Scope of Mathematical Programming in Sugar Industry-Harvesting and Transportation of Sugarcane

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Abstract

India is the major sugar producing country in the world, the first being Russia, Brazil and Cuba. Sugar industry occupies an important place among organized industries in India. Sugar industry is the one of the agro-based industry in India, has been instrumental in resource mobilization, employment generation, income generation and creating social infrastructure in rural areas. Indeed sugar industry has facilitated and accelerated pace of rural industrialization. India has 566 sugar mills in the country, of which 56% are in co-operative sector, 34% in the private sector and remaining 10% are in the public sector. These processing units are located in 80 major districts and a large number of these units are in Maharashtra (142 in co-operative sector and 12 in the private sector during 2008-2009) And Uttar Pradesh (28 in co-operative sector, 64 in the private sector and 22 in the public sector as at the end of 2005-2006). The sugarcane harvest is the complex logistical operation that involves the cutting and loading of cane in the fields, the transportation to the factories and the unloading of the cane in order to meet a daily quota.

Keywords: Mathematical programming; Simulation techniques; harvesting schedule; sugarcane stalk.

INTRODUCTION:
Sugar industry one of the major agro-based industry in India, has been instrumental in resource mobilization, employment generation, income generation and creating social infrastructure in rural areas. Indeed sugar industry has facilitated and accelerated pace
of rural industrialization. India has 566 sugar mills in the country, of which 56% are in co-operative sector, 34% are in private sector, and remaining 10% are in public sector. The increased number of sugar factories has affected the availability of sugarcane for processing and in turn the viability. More than 4.50 crore farmers are engaged in sugarcane cultivation and about 5 lacs rural people got direct employment in the industry. India ranks first in sugar consumption and second in sugar production in the world, but its share in global sugar trade is below 30%. Indian sugar industry has been facing raw material and resource as well as infrastructural problems. Globalization has brought a number of opportunities, but at the same time posed certain challenges before sugar industry. Most of sugar units in India utilize production capacity below 50%.

In India sugar is a controlled commodity under essential commodity act 1955. Government of India imitated de-licensing policy in sugar industry in 1998. In view of globalization process, and since then industry has experienced significant changes. Central Government announced Statutory Minimum Prices (SMP) of sugarcane and on this basis state Governments fix State Advised Prices (SAP). Unfortunately, SAP is being used as a political tool and has been main concern of sugar mills as it results in escalation of production costs. Along with this sugar industries also faces another problems like Roll of co-operative sector, Competition from Gur production, problems of production of sugar, the problems of by-products, problems of faulty Government policy, the questions of minimum economic size, old machinery, competition from cheaper imports, Low sugar Recovery, Cane Price, Levy sugar obligations, Imports / Exports Policy etc.

In this paper, the main concern is to review the literature on Mathematical Programming used in sugar industry. A Mathematical Model is to be developed for Harvest Scheduling, Transportation of sugarcane to mill so as to Maximize Recovery of sugar from sugarcane.

**LITERATURE REVIEW:**

There is literature base of sugar industry related issues like sugarcane quality, simulation and optimization of sugarcane, logistic supply system, harvest planning and scheduling, production optimization etc. is carried out globally in developed countries like Cuba, Brazil, Australia, France, South Africa etc. The literatures of sugar industry of these countries are available. It is observed that tools and techniques has several constraints, with respect to decision support on organizational issues within poorly integrated sugarcane supply chains. In India almost all sugar mills depend for their supplies of sugarcane on large number (5000 to 25000) of independent farmers. The sugarcane harvest is a complex logistical operation that involves the cutting and loading of cane in the fields, the transportation to the factories and the unloading of the cane in order to meet a daily quota. Manual sugarcane cutting provides employment to people in nearby areas where jobs are scarce. Once a complete bundle has been assembled, it is removed from the field with the help of laborers and transferred to a larger vehicle for transport to the mill. Then depending on the quota for a particular day, resources such as Bullock Carts, Tractors
The harvested sugarcane should be crushed within 8-12 hours to get a good recovery of sugar. In brief, the most important aspect of cane harvesting is being able to determine the optimal combination of transportation means; this result in a minimization of transportation cost and the fulfillment of daily sugar mill supply needs with an acceptable level of quality, avoiding at the same time losses caused by not harvesting in the factory. Each sugar factory has a number of teams, which cut cane with hand (Manual harvesting).

