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## DATA ANALYSIS OF SUGARCANE SUPPLY CHAIN MANAGEMENT PRACTICES ADAPTED FOR PERFORMANCE IMPROVEMENT

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**Abstract:** In today's global market, managing the entire sugarcane supply chain becomes a key factor for the successful business. These issues often bring into question the survival of the Indian sugar industry, especially that of the mills. The search for profitability for sugarcane operations becomes imperative for the long term survival of the sugar industry. In order to ensure profitability, the industry must focus on novel management tools for harvest and transport operations of sugarcane. The harvest, transport, reception, and crushing system for sugarcane are very important components of sugar production that require a systems approach through modeling in order to facilitate the optimal use of the resources involved. The study was aimed at to develop the simulation model on the aspects of the harvesting, transporting and unloading of sugarcane at mill. The model was developed for the M, S, S, K. Ltd., Faizpur (India) but could be adapted to all other sugar industries in India. WITNESS was identified as the appropriate software for the modeling exercise. The model was used to determine the optimal number of sugarcane carriers, its allocation plan in the farm groups. Simulation results show that the number of sugarcane carriers could be reduced by 28.41% and, at the same time, the capacity utilization factor and the whole performance could be improved

**Keywords:** Harvesting, Transport, Model, Simulation, Scheduling

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## INTRODUCTION

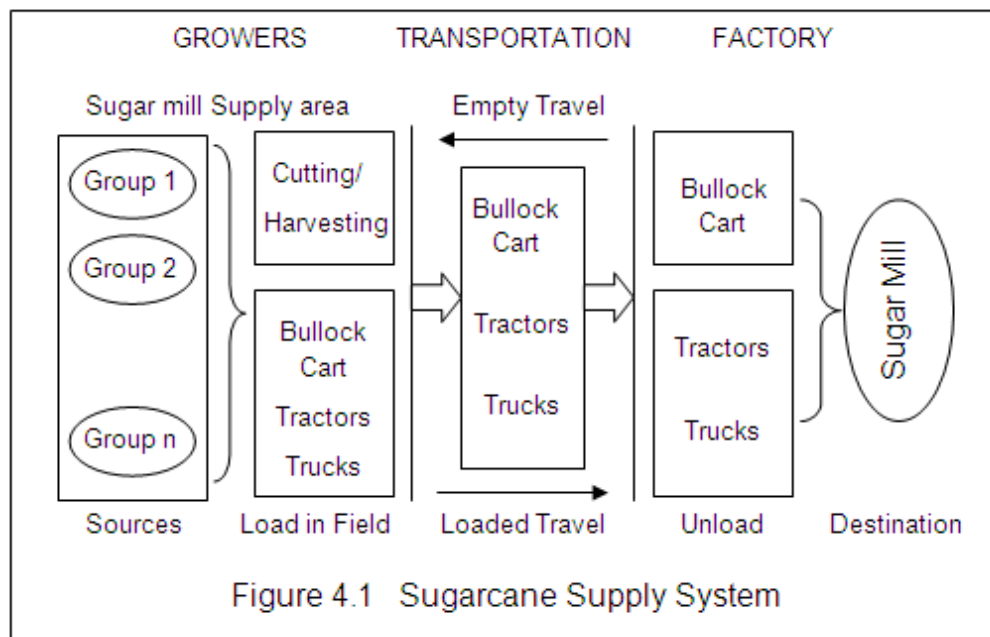
India is one of the largest producer and consumer of sugar in the world. Sugar is also India's second largest agro consumable product processing industry therefore, Sugar cane growers and sugar manufacturing sectors are quite important segments of the Indian agriculture sector with great potential for impacting rural development. Sugar industry has proved itself to be a nucleus of rural development, particularly in its surrounding areas and has carved for itself a very significant role in the national economy. The sugar cane supply management plays very important role to improve the overall performance of the mill. In the sugar industry, millers plan their cane supply to ensure that the mill operates at optimum capacity throughout the entire season. They also take into account variations in cane quality within the supply area and at different times during the season to maximize sugar production. Many researchers have focused on modeling sugarcane harvesting, transporting and crushing systems throughout the world. Most of them used, whatever their objectives, queuing theory and simulation techniques to develop their models. These work has included optimization of harvest group scheduling (Higgins 2002) and Raicu, Taylor (2001) developed a simulation model for sugarcane road transport system for particular sugar mill in Australia. In South Africa, Hansen et al. (2006), Barnes et al. (2000) developed simulation model of harvest to mill delivery system. In Morocco Jorio R et al. (2006) developed an interactive computer based model that incorporates sugarcane harvest, transport, reception and crushing system. A simulation model to evaluate sugarcane supply system has developed in Brazil (Rangel et al. 2010). Jose A. Daiz (2000) developed simulation and optimization of sugarcane transportation in harvest season in Cuba. In the United State, Salassi et al. (2008) conducted a study to estimates the cost of waiting time on harvest cost and to develop a framework for coordinating harvest and transport of sugarcane to minimize waiting time.

