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Strategic Agribusiness Operation Realignment in the Texas Prison System

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ABSTRACT

Mathematical programming-based systems analysis is used to examine the consequences of alternative operation configuration for the agricultural operations within the Texas Department of Criminal Justice. Continuation versus elimination of the total operation as well as individual operating departments are considered. Methodology includes a firm systems operation model combined with capital budgeting and an integer programming based investment model. Results indicate the resources realize a positive return as a whole, but some enterprises are not using resources profitably. The integer investment model is found to be superior for investigating whether to continue multiple interrelated enterprises.

Key Words: *agribusiness, enterprise selection, mathematical programming, optimal enterprise organization.*

In recent years, *realignment, dissolution, merger, acquisition, downsizing,* and *fiscal responsibility* have become prevalent terms in corporate America and government circles. Many businesses have reconfigured business operations in response to economic factors. There often are difficulties in realigning integrated enterprises since the vertical and horizontal linkages among divisions often hinder identification of the consequence of realignment decisions.

The Texas Department of Criminal Justice's (TDCJ) farming operations provide an opportunity to examine such questions within a highly diversified, integrated agribusiness.

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The TDCJ Agriculture Department (TDCJAG) is under considerable realignment pressure, having been twice put on the State Comptroller's hot list of State activities to be discontinued (Sharp 1994; 1996).

In this paper the potential effects of realigning TDCJ agricultural operations are examined in several ways. First, we examine the effects of (1) discontinuing all TDCJAG operations and (2) eliminating the beef production division. In doing this, we consider tradeoffs between the fixed cost of resources employed and the operating value of the TDCJAG division. Subsequently, we formulate an enhanced model which endogenously considers trade-offs between the fixed costs associated with individual divisions' continuance and the savings that would be generated by discontinuing individual division operations.

Methodologically, the study is conducted using a TDCJAG systems model (PRISAG) which has been developed during a seven-year cooperative project with the TDCJ agency (Rister *et al.*; Ziari *et al.*; Ward; Ward *et al.*). PRISAG is a linear programming, system-wide mathematical programming model considering farms, processing plants, storage facilities, inter-regional transportation, and inmate diet formation, among other system components. For the second part of the paper we augment PRISAG with a mixed-integer investment component; the resulting PRISAG-MIP model is further described in Ward. In both sets of evaluations, when divisions and/or individual enterprises are eliminated, TDCJ as a whole no longer has access to the divisions' or enterprises' products and then must use external purchases to acquire needed products and services formerly provided by the divisions.

Problem Background and Impetus for Modeling

On a daily basis, TDCJ provides dietary and other needs for about 163,000 people, including over 127,000 inmates (Holcomb).[1] The TDCJ Agriculture Department provides a considerable share of these needs. TDCJAG is a highly diversified, vertically integrated agricultural operation, operating 38,300 acres of vegetable and field crops; 67,700 acres of pasture; numerous swine, beef, and poultry livestock operations; two feed mills; an egg-processing facility; two meat-packing plants; two cotton gins; an alfalfa dehydrator; four grain elevators; and a vegetable cannery.

Three goals are pursued by TDCJAG management: (1) to provide agricultural commodities to meet inmates' dietary and other needs, thereby reducing the cost of buying outside products, (2) to provide employment for inmates, and (3) to realize maximum returns to State resources through efficient management (Rister *et al.* 1989). Recently, State government officials have raised the downsizing question, suggesting that resources devoted to TDCJAG could be used more efficiently elsewhere (Eller; General Land Office; and Sharp 1994, 1996).

Literature Background

The basic problem treated herein involves identifying optimal activities for individual divisions of an integrated business firm and possibly downsizing the firm if warranted by economic considerations. We could not find items in the literature focusing on choice of firm operations to downsize or on downsizing implications for the firm as a whole. However, a number of related problems largely involving growth, investment selection, or project choice have been investigated. Many studies have used mathematical programming formulations to examine the consequences of adding enterprises or investments. Weingartner (1963, 1966) provides the basis for conducting capital budgeting in a mathematical programming setting. Candler and Boehlje discuss agricultural applications while Bassoco, Norton, and Silos provide an empirical example as do numerous others. Several facility expansion studies have been done to examine trade-offs between the fixed cost of expansion versus the savings in transportation costs using mixed-integer programming (refer to Revelle and Laporte for a

[1] Besides inmates, security personnel and other TDCJ employees are also routinely fed by the TDCJ Food Services Department (McCray; Anderson; Thomas).

literature review; and Hilger, McCarl, and Uhrig; or Fuller, Randolph, and Klingman for examples). There is also a substantial body of work using mixed-integer programming to consider issues such as machine selection (e.g., Danok, McCarl, and White). Mixed-integer based techniques can be used to optimize the configuration of enterprises. Integer variables depict "have" or "not have" decisions of inter-related components. Just as removing one enterprise from the firm will affect all of the other related enterprises, removing a facility will also have an effect on the rest of the facilities.

