Engineering Systems for Seed Cotton Handling, Storage and Ginning

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Abstract

The number of operating cotton gins in Texas has steadily declined in the past 40 years from 1400 to less than 280 while the production of cotton has remained at approximately 4-5 million bales. In order to market the 5 million bales with fewer gins, the remaining gins will be processing more seed cotton in the future. It is likely that the cotton ginning industry will be faced with longer seasons with associated issues relative to variable and fixed costs, transporting modules longer distances from farm to the gin and finding acceptable methods of at least partially paying producers for the cotton lint and seed value. These changes in the harvesting/ginning interface will likely result in a new system of handling and ginning of seed cotton. The goal of this study 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 future of the cotton industry.

Results from this study have shown that the fixed cost per bale follows a negative exponential trend as the percentage utilization of gin is increased. The average fixed cost per bale was estimated to be about $30 while the average variable cost was estimated at $20 per bale following the assumptions used. The average total cost was estimated at about $50/bale. A relationship was developed relating the total cost of gin operations as a function of utilization rates for the different ginning rate categories. This initial result provided a general trend on how the operation of cotton gins could be made more efficient.

The term "percent utilization" of a gin is defined in this study. One-hundred percent (100%) utilization is the ginning rate multiplied by 0.8 efficiency and 1000 hours. It is anticipated that this mathematical descriptor may be used in the future for management decision support. It may be possible for gins to take advantage of economies of scale in their ginning operations. The immediate consequence of ginning more cotton with fewer gins will be the expected transport issues associated with moving large numbers of seed cotton modules over longer distances and the problem of transporting them utilizing the Interstate Highway System. This will be the topic for subsequent systems analysis work.

Introduction

Cotton producers in the United States (U.S.) produce, harvest, and process approximately 18 million bales of cotton per year of the world-wide production of 100 million bales. Post-harvest processes have evolved from hand harvesting to machine harvesting, placing seed cotton in modules rather than trailers, storing modules on the turn-row and transporting cotton modules to gins with module trucks. Agricultural engineers have played major roles in the development of the current system. Faculty in the Texas A&M University (TAMU), Department of Biological and Agricultural Engineering (BAEN) have led the efforts to advance technology for handling, storage, and preservation of lint and seed quality from the harvesting point through the gin. Professor Emeritus Lambert Wilkes (Wilkes et al, 1974) was credited with developing the 'module builder' method of seed cotton handling and storage with funding from Cotton Incorporated in the early 1970s. Approximately 90% of all cotton produced in the U.S. today is placed in 10 to 16 bale modules. The primary reason that the US has fewer cotton gins operating today is largely due to the module system of handling seed cotton. Although there are fewer gins, the US has maintained cotton production at a relatively constant or increasing level (Figure 1).

In Texas alone, gin numbers since 1960 have plummeted from close to 1,400 to less than 280 active gins in the 2004 ginning season (Figure 1). The number of operating gins for cotton producing states in the U.S. followed similar declining trends. Regression results with number of Texas active gins as a function of time from 1983 to 2003 suggests that there will be no operating gins by 2018 (R^2 value 0.98). Of course this will not happen. From Figure 1, it is evident that Texas production numbers are remaining steady and even increasing slightly at around 5 million bales. It is anticipated that there will be a production of 7 million bales in this state this year (2004/2005).

The reduction in number of operating gins across the cotton belt as demonstrated by data from Texas, suggest that gins will either increase their respective ginning rates, increase the length of the ginning season, transport seed cotton for longer distances from the turn-row to the gin storage site, or adopt a combination of all of these scenarios.

Transportation of modules over longer distances and transporting along the Dwight D. Eisenhower System of Interstate and Defense Highways (Interstate System) now becomes critical. Currently, seed cotton module transportation trucks, when loaded with a module, will exceed the federal requirement of 34,000 pound tandem-axle weight limit. Drivers for gins must not use the Interstate System when transporting modules from the field to the gin. For those gins located near Interstate System roads, owners have experienced large fuel and maintenance costs due to longer return-trips along (lesser load-bearing) farm-to-market, county or state roads. Costs could be reduced significantly by establishing a different transportation method that would keep axle weight within requirements and allow the use of the Interstate System.