However, no study or research was initiated that focused on its optimization for performance improvement in Indian sugarcane supply management practices. The main objective of this study was to develop an interactive computer based model that could be used to determine:

1. Optimization of fleet size required to meet the daily needs of the mill.
2. Crushing duration ( Length of crushing season)
3. Utilization of full crushing capacity of factory.
4. Improvement in profitability of the sugar mill.

## 1. DESCRIPTION OF INDIAN SUGARCANE SUPPLY SYSTEM

Sugar cane flow from the fields to the factory at harvest time is a process that includes cutting, loading, transporting and unloading. It is a multisource system with one destination i.e. Sugar Mill. The sugarcane for the mill originates from different farm groups which constitutes the sugar mill supply area. The service facilities located at the point of origin of sugarcane are cutting and loading of cut cane in transport carriers which delivers it to the Sugar Mill. At the mill reception, service facilities are carrier's registration, weigh in and unloading. This cycle is repeated continuously during the day until the team meets its daily quota. In view of the process involved and the numbers of carriers i.e. Bullock carts, tractors, and trucks allocated to each team, time could be wasted at various stages and holdups of greater or lesser duration could occur, and this has a direct bearing on the efficiency of the team and on the total quantity of sugar cane that can be harvested and transported in a given day. An outline of the operation of the system is shown in the Figure 4.1. In this transportation system cane flows associated with a given logistic chain. The modeling structure is based on three modules: (i) growers. cane fields, (ii) Transportation and (iii) Factory / Mill yard. The modules are linked by cane transport from field to mill



The transportation system has to maintain a constant flow of ripe cane to the mill so that either factory should not be stopped due to want of cane or cane should not be dried in field or in the yard after harvesting due to excess cane cutting. This requires management concept and skill as

well as planning because road transport is adequately available in the country and at night road transport stop working. However, main problem is post harvest control because losses occurring during this period. Post harvest deterioration of cane is major factor affecting sugar recovery. Once the cane crop is harvested the microbial infection through the cut ends add to the problem and not only stored sucrose is lost but the workability of extracted juice is very much impaired. This problem of post harvest deterioration of cane cannot completely eliminated but can be minimized by proper indenting of cane for crush, quick and timely transport and regular working of factory. Under these circumstances, in order to solve these problems one has to take into account the conditions, restrictions and requirements of the real operation in its very complexity and details. This processes need to be effectively streamlined and integrated in order to achieve a reliable and efficient sugarcane flow. This can only be achieved through a sound understanding of the full system.

It has been observed that, the harvesting, transporting and crushing system of sugarcane are both stochastic and dynamic. They are stochastic because most of parameters and service time vary randomly. They are dynamic in nature because their behavior varies over time. In practice, Simulation is most widely used and appropriate for applications that involves such a complex system. Simulation is also used because of lack of adequate analytical tools to describe and analyze such a complex system. WITNESS, a visual interactive modeling system, was chosen as model development platform because this software allows incorporation of both dynamic and stochastic factors. The interactive nature of WITNESS allows the user to easily modify the model and perform experiments.