Methodology

Analysis of optimal firm operations and possible downsizing effects requires explicit recognition of enterprise interlinkages. For example, eliminating TDCJAG's livestock operation would affect the demands placed on the feed mill and crop production enterprises. A linear programming systems model of the total TDCJAG-related component of TDCJ was developed to account for the numerous interactions among various TDCJ Agriculture and non-Agriculture Divisions.

Economic appraisal of whether to continue or close an enterprise should not only consider variable costs and returns but also fixed costs. Two methods are used to capture enterprise fixed costs, including the opportunity costs of the capital resources devoted to agriculture. In our first approach, the linear programming model PRISAG is used to account for the variable costs and revenues. Then, external capital budgeting analysis is used to incorporate the fixed costs. In the second approach, integer variables will be incorporated into the mathematical programming model (PRISAG-MIP) to include consideration of fixed costs directly in the optimization process. The next section discusses the PRISAG model while discussion of the PRISAG-MIP model is deferred until later in the paper.

The PRISAG Linear Program

A tableau of the general structure of PRISAG is provided in Table 1. A brief description of the model follows. For a more detailed discussion of the model, refer to Ward.

PRISAG is designed to identify optimal activity levels for virtually all TDCJAG enterprises, plus the cost of food, fiber, and broomcorn purchased to meet TDCJ inmate dietary and other requirements. The enterprise activity levels chosen include (1) acres of vegetable crops, field crops, and pasture alternatives; (2) number of animals present in each of the livestock operations for poultry, beef, and swine; (3) activity levels in the processing facilities for cotton, canned goods, meat, feed, and eggs; (4) internal commodity transportation; (5) diet composition; and (6) commodity purchases and sales. The enterprise activity levels are chosen to maximize the net returns subject to (1) dietary and other requirements of inmates; (2) balance constraints on commodities, livestock, vegetables, canned goods, meat, etc., which force the use of an item to not exceed supply; (3) capacity constraints limiting the operation size; (4) inmate labor availability; and (5) land availability.

PRISAG Validation

Before using the model for analysis, we performed extensive model validation experiments. The first step involved iteratively running the model with different prices and resource endowments and, if needed, fixing the structure. In that phase we made certain that the model responded in accordance with theory and our expectations. Once we felt the model was responding correctly, we held meetings with TDCJAG management personnel to verify base assumptions and update data. After these model parameters were verified, the next step involved running the model constrained to TDCJAG current practices. After making sure those scenarios were feasible within the model, we held additional meetings with TDCJAG management to compare the model's optimal solution to current practices, examine prominent differences, suggest revisions, and ultimately, to secure the TDCJ staff's confidence in the model's capabilities and accuracy.

Table 1. PRISAG-General Linear Programming Model, Texas Department of Criminal Justice Agriculture Department, 1997

	Activities					
Constraints	Produce Crop	Produce Forage	Produce Vegetable	Produce Livestock	Feed Mix	Meat Packing
Obj Function	−[a]	−	−	−	−	−
Crop Balance	−			+[a]	+	
Lint Balance						
Broomcorn Balance						
Forage Balance		−		+		
Feed Balance				+	−	
Final Livestock				−		+
Interm. Livestock				+/−		
Raw Vegetable Bal.			−			
Canned Veg. Bal.						
Diet Veg. Required						
Diet Veg. Min						
Diet Veg. Max						
Diet Meat						−
Crop Land	+		+			
Labor	+	+	+	+	+	+
Forage Land		+		+		
Capacity	+	+	+	+	+	+
Cash Flow	+	+	+	+	+	+

Model Analysis of Eliminating TDCJAG

The first model analysis involved identification of the net benefits of discontinuing TDCJAG. To examine this scenario, the PRISAG model was solved with and without constraints requiring all TDCJAG agricultural production and processing activities to be zero. The difference in the two scenario solutions is an estimate of the net annual TDCJ operating costs which would occur in the absence of TDCJAG under optimal operations. That estimate is then used in a capital budgeting exercise in conjunction with fixed costs to see if the adjusted TDCJ system-wide costs with TDCJAG operating is less than the costs without its operations. If the estimated difference is positive, there appears to be economic value associated with the agricultural operation.[2]

