of moisture damage due to improper module storage "systems" have occurred in the 2006 season. Data from those gin locations may be available as well. Data analysis of historical rainfall records is underway in an effort to assess the probability of damaging stored seed cotton when using covers of differing quality.

Seed Cotton Transport, Storage, and Ginning System Optimization – Objective 2

Project Scope

The ginning rates for newer gins have progressed to the point that a number of cotton gins can now process 60 bales-per-hour (bph). This rate of ginning will result in a 500-pound bale from the bale press every minute. One ginner has expanded his operation to 90 bph requiring two bale presses.

The goal of this study is to develop a mathematical (systems) model that can be used by the ginning industry to provide answers to the following questions:

1. How many gins are needed in each production area?
2. Is there a more efficient work schedule for cotton ginning than 24-hours per day, 7-days per week?
3. Can we “farm out” a portion of the cotton dedicated to one gin that may be exceeding 200% utilization to another having a commitment of less than 100% utilization and provide a more efficient harvesting/ginning system?
4. Is there a process that can be used to partially pay producers for the cotton in modules that may not be ginned for four to six months after harvesting?
5. How far can gins travel to acquire modules for ginning before it is too costly? On what basis will this decision be made?
6. Can we develop an alternative for module mover trucks that will satisfy transportation limitations for axle loadings?

The structure of the ginning and seed cotton transport simulation model is contingent on the following priorities and assumptions:

1. Maintain the option of producing and ginning cotton at levels of five million bales per

year for Texas and 18 million bales per year nationally.

2. With the increasing speed associated with harvesting, it was assumed that producers will opt to harvest their cotton crops as quickly as possible and place their cotton in modules or similar systems.
3. Quality losses associated with weathering of cotton in bolls far exceeded quality losses with seed cotton in modules.

<u>Using GIS to Determine Costs of Transporting Seed Cotton from the Turn-row to the Gin</u>

Project Scope

Modules are being transported further distances as the number of gins decline (figure 1). Transporting modules along the US Interstate System now becomes crucial. Currently, it is likely that many seed cotton module trucks with a load of cotton will exceed the federal tandem-axle weight limit of 34,000 pounds. Drivers in Texas are not allowed to use the Interstate Highway System when hauling modules that exceed the 34,000 pound limit. Fines for doing so are large. Gin owners have experienced large fuel and maintenance costs because they are forced to take a longer return route from the field. The smaller Farm-to-Market, county or state roads may not be as direct a route compared to Interstate System highways. On a long-distance haul this is most certainly true. Costs could be reduced significantly by developing a different transportation method that does not have the axle weight limitation.

Engineering Cost Analyses

Module transport costs must be determined. Avant (2004), developed a model to predict the costs associated with the use of module trucks for hauling seed cotton modules. In the model, assumptions are made for various costs including: purchase of used truck/semi-tractor and trailer, labor, fuel, maintenance, license, insurance; fuel use; shift time; truck speed; amount of cotton per load; and loading/unloading time. The Avant model was adjusted and refined to include straight-line depreciation over 10 years; accounting for stripper and picker cotton; and changes in costs. All assumptions made are:

- A used module truck will cost $50,000 @ 6% interest for a 5 year period
- Straight line depreciation of the module truck over 10 years
- Fuel mileage of 5 mpg
- Diesel cost @ $2.65/gal
- Module truck average speed 45 mph when within 15 miles of gin
- Maintenance costs $1000
- Insurance costs $1000
- License cost $500
- Driver can work a 10 hour day and is paid $15 per hour including benefits
- Module weighs 22,500 pound per load
- 15 bales per module for picker cotton
- 12 bales per module for stripper cotton
- 1 hour loading & unloading time per module

The resulting model of transport cost per bale shown in figure 13, remains flat from 0 miles to 15 miles. In that range, the cost per bale for picker cotton is $4 and for stripper cotton is $5. Past 15 miles the costs increase at different rates, higher for stripped cotton compared to picked cotton. The transport cost per module is the same for stripped and picked cotton and is calculated using equation 1.

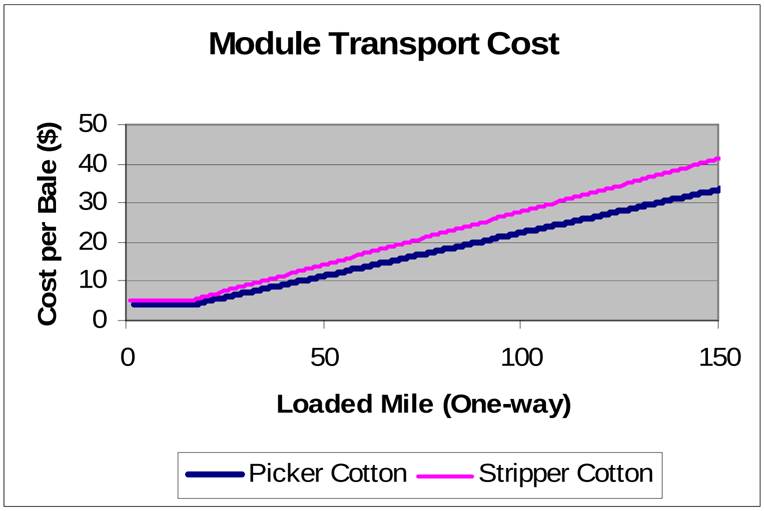


Figure 13. Module transport costs on a per bale rate for picker and stripper cotton.

$$
\begin{aligned}
TC_M &= 60, \qquad d \le 15 \\
TC_M &= 60 + 3.35(d - 15), \qquad d > 15 \qquad (1)
\end{aligned}
$$

d = one-way truck haul distance.