Considerable research has been conducted in other sugarcane producing countries, focusing primarily on optimizing harvest and transport operations. This work has included optimization of harvest group scheduling in Australia (Higgins, 2002), simulation of harvest to mill delivery system in South Africa (Hansen et al., 2002), economic case study analysis of regional harvest operations in Australia (Higgins et al., 2004), as well as PC-based decision support tools to evaluate alternative harvest and transport situations in Thailand (Sing and Pathak, 1994) transformed this model into a user-friendly tool for traffic officers. Little research has been conducted on the impact of waiting time at the farm on harvest costs as well as scheduling harvest and mill delivery operations to reduce waiting time impacts. A routing and scheduling problem for a rail system (Abel et al., 1981) was the first to develop a sugarcane railway scheduling model for the pick-up and delivery of cane rail transport scheduling system (Pinkeny and Everitt, 1977) presented scheduling road transport for sugarcane has mainly been attempted using simulation. Using computer simulation to evaluate sugarcane harvest-to-mill delivery systems (Hansen et al., 2001) addressed simulation method and its effective application in scheduling of harvesting pattern and transportation of sugarcane to mill so as minimize the time required that also minimize lost. Such models has been used to test different transport operation scenarios to reduce the number of vehicles required in sugarcane transportation in Cuba, a case study (Esteban Lopez Milan et al., 2006) proposed a linear programming model to solve the problem of cost minimization of sugarcane removal and its transportation from the fields to the sugar mill at operational level in Cuba. The model presented by researcher is capable to solve the problem of cost minimization of sugarcane transport from fields to the mills for a working day. The model determines the capacity of road and rail transport capacities for transportation cane to ensure an uninterrupted supply of it to the mill. The mathematical formulation of the model integrates rail and road transport system emphasis on the reduction of transportation cost. The model also controls sugarcane freshness through the constraints of minimum supply to the sugar mill with direct transport. Reducing harvest cost through coordinated sugarcane harvest and transport operations in Louisiana (Michael E et al., 2008) developed the model that allows sugar mill manager to schedule automatically daily transport plans based on either objective criteria or those that have been acquired through professional experience. The study reveals the harvest cost studies in Louisiana and U. S. The total cost of harvest accounts 32.5 % of total cost production. The study focus on waiting time requires to the trucks to unload the sugarcane in the mill as the waiting time increases the unloading time and empty trucks return time to the farm increases. The study was conducted to estimate the cost of waiting time on harvest cost and to develop a
framework for coordinating harvesting and transport of sugarcane to minimize waiting time. Mathematical programming model results the ability to coordinate harvest and delivery schedule can reduce truck waiting time at the mill. The model develop here provide a framework for scheduling sugarcane harvest at the firm and delivery to the mill with goal of distributing mill delivery out more early over the delivery time window thereby indirectly reducing the waiting time.

Low capacity utilization and inadequacy of raw material lead to closure of 100 sugar factories in India. Mounting losses and decreasing net worth of sugar factories have been responsible for sickness of sugar industry. Sickness of sugar industry has reached to an alarming proportion. Indian sugar industry has been cash striven for decades. Low cash inflow due to piling leads to serious financial crisis and finally to closing sugar factories. Sugar prices have been a political issue rather than economical issue. Many a times it worsens economy of sugar factories.

The main concern of sugar industry in India is fluctuations in sugarcane production due to inadequate irrigation facilities, lower sugarcane yield, and frequent droughts in tropical and sub-tropical areas where sugarcane is grown on a large scale.