When agricultural operations are discontinued, livestock and crop production, along with all agricultural processing activities, are assumed discontinued. Cotton lint and broomcorn requirements as well as the Food Services Department's food requirements for the diet are assumed to be purchased externally. All land, except perimeter buffers surrounding each prison unit (for security purposes), would be sold and the associated sales proceeds would be invested at an annual opportunity cost rate of 5 percent.[3] All feed required for security horses and dogs would be purchased externally. In addition, a number of auxiliary services performed by the Agriculture Department would either need to be performed by other TDCJ departments or externally purchased. For example, among other activities,

[2] These analyses results are purely financial in form, disregarding the intangible benefits associated with inmates working outside their cells in Agriculture Department Activities. That is, values for the alleged lessened security costs and potentially reduced recidivism rates associated with inmates working are not incorporated into these analyses.

[3] This is the State's bond rate of 4.6 percent (Merrill-Lynch) rounded up to 5 percent to include a small risk premium.

Table 1. (Continued)

Activities						
Can Goods Produced	Sell Goods	Buy Goods	Consume Raw. Veg.	Consume Can Veg.	Shipping & Storage	RHS
−	+	−			−	Maximize
	+	−			+/−	≤ 0
					+	≥ Lint Required
					+	≥ Broom Required
						≤ 0
		−			+/−	≤ 0
	+	−			+/−	≤ 0
		−			+/−	≤ 0
+		−	+		+/−	≤ 0
−		−		+	+/−	≤ 0
			−	−		≤ -Veg. Required
			+	+		≤ Max Veg. Req.
			+	+		≥ Min Veg. Req.
		−				≤ -Meat Required
						≤ Land Available
+						≤ Labor Available
						≤ Pasture Available
+					+	≤ Equipment Cap.
+		+			+	≤ Cash Available

[a] The + and − notations in the table indicate the signs of the coefficients in the PRISAG model.

the farm shop currently spends 75 percent of its time performing maintenance on non-agricultural vehicles (Armstrong). The cost of having someone else perform this service would be an additional cost of discontinued agricultural operations. Fixed costs include the annual fixed cost of the different enterprises along with the opportunity cost of having resources tied up in the agricultural practices. Details on the calculation of the fixed costs are presented in Ward.

Results of Eliminating TDCJAG

When the PRISAG model is solved with TDCJAG in operation, the objective function reveals a $33.2 million net cost of operating (Table 2). This cost includes $28.5 million in operating costs and $18.6 million in food purchases, but these costs are partially offset by $13.9 million in sales of agricultural commodities. When an opportunity cost of 5 percent on the capital investment is considered, along with other fixed costs, the total net cost for all activities represented within the PRISAG model is $58.3 million. This cost includes $2.3 million for providing services to other TDCJ Departments.

When the model is solved assuming TDCJAG does not operate (i.e., "without Agriculture"), all of the dietary and other TDCJ requirements represented within PRISAG are purchased from external sources and the diet is re-optimized. Simultaneously, all of the kitchen garbage needs to be commercially disposed of at a cost of $3.3 million since the swine operation could no longer feed cooked kitchen refuse to the hogs. It is also assumed that the garden plots next to the kitchens will continue to operate in the absence of the Agriculture Department. The PRISAG model's estimation for all of these costs is $71 million (Table 3). Additional fixed costs will also be incurred by the TDCJ in the absence of an Agriculture Department. Such costs include the fixed costs of the garden plots, the cost for hiring the grounds maintenance and pesticide control, costs associated with Security horses

Table 2. TDCJ Costs for Agriculture Department Operating at Optimal Levels Scenario, Texas Department of Criminal Justice Agriculture Department PRISAG LP Model, 1997

PRISAG Obj Fcn		$33,220,845
Sale of Agricultural Commodities[a]	(13,929,220)	
Cost of Operations	28,535,010	
Cost of Food Purchased	18,615,055	
Non-PRISAG LP Model Costs		
Opportunity Costs of Land and Capital Investments @ 5%		8,515,834
Maintenance/Replacement/Depreciation Costs		2,585,342
Management Salaries and Fringes[b]		11,702,962
Non-agricultural Services Provided by TDCJAG, but Not in PRISAG Model[c]		2,300,378
Cost with TDCJAG		$58,325,361

[a] This revenue is decreasing the net cost.
[b] Including $8,933,559 in salaries and 31 percent benefits (Armstrong).
[c] Fixed and variable costs of these operations.
Note: TDCJ stands for Texas Department of Criminal Justice.