## 2. MODEL FRAMEWORK FORMULATION

The model was developed on the scale of the MSSK Ltd. Faizpur sugar mill and the area supplying it with cane, because it is very often the interaction of factors, such as harvesting, transportation and Unloading and fleet that have an influence on the amount of sugarcane delivered daily to the sugar mill. The sugarcane harvesting, transport, reception, unloading and crushing system of MSSK Ltd. Faizpur sugar mill includes three sub-systems. The first is the supply area with its cutting and loading facilities located in different farm groups. The second is transportation of sugar cane from farm groups to Mill by means of sugar cane carriers i.e. bullock carts, Tractor trailers and Trucks. The farm groups are located at different locations. Third is registration, weighing loaded, unloading, weighing unloaded. These three sub-systems are modeled and connected to each other within WITNESS according to the way they interact in the real system. Transport, initially modeled as a non-limiting resource, was then optimized by

progressively increasing number of sugarcane carriers and at the same time reducing the number of working days assigned to each farm group to reduce transport costs.

Normally the Bullock carts and Tractor trailers operate up to 25 kms in the area of operation and trucks beyond 25 kms. But for the model purpose the Bullock carts operate up to 10 kms, Tractor trailers from 11 to 25 kms and Trucks beyond 25 kms. Therefore sugar cane in Groups 1 to 5 was transported by Bullock carts, Group 6 to 13 by Tractor trailers and Group 14 onwards by Trucks

The theoretical calculations to allocate carriers for first iteration are given as follows:

Initially the total yield for each group is calculated based on the registered cultivation data in each farm group as shown in table 1.

Then the working days required for each program are determined as follows

$$WD_n = \frac{HT_n}{TCD}$$

Where,

$WD_n$  is working days required for  $n^{th}$  program

$HT_n$  is the estimated harvesting tonnage of supplying area for the season of  $n^{th}$  program

TCD is mill crushing capacity per day

**Table 1: Total yield of each farm group for each program.**

Gr No	Fram Group Name	Dist km	Prog:1 Yield (Tons)	Prog:2 Yield (Tons)	Prog:3 Yield (Tons)	Prog:4 Yield (Tons)	Prog:5 Yield (Tons)	Prog:6 Yield (Tons)	Prog:7 Yield (Tons)	Prog:8 Yield (Tons)
1	Faizpur	2	1137.5	2258.8	1046.5	1241.5	412.75	204.75	139.75	243.75
2	Bamnod	6	5089.5	3250	3029	1111.5	572	435.5	113.75	0
3	Hingona	6	4010.5	4966	3464.5	2905.5	1693.3	208	0	0
4	Savda	6	572	1657.5	679.25	1443	672.75	513.5	598	409.5
5	Khiroda	9	341.25	578.5	1134.3	1189.5	611	65	169	0
6	Maskavad	11	1196	2333.5	1612	2678	1257.8	559	172.25	0
7	Padlse	11	1417	2947.8	1121.3	1426.8	432.25	429	0	0
8	Nimbhora	14	19.5	949	65	650	1267.5	227.5	0	0
9	Kathora	15	1384.5	2109.3	1329.3	2645.5	728	598	0	0
10	Yawal	15	461.5	1504.8	1456	2047.5	390	52	0	0
11	Duskheda	18	182	2301	702	916.5	676	552.5	149.5	0
12	Kolwad	19	2606.5	4088.5	2502.5	2405	1108.3	84.5	0	0
13	Satod	19	3211	5135	2629.3	2093	162.5	198.25	0	0
14	Korpavli	25	3942.3	4264	3669.3	3519.8	279.5	0	0	0
15	Dahigaon	25	5879.3	7965.8	3012.8	2632.5	341.25	0	0	0
16	Vadri	25	5089.5	5114.2	3825.3	3214.3	383.5	432.25	165.75	0
17	Raver	25	4010.5	188.5	334.75	932.75	221	513.5	0	0