The use of semi-tractor trailers (STT) to transport conventional seed cotton modules has been discussed and experimented with on a limited basis in the U.S. The Australian seed cotton transportation infrastructure uses STTs to transport seed cotton from the field to the gin (Simpson et.al., 2004). The module transport cost model was used with some of the same assumptions. Assumptions are given as:

- A used semi-tractor truck will cost $25,000 @ 6% interest for a 5 year period
- A used semi-trailer with live bottom flooring will cost $50,000 @ 6% interest for a 5 year period
- Straight line depreciation of the semi-tractor and trailer over 10 years
- Fuel mileage of 5 mpg
- Diesel cost @ $2.65/gal
- Average speed 45 mph when within 15 miles of gin
- Maintenance costs $1500
- Insurance costs $1500
- License cost $900
- Driver can work a 10 hour day and is paid $15 per hour including benefits
- Module and one half weighs 33,000 pound per load
- 22 bales per load for picker cotton
- 18 bales per load for stripper cotton
- 1.5 hours loading & unloading time per load

Differences included the need for a module truck to load and unload the modules at the field and at the gin since a STT has no tilt bed. Another added feature is 20% time of an extra laborer to retrieve modules with the extra module truck and store them in a field location within a 10 mile radius at the STT destination for pickup. The time to load and unload modules from a module truck to a STT will increase. It is assumed that the STT driver can load the modules from the module truck alone. The STT is assumed to haul 33,000 pounds. This is considerably more seed cotton than a conventional module holds. Two ways to accomplish an 18 to 22 bale module (depending on stripped or picked cotton) are to construct a larger module builder, or build a module and a half with conventional module builders. The latter has been done successfully on a trial basis. However, loading and unloading the module and a half from a module truck to a STT with a live bottom trailer was not successful in the trial. The problems encountered with chain speed and synchronization can be overcome. The possible cost savings certainly warrant a look at STT use.

The STT model developed and shown in equation 2, indicates that savings can be realized on a per bale basis for long haul distances (figure 14). The STT transport cost model has a higher slope, 90, and y-intercept, 4.5, than the module model 60 and 3.35, respectively. The transport costs resulting from equations 2 and 3 are per load of seed cotton, therefore, one module and one half for STT versus one module for module truck. The transport costs illustrated in figures 13 and 14, on the other hand, are per bale. These models indicate that picking up seed cotton 100 miles away from a cotton gin would cost on average, \$20.13 per bale for picker cotton transported with STT and \$24.56 per bale for stripper cotton and STT; while using a module truck the costs would be \$22.13 per picker bale and \$27.74 per stripper bale.

$$
\begin{aligned}
TC_{STT} &= 90, \quad d \le 15 \\
TC_{STT} &= 90 + 4.5(d-15), \quad d > 15
\end{aligned}
\qquad (2)
$$

where d = one-way STT haul distance.

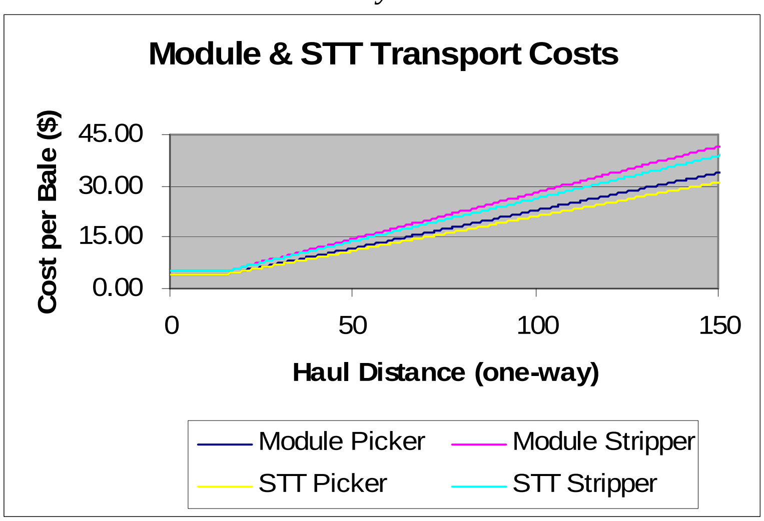


Figure 14. Comparison of transport costs on a per bale basis versus one-way haul distance for module trucks and semi-tractor trailers.

GIS Spatial Analyses and Transport Routine Development

The equations presented above for module truck and STT hauling can now be used for modeling specific transport issues seen in the cotton production areas of Texas. Geographical information systems (GIS) software ArcGIS 9.1, available from ESRI, has been employed for performing spatial analyses. Cost of transport from fields close to and far away from a gin location can now be determined. Routing around a load zone bridge or interstate highway also can be accomplished. The decisions to use a module truck or STT for transport could be made based on cost.

A database of cotton production and ginning information was created using sources including USDA-National Agricultural Statistics Service, Texas Cotton Ginners' Association, and Texas Commission on Environmental Quality. Parameters known for Texas include:

- cotton production for each cotton producing county
- cotton acreage for each county
- cotton ginnings for each county
- number of gins and locations
- permit allowable ginnings for each gin

ArcGIS was used to map the cotton production and ginning situation for Texas. Layers are used in ArcGIS to keep track of separate parameters. A cotton production layer was received from Texas Boll Weevil Eradication Foundation, and included cotton field boundaries and acreage for all of Texas based on 2005 data. A cotton gin layer was produced by locating every active cotton gin using either physical address or latitude/longitude. A color infrared photography layer was received from USDA-FSA Specialist Bryan Crook in College Station, Texas. The color infrared layer was used to check the location of many gins to make sure the address or lat./long. information was correct. A Texas highway and road layer from Tele Atlas was specially purchased from ESRI and provides the vast network of road system from Interstate Highways to local roads for Texas.

The cotton field boundaries were received as polygons but were converted to points in order to calculate transport distances from the individual fields using the Transport Analyst feature in ArcGIS 9.1. Each field point was located in the centroid of the polygon. The closest road within 1000 meters was used to begin the transport of each module built in the field. Modules were transported to the closest gin.

An example of the spatial data gathered is displayed for Lubbock county in figure 15. Gins and cotton fields are laid out on a road map for the area. The centroid points of the fields are determined and replace the polygons. The transport routine is run for each of the fields in the county and routed using local, county and state roads. The Intersate Highway is avoided in figure 15. Each destination is the closest gin no matter if it is located in Lubbock county or an adjacent county.