Table 3. Total TDCJ Costs for Without Agriculture Scenario, Texas Department of Criminal Justice Agriculture Department PRISAG LP Model, 1997

Transportation	$ 1,647,613
Crop Production Variable Costs[a]	215,418
Commercial Garbage	3,343,989
Buying Pork Products	11,971,379
Buying Beef Products	14,970,894
Buying Fish Products	2,015,926
Buying Chicken Products	3,622,188
Buying Food For the Diet	29,161,224
Buying Cotton Lint for Industry	3,212,794
Buying Broomcorn for Industry	150,000
Buying Hay for Horses	69,494
Buying Rations for Horses and Dogs	692,794
PRISAG Model Costs Without Agriculture	$ 71,073,714
Non-PRISAG LP Model Costs	
Grounds Maintenance[b]	$ 1,119,729
Pest Extermination	369,205
General Maintenance[c]	751,873
Garden Plots	360,604
Purchase Horses	206,400
Horse Management	117,900
Horse Non-feed Costs	33,282
Dogs & Pups	68,880
Mechanical	516,842
Total	**3,544,715**
Total Costs for Without TDCJAG Scenario	**$ 74,618,429**

[a] This represents the variable costs of the garden plots. In the absence of an Agriculture Department, it is assumed that the gardens will still be grown on land next to the prisons (Armstrong).
[b] Mowing of grounds at TDCJ unit locations.
[c] Maintaining general plant and equipment at TDCJ unit location.
Note: TDCJ stands for Texas Department of Criminal Justice.

and dogs, and costs of other maintenance activities. The total cost of operating without agriculture is $74.6 million (Table 3).

Comparing the $58.3 million cost with TDCJAG operations (Table 2) to the $74.6 million cost without TDCJAG operations (Table 3), it is found that if TDCJAG were to be discontinued the State of Texas should expect to have to increase the annual budget to TDCJ by $16.3 million. Thus, there exists the potential, assuming an optimal operating environment, for TDCJAG to annually contribute a positive net benefit of $16.3 million over and above all variable and capital fixed costs.[4]

Model Analysis of Eliminating the Beef Operation

The beef enterprise uses many State resources and has been questioned from a profitability standpoint by other state agencies (e.g., Sharp 1994, 1996, and General Land Office). PRISAG was also used to examine the downsizing implications of eliminating the beef operation within TDCJAG. The beef enterprises exists solely as a commercial cattle operation to produce weaned calves to be sold externally. Lower grade beef is purchased to meet dietary requirements. Currently, TDCJAG has an over 10,000-head cow-calf operation geographically dispersed across 11 TDCJ locations (i.e., nine cow-calf operations plus the bull and replacement heifer herds). While the profitability of the beef enterprise actually may vary from farm to farm, the beef enterprise is considered here as an all-or-nothing proposition with all cow-calf farms' returns ($/hd) considered identical.

[4] This overestimates the value of current TDCJAG operations since the diet and some other operations are not "optimal" as analyzed in Ward. Ward estimates that under current operational procedures, positive overall returns to TDCJAG operation fall to $3.9 million and the basic conclusion of positive returns remains intact.

For this analysis, PRISAG is run with and without the cattle operation. The model also adjusts feed mill activity and crop production to account for the decrease in demand for rations and forage. The difference in the model's solutions for the scenarios with and without beef are adjusted for fixed-cost savings that occur in association with the elimination of the beef enterprise. Fixed-cost savings include investment returns associated with selling the pasture land and breeding herd and investing the proceeds, reduced management salaries, and eliminated veterinary costs.

Results of Eliminating the Beef Operation

Consideration of the elimination of the cattle operation reveals that the potential annual net gain to TDCJ including fixed-cost savings is over $1 million. Enterprise activity levels for scenarios with and without the cattle operation are provided in Table 4. Since the cattle are currently sold externally and not used to satisfy dietary requirements, the effects of eliminating the cattle operation do not include any effects on the costs of providing dietary requirements to the TDCJ Food Services Department. Foregoing cattle production results in a $4.1 million loss in TDCJAG sales revenue, but saves $507,000 in the cattle-raising costs and $666,000 in pasture production (Table 5). Cattle elimination also saves $316,000 in ration ingredients, $1,096,000 in ration production, and $23,000 in hay purchases. Fewer field crop acres are required for the production of ration ingredients, allowing more acres of crops to be grown for external sales. In doing so, the field crop operation incurs $36,000 more in variable costs of crop production but also increases the sales of commodities by $376,000. The rest of the indirect effects are relatively minor. They include changes in transportation and storage costs. Considering only the cattle enterprise, positive returns above specified variable costs are just over $1 million.