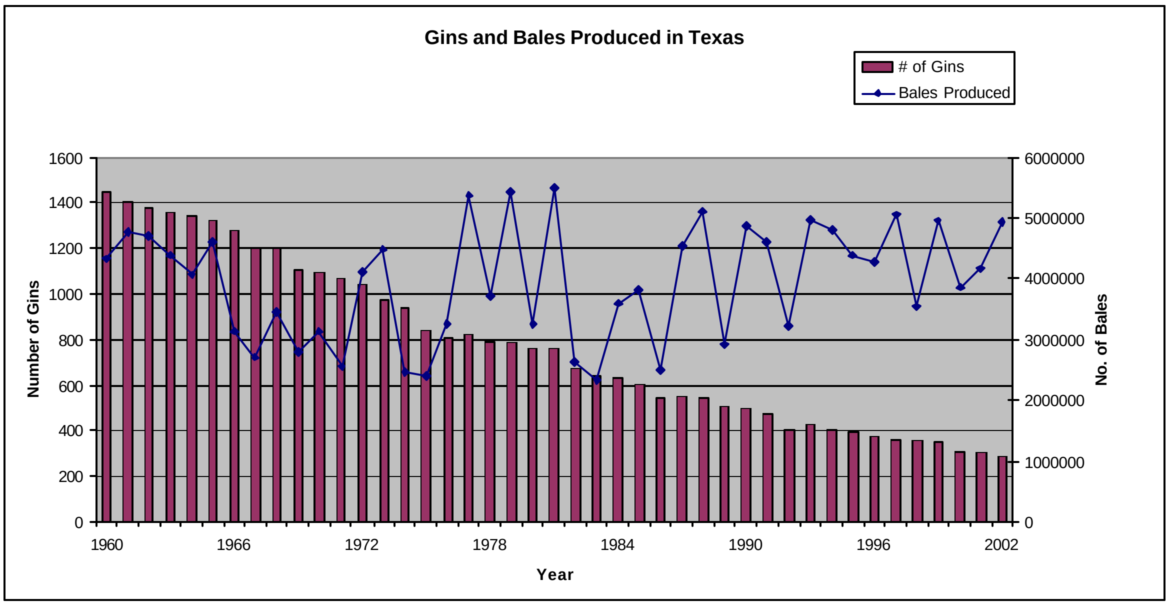

Figure 1: Number of operating gins and cotton production in bales from 1961 through 2003 in Texas.

It was assumed that the goal of any new paradigm of harvesting/ginning will have the following priorities:

1. Maintain the option of producing cotton at levels of 5 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. This priority presumes that the quality losses associated with weathering of cotton in bolls far exceeded quality losses with seed cotton in modules.

The ginning rates for the 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 indicated a possible expansion to 90 bph. (This will likely require two presses.)

Goals and Objectives

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 4-6 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 research goals are as follows:

1) Formulate practical scenarios for a new seed cotton handling, storage and ginning system that would result in extended ginning seasons and cost reductions. The issues addressed would include (a) the optimum gin size (ginning rate) (b) optimum ginning season, (c) maximize energy savings (operating off-peak), (d) maximize labor savings, (e) minimize insurance costs, and (f) minimize gin equipment maintenance costs. The evaluations will be made using Monte Carlo simulations.

2) Formulate feasible seed cotton transport systems that could be implemented in Texas with the gin service area expanded to 100 and 150 miles.
   a) Study the use of semi-tractor trailers (STT), or other system, for moving seed cotton modules from the farm to long-term storage locations near a gin with simulations.
   b) Develop a method of loading and unloading seed cotton modules into STT, or other system, and demonstrate the feasibility of this method on model systems.

Systems Model Structure

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 quickly. 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 rated processing rate.
- Ginning costs will include variable and fixed costs.

Variable costs include (1) bagging and ties, (2) repairs, (3) drying, (4) electricity, and (5) labor. Variable costs increase or decrease with the number of bales ginned.

Fixed costs include (1) depreciation, (2) interest, (3) insurance, (4) taxes, and (5) management. Fixed costs typically were assumed to be independent of the number of bales ginned. It is anticipated that the cost of transporting seed cotton from the turn-row to the storage location near the gin would be calculated using the following equation (Simpson et al, 2004).

$$TC = \$60+\$2*X \qquad (1)$$

TC = transportation costs, and
X = number of miles beyond 15 miles

Transportation costs were not incorporated in this paper. It will be the subject of a future paper.

- The 'X' in equation 1 is dependent upon the probability distribution describing bales of cotton as a function of distance from the gin in the cotton gin's service area. At present, the following relatively simple distribution will likely be used.
   - For a gin operating at 100% utilization, 50% of the cotton will be gathered inside a 15-mile radius defined by a uniform distribution. The remaining 50% will be gathered at a distance that is defined

by a linear line from the peak of the uniform distribution to a distance equivalent to the remaining 50%.

- For a gin operating at 200% utilization, a similar process will be used to define the distances with the assumption that the yield inside the 15 mile radius can approach a limit of the number of bales defined by 200% utilization.

Ginning cost survey data were gathered from Texas ginning facilities (Valco et. al. 2003 and Valco, et al., 2004). Fuller et al., (1993) published procedures for estimating fixed and variable costs per bale for gins. The Valco data were arranged by gin category according to ginning rates. Variable costs were obtained from the survey results or estimated. The variable costs reported by Valco et al (2003) were used in this paper. Fixed costs were calculated using data provided in the Valco survey and some assumptions were made for insufficient data.

Results

The following tables illustrate the results of calculating variable and fixed costs for the operations of the gins using the data from the Valco survey. The ginning rate categories were as follows: (1) <10bph, (2) 10-15bph, (3) 15-25bph, (4) 25-35bph, and (5) >35bph. Table 1a shows an example of a fixed cost data table for the 10-15 bph capacity gins. Data in columns 1-3 came from the Valco survey. The percentage utilization was calculated using the definition of 100% utilization (0.8*bph*1000). The percent (%) utilization was determined using the ratio of the data in column 2 divided by the corresponding data in column 4. The hours-per-season data were calculated from the percent utilization multiplied by 10 or the fraction of percent utilization multiplied by 1000 hours. Investment cost was approximated using $0.05 million * bph. Table1b shows additional fixed cost data for the 10-15 bph capacity gins. Depreciation was calculated based upon 10-year life span and zero salvage value. The initial investment cost was amortized at 5% interest rate over a 10 year life span of the project. A 25% corporate tax rate was used based upon an assumed $5 per bale profit. The fixed management cost was estimated following the procedure described by Fuller et al (1993). Table 2 shows the results of calculations for the variable costs. Data in all columns came from the Valco (2003) survey. Missing data were estimated using average values. Some data points were outside of 3 standard deviations of the mean and were replaced with average values. Table 3 shows the summary of analysis of the variable, fixed, and total costs for the five ginning rate categories. The average fixed and total costs for the gin category of 10-15 bph excluded the high fixed costs for gins 1, 10 and 14 corresponding to very low utilizations for these particular gins.