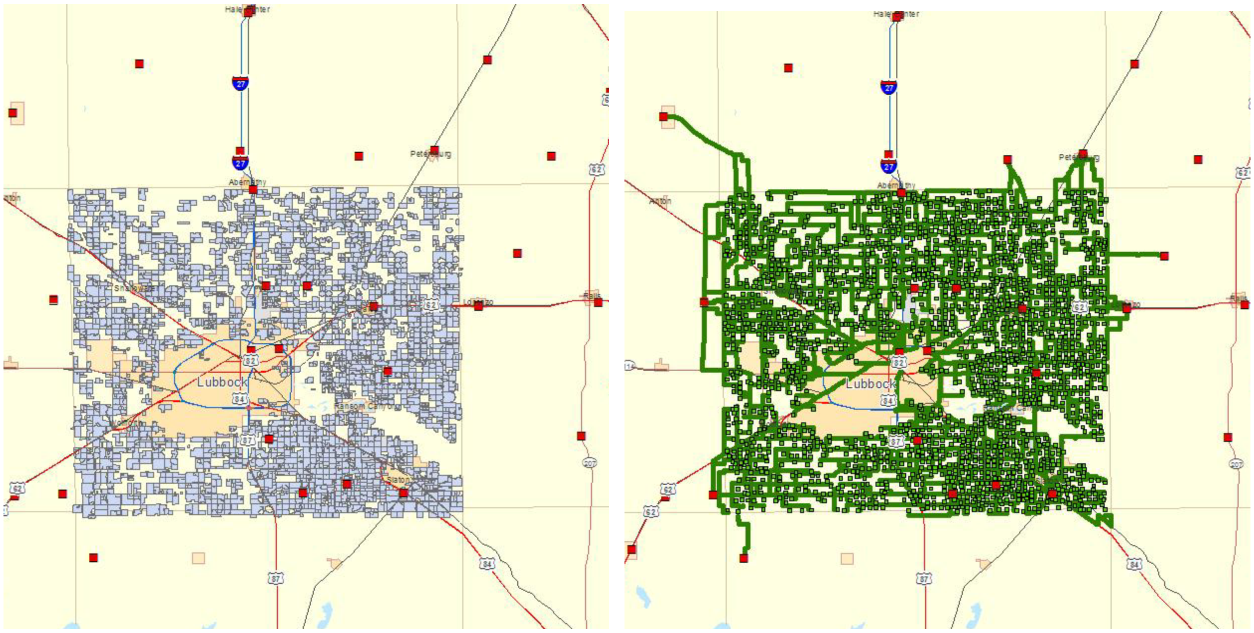


Figure 15. Lubbock county area is shown with gin locations as red dots and the highway system. A) Grey-blue polygons indicate field boundaries where cotton was grown in 2005. B) Green dots represent the centroid of cotton fields and green lines are transport routes from fields to gins.

Combining the data base of information for production yield, an engineering cost analysis was performed for transport costs within Lubbock cotton. In this area 288,000 acres produced 29,500 modules of seed cotton from 2013 fields. Those 29,500 modules were transported a total distance of 11,300 miles to the nearest gin. The resulting costs were $1,770,000, using equation 1, when transported by module truck. However, the costs when transported by STT were $1,800,000, using equation 2, resulting in a $30,000 increase. The STT system did not provide a savings in this example due to the short distance of haul, because all of the fields were within 15 miles to the closest gin.

An example of long-distance transport is shown in figure 16, for West Texas. Producers many times want to process cotton with a gin that is further away than the local area gins. In the example, cotton was transported from ten fields approximately 150 miles, one-way haul distance, to the gin.

Figure 16. ArcGIS output showing the transport route for cotton from Del City to Gaines County, Texas.

The engineering cost analysis for the above example is presented in Table 9. Each row represents a field of cotton and provides the one-way mileage the number of bales, module or STT loads, and cost using either equation 1 or 2 as applicable. Trips made with the module system total 318, while only 214 trips are made with the STT system. At a 150 mile distance from field to gin, the module trucking costs is $159,960, compared to $150,530 for the STT costs. A cost savings of $9,430 is realized with the STT system.

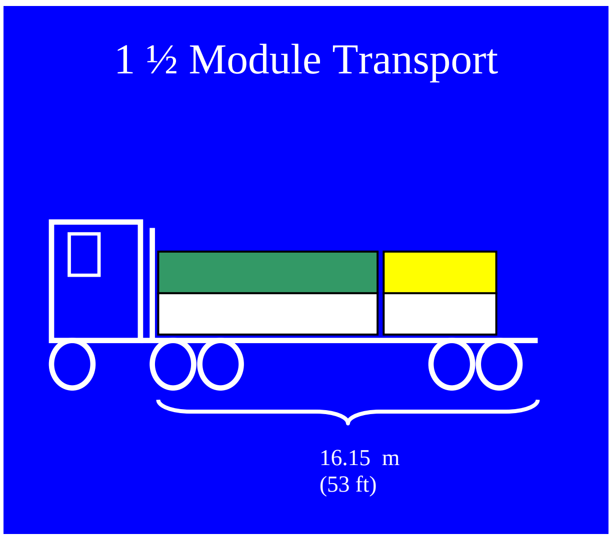
Table 9. Engineering cost analyses of transport using module trucks versus STT for transport from Del City to Gaines County.

Miles	Bales	Modules	STT Loads	Model Cost Module Truck	Model Cost STT
150	245	21	14	$ 10,495	$ 9,785
150	251	21	14	$ 10,488	$ 9,778
150	249	21	14	$ 10,479	$ 9,769
149	347	29	20	$ 14,403	$ 13,892
150	618	52	35	$ 25,893	$ 24,373
153	285	24	16	$ 12,203	$ 11,375
153	275	23	16	$ 11,671	$ 11,352
154	279	24	16	$ 12,252	$ 11,420
153	276	23	16	$ 11,704	$ 11,384
152	949	80	53	$ 40,373	$ 37,402
SUM 1514	3774	318	214	$ 159,960	$ 150,530

The transport of one and one half modules worth of seed cotton may be accomplished rather easily with the new Case IH Module Express 625 system in which a 2.44 m (8 ft) tall by 2.44 m

(8 ft) wide by 4.87 m (16 ft) long module is produced. Three of these half modules could be loaded onto a 16.15 m (53 ft) trailer. A conventional module system would require either modification to the module builder to make a half module, or building a full module then pulling forward half way and building a half module, making sure to place a separator between the full module and half module. A full module and a half module would then fit easily onto a 16.15 m (53 ft) trailer as exemplified in figure 17a.