MATERIALS AND METHODS

Collecting Information:

After visiting sugar mills located in Indoli Tal-Karad of Satara district and managers interview, the characteristics of problems and collect some data were represented as:

- Sugarcane breed planted by each farmer, in general, of hard breed, medium breed or light breed.
- The increasing of sugarcane weight in different season could not be collected. However, the production rate per acre can be investigated.
- The mill has faced the problem of insufficient supply due to transportation problem and the lack of labor man power.

Model Description:

Field area around the factory from where sugarcane is to be supplied to factory $f_i$ denotes $i^{th}$ field where cutting of sugarcane is done ($i = 1, 2, ..., n$).

It is assumed that there is at least good connectivity (by road) between field and factory for transporting means i.e. trucks, trolleys and bullock carts.

Let $n_1$, $n_2$, $n_3$ be number of trucks, trolleys and bullock carts respectively are available for transportation.

It is obvious assumptions that there transportation units differs in the capacity of transporting sugarcane stock bundle.

Let,

- $C_t$-capacity to transport ton of sugar per truck ($t = 1, 2, ..., n_1$).
- $C_l$-capacity of transport ton of sugar per trolleys ($t = 1, 2, ..., n_2$).
- $C_b$-capacity of transport ton of sugar per bullock cart ($t = 1, 2, ..., n_3$)

Let,

- $t_t$-number of trips made by truck / day.
- $t_l$-number of trips made by trolleys / day.
tb-number of trips made by bullock carts / day.
\[ \sum C_t \cdot t_t + \sum C_l \cdot t_l + \sum C_b \cdot t_b \geq T \]

Normally during peak period transportation is carried 24 hours round the clock. Even though there is a constraints on maximum capacity for covering distance from field to mill.

Let \( d_1, d_2, d_3 \) be maximum distance covered through truck, trolleys and bullock carts for a particular field \( f \) around a mill.

\[ d_1 + d_2 + d_3 = D \]

Where, \( D = \) Maximum distance covered per day by all form of transportation means.

One more constraints that has to be consider is harvesting of sugarcane per day that is possible by two ways, either manual or by machine. In Indian scenario of sugarcane industries, major share of harvesting is done through manual cutting. Less but significant cutting of sugarcane is done through machines too. It is assumed that cutting and making stake bundles of sugarcane must satisfies the requirement of transportation.

For that, a fair assumption is that it must be equal to a daily processing quota of factory.

Let, \( F_d \) be minimum daily processing quota of a factory.

So equation can be re-written as,
\[ \sum C_t \cdot t_t + \sum C_l \cdot t_l + \sum C_b \cdot t_b \geq F_d \]

Keeping in mind above constraints the determination of a harvest schedule was formulated as a linear mathematical programming model which maximized producer net returns above harvest costs over total farm average. Since pre-harvest production costs were assumed to be independent of harvest operations, only harvest costs were included in the model. Harvest cost were assumed to be a function of the total tonnage of sugarcane harvested. The objective function for the model was defined as follows:

\[ Z = (P_s \times S_p) + (P_m \times M_p) - (C_h \times T_t) \]

Where,
\( Z \)-represents total farm level producer net returns from sugar and molasses production above harvesting costs.
\( P_s \)-represents the price received per kilogram of sugar (Rupees per kilogram).
\( S_p \)-is the producer's share of sugar produced (kilogram)
\( P_m \)-is the price of molasses (Rupees per gallon)
\( M_p \)-is the producer's share of molasses (gallon)
\( C_h \)-is cost of harvesting sugarcane (Rupees per ton)
\( T_t \)-is the total tons of sugarcane harvested.

Mathematical Model: A linear programming is modelled in order to design a schedule of cultivation and harvest to meet the mill demand. There is a mutually dependant relationship between the farmers and millers. Therefore it is essential that the harvesting-transport-processing (HTP) system is viewed as integrated system. The HTP system is very complex, comprising an integrated chain of activities that stretch form farmers’ to millers through to transport and mill processing. Sugarcane yield (the amount of sugarcane that can be harvested from a field) is affected by a combination of deterministic parameters (e. g. variety, age and season) and stochastic parameters (e. g. weather conditions and soil type, farming practices etc.). Hence,
modelling of the sugarcane yield is a complex task. The amount of raw sugar in a field of sugarcane is a function of several variables. Two of them are important—tons of sugarcane per acre and kilogram of raw sugar produced per acre. The relationship can be shown as:

\[ SA = TRS \times TONS = TRS \times POP \times STWT \]

Where,

- SA is the total kilograms of raw sugar per acre.
- TRS is theoretical recoverable sugar in kilograms of sugar per ton of cane.
- TONS is the tons of sugarcane produced per acre.
- POP is the per acre population of sugarcane stalk in the field.
- STWT is the stalk weight.

