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Research Article

Cost Drivers Analysis for Sugar Processing in Kenya using Optimization Models with Adoption of Goal Programming

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Abstract

The cost of production in Kenya has been high when compared to other regional producers and world market prices, which for political and economic reasons are lower than the production costs in most factories in Kenya. For these reasons, production cost drivers analysis for sugar processing in Kenya is in inevitable so that good production mix can be put in place by the various companies. The objective was to analyse cost variables using optimization models with goal programming. Use of questionnaire, observation and interview schedules were used to collect data. The findings from goal programming application on cost analysis on resource allocation reveals that, with current level of operation strategies it is still a challenge for the Kenyan sugar manufacturer to produce sugar at 300 USD or less. The result gives an under achievement of 86 USD. Meaning with the current state of our factories and built in strategies, the operating resources projected at optimal level (current constraint still in place), for example Sony sugar company producing at a cost of 841 USD can only minimise production cost to 755 USD and Mumias with relatively improved technology, which does its production at a cost 465 USD can manage 379 USD with optimal production mix. It is also important to recognise that with sugar cost which is sighted as optimal ($X_1 = 0$), the cost of 35 USD is still revealed as relatively high and needed to be reduced further, this can be done by introducing high sugar variety that can yield so much from an hector to compensate for primary farm inputs.

Keywords: Cost drivers analysis, optimization, sugar processing and goal programming.

Introduction

A study on influence of modern technology on cost optimization of sugar processing in Kenya has been considered recently by several researchers [1]. Globally the vast majority of the works reviewed opt for the linear programming-based modelling approach, particularly mixed integer linear programming, though a few investigations also adopted non linear programming [2]. A stochastic goal programming (SGP) model was proposed and they considered the goals as uncertain variables with normal distribution, this model maximizes the probability that the consequence of the decision will belong to a certain region encompassing the uncertain goal. Thus, this model tries to generate a solution that is close to the uncertain goals [3].

The optimized process cost with the generic and goal programming algorithm, considering a multitude of constraints; the overall optimization criterion was made of; cost of production, work force, inventory and sub contracting as variables [4]. The result of this strategy revealed areas that desired improvement to avoid constraining the operating cost, so that the same can be minimized [5-8]. The optimized model was:

$$Tc = \sum_{t=i}^{52} (Pc + Wc + Lc + Sc) \text{..........} \quad (1)$$

Research methodology

The study used cross-sectional survey design. Descriptive survey has been described as the method that involves seeking the opinion of a large group of people by questioning them about a particular issue [9]. The methodology involved time study analysis on site for a day, use of

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factor operation trend analysis as quantified in previous reports and use of questionnaires. The data was collected based on the management system model, technology, operation cost drivers and process structure and procedures. The study evaluated the current management models adopted, established their limitations and proposed use of stochastic optimization model with goal programming. Sensitivity analysis based on 'what if' or scenario analysis was conducted using pre emptive values to establish working accuracy of goal programming based production objectives. The modelling was done based on maximization and minimization of the expected value of the proposed objective variables of the system. The problem setting contained the usual optimization components; decision variables, objective function and constraints. Based on trend analysis, the design parameters of the real system was be set to optimal values for analysis [10].

The design appropriately established the determinants of the objective variables in the five sugar companies of western Kenya (Mumias Sugar Company, Sony Sugar Company, Chemelil Sugar Company, Muhoroni Sugar Company) and Sukari Industries. The Surveys also concerned with status of the current operating data, opinions held by the personnel on processes schedules, operations and processes management models existing, effects evident or trends developing as known by the technicians and management [11-12]. The population of study was drawn from sugar companies, that included: Mumias Sugar company, Sony Sugar company, Chemelil sugar company, Sukari Industries and Muhoroni [9].

Result and discussions

This section presents findings with an effort to establish the following; establish the number of respondents that can be able to estimate the cost associated with several cost driver segments, assess the extent to which the reduction of material cost, control, readjustment and reengineering of labour (human capital allocation) can reduce cost, rate to what extent maintenance need to improved by adopting information technology. Ideally, a cost driver is an activity that is the root cause of why a cost occurs. In the past century, the root cause of indirect manufacturing costs has changed from a single cost driver (labour in hours) to several cost drivers.