Thus, without considering the fixed-cost savings, the beef cattle operation appears to have a positive value to TDCJAG and the State's taxpayers in excess of $1 million (Ta-

Table 4. Comparisons of Solutions for the PRISAG Model's Base Optimal Scenario to the Without a Cattle Operation Scenario, Texas Department of Criminal Justice Agriculture Department, 1997

Item	Units	Optimal Ag and Menu	No Cattle	Numeric Difference	Percentage Difference
PRISAG Obj Fcn	$	(33,220,845)	(34,237,807)	(1,016,962)	3
Crop Land Used	Acres	38,555	38,182	(373)	<1
Pasture Used	Acres	50,483	0	(50,483)	−100
Veg. Land Used	Acres	6,738	6,865	127	2
Cows	Head	12,774	0	(12,774)	−100
Hens	Head	193,575	193,575	0	0
Sows	Head	3,170	3,170	0	0
Hogs Slaughtered	Head	1,691	1,691	0	0
Pork Processed	Pounds	4,774,629	4,774,629	0	0
Beef Processed	Pounds	10,000,000	10,000,000	0	0
Meat Bought[a]	Pounds	1,000,807	1,000,807	0	0
Veg. Canned	Cases	501,280	501,280	0	0
Feed Mixed	Tons	42,663	33,261	(9,402)	−22
Garbage Disposal	Tons	41,823	41,823	0	0

[a] Includes both beef and pork.

Note: Parentheses indicate negative numbers representing costs or a negative difference between the results from the two scenarios.

ble 4 and Table 5). There are also fixed-cost savings arising from elimination of the cattle operation; however, these savings include $445,000 in reduced TDCJAG management salaries and benefits, $1,009,600 in annual investment returns associated with selling pasture land, $87,574 in reduced veterinary costs, and $510,960 in annual returns associated with selling the breeding herd. Thus, the total fixed costs savings are $2,053,194. When these potential savings are subtracted from the $1 million the beef cattle operation realizes above specified variable costs, the TDCJAG beef cattle operation is revealed to annually lose approximately $1 million.[5]

More On Methodology—PRISAG-MIP

The PRISAG model does not endogenously account for the fixed costs. Fixed costs must be factored in outside the model using capital budgeting. The PRISAG model is incapable of readily determining if eliminating one enterprise will cause another to be eliminated. For example, as discussed in the previous section, through the use of PRISAG and external budgeting it was found that the beef cattle operation is not profitable. However, this methodology did not automatically consider whether removal of the beef cattle could lower demand for feed such that, considering fixed costs, one or both feed mills would no longer be justified. Such secondary effects of terminating one enterprise must be assessed through trial-and-error intuition when using a mathematical programming model such as PRISAG, i.e., the analyst must preselect "with" and "without" exercises to be run regarding other possibly interrelated enterprises.

To investigate such issues more directly and more robustly, a variant of PRISAG was developed (PRISAG-MIP), which includes in-

[5] One argument frequently offered as justification for the beef cattle operations's existence is associated with the need for substantial acreage surrounding TDCJ units for security purposes. In conducting this economic analysis, perimeter buffer acreage was required at all TDCJ unit locations consistent with the 600–1,000 acres comprising recently built TDCJ units, with the excess acreage over and above that amount considered not necessary for TDCJ purposes and assumed sold with the resulting revenue invested at 5 percent annually.

Table 5. Comparison of Components of the PRISAG Objective Function for the Base Optimal Solution and Without Cattle Operation Scenarios, Texas Department of Criminal Justice Agriculture Department, 1997