Transport of two modules per trailer is shown in figure 17b. The problem with two modules per trailer is a length issue. Conventional modules are 10.06 m (32 ft) long and would require at least a 20.12 m (66 ft) trailer. The Texas DOT and other states have restrictions for single trailer lengths of 18 m (59 ft) or 8.70 m (28.5 ft) for two trailers pulled by one tractor. An argument to the DOT for allowing longer trailers may be possible if the load per axle were reduced.



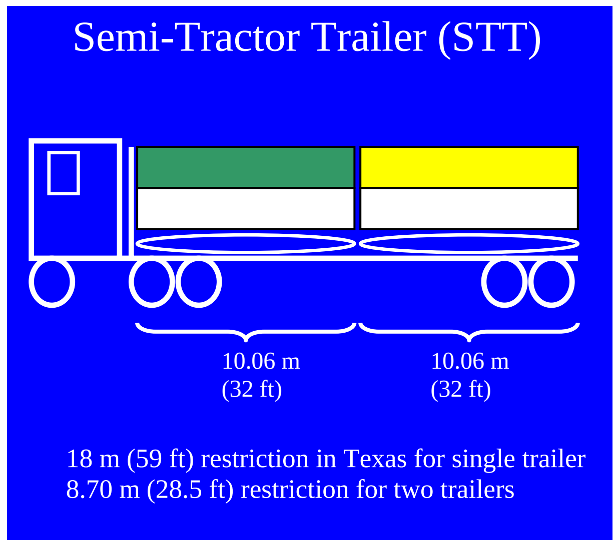


Figure 17. A) Transport of one and one half modules would fit on a regular 16.15 m (53 ft) trailer. B) Transport of two modules would require a 20.12 m (66 ft) long trailer.

Figure 17b also illustrates the idea of having a live bed trailer for loading and unloading modules. A module truck operator backs up to the trailer and the bed chains, walking floor, or other system would be synchronized with the trailer chains for moving the modules at the same rate.

The ArcGIS transport analyst feature may be used as a decision aid not only for reducing costs by deciding between module trucking and STT trucking, but also for directing custom haulers or new gin employees on local roads with which they are not familiar (figure 18); or determining the best route for transport (figure 19).

In the Corpus Christi, Texas area this past ginning season, one gin did not operate due to crop losses. There are six other gins in the immediate area. Parnell, et. al (2006) describes a process where gin managers at gins operating at percent utilizations above 100%, “farm out” cotton to adjacent gins that are operating below 100% utilization. To accomplish this “farming out” process, the module truck operators may need aid in locating fields. The transport analyst provides that aid in the form of turn-by-turn directions.

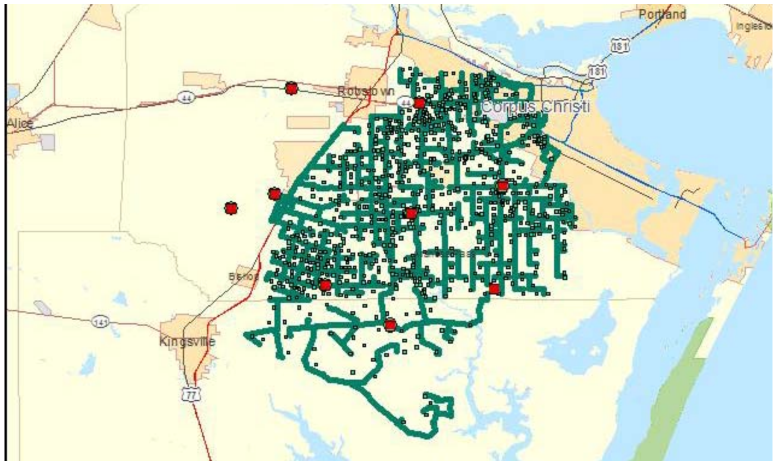


Figure 18. Transport routing for Corpus Christi area fields and gins.

The two maps of the Amarillo area show different routes for transporting modules from 124 fields to the same gin. Module truck drivers will use Interstate Highways or access roads on a return trip with a full load of cotton. Using Interstates and even the access roads is illegal, as mentioned before. However, the risk and cost of being pulled over and ticketed on the Interstate is lower than the cost of traveling much further distances to avoid the Interstate. Figure 19a is the routing using the Interstate access roads and 19b shows routing using roads other than the Interstate. If we assume 10 modules per field, using the Interstate access roads, the total distance traveled would be 102,500 miles. Comparing to 124,200 miles for the non-Interstate roads, we see a difference of 21,700 miles.