Due to sophisticated manufacturing and increased demands from customers, direct labour or material cost is no longer the main cost driver of manufacturing. In addition to direct labour or materials, today's drivers of indirect manufacturing costs include the number of machine setups required, the number of engineering change orders, the demands from customers for special inspections, handling and storage, the number of components in the units produced, and the number of production machine hours. Manufacturers that want to know the true costs of their products need to know what is driving their indirect manufacturing costs. For these companies it is not sufficient to merely spread overhead costs to products by using a single factor such as direct labour hours or production machine hours [12]. Therefore, there is need for optimization as indicated in eqn. 1. From the findings in table 1 it was realised that 76.7% of the respondents don't know the cost of producing one tonne of sugar. Deliberate effort should be made to make them aware so that they can be involved in controlling waste.

Table 1. Number that can and cannot estimate the cost of various cost drivers

Response	No		Yes			
	f	%	f	%	∑f	%
	49	76.7	33	23.3	192	100

Table 2. Estimation of cost drivers per variable per company (amount in USD)

COMPANY	COST DRIVER SEGMENT (IN US DOLLARS) Raw materials	Labour	Operations	Transport	Overheads	Other Costs	Total
Sukari	30	128	170	9	68	120	525
Sony	38	239	280	12	82	190	841
Muhoroni	40.5	224	200	12	90	170	752.5
Mumias	30	150	100	10	53	125	465
Chemelil	40	155	240	9	65	132	641
Mean	35.7	179.2	198	10.4	71.6	148	644.9

Source: Mumias, Sony, Chemelil, Mohoroni and Sukari, Company data records, 2016.

From the findings in table 2, it is evident that operations/manufacturing constitutes the largest percentage of cost (198 USD), that go into the production of one tonne of sugar. This implies that there is need for proper process schedule, incorporation of best operating practice (BOP) and adaptation of optimal technology to reduce this cost segment. This section presents findings with an effort rate the extent to which improved raw material (sugar cane variety) can act to improve on overall sugar processing cost, rate to what extent do the control readjustment and reengineering of labour (human capital allocation) can reduce cost of producing sugar in Kenya, rate to what extent do the control readjustment and reengineering of operation.

Table 3. Rating the extent to which reduction of the operation cost drivers can reduce the cost of production

Response	Mean per Var.	Not at all		Little extent		Moderate extent		Great extent		Very great ext.		Total	
		f	%	f	%	F	%	F	%	f	%	∑f	%
Rate to what extent raw materials (sugar variety) need to be improved to reduce cost of producing sugar in Kenya	1.81	42	21.9	147	76.6	-	-	3	1.6	-	-	192	100
Rate to what extent do the control readjustment and reengineering of labour (human capital allocation) can reduce cost of producing sugar in Kenya	4.17	-	-	6	3.1	21	10.9	99	51.6	34	66	192	100
Rate to what extent do the control readjustment and reengineering of operation costs (water, electricity, fuel etc) can reduce cost of producing sugar in Kenya	4.16	-	-	3	1.6	15	7.8	123	64.1	51	26	192	100
Rate to what extent maintenance need to improved by adopting information technology	4.02	3	1.6	3	1.6	30	15.6	105	54.7	52	26	192	100
Overall mean	3.54												

Key: Not at all– 1, little extent – 2, moderate extent -3, To a great extent -4, To a very great extent - 5

The findings in table 3 showed that, the control readjustment and reengineering of operation costs (water, electricity, fuel etc) can reduce cost of producing sugar in Kenya to a great extent with a weighted Likert scale of 4.16. Raw material improvement had the least effect with a weighted Likert score of 1.8. It is evident that organizational policy needs to be reorganized or reengineered to adhere to optimal use of resources. Technology need also to be looked into i.e on that minimize use of energy and work faster. The findings also established that the adaptation of goal programming as a stochastic optimization tool can enhance pre-emptive forecasting to assist on deciding on the right operating level, in terms of grinding hours, production mix strategy and decision on downstream processes to minimize the cost of producing a tone of sugar.