	Optimal Ag and Menu	No Cattle	Difference	
			Numeric	Percent
			$	%
Transportation	(1,817,683)	(1,750,112)	67,571	−4%
Packing Plant Variable Cost	(3,414,720)	(3,414,720)		
Buying Meat Cuts	(6,398,083)	(6,398,083)		
Sales of Byproducts	6,230	6,230		
Buying Pork Products	(769,313)	(769,313)		
Buying Beef Products	(725,950)	(725,950)		
Buying Fish	(2,015,926)	(2,015,926)		
Buying Chicken	(3,622,188)	(3,622,188)		
Buying VSIs	(9,817,173)	(9,817,173)		
Buying Other Food	(1,664,504)	(1,664,504)		
Feed Mill Variable Cost	(3,548,788)	(2,452,466)	1,096,322	−31%
Buying Ration Ingredients	(1,017,721)	(701,785)	315,936	−31%
Field Crops Variable Cost	(3,993,081)	(3,957,409)	35,672	−1%
Custom Harvesting	(46,309)	(46,309)		
Selling Crops	2,951,227	3,327,694	376,467	13%
Vegetable Variable Cost	(953,290)	(962,700)	(9,410)	1%
Pasture Variable Cost	(665,769)	0	665,769	−100%
Garbage Disposal	(2,141,797)	(2,141,793)	4	<1
Minor Vegetable Production	(215,418)	(215,418)		
Alfalfa Dehydrator Variable Cost	(22,308)	(22,301)	7	<1
Egg Processing	(996)	(996)		
Cattle Variable Cost	(507,270)	0	507,270	−100%
Swine Variable Cost	(330,383)	(330,381)	2	<1
Poultry Variable Cost	(548,785)	(548,785)		
Sale of Cattle	4,122,799	0	(4,122,799)	−100%
Sale of Swine	5,990,578	5,990,578		
Cannery Variable Cost	(2,110,797)	(2,110,797)		
Buying Vegetables	(158,702)	(136,652)	22,050	−14%
Buying Hay	(31,705)	(8,235)	23,470	−74%
Canned Good Storage	(28,398)	(28,244)	154	−1%
Cotton Gin Variable Cost	(199,621)	(199,621)		
Free-world Cotton Ginning	(91,274)	(91,274)		
Selling Cotton Seed	393,497	393,497		
Selling Cotton Lint	464,889	464,889		
Vegetable Cold Storage	(258,260)	(257,425)	835	<1
Grain Storage	(33,852)	(29,975)	3,877	−11%
PRISAG Obj Fcn	(33,220,844)	(34,237,647)	(1,016,803)	3%

Note: Parentheses indicate negative numbers representing costs.

teger investment variables with the fixed costs attached. Namely, binary, integer decision variables ("Have-Enterprise") are added to the basic PRISAG model structure. Table 6 is an illustration of the general structure of the PRISAG-MIP model. The objective function parameters for the "Have-Enterprise" variables are the respective fixed costs excluding

Table 6. PRISAG-MIP—Mixed-Integer Linear Programming Model, Texas Department of Criminal Justice Agriculture Department, 1997

Constraints	Have Enterprise	Produce Crop	Produce Forage	Produce Vegetable	Produce Livestock	Feed Mixing
Obj Function	−[a]	−	−	−	−	−
Enterprise Bal.	−	+[a]		+	+	+
Crop Balance		−			+	+
Forage Balance			−		+	
Feed Balance					+	−
Final Livestock					−	
Interm. Livestock					+/−	
Raw Veg. Bal.				−		
Canned Veg. Bal.						
Dietary Veg. Req.						
Dietary Meat Req.						
Crop Land		+		+		
Labor	+	+	+	+	+	+
Forage Land			+		+	
Capacity	+	+	+	+	+	+
Cash Flow	+	+	+	+	+	+

[a] The + and − notations in the table indicate the signs of the coefficients in the PRISAG-MIP model.

land for each enterprise.[6] If an operation appears in the solution, the value of one for the respective "Have-Enterprise" variable allows inclusion of the entire amount of the fixed costs, excluding land, in the objective function. If the binary variable is zero and the operation is discontinued, none of the fixed costs are included in the objective function value.

Each "Have-Enterprise" variable appears in an enterprise-balance constraint with a coefficient of a large negative number[7] representing the supply of enterprise capacity. The production variables for the respective enterprise are included in the enterprise-balance constraint as a use of enterprise capacity. In all, 13 "Have-Enterprise" variables and 13 enterprise-balance constraints are associated with the 13 various enterprises identified as discrete in PRISAG-MIP. These "mixed-integer" enterprises are identified in Table 7. When PRISAG-MIP is allowed to optimize unhindered by any external control on the MIP variable, the results indicate the best economic solution considering both variable and fixed costs as specified in the data set. To identify the additional costs associated with including non-optimal enterprises and/or divisions, such non-optimal activities can be "forced" into the solution and the resulting optimal objective future value compared to that of the unconstrained scenario.