18	Mohrale	26	572	4491.5	3997.5	4052.8	380.25	0	0	0
19	Savkeda	27	341.25	5970.3	3077.8	2346.5	923	448.5	0	0
20	Kehralla	30	1196	1222	208	1316.3	1638	1176.5	295.75	221
21	Kingaon	30	3461.3	2661.8	3051.8	5863	1436.5	812.5	130	0
22	Naygaon	32	3581.5	2957.5	5190.3	4400.5	1147.3	266.5	0	0
23	Varangaon	34	1560	6243.3	3643.3	5362.5	4683.3	1027	260	0
24	Nashirabad	34	1033.5	3084.3	2590.3	3061.5	1075.8	607.75	0	0
25	Muktainagar	37	312	2112.5	1703	2746.3	3718	1449.5	253.5	52
26	Idgaon	43	1241.5	2483	2219.8	3760.3	1212.3	325	338	136.5
27	Kinod	43	0	903.5	0	0	0	0	0	0
28	Paldhi	58	533	1488.5	1228.5	2697.5	3744	2346.5	65	0
29	Kurha	72	0	0	234	0	234	1514.5	3419	0
30	Harsoda	75	341.25	685.75	1053	0	507	2132	2541.5	2086.5
31	Takarkheda	76	0	0	0	0	52	572	1475.5	630.5
32	Bhadgaon	80	1033.5	2249	916.5	507	260	26	0	0
33	Parola	80	0	474.5	195	533	864.5	477.75	0	169
34	Erandol	85	481	975	2099.5	1235	2535	299	507	0
35	Salva	90	0	416	1199.3	507	968.5	0	0	0
36	Shirpur	105	0	802.75	146.25	52	0	0	0	0

Thus, the numbers of carriers needed of each type for each program are calculated as follows

$$N_{BC} = \frac{HT_{BC}}{WD_n \times CC_{BC}} , \quad N_{TT} = \frac{HT_{TT}}{WD_n \times CC_{TT}} , \quad N_T = \frac{HT_T}{WD_n \times CC_T}$$

Where,  $N_{BC}, N_{TT}, N_T$  is number of bullock carts, tractor trailers and trucks required.

$HT_{BC}, HT_{TT}, HT_T$  is the estimated harvesting tonnage of supplying area which transported by bullock carts, tractor trailers and truck respectively in tons.

$CC_{BC}, CC_{TT}, CC_T$  is carriers capacity.

**Table 2: Working days and numbers of carriers needed of each type for each program**

Program Number	Estimated harvesting amount (HT <sub>n</sub> ) tons	Working days (WD <sub>n</sub> )	Number of carriers required(N)		
			Bullock carts (N <sub>bc</sub> )	Tractor trailers (N <sub>tt</sub> )	Trucks (N <sub>t</sub> )
1	55958.5	21	236	25	109
2	90832.95	33	177	33	118
3	64366.25	24	173	24	121
4	71493.5	26	135	29	125
5	36588.5	14	126	22	127
6	18554.25	7	91	19	137
7	10793.25	4	113	4	158
8	3995.5	2	145	0	110

### 3. MODEL FRAMEWORK CONSTRUCTION

The WITNESS simulation software package was used to implement the model. Software implementation followed the key design principles developed in the conceptual model. WITNESS facilitates a flowchart type methodology when a system is constructed, thus the

components found within the conceptual model could be represented accordingly. Figure 1(a) and (b) shows input data and representation of the Simulation Model with in WITNESS.