The goals statement for the sugar subsector to make sugar produced in Kenya to be competitive globally should be as follows:

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Goal 1: Overall production cost to be 300USD per ton

Goal 2: Produces average tonnage of 5000 MT/month

Table 4. Goal programming variables

Variables	Cost/ unit ton in USD		Estimated total cost '000'
	Sugar	Molasses	
Labour	120	59	2,685
Raw materials	35	-	525
Operation costs	158	40	2970
Overheads	59	23	13
Cost/ton of sugar	400	145	-
Total tones project for production	5000	2000	3290

The goals of the problem can therefore be stated from values in table 4 as follows:

Objective Minimize $Z = 400X_1 + 145X_2$

Subject to:

400X1 + 140X2 + Du1– Do1 = 1740 (Total cost of producing sugar plus Molasses)

$120X_1 + 59X_2 \leq 2{,}865$ (projected labour cost per month)

$35X_1 \leq 5250$ (projected material cost per month)

$158X_1 + 40X_2 \leq 2970$ (projected operation cost per month)

$59X_1 + 23X_2 \leq 1357$(projected overhead cost per month)

$X_1 \leq 5000$ (mean sugar production level per month)

We first define the deviational variables;

Du_1 = Under achievement of cost target

Do_1 = Over achievement of cost target

Du_2 = Under achievement of production level target

Do_2 = Over achievement of production level target

The following goals are targeted:

Goal 1: Produce sugar at a cost of 300 USD

Goal 2: Meet total projected production level of 5000 MT / month

Deviational variables are introduced in each of the constraints to allow for solution by simplex method (Dantzig, 1947), as adopted from Jacobian matrix iteration.

Let Do_1 = the total amount above the recommended cost of 300 USD per ton

Du_1 = the total amount below the recommended cost of 300 USD per ton

Do_2 = over achievement above the production level of 7500 sugar produced

Du_2 = under achievement below the production level of 7500 sugar produced

The solution is then seeked which minimize the under achievement of the operating variables.

Note that sugar to cost 300USD and molasses to cost120 USD

Minimise: $Z = Du_1 + Du_2$ (taking cost of sugar as 300 USD & molasses as 180 USD)

Subject to:

$400X1 + 140X2 + Du_1 – Do_1 = 145{,}200$

$X_1 + Du_2 + D0_2 = 5000$ (Production level in MT)

$120X_1 + 59X_2 + s_1 = 2{,}865$ (projected labour cost per month)

$35X_1 + s_2 = 5250$ (projected material cost per month)

$158X_1 + 40X_2 + s_3 = 2970$ (projected operation cost per month)

$59X_1 + 23X_2 + S_4 = 1357$(projected overhead cost per month)

X1, X2, S1, S2, S3, Du1, Do, Du2, Du2, ≥ 0

The solution is done with the use of iteration method (using Jacobian operator principles).

Du_1 = 137600 (Cost level/ton was not achieved by 86 USD)

Du_2 = 4810 (Under achievement)

S_1 = 4585 (under achieved)

S2 = 0 (fully achieved)

X_1 = 19 (Under produced by 19 MT/Month)

S_3 = 236 (Under achievement of operation costs)

S_4 = 585 (Under achieved the overall over head cost)

X_2 = 0 (fully achieved)

From table 5 and table 6, the findings from goal programming application on cost analysis on resource allocation reveals that, with current level of operation strategies it is still a challenge for the Kenyan sugar manufacturer to produce sugar at 300 USD or less. The result gives an under achievement of 86 USD. Meaning with the current state of our factories and on built in strategies with operating resources projected at optimal level (current constraint still in place), for example SONY sugar company producing at a cost of 841 USD can only minimize production cost to 755 USD and Mumias which does its production at a cost 465 USD can manage 379 USD with optimal production mix. It is also important to recognise that with sugar cost which is sighted as optimal (X1 = 0), the cost of 35 USD is still revealed as relatively high and needed to be reduced further, this can be done by introducing high sugar variety that can yield so much from an hector to compensate for primary farm inputs.