Results of Using the PRISAG-MIP Model

The solution to the unrestricted PRISAG-MIP model chooses to eliminate the beef enterprise for the reasons discussed in the last section; however, a feed mill is also shut down. Deductive reasoning and "outside-the-model" budgeting indicates the variable-cost savings from having that feed mill in operation when the cattle are removed are less than the annual fixed costs associated with it, thus causing its overall contribution to TDCJAG to be negative, that is, it is an uneconomic venture in the

[6] Land opportunity costs are considered in the model using net cash rent activities. Such activities are continuous, allowing land to be leased on an incremental basis.

[7] This is a mixed-integer programming convention whereby it creates an nonbinding constraint when the variable is activated (McCarl and Spreen).

Table 6. (Continued)

Meat Packing	Cannery Prod.	Sell Goods	Buy Goods	Cons. Raw Vegeta-ble	Cons. Can Vegeta-ble	Internal Shipping & Storage	RHS
–	–	+	–			–	Maximize
+	+						≤ 0
		+	–			+/–	≤ 0
							≤ 0
			–			+/–	≤ 0
+		+	–			+/–	≤ 0
			–			+/–	≤ 0
	+		–	+		+/–	≤ 0
	–				+	+/–	≤ 0
			–	–	–		≤ -Veg. Req.
–			–				≤ -Meat Req.
							≤ Land Avail.
+	+						≤ Labor Avail.
							≤ Pasture Avail.
+	+					+	≤ Equipment Cap.
+	+		+			+	≤ Cash Available

absence of inclusion of the beef operation. These same results could have been found with PRISAG plus capital budgeting if we had the insight to try feed mill elimination in combination with discontinuance of the beef cattle operation.

Table 7. Mixed-Integer Enterprise Sets Included in the PRISAG-MIP Solutions Using Different Values of Inmate Labor, Texas Department of Criminal Justice Agriculture Department, 1997

Mixed-Integer Enterprises	Trustee Labor Cost Per Hour			
	–$5	$0	$5	$10
Agriculture	yes	yes	yes	yes
Cannery	yes	yes	no	no
Poultry	yes	yes	yes	yes
Beef	no	no	no	no
Swine	yes	yes	no	no
Field Crops	yes	yes	yes	yes
Vegetables	yes	yes	yes	yes
Cotton Gins	yes	yes	yes	yes
Alfalfa Dehydrator	yes	yes	yes	no
Clements Packing Plant	yes	yes	yes	yes
Michael Packing Plant	yes	yes	yes	no
Coffield Feed Mill	no	no	no	no
Eastham Feed Mill	yes	yes	yes	yes

Factoring In Labor Opportunity Cost—PRISAG-MIP

TDCJAG makes heavy use of inmate labor, but does not include a cost for inmate labor while conducting strategic decision-making regarding enterprise levels. Such labor may have an opportunity cost due to added security measures of guarding inmates while working and potential uses in non-agricultural operations, such as making license plates. On the other hand, there may be a positive return to the work opportunity. It has been argued that if inmates are working, they pose less of a security threat, as inmates tired from working cause fewer violent incidents (Rister and Long). Also, working inmates may develop a work ethic, enhanced and/or increased skills, and a decrease in the recidivism rate (Turner and Petersilia; Maguire, Flanagan, and Thornberry; Cushing and Williams).

We attempted to look at the opportunity cost of labor via the model's generation of shadow prices, but since for the most part the labor constraint is not binding that was unsuccessful. Therefore, in the current paper, we embark on a method of analysis whereby labor is assigned a range of costs (both positive and negative) to see which enterprises are generating returns sufficient to meet those costs or alter production to use additional labor.

Assumptions about the Use of Inmate Labor and Adjustments to PRISAG-MIP

There are two types of inmate labor at TDCJ: trustee labor and line labor. Trustees work with less supervision and security, performing higher valued jobs such as machinery and equipment operation. Line labor must be closely supervised and performs lesser valued jobs such as hoeing crops, hand harvesting of vegetables, etc. This value difference generally carries over to other enterprises. For these reasons, we arbitrarily chose to assume that the cost (or return) of using trustee labor was twice that of using line labor.