Table1a. Fixed cost data for gins between 10-15 bales per hour capacity.

Gin	Bales per Season	Bales per hour-rated bph	Bales @ 100% util	% utilization	Hours per Season	Investment Cost $M
1	1,412	10	8000	18	177	0.5
2	14,471	12	9600	151	1507	0.6
3	5,404	12	9600	56	563	0.6
4	10,934	14	11200	98	976	0.7
5	5,350	10	8000	67	669	0.5
6	8,599	10	8000	107	1075	0.5
7	13,404	11	8800	152	1523	0.6
8	5,466	14	11200	49	488	0.7
9	5,779	10	8000	72	722	0.5
10	2,403	13	10400	23	231	0.7
11	9,187	12	9600	96	957	0.6
12	11,459	12	9600	119	1194	0.6
13	6,436	11	8800	73	731	0.6
14	3,095	12	9600	32	322	0.6
average	7,386	11.6	9314	80	795	0.6
min	1,412	10.0	8000	18	176	0.5
max	14,471	14.0	11200	152	1523	0.7

Variable and Fixed Costs for Different Ginning Rate Categories

The average variable and fixed cost for the different ginning rate categories were estimated at $22 and $26, respectively. The variable cost ranged from $18/bale to $25/bale. The fixed cost ranged from $19/bale to $29/bale. The total cost was calculated at $48/bale. The average total cost ranged from $36/bale to $53/bale.

For higher ginning rate categories, the average percent utilization of the gins surveyed increased. This suggests that larger gins will tend to meet or exceed 100% utilization while smaller gins will have utilizations less than 100%. The average utilization rate ranged from 80% to 133%.

Table 1b. Additional fixed cost data for gins with capacity between 10-15 bales per hour.

Gin	Depreciation $M	Interest $M	Insurance $	Taxes $	Management expenses ($)	Total Fixed ($1,000)	Total Fixed/bale
1	0.050	0.065	11824	1765	58000	$248.13	$17.15
2	0.060	0.078	39742	18089	58000	$218.67	$40.46
3	0.060	0.078	21608	6755	58000	$260.49	$23.82
4	0.070	0.091	34468	13668	58000	$194.64	$36.38
5	0.050	0.065	19700	6688	58000	$205.20	$23.86
6	0.050	0.065	26198	10749	58000	$232.74	$17.36
7	0.055	0.071	36708	16755	58000	$242.72	$44.40
8	0.070	0.091	23532	6833	58000	$196.03	$33.92
9	0.050	0.065	20558	7224	58000	$220.84	$91.90
10	0.065	0.084	16506	3004	58000	$230.96	$25.14
11	0.060	0.078	29174	11484	58000	$238.34	$20.80
12	0.060	0.078	33718	14324	58000	$210.09	$32.64
13	0.055	0.071	22772	8045	58000	$211.16	$68.23
14	0.060	0.078	16990	3869	58000	$248.13	$17.15
Average	0.06	0.08	25250	9232		221	29
Min	0.05	0.06	11824	1765		182	17
Max	0.07	0.09	39742	18089		260	44

Table2. Variable costs for ginning operations with capacities between 10-15 bales per hour based on the Valco (2003) survey (* NA data replaced with nominal average value).

Gin	Bales/ Season	GR bph (rated)	Bagging &Ties ($/bale)	Repairs ($/bale)	Electricity ($/bale)	Drying ($/bale)	Labor ($/bale)	Total Variable ($/bale)
1	1,412	10	4.00	7.01	2.70	1.89	5.29	$20.89
2	14,471	12	3.50	6.57	3.84	0.46	8.20	$22.57
3	5,404	12	3.50	2.79	3.00	0.86	10.40	$20.55
4	10,934	14	3.40	5.0*	4.47	1.48	8.69	$23.04
5	5,350	10	4.15	5.0*	4.41	1.03	13.95	$28.54
6	8,599	10	3.65	5.0*	3.02	1.05	5.74	$18.46
7	13,404	11	3.31	4.83	3.41	2.36	11.63	$25.54
8	5,466	14	3.50	5.31	4.27	1.81	18.07	$32.95
9	5,779	10	3.59	6.98	3.56	2.11	11.31	$27.55
10	2,403	13	3.59	9.02	1.27	2.89	16.13	$32.89
11	9,187	12	3.43	2.75	4.71	0.83	7.82	$19.54
12	11,459	12	3.50	4.37	3.67	0.42	7.15	$19.11
13	6,436	11	3.34	2.28	3.89	1.01	5.63	$16.15
14	3,095	12	3.70	5.17	7.11	0.69	20.46	$37.12
Average	7,386	11.6	3.58	5.15	3.81	1.35	10.75	$24.64
Min	1,412	10.0	3.31	2.28	1.27	0.42	5.29	$16.15
Max	14,471	14.0	4.15	9.02	7.11	2.89	20.46	$37.12

Table3. Summary of analysis of the variable, fixed, and total costs for the five ginning rate categories.