It is observed that theoretical recoverable sugar and stalk weight both increases as harvest season progresses.

Proposed model is supported by simulated data.

Simulation Model:

Simulation studies can contribute a lot towards solving the problems associated with the operation of a complex system, such as the HTP system. To obtain reliable and meaningful results from simulation studies, one has to take into account the conditions, restrictions and requirement of the real operation viz;

- Harvesting is a stochastic process
- Loading-unloading truck is random process
- Harvesting and transport daily duration are different
- Waiting time for unloading truck at mill is negligible

The simulation model considers the most common and economic cycle—truck loads stalk from field and haul it to the mill. Here it is assumed that harvesting is completed during the daylight time (say 12 hours/day) and transportation took place round the clock.

Developed model has been applied to mills situated in Satara district of Maharashtra state. To support model numerically simulated data is used. Statistical analysis of one day of the season, data collected for Jayavant sugar factory. In most of the cases truck trip times were described by normal distribution, while loading time were described by uniform distributions.

Following table shows some of the observed results for above mentioned sugar factory:

<table>
<thead>
<tr>
<th>Field</th>
<th>Avg. trip time (in Hrs)</th>
<th>Std. Dev</th>
<th>CV</th>
<th>Avg. Loading time (in Hrs)</th>
<th>Std dev</th>
<th>CV</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6.5</td>
<td>1.2</td>
<td>0.18</td>
<td>5.3</td>
<td>1.5</td>
<td>0.28</td>
</tr>
<tr>
<td>2</td>
<td>5.3</td>
<td>0.9</td>
<td>0.16</td>
<td>5.8</td>
<td>2.0</td>
<td>0.34</td>
</tr>
<tr>
<td>3</td>
<td>4.9</td>
<td>1.3</td>
<td>0.26</td>
<td>5.2</td>
<td>1.9</td>
<td>0.36</td>
</tr>
<tr>
<td>4</td>
<td>5.6</td>
<td>1.5</td>
<td>0.27</td>
<td>5.7</td>
<td>1.9</td>
<td>0.33</td>
</tr>
<tr>
<td>5</td>
<td>6.4</td>
<td>1.7</td>
<td>0.26</td>
<td>5.5</td>
<td>1.7</td>
<td>0.26</td>
</tr>
<tr>
<td>6</td>
<td>3.9</td>
<td>0.9</td>
<td>0.23</td>
<td>6.6</td>
<td>2.1</td>
<td>0.31</td>
</tr>
<tr>
<td>7</td>
<td>4.5</td>
<td>1.1</td>
<td>0.24</td>
<td>5.4</td>
<td>2.0</td>
<td>0.37</td>
</tr>
</tbody>
</table>
RESULTS AND DISCUSSION:
The number of trucks required and tonnage of sugar cane delivered is given as below on the basis of simulation results in 3 trials:

<table>
<thead>
<tr>
<th>Trial</th>
<th>Number of trucks</th>
<th>Sugarcane delivered to Mill (in ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>107</td>
<td>1498</td>
</tr>
<tr>
<td>2</td>
<td>84</td>
<td>1176</td>
</tr>
<tr>
<td>3</td>
<td>95</td>
<td>1270</td>
</tr>
</tbody>
</table>

Conclusion: Proposed model is not specific but it can be used for planning purpose at any of the sugar cane mills using road transport system exclusively. This model has facility to changes in the characteristics of resources. In the long term movement of sugar industries it should to find out ways to produce sugar more economically by reducing production costs and managing available resources efficiently.

REFERENCES:
