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ENGINEERING OF SEED COTTON TRANSPORT ALTERNATIVES

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Abstract

Seed cotton transport from the field to the gin is currently accomplished by building modules and hauling them with a module truck. Costs of module transport have not been characterized fully. Engineering economic analyses were performed to develop equations that are used to estimate the cost of module transport based on various assumptions. The use of a semi-tractor trailer (STT) for seed cotton transport is a possibility for reducing costs. Equations also were developed for modeling STT transport costs. Within 15 miles from a gin, the cost of seed cotton transport is \$60 per module truck load and \$90 per STT load. Outside of 15 miles, the transport costs increased linearly and more rapidly for STT than module truck costs. However, it was assumed that STT would haul 50% more seed cotton per load. The transportation costs of stripper cotton were higher than picker cotton. Comparisons of the module truck versus STT system costs were made using geographic information system (GIS) software. An ArcGIS project was developed using gin location, production areas, highway and road system, and other items of interest. A transport analysis routine in ArcGIS allowed for routing of modules from field to gin and determination of distances. The cost equations developed were used for comparing costs of module transport and STT transport. One transport example where ten fields of seed cotton were transported 150 miles one-way distance to the gin indicated that STT transport cost \$9,430 less than module truck transport.

Background

Module trucking has been a concern to gin managers since the adoption of the module builder. In several states, module trucks are not in compliance with state departments of transportation (DOT) regulations concerning height, width, and weight restrictions for commercial vehicles. A typical tandem-axle module truck today can have tare weights exceeding 15,400 kg (34,000 pounds). A well built module can reach weights of 11,300 kg (25,000 pounds). It is not unusual for the combined gross weight to reach 26,700 kg (59,000 pounds).

According to the ASABE (2006) standard describing module truck dimensions, the width should be 2.74 m (9.0 ft) or less, the length should be 14.6 m (48 ft) or less, and the height should be 4.42 m (14.5 ft) or less. Weight limits are not addressed in the standard. Over-the-road transport rules and regulations from the 17 states in the cotton producing region of the U.S. were compiled and reported by Whitelock (2004). States in the U.S. cotton production belt have weight, length, width and height restrictions on non-federal highways. Comparing the ASAE standard and the various state rules and regulations, many differences in dimensions and weight allowances are used.

In addition to state and local road restrictions, the federal government limits the weight supported by the tandem-axle of a commercial truck to 15,400 kg (34,000 pounds) on the Dwight D. Eisenhower System of Interstate and Defense Highways (Interstate System) (DOT, 2006). Since much of the module weight is positioned over the tandem-axle of a module truck, the tandem-axel may exceed the Interstate System limit. States are allowed to provide special permits for oversize and overweight vehicles on non-federal roadways (Texas Statutes, 2006). However, permits can be quite costly and may prevent gin managers from purchasing them, making over-weight loads subject to fines.

Gins located close to an Interstate Highway are forced to route drivers along longer paths in order to avoid the Interstate System. Large fuel and maintenance costs are incurred due to longer return-trips along farm-to-market, county or state roads. Seed cotton transportation 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.

Costs will continue to rise with increasing fuel and labor costs. The number of ginning facilities is continuing to decrease each year. We have lost approximately 17 gins per year in Texas since 1990 (Simpson et.al, 2004). Increases in production are seen across the Cotton Belt; Texas production has been much higher than the average over the last three years. Faster harvesting methods due to more picking/stripping heads per machine increase the time pressure on the module builder operator. Modules are stored longer in the fields as gin seasons stretch into January, February and March in Texas. The risk for rain events increases with time and modules are difficult to retrieve from wet fields.

The goal of this on-going research effort in the Department of Biological and Agricultural Engineering at Texas A&M University is to provide the cotton industry tools for:

- Minimizing module transport time and cost; and
- Ensuring appropriate and safe transport of seed cotton on roads and Interstate Highways.

Engineering Economics of Transport

The initial step in developing a model for evaluating alternative transport systems is to determine module transport costs. Avant (2004) reported a model to predict the costs associated with hauling seed cotton modules. In the model, assumptions were 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 were as follows:

- 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; and
- 1 hour loading & unloading time per module.

The results using the Avant model of transport cost per bale are shown in figure 1. The cost per bale remains flat from 0 miles to 15 miles. In this range, the cost per bale for picker cotton is $4 and for stripper cotton is $5. Past 15 miles, the cost per bale increases at different rates. The costs per bale are higher for stripped cotton compared to picked cotton. Equation 1 was used to calculate the cost per bale beyond 15 miles.