Ginning Rate Categories	Number of gins	Average Variable Cost	Average Fixed Cost	Average Total Cost	Average % Utilization
<10 bph	11	23.49	26.80	50.29	88
10-15bph	14	24.64	28.72	53.36	80
15-25bph	21	20.46	28.57	49.03	120
25-35bph	14	21.62	27.99	49.61	107
>35bph	7	17.66	18.75	36.41	133
Average		21.58	26.17	47.74	

Cotton Producing Regions in Texas

For this particular study, the cotton producing regions in Texas were divided into five categories. These included the following numbered regions: (1) Plains Region, (2) Central Region, (3) Western Region, (4) Gulf Coast Region and (5) Lower Rio Grande Valley Region. These regions are illustrated in Figure 2. The regional trends of production and the number of operating cotton gin facilities for each decade from 1960 to 2000 and for the two year period from 2000 to 2002 are illustrated in Figure 3 a-e.

The number of gins during the period in all of these regions declined but production declined in some regions and increased in others. Production in the Plains Region has increased to close to 4 million bales in 2002 while cotton production in the Central Region has stabilized to about 0.3 million bales. The cotton production in the Western Region has also stabilized to a constant 0.1 million bales while the production in the Coastal Bend Region has significantly increased to about 0.7 million bales. The cotton production in the Lower Rio Grande Valley Region increased to 0.3 million bales in the 90's but declined to a relatively constant 0.1 million bales in 2002. Clearly, in some regions, production has declined while gin numbers have declined. In other regions, gin numbers have declined but production has increased. This is particularly evident for the Plains Region and Coastal Bend Regions. There have been shifts in production between regions. Much of the cotton production in Texas is being concentrated in the Plains Region of the Panhandle.

Based from public data reported by TCEQ, the number of operating gins with ginning rates similar to those reported by Valco et al., (2003) and their annual throughputs are shown in Figure 4. These data are further illustrated in Figures 4a and 4b. It should be noted that the data in figures 4, 4a and 4b reflect TCEQ permit allowable data rather than actual bales ginned. When permitting gins, it is common to specify throughputs at projected maximum levels to ensure that permit conditions are not exceeded.

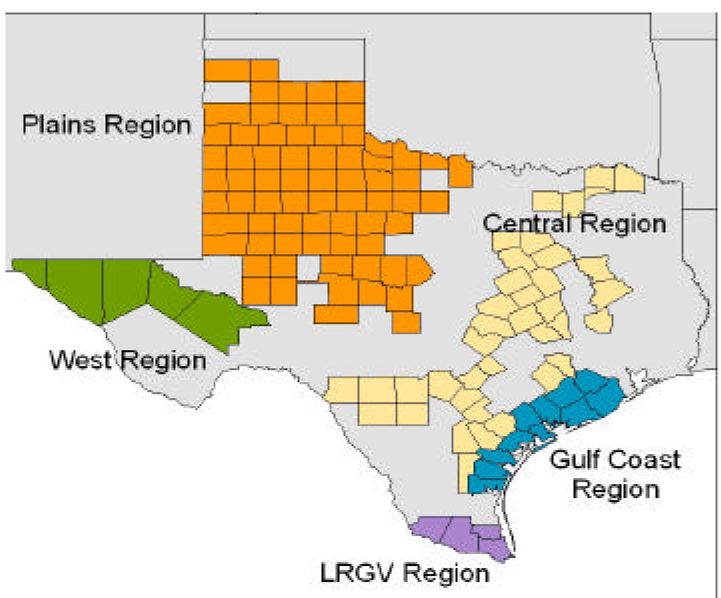

Figure 2: Five cotton production regions in Texas used for the TAMU, BAEN systems study.