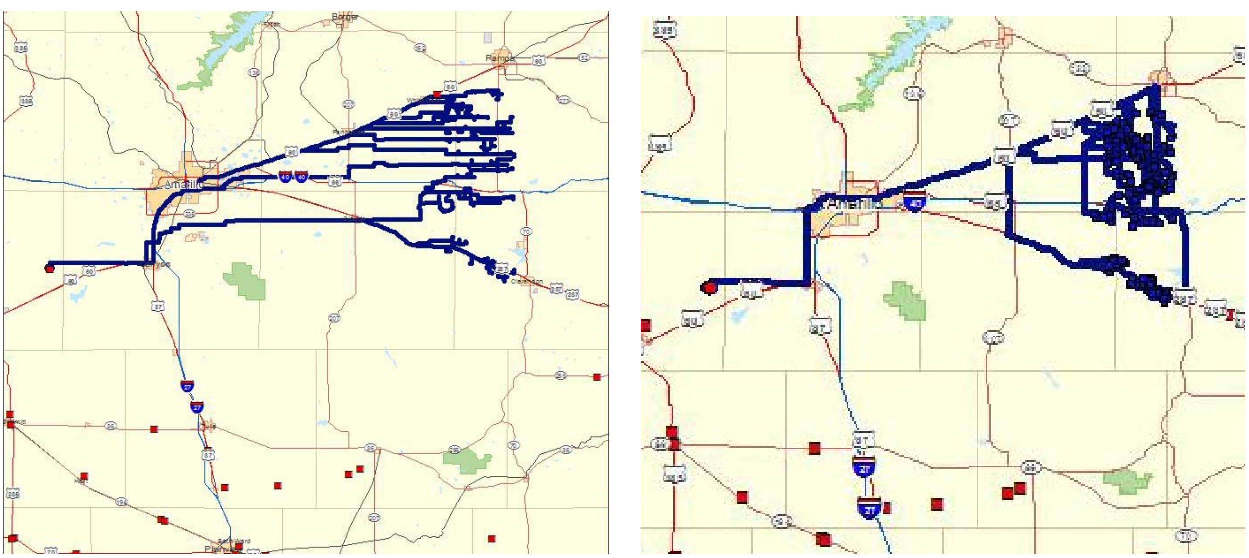


Figure 19. A) Routing fields on the east side of Amarillo to a gin on the west side of Amarillo with the use of Interstate access roads. B) Routing the same fields to the gin using roads other than the Interstate access roads.

At some point, the highway patrol may tighten surveillance or stiffen penalties for overloaded vehicles traveling on the Interstate. The STT system and GIS transport analyst routine would then provide great tools for the ginning industry to lessen costs and remain in operation.

Summary

Equations for modeling costs of module truck transport and STT transport have been determined using assumptions for fixed and variable costs. Picker cotton transport costs are lower than stripper cotton transport costs due to different amounts of seed cotton versus trash being hauled. The cost for transport of modules using the conventional module truck or STT system within fifteen miles to the gin is a flat rate of either \$60 or \$90, respectively.

Geographic Information Systems (GIS) tools are being applied to cotton transport situations for optimization of resources. A transport analyst routine allows determination of distances and various routing for module transport. Combining the results from the analyst with the cost equations allows researchers to perform an engineering economic analysis.

The gin manager and cotton producer both can benefit from a semi-tractor trailer (STT) based module transport system as well as a computer based transport tool which automates the logistics of hauling seed cotton modules. Costs can be reduced, time saved, and efficiencies in transport and ginning gained. The main advantages of using a computer based logistics tool are:

- Optimizing truck routes to minimize travel time and distance traveled,
- Scheduling trips to and from fields,
- Providing directions to truck drivers,
- Using GPS in truck to guide drivers directly to fields/modules, and
- Locating modules in fields.

Future Work

Development of the transport tool is on-going in the Department of Biological and Agricultural Engineering at Texas A&M University.

The physical challenges of STT transport are a key factor for success of transporting more seed cotton per load from field to gin. Several trailer ideas and half module transport ideas have been implemented on a trial basis in the cotton industry to overcome the physical challenges described. However, most ideas have been abandoned. The farmers and ginners that were trying those systems may provide input and cooperation on additional experiments with transport.

<u>Seed Cotton Handling and Ginning – Cotton Ginning Simulation Model (CGSM)</u>

<u>Ginning Operation</u>

Method of Research

One of the goals of this research effort is to develop a model of ginning costs (fixed and variable) using data from surveys and historical data provided by cooperating Texas gins. The annual report for 2004-05 reported progress on this goal using data from a survey performed by Valco (2002). Progress made has included the addition of results from a later survey by Valco (2004). In this progress report we will be including results from the combination of the two surveys. The total number of gins included from survey data was 100. The survey data focused on variable costs with limited information on fixed costs. Not all of the variable costs were included in the survey results. In addition to the survey data, we were able to obtain two to six years of historical data from cooperating Texas gins. The historical data provided by the cooperating gins provided the basis to approximate missing variable cost information as well as fixed costs.

Procedures – Economic Data of Gin Surveys

Historically, harvested cotton is ginned as quickly as possible so that producers can realize income from selling their lint and seed. In addition, the fiber and seed quality losses are minimized when the seed cotton is ginned soon after it is harvested. As the number of active gins decline, the option to process seed cotton upon delivery to the gin will not be possible. Hence, a new harvesting, seed cotton storage, and ginning management system will be adopted in the future. The structure of this proposed model is described as follows:

- A cotton gin rated at 'R' bales-per-hour (bph) will process seed cotton at a rate of 0.8*R (bph).
- A cotton gin operating at 100% utilization is defined as processing seed cotton at the average rate of 0.8*R (bph) for 1000 hours. In other words, 100% utilization corresponds to a 1000-hour season operating at 80% of the gin's rated capacity.
- Ginning costs will include variable and fixed costs.

Variable costs include (1) bagging and ties; (2) repairs and maintenance; (3) drying; (4) electric power; (5) seasonal labor; (6) module hauling (using equation 1); and (7) tarps. Variable costs increase or decrease with the number of bales ginned.

Fixed costs include (1) depreciation; (2) annual loan payments (annuity); (3) management; and (4) taxes, shelter, and insurance (TSI). Fixed costs were assumed to be independent of the number of bales ginned.

Fuller et al., (1993) published procedures for estimating fixed and variable costs per bale for gins and introduced the concept of percent utilization. Ginning cost data obtained from surveys conducted by Valco (2002 and 2004) were used to formulate variable, fixed and total costs versus percent utilization equations. The survey data were subdivided into categories defined by by ginning rates. Variable costs were obtained from the survey results or estimated. The variable costs reported by Valco (2002 and 2004) were used for this progress report. These survey data contained limited information on fixed costs. Assumptions were made with the historical data to approximate fixed costs (Parnell et al 2005 and 2006).

Results

The following tables illustrate the results of calculating variable and fixed costs for the operations of the gins using survey and historical data. The ginning rate categories were as follows: (1) <15 bph, (2) 15-25 bph, (3) 25-40 bph, and (4) >40 bph.

Table 10 shows a sample of how the survey data were used to calculate hours per season and percent utilization. The survey data provided the bales per season and the ginning rates. Hours per season were determined based on the definition of percentage utilization (%U). For example, gin #1 processed 1412 bales. Had this gin operated at 100 % U (1000 hours at 80% of its reported ginning rate of 10 bph), 8000 bales would have been ginned. From the survey, only 1412 bales were ginned. Hence, the number of hours needed to process 1412 bales can be calculated as follows: [(1412/8000)*1000=177 hours] Percent utilization was calculated by dividing the hours needed by 1000. For this gin, its %U = 18%.

Table 10. Sample calculations of hours per season and percent utilization for 8 gins in the <15 bph category. The bales per season and rated ginning rate (GR) were taken from survey data.

Gin	Bales per Season	Rated GR bph	Hours per Season	Utilization %
1	1,412	10	177	18
2	14,471	12	1507	151
3	5,404	12	563	56
4	10,934	14	976	98
5	9,187	12	957	96
6	11,459	12	1194	119
7	6,436	11	731	73
8	3,095	12	322	32

The average variable cost per bale for each gin size category are listed in Table 11. The average cost of electric power, seasonal labor, and bagging & ties decreased with increasing gin size. Repairs and maintenance and drying costs seem to fluctuate or even increase for increasing gin size. It is difficult to make general statements about the average costs of the two categories “repair and maintenance” and “drying costs”. In wet harvesting seasons, the cost of drying seed cotton is significantly higher than in dry harvesting seasons. In addition, some gins use propane while others use natural gas. In the past natural gas drying was less expensive. Likewise, older gins will require more expenditures for “repair and maintenance” than newer gins. It is likely that larger gins have higher costs associated with repair and maintenance than smaller gins just because the equipment that breaks down is larger and more expensive. The variable costs associated with “module hauling” and “tarps” were approximated using historical data. It is likely that these categories will vary significantly with varying service areas (module hauling) and % U (Tarps). The average variable cost for all gin sizes for use in modeling was determined to be $26 per bale.

Table 11. Average variable costs per bale for each gin size category. Averages were based upon Valco et al. (2002 and 2004) survey data except for the variable costs associated with “module hauling” and “tarps”. The module hauling and tarp variable cost averages were estimated from limited historical data.

	Electric Power	Drying	Labor	Repairs & Maintenance	Bagging & Ties	Module Hauling	Tarps	Variable Cost per Bale
<15 bph	$4.00	$1.30	$10.20	$5.10	$3.60	$4.00	$1.10	$26.30
15-25 bph	$4.00	$1.20	$7.50	$4.10	$3.60	$4.00	$1.10	$25.50
25-40 bph	$3.90	$1.10	$7.20	$5.20	$3.40	$4.00	$1.10	$25.90
>40 bph	$3.20	$1.30	$5.50	$6.20	$3.20	$4.00	$1.10	$24.50

These variable cost data were combined with fixed cost data to produce total costs per bale. The methods used to estimate fixed costs were reported by Parnell (2004, 2005, and 2006). The total fixed cost per bale vs. percent utilization equations that were generated are displayed in figures

19 through 22. Figure 19 shows data for 29 gins in the category < 15 bph, with a majority of gins operating below 100 percent utilization. The slope of the total fixed cost per bale from 0%U to 100%U is high. This result illustrates that the per bale ginning costs increases rapidly as the %U decreases from 100 %U. These high ginning costs at low %U may be partially responsible for the reduction in numbers of smaller gins. The optimum operating point for total cost per bale occurs at 170 %U. All gins surveyed in this size category were operating at levels of less than the optimum of 170 %U.

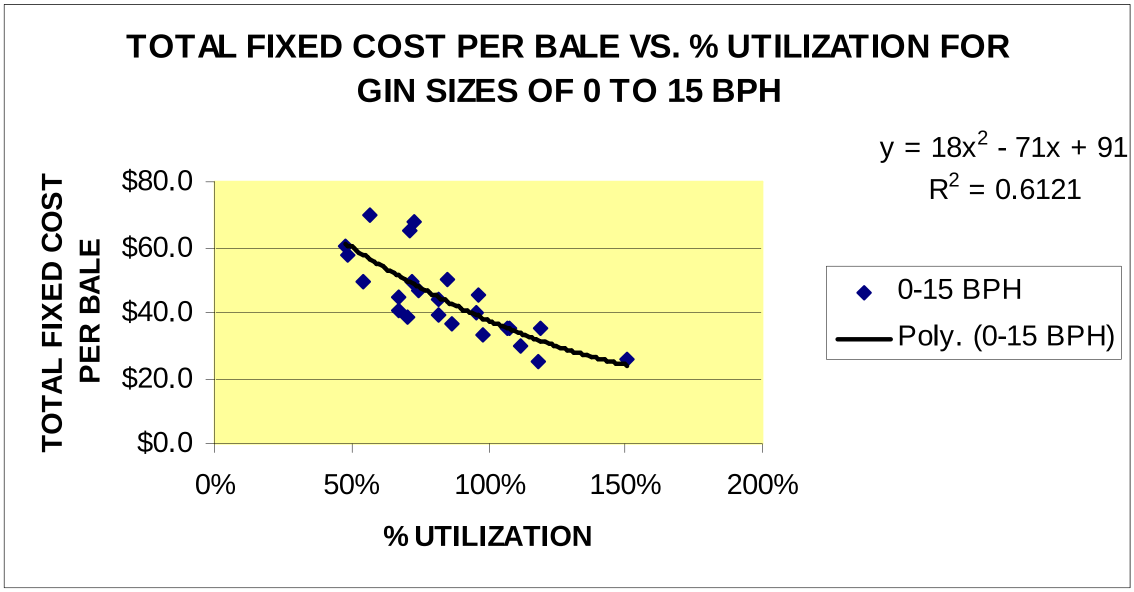


Figure 19. Total fixed cost per bale versus percent utilization from survey data for gins less than 15 bph (Valco, 2002 and 2004).