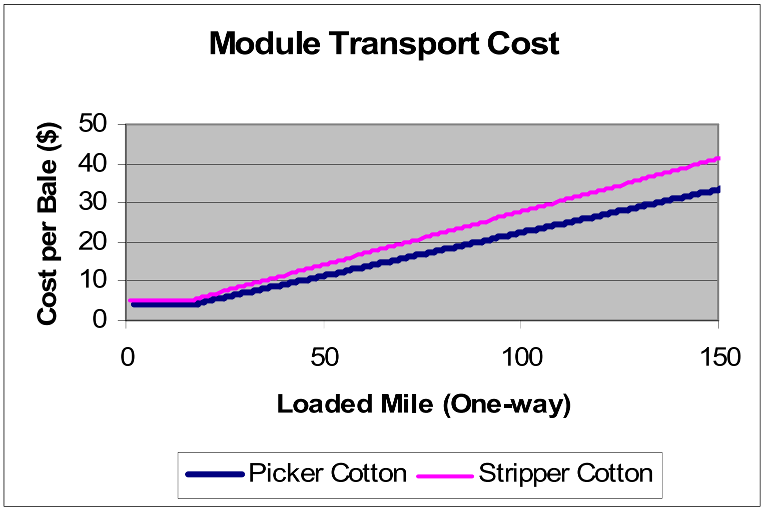


Figure 1. Module transport costs on a per bale rate for picker and stripper cotton.

$$TC_M \quad = \quad 60+3.35(d-15) \tag{1}$$

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 following assumptions:

- 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; and
- 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. The two ways to achieve 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.

Equation 2 was used to calculate cost per bale using STT. Figure 2 shows the comparative cost per bale using module trucks and STT. These results suggest that STT transport of seed cotton will be less costly per bale compared to module hauling for long haul distances. The transport costs using equations 1 and 2 are per load of seed cotton. An STT load contains one and one half modules versus one module for a module truck. The transport costs per bale illustrated in figures 1 and 2 were derived from equations 1 and 2. These results indicate that picking up seed cotton 100 miles away from a cotton gin using STT would cost on average, \$20 and \$25 per bale for picker and stripper cotton, respectively. Using a module truck, the costs per bale would be \$22 per picker bale and \$28 per stripper bale.

$$TC_{STT} \quad = \quad 90+4.5\left(d-15\right) \qquad (2)$$

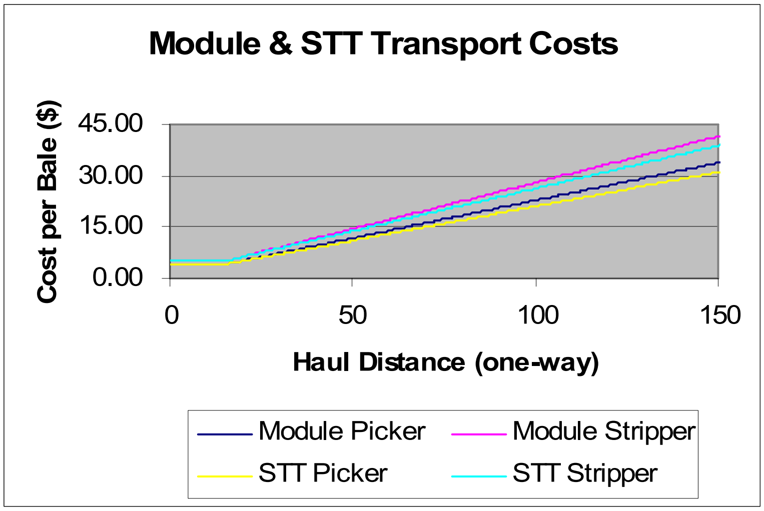


Figure 2. Comparison of transport costs on a per bale basis versus one-way haul distance for module trucks and semi-tractor trailers.

Using Geographical Information Systems for Transport

The equations and results presented above for module truck and STT hauling were used for modeling specific transport problems 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 could be determined. Routing around a load zone bridge or interstate highway could 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 (Allen, 2006), 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 latitude/longitude 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.

Figure 3 is an example of the spatial data gathered is displayed for Lubbock County. Gins and cotton fields are laid out on a road map for the area. The centroid points of the fields were determined and replaced the polygons. The transport routine was run for each of the fields in the county and routed using local, county and state roads. The Interstate Highway was avoided in figure 3. Each destination was the closest gin no matter if it was located in Lubbock county or an adjacent county.