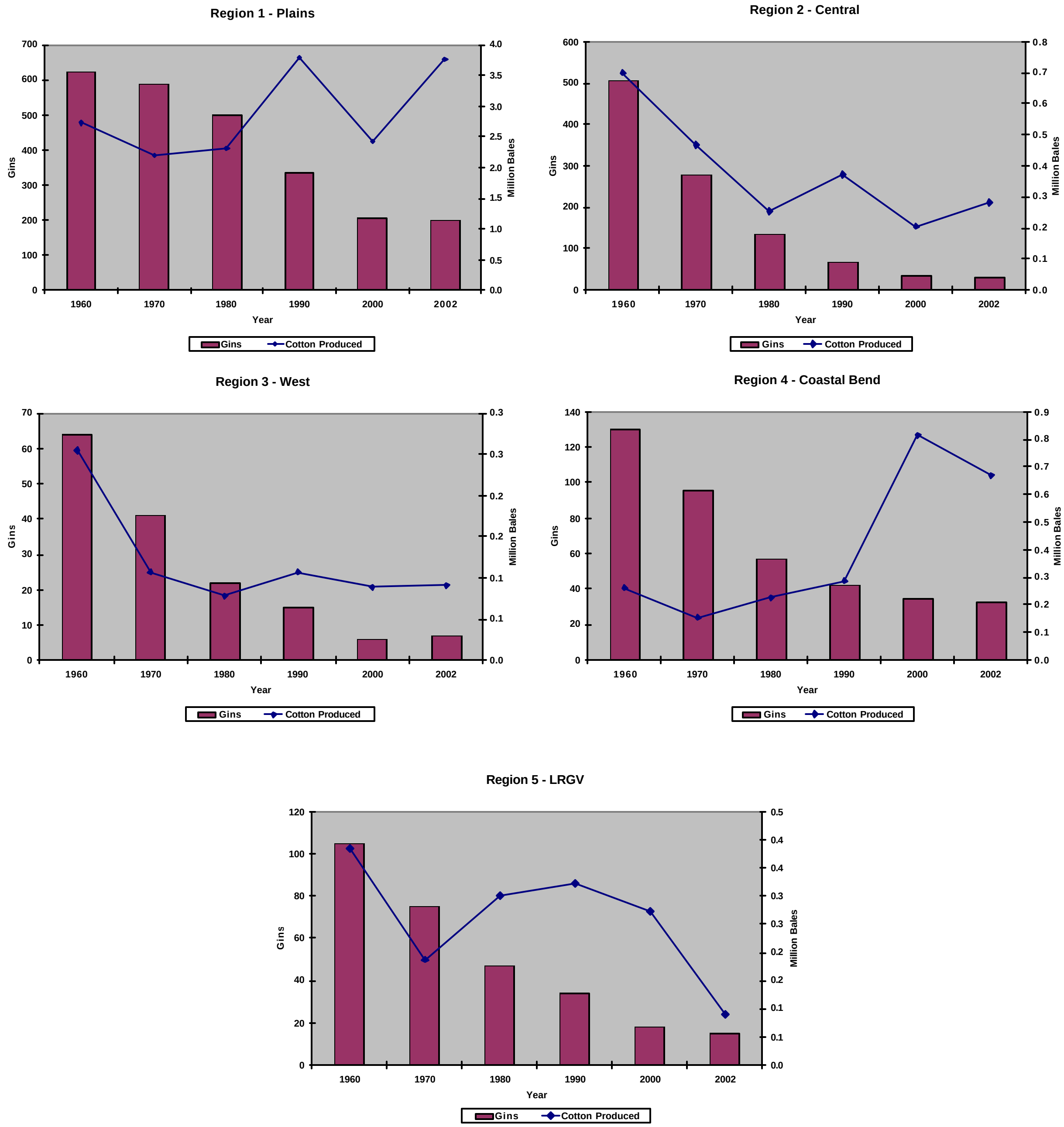

Figure 3 a-e: Regional trends of production and number of operating cotton gin facilities for each decade from 1960 to 2000 and 2002.

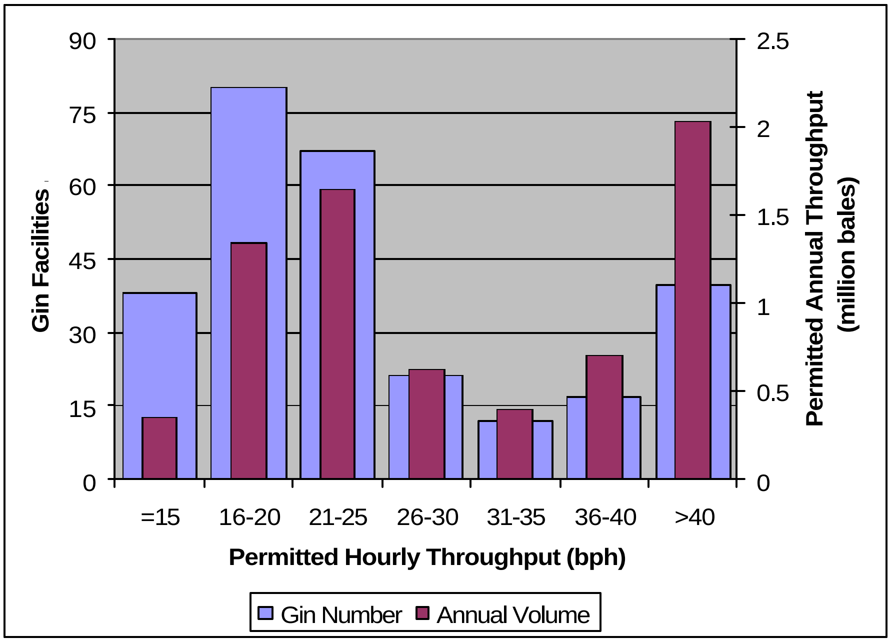

Figure 4. Number of gin facilities and annual throughput (ginning rate) of Texas gins obtained from the public record of air pollution permits submitted to the Texas Commission on Environmental Quality (2004).