Figure 20 shows the results of the analysis of cost data versus %U for gins ranging in size from 15 to 25 bph. The total fixed cost per bale was less variable and the slope of the line from 50 to 100 %U was less than that for gins less than 15 bph (figure 19). Many of the 36 gins in this category achieved over 100 percent utilization and some approach 200 percent utilization. The optimal operating point for gins in this category was 180 percent utilization. We included five years of historical data for a 25 bph picker gin that was in this size range. The historical data closely followed the trend line calculated from the survey data.

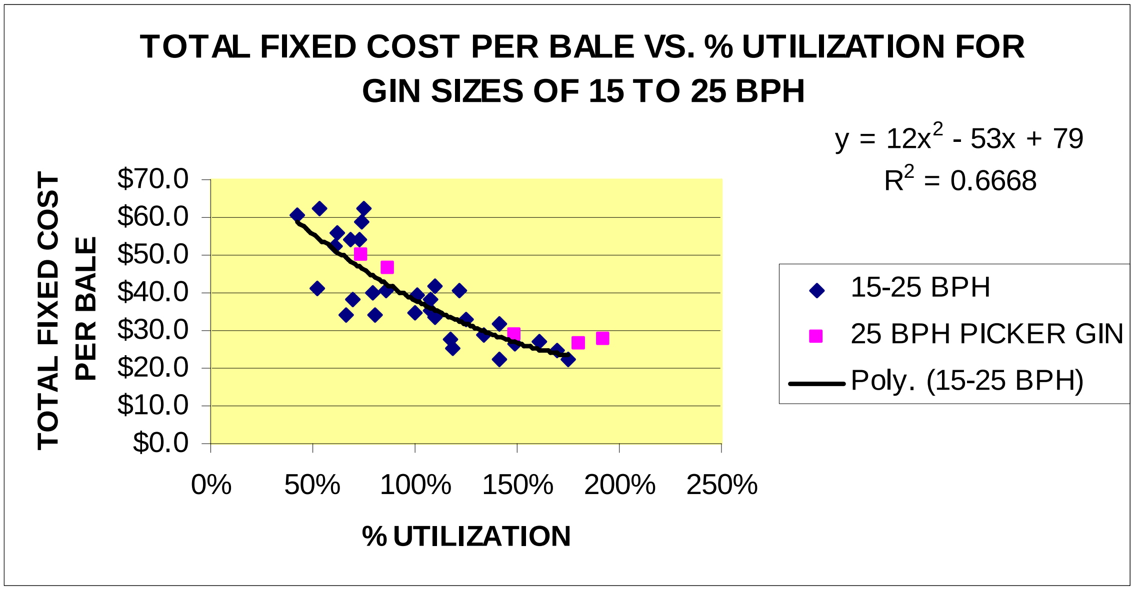


Figure 20. Total fixed cost per bale versus percent utilization for 36 gins from survey data for 15 to 25 bph (Valco, 2002 and 2004) and 5 years of historical data from a 25 bph picker gin .

Figure 21 shows the results of the analysis of cost data versus %U for gins in the size category of 25 to 40 bph. Survey data from a total of 22 gins were included. Also displayed are historical data for a 40 bph gin processing stripper cotton. The historical data closely followed the trend line calculated from the survey data. Many of the survey gins were operating at higher than 100%U. A few of these gins exceeded 200%U. The optimal operating point determined for this gin size category was 180 %U.

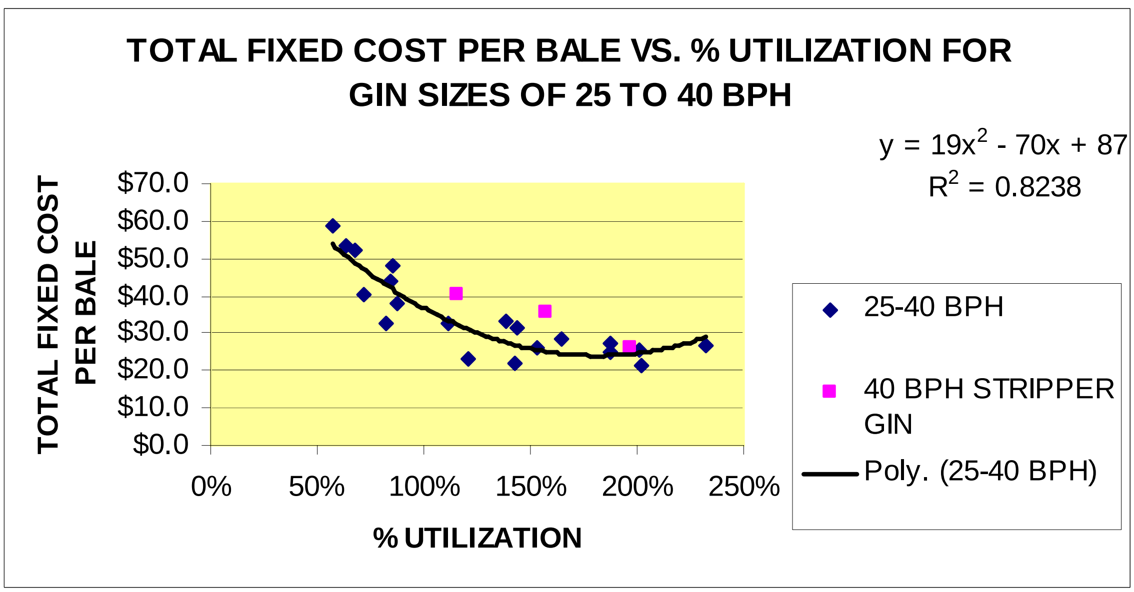


Figure 21. Total fixed cost per bale versus percent utilization from survey data (Valco,2002 and 2004) for gins 25 to 40 bph and historical data from one gin.

Data from 15 survey gins and 11 years of data from two historical gins are shown in figure 22. Gins that were rated at greater than 40 bph consistently operated between 100 and 200 percent utilization with several of the gins operating in excess of 200 %U. The historical data closely follows the trend line calculated from the survey data. The optimum operating point for gins in this category was 240 %U.