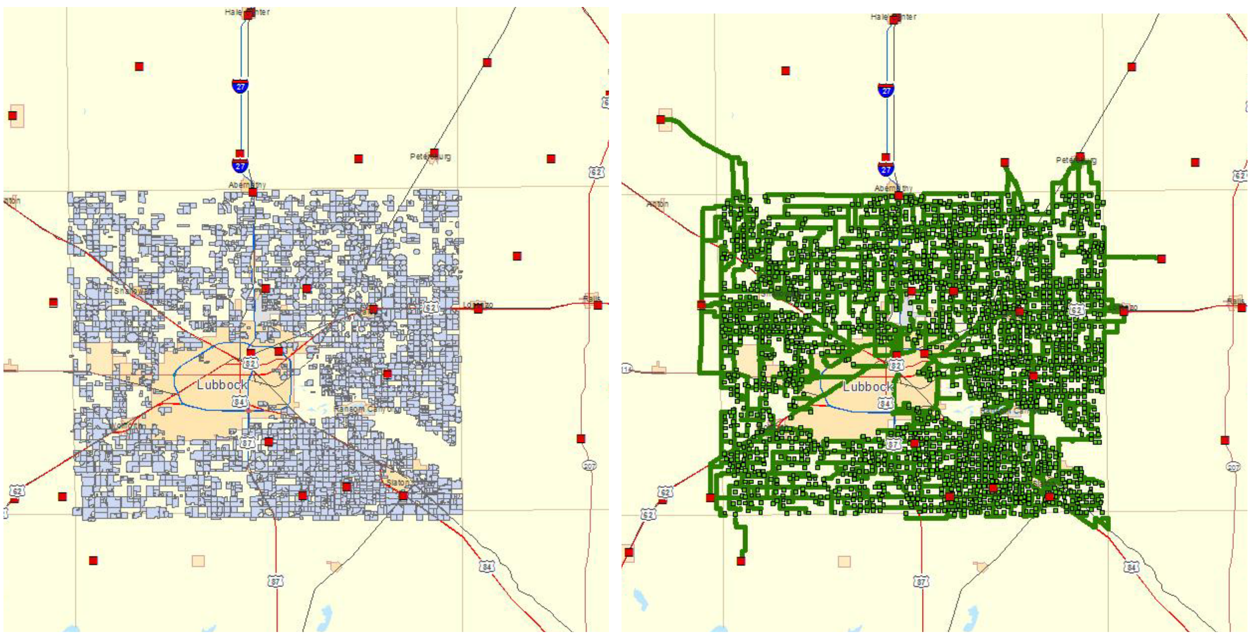


Figure 3. Lubbock county area is shown with gin locations as red dots and the highway system. A) Grey-blue polygons indicate field boundaries where cotton was grown in 2005. B) Green dots represent the centroid of cotton fields and green lines are transport routes from fields to gins.

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 4, for West Texas. There are times producers want to process cotton with a gin that is further away than the local area gins. In the following example, cotton was transported from ten fields approximately 150 miles, one-way haul distance, to the gin.

Figure 4. 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 1. 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. 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 was estimated with the STT system.

Table 1. 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 fit easily onto a 16.15 m (53 ft) trailer as shown in figure 6a.

Transport of two modules per trailer is shown in figure 6b. 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 load were reduced.

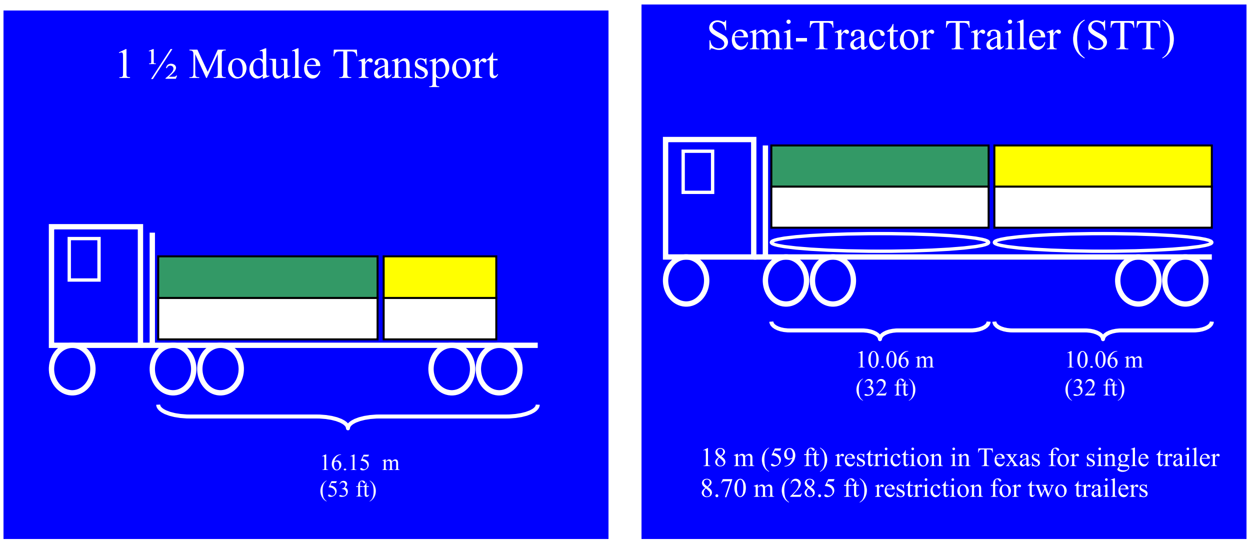


Figure 6. A) Transport of one and one half modules would fit on a regular 16.15 m (53 ft) trailer. B) Transport of two modules would require a 20.12 m (66 ft) long trailer.

Figure 6b 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 7); or determining the best route for transport (figure 8).

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.

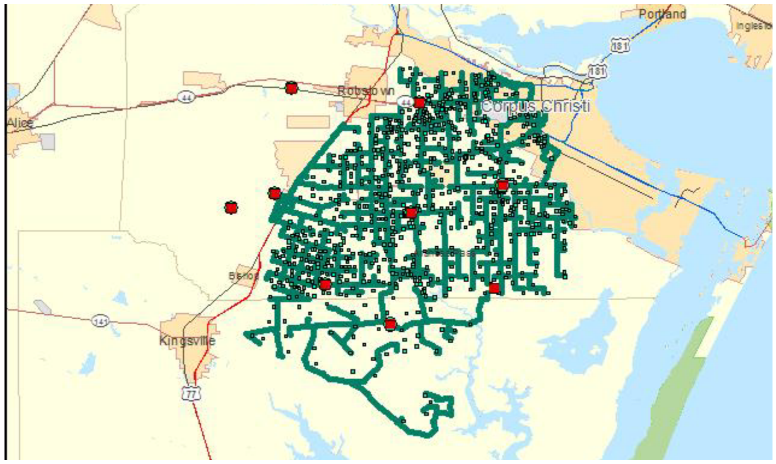
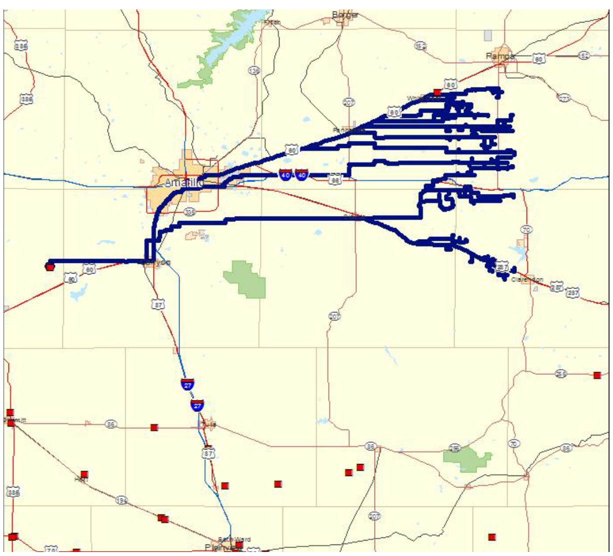


Figure 7. Transport routing for Corpus Christi area fields and gins.

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 8a is the routing using the Interstate access roads and 8b 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.



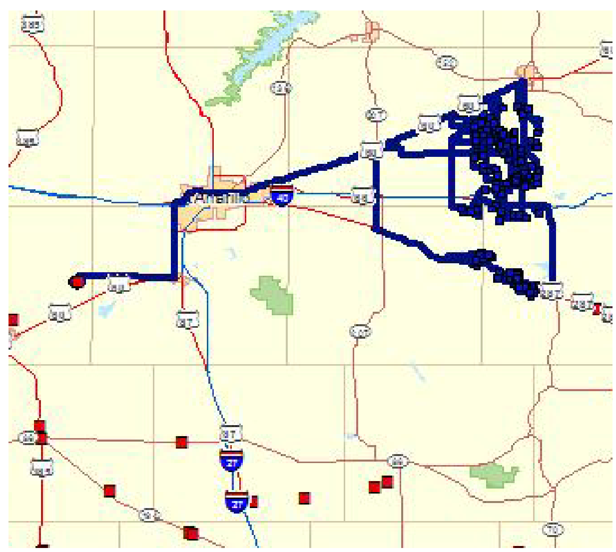


Figure 8. A) Routing fields on the east side of Amarillo to a gin on the west side of Amarillo with the use of Interstate access roads. B) Routing the same fields to the gin using roads other than the Interstate access roads.

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 and number of bales per module. Results suggested that picker cotton transport costs per bale were lower than cost per bale for stripper cotton. 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 were applied to seed 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.

Future Work

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 who have experience using alternative transport systems may provide input and serve as cooperators on additional experiments with transport.

Acknowledgements

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