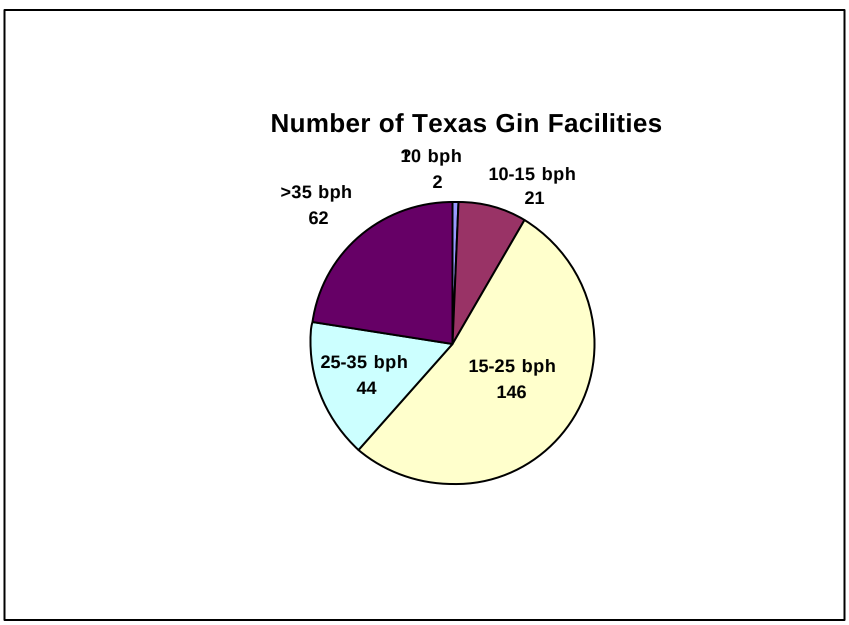

Figure4a. Number of operating Texas gins (TCEQ, 2004) with ginning rates similar to the rates reported by Valco et al (2003).

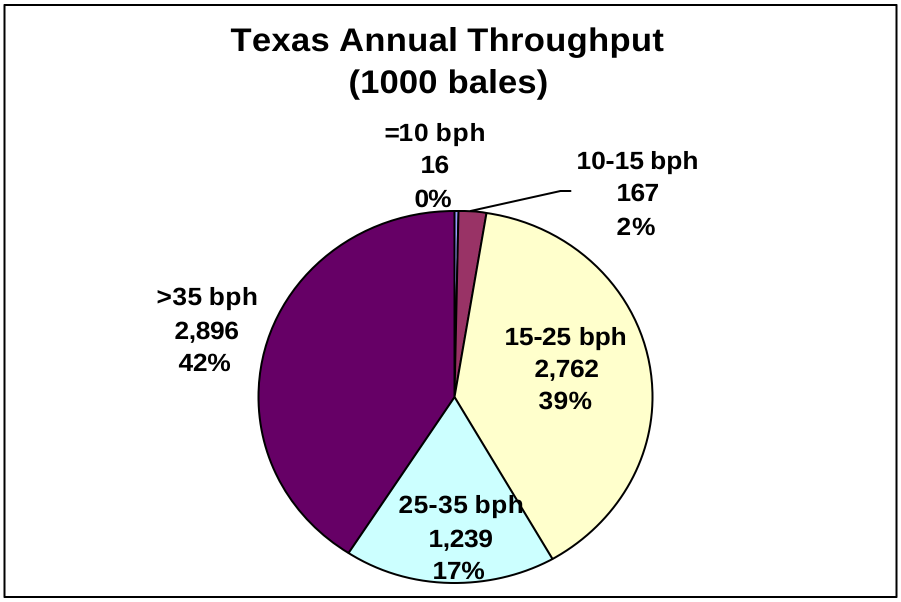

Figure4b. Annual throughput of cotton for Texas gins (TCEQ, 2004 with ginning rates similar to the rates reported by Valco et al (2003).

Effect of Percent Utilization on Ginning Operations

Fixed, variable and total costs from all of the ginning capacity categories were plotted against their respective percentage utilization. The data for ginning rate categories 10-15 bph and 15-25 bph are shown in figures 5-10. The fixed versus percent utilization plot for the 10-15 bales per hour group is illustrated in Figure 5. As percentage utilization increased, fixed cost decreased. This relationship follows a negative exponential trend converging to a fixed cost of approximately $20/bale at a percent utilization close to 150%. The variable cost was expected to be constant throughout the range of utilization rate. Results suggest that variable costs fluctuate at an increasing degree of fluctuation for gins operating at less than 100% utilization. (See figure 6.) The variable costs ranged between $20-$35/bale for both 10-15 bph and 15-25 bph categories (See figures 6 and 9). The total cost versus percent utilization relationship followed a negative exponential trend and approached a constant value of approximately $50/bale as utilization rate increased to 100% (See figures 7 and 10). For the 15-25 bales per hour ginning category, the results were the same with the fixed cost approaching $10/bale (Figure 8), while the variable cost ranged between $10-$30/bale (Figure 9). The total ginning cost for this category approached $40/bale at a utilization rate of 100% (Figure 10).

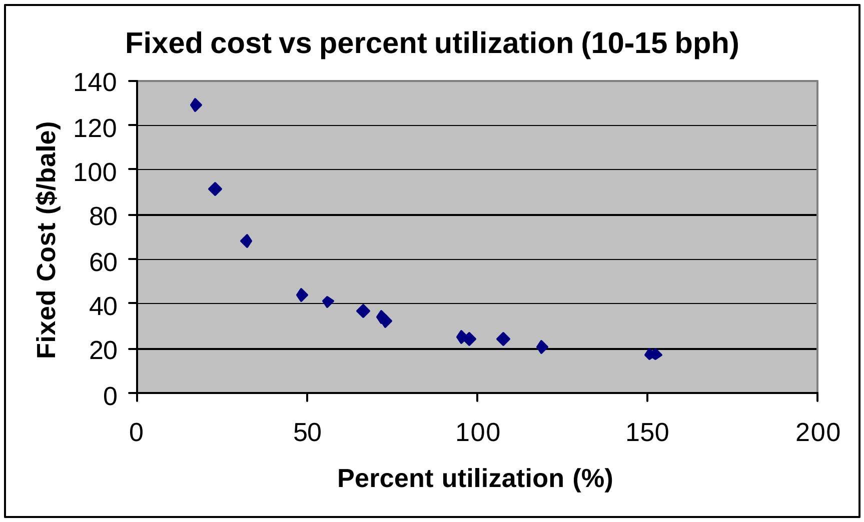

Figure 5. Fixed costs versus percent utilization for the 10-15 bph data in tables 1a and 1b.