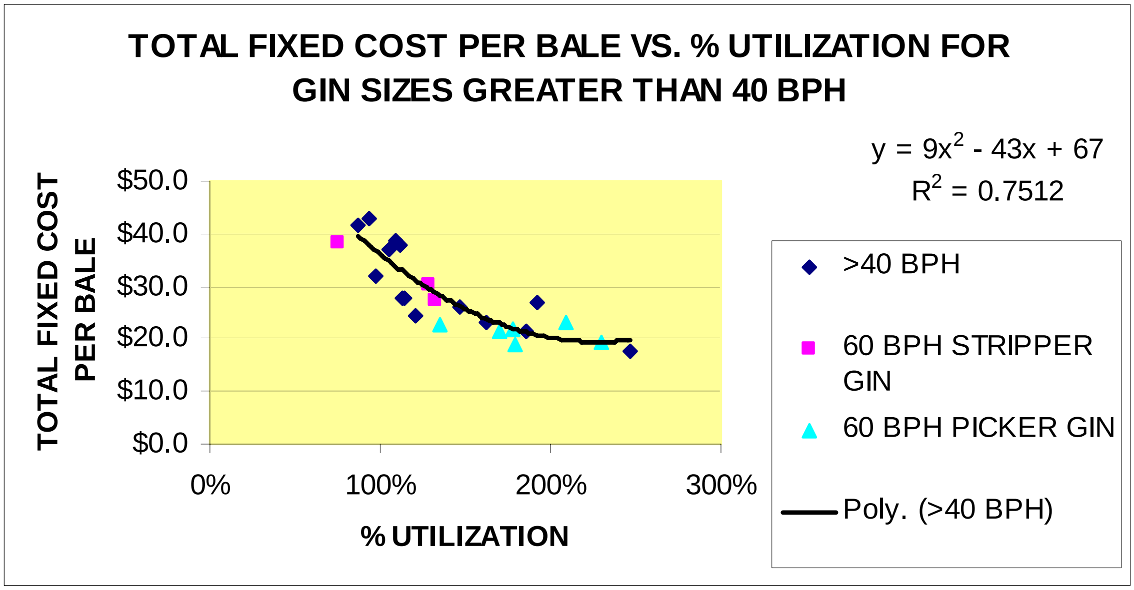


Figure 22. Total fixed cost per bale versus percent utilization from survey data (Valco, 2002 and 2004) and historical data from two gins.

The equations determined using regression to represent the data from figures 19-22, are each quadratic. These quadratic representations were developed into a preliminary Cotton Ginning Simulation Model (CGSM) for answering the questions posed in the project scope. The initial question to begin the modeling process and one that many ginners need to look at in the near future is: Should I expand my rated capacity (or bph capability)?

A single yes or no answer is quite difficult to provide and not the goal for the CGSM. The CGSM is being developed to be decision support software that will aid ginners in answering the question. One example shown in table 12 looks at a theoretical gin that would presently operate at a 30 bph rated capacity. With production levels above average production, the gin manager may want to consider adding or expanding equipment to increase to 45 bph rated capacity. Using the CGSM and assuming that next year's expected throughput will be 48,000 bales, the added cost per bale for ginning is $1, and the added total cost is $60,800. If the ginner is confident that production levels will remain high for the service area, then expanding may be a good decision.

However, if the gin is in an area of unstable production and could be affected by price of alternative crops or lack of rain, expansion may not be good. Consider the same gin with an expected throughput of only 24,000 bales. The cost per bale increases in table 12 for both scenarios of a 30 bph and 45 bph gin. The expanded gin results in higher per bale costs and a cost increase of $118, 400.

Table12. CGSM output for determining if 30 bph gin should expand to 45 bph.

Annual throughput expected = 48,000 bales			
	% Utilization	Total Cost	Total cost per Bale
Present Gin (30 bph)	200	$2,347,200	$49
New Gin (45 bph)	133	$2,408,000	$50
(Cost)/Savings per Year		($60,800)	
Annual throughput expected = 24,000 bales			
	% Utilization	Total Cost	Total cost per Bale
Present Gin (30 bph)	100	$1,485,600	$62
New Gin (45 bph)	67	$1,604,000	$67
(Cost)/Savings per Year		($118,400)	

A second example using the CGSM is presented in table 13. Here another hypothetical gin operates at 50 bph and the gin manager considers expanding to 75 bph. At current production levels an expected throughput of 40,000 bales results in $58 per bale cost at 100%U for the 50 bph rated capacity. Of course the 75 bph rated capacity gin will operate at higher per bale costs of $67, due to the lower %U. However, assume the expected throughput is increased to 80,000 bales due to increased irrigation capacity and increased production. The 75 bph rated gin would operate at 133%U and only $50 per bale costs. The decision to expand may a positive. If the manager did not expand and remained at 50 bph, the gin would operate at 200%U and costs would decrease even more to $42 per bale. But, the gin equipment and seasonal labor may be exhausted and difficult to retain.

Table 13. CGSM output for determining if 50 bph gin should expand to 75 bph.

Annual throughput expected = 40,000 bales			
	% Utilization	Total Cost	Total cost per Bale
Present Gin (50 bph)	100	$2,300,000	$58
New Gin (75 bph)	67	$2,673,333	$67
(Cost)/Savings per Year		($373,333)	
Annual throughput expected = 80,000 bales			
	% Utilization	Total Cost	Total cost per Bale
Present Gin (50 bph)	200	$3,320,000	$42
New Gin (75 bph)	133	$4,013,333	$50
(Cost)/Savings per Year		($693,333)	

Findings

- Variable cost per bale versus %Utilization is a flat relationship and best described as $26 per bale.
- Multiple year, historical data from 10 gins provided additional confidence in the fixed cost per bale versus %Utilization relationship. A curve represented by a quadratic equation was fit to the fixed cost data. The optimal point or vertex of each curve and the

portion of the curve to the left of the vertex fits our models very well. The portion to the right of the vertex is more ambiguous and additional historical data should be used to either confirm the quadratic representation or determine the correct model to use for that portion past the optimal.

- The Cotton Ginning Simulation Model (CGSM) is new decision support software under development. Cotton gin managers will be able to use the CGSM to aid them in choosing to upgrade their facility based on engineering economics.

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