It was also evident that, full demand level of 5000 MT/ month, may not be attainable. From the operating environment with the current constraints the factories can only achieve up to 4810 MT /month, under production of 190 Tonnes. This still justify the need for capacity utilization, long grinding hours and faster and flexible technology Analysis of standard cost drivers in sugar processing.

Table 5. Simplex table 1

	Cj	0	0	0	0			1	0	1	0		
C_B	Basis	X_1	X_2	S_1	S_2	S_3	S_4	Du_1	Do_1	Du_1	Do_2	B	b/a_j
1	Du_1	400	140	0	0	0	0	1	-1	0	0	145,200	363
1	Du_2	1	0	0	0	0	0	0	0	1	-1	5000	5000
0	S_1	35	0	1	0	0	0	0	0	0	0	5250	150
0	S_2	(158)	40	0	1	0	0	0	0	0	0	2970	19
0	S_3	59	23	0	0	1	0	1	0	0	0	1357	23
	S_4	120	59	0	0	0	1	0	0	0	0	2865	24
	Z_j	401	140	0	0	0	0	1	-1	1	-1		
	C_j -Z_j	-401	-140	0	0	0	1	0	1	0	1		

Solution feasible but not optimal

Table 6. Simplex table 2

	Cj	0	0	0	0	1	0	1	0	1	0	
C_B	Basis	X_1	X_2	S_1	S_2	S_3	S_4	Du_1	Do_1	Du_1	Do_2	b
1	Du_1	0	138	0	-2.4	0	0	1	-1	0	0	137600
1	Du_2	0	-0.005	-0.006	0	0	0	0	0	1	-1	4810
0	S_1	0	-0.175	1	-0.21	0	0	0	0	0	0	5231
0	X_1	1	-0.005	0	0.006	0	0	0	0	0	0	190
0	S_3	0	22.705	0	-0.354	1	0	1	0	0	0	236
0	S_4	0	58.4	0	-0.006	1	0	0	0	0	0	585
	Z_j	0	0	0	0	0	0	1	0	1	0	
	C_j -Z_j	0	0	0	0	0	0	-1	0	-1	0	

Solution optimal

The findings showed that, the control readjustment and reengineering of operation costs (water, electricity, fuel etc) can reduce cost of producing sugar in Kenya to a great extent with a weighted Likert scale of 4.16. Raw material improvement had the least effect with a weighted Likert score of 1.8. It is evident that organizational policy needs to be reorganized or reengineered to adhere to optimal use of resources. Technology need also to be looked into i.e on that minimize use of energy and work faster.

On cost driver segment, it was established that, Cost of spares, VAT on inputs, Transport, Electricity, technology adopted, Labour (over employment) and rain feed sugar cane agriculture as major contributors to high cost. Due to rain feed agriculture there is usually idle time on production due to no cane.

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Conclusions

From the results, the study attempted to find "best" solutions to factors that would ensure that the cost of producing sugar in Kenya is reduced and optimal. In this regard, a Pre-emptive Goal Programming model was applied to the first two goals that were adopted for this study, which is cost reduction and maintaining production level at a mean of 5000 tons per month for each factory. Even though it is mathematically complex to formularize the relationships between the goals and model variables given that the model reflects reality, it provides interesting results depicting the effects of various goals on the remaining system variables and goals. Hence, the model can also be utilized as a cause-effect impact analysis tool to understand the sensitive relationships between the variables. In future, it is proposed that all the goals of a given factory can be embedded in the model and the model can be adjusted according to the changing variables. The obsoleteness of technology adopted by the sugar industry in Kenya was also evident. And it is the prayer of every stakeholder that this be improved to conform to the more state of the art facilities that many countries have adopted in sugar production. This will in effect reduce production cost to manageable level.

Conflict of interest

Authors declare there are no conflicts of interest.

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