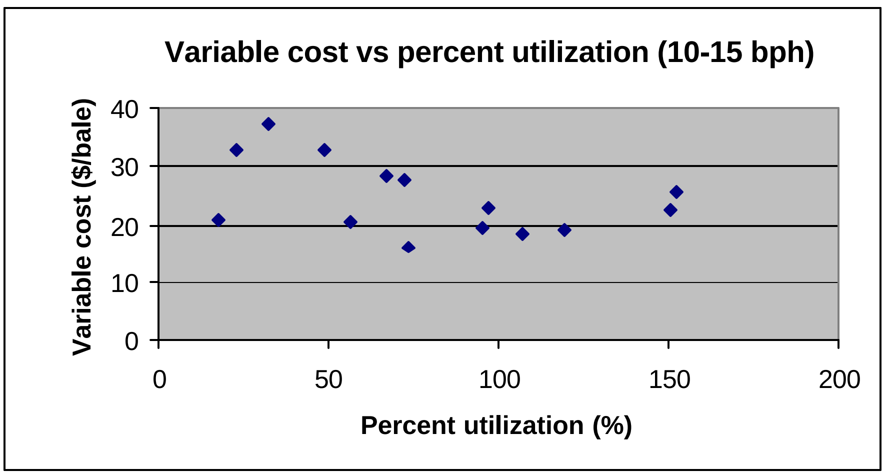

Figure 6. Variable costs versus percent utilization for the 10-15 bph data in Table 2.

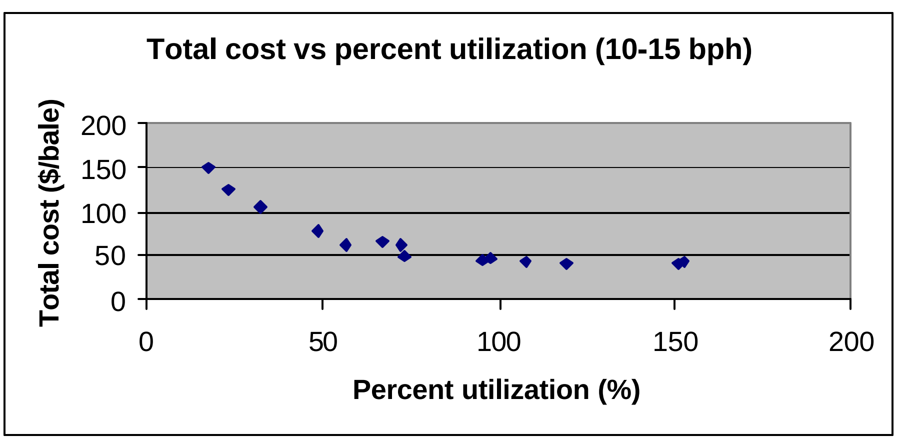

Figure 7. Total costs (fixed plus variable) versus percent utilization for the 10-15 bph data in Tables 1a,1b, and 2.

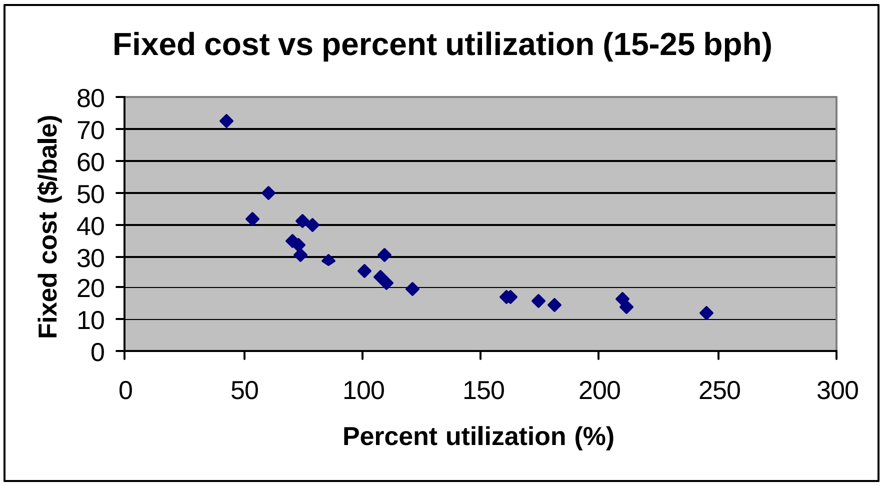

Figure 8. Fixed costs versus percent utilization for the 15-25 bph data in tables 1a and 1b.