PRISAG-MIP results are generated for four sets of labor costs: −\$5 per hour of trustee labor (a return to providing work), no cost for inmate labor, and \$5 and \$10 per hour for using trustee labor, with accompanying 50% rates for line labor. The above wage rates were chosen for several reasons. The highest cost (\$10 per hour) is equivalent to the cost of skilled Texas farm labor. Inmates may not be as productive as farm workers, so a \$5-per-hour cost of trustee labor is also evaluated. The current practice of not charging for the use of inmate labor justifies the zero case. Finally, an alternative case where a benefit is accruing for the use of inmate labor is assumed, with the use of trustee labor accruing a \$5 per hour benefit.[8]

Results of Factoring Labor Costs

As Table 7 shows, when there is no labor cost the beef enterprise and the Coffield feed mill are shut down (consistent with the results of the PRISAG model discussed in the previous sections). Even when trustee labor has a negative cost (i.e., a positive benefit) of \$5 per hour and line labor has a cost of −\$2.50 per hour, the beef cattle operation and the Coffield feed mill are not profitable. In addition, as the cost of using inmate labor increases from the base assumed zero cost level, first the cannery and swine operations are shut down. Then, as the cost of trustee labor increases to \$10 per hour and line labor increases to \$5 per hour, the alfalfa dehydrator and the Michael Packing Plant are added to the "shut down" list.

It is interesting also to investigate what happens to the TDCJ non-labor returns above variable costs. Such a value is similar to the PRISAG objective function value. When the labor cost is −\$5 (i.e., a positive return) per hour of trustee labor, the non-labor returns above variable costs are slightly lower. This is because using inmate labor has a value. As a result, some enterprise activities that use inmate labor but were not included in the base solution are now being used to obtain the value of using the labor. However, this causes the non-labor returns above variable costs to decrease. When inmate labor costs rise to \$5 and \$10 per hour of trustee labor, the non-labor returns above variable costs decrease significantly, dropping by 20 and 33 percent, respectively. This is because, in response to the positive costs of using inmate labor, practices that were using the free labor in the \$0.00 cost of inmate labor scenario are now being shifted to less economically efficient practices that require less inmate labor. TDCJ net revenue, which includes the labor and fixed costs, is highest when using inmate labor has a positive return and lowest when the cost of using inmate labor is the highest. The range in difference among the results approach \$20 million on a total cost basis and \$10 million on a cash variable cost basis.

Concluding Remarks and Implications

Questions raised by various Texas State agencies of whether resources devoted to TDCJAG could be used elsewhere have complex an-

[8] The authors attempted to obtain quantitative measures of the benefits of inmates working both from TDCJ (Rister and Long) and via literature searches but were unsuccessful. The noted positive \$5 benefit represents a simple proxy for illustrative purposes.

swers. As a whole, the results here indicate the resources devoted to TDCJAG provide a positive return, but there is indication that some TDCJAG enterprises, particularly the beef operation and one of the associated feed mills, are not using resources profitably.

The model results suggest TDCJAG's financial and economic profitability could be increased if the beef enterprise is discontinued. The mixed-integer model, which endogenously considers the impact of the fixed cost and interrelated enterprises, also identified that a feed mill could be discontinued when the beef enterprise is discontinued. Recognizing that the reported analysis considered the total beef cattle operation as comprising one entity, further analyses are warranted to investigate the economic merits of individual unit beef cattle operations.

The optimal TDCJ enterprise structure was found to be sensitive to the assumption about opportunity cost of inmate labor. The beef enterprise and a feed mill were found unprofitable for all assumptions. As a positive cost was added to the use of inmate labor, more enterprises were discontinued. First, the cannery and swine operations were discontinued. Then, as the cost of using labor increased further, the alfalfa dehydrator and the pork packing plant were eliminated. This shows that the cost (benefit) of using inmate labor has a significant impact on the optimal structure of TDCJAG.[9]

The approaches used in this paper worked well for the problem of finding the optimal structure of an operation. Using either a linear programming model combined with capital budgeting (PRISAG) or a mixed-integer programming model (PRISAG-MIP) could work when determining the value of the operation as a whole. Such models allow a complex structure to be imposed and the interlinkages of the enterprises to be considered. When determining the value for a particular enterprise, the approach using a linear programming model combined with exogenous capital budgeting did not readily find the optimal results. While it found that an unprofitable enterprise should be eliminated, it did not identify whether other related enterprises should also be eliminated. This implies that the use of the more complex, mixed-integer model works better when looking at whether to continue or close down interrelated enterprises. Such a model requires using more time to both create and solve the model. It may be that in a practical setting the same results could be achieved with the use of the linear model, exogenous capital budgeting, and intensive and extensive discussions with management. The inmate labor cost study component further revealed the benefit of the mixed-integer model. Management expertise could not readily identify the type of changes that would arise and the formal mixed-integer approach provided additional information.

[9] Readers are reminded that these analyses results are purely financial, disregarding the intangible benefits associated with inmates working outside their cells in Agriculture Department Activities.

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