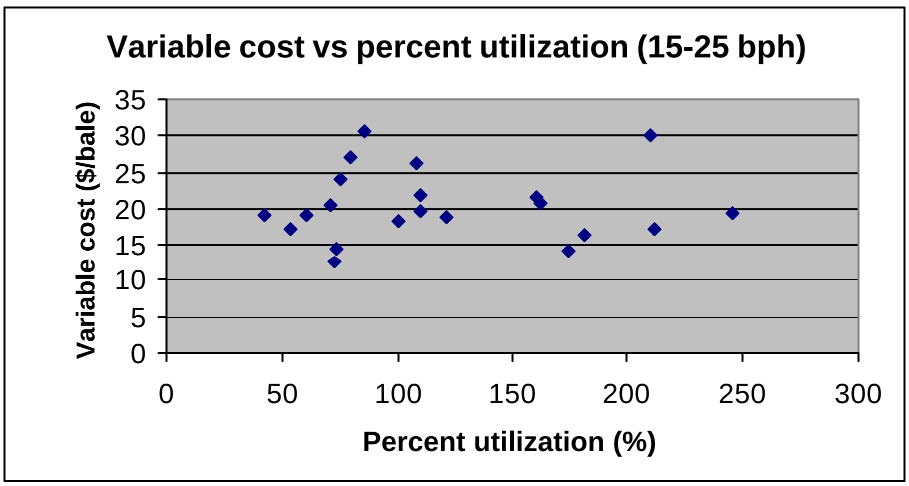

Figure 9. Variable costs versus percent utilization for the 15-25 bph data in table 2.

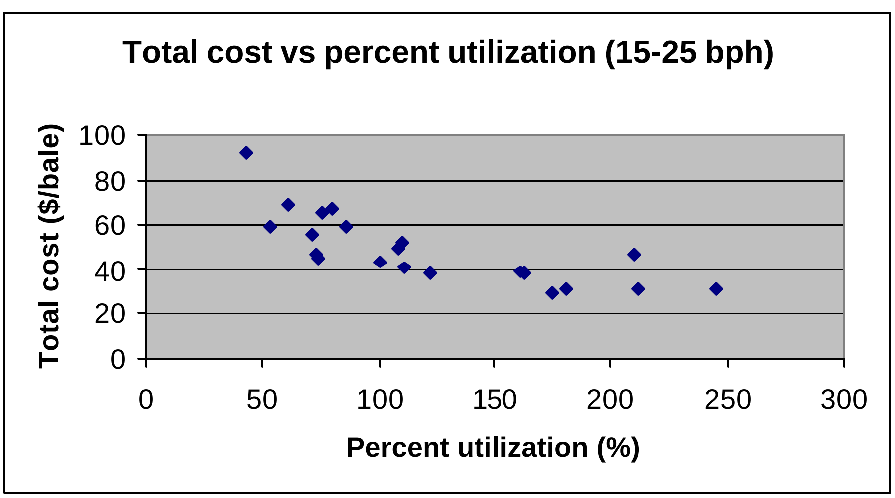

Figure10. Total costs (fixed plus variable) versus percent utilization for the 15-25 bph data.

Summary and Conclusions

A relative constant cotton production rate from 1960 through 2002 along with a corresponding significant decrease in numbers of cotton gins in Texas and across the cotton belt suggest that a change in the harvesting/ginning system will occur in the near future. The remaining gins will be processing more cotton per season. In addition, advances in cotton harvesting equipment have producers able to harvest and place their seed cotton into modules at faster rates than ever before. There has been an increase in the number of larger gins with some able to process 60 bph. If we assume that the constant production rate will continue with the number of gins continuing to decline, the result will be a paradigm shift in the harvesting, seed cotton storage, and ginning system. The systems engineering approach adopted in this study could be used as a tool in presenting several scenarios that could help cotton producers and cotton ginners achieve an optimum return for their product and services that would bring attractive economic incentives to both parties.

The concept of using percent utilization with 100% utilization defined as 80% of the manufacture-rated ginning rate times 1000 hours is presented as a tool for evaluating gin performance. One salient result of this study was that fixed cost per bale varies following a negative exponential trend as the percentage utilization of gin is increased. The average fixed cost per bale was estimated to be about $30 while the average variable cost was estimated at $20 per bale with the assumptions used in this study. The average total cost was estimated at $50/bale. A relationship was developed relating the total cost of gin operations (variable, fixed, and total costs) as a function of utilization rates for the different ginning rate categories. While the assumptions made from this study were not as robust as desired, the results provided a general trend on how the operation of cotton gins could be made more efficient.

As gins process more cotton per season, questions of the merits of alternative to standard-operating-practices of ginning cotton as quickly as possible need to be addressed. The use of the systems engineering approach adopted for this study is the only approach possible to test new concepts. For example, can we process cotton for nine months and reduce labor, electricity, and drying energy costs with the gains being sufficient for producers and ginners to be attracted to the new operating practice? It is anticipated that there will be a portion of cotton produced with seed cotton transport from the turn-row to the gin storage site in excess of 50 to 100 miles. The immediate consequence of such a scenario would be the expected transport issues associated with moving modules over longer distances and the problem of transporting them through Interstate Highways. This study will have to incorporate an efficient transport system to bring modules of seed cotton to designated gins in a timely manner.

Future work will be focused on the transport issues surrounding the scenarios presented in this systems engineering study. This approach will provide a tool that would simplify changes in the strategies that could be implemented by ginners and producers.

Acknowledgments

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