All inputs are contained within a MS Excel spreadsheet and are read into the model. Input includes ranges of distances for each carrier type, loaded and unloaded (empty) speed of each type of carrier, capacity of carriers, minimum and maximum loading and unloading time of each carrier type, number of unloading stations, maximum unloading at the factory, group wise yield of sugarcane from each harvesting program, the distance of each farm group from the factory to decide the type of carriers as mentioned above and the fleet size

When inputs have been read, the daily requirement of sugarcane can start flowing from subsystem to subsystem. First the empty Bullocks carts were move to farms groups where sugar cane is available for harvesting also Tractor trailers and Trucks were directly goes to

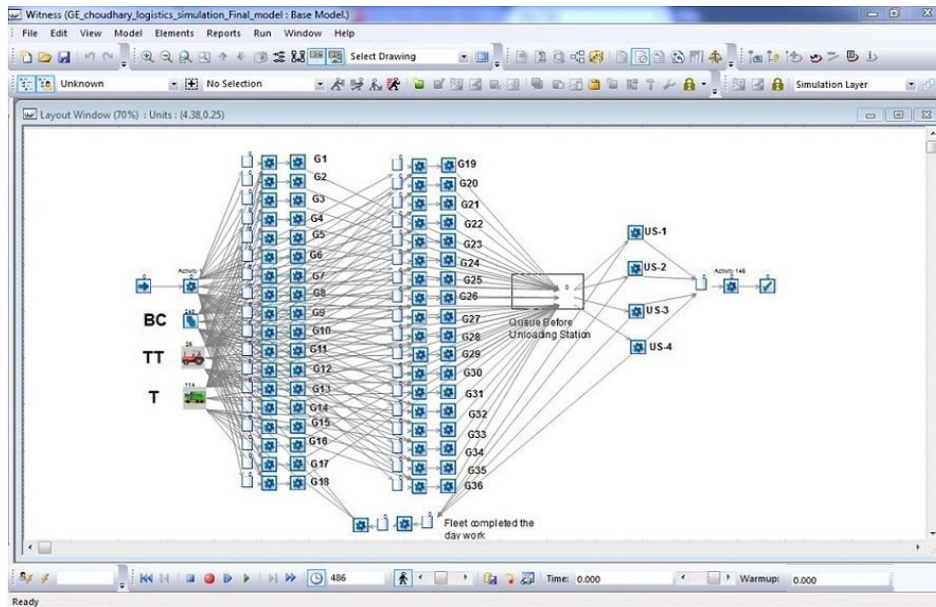
Carrier Type	Minimum Distance (km)	Maximum Distance (km)	Unloaded Speed (km/hr)	Loaded Speed (km/hr)	Capacity (Tons)	Fleet size	Program Number
Cart	0	10	10	8	2.25	91	6
Tractor	10	24	25	20	20	19	
Truck	24	200	40	30	15	137	

Carrier Type	Minimum loading Time (Hr)	Maximum loading Time (Hr)	Minimum Unloading Time (Hr)	Maximum Unloading Time (Hr)	Average Unloading Time (Hr)	Unloading Stations	Maximum Unloading at Mill
Cart	1	1.5	3	5	4	2	3200
Tractor	3	5	10	14	12	2	
Truck	2	4	8	12	10		

**Fig1(a):Input data for Simulation Model**





**Fig1(b):Representation of the Simulation Model**

farm groups as mentioned. After sugar cane is cut, the sugar cane was loaded on to the carriers. The cane is then routed to the Mill directly. When the carriers reach the Mill they enter the Mill yard, then it goes to mill gate and subsequent reception facilities according to FIFO discipline. After unloading, the carriers weighed empty to determine amount of cane it carried to Mill. Thereafter, if the maximum unloading for a day is reached then the model is stopped for that day and the carriers are waiting for the next day. And if the maximum yield for that particular program was unloaded, then the model was stopped. Thus, the optimum fleet size and the optimum duration of working days for that program were obtained in Excel. Otherwise, the carriers are travelled to the concerned farm groups for harvesting of remaining sugar cane on the next day.

**Table 3: Simulated results of optimum fleet size, crushing duration**

Prog. No	No.of Bollock Carts	No.of Tractor Trailers	No. of Trucks	Total Fleet size	Average daily tonnage delivered (tons)	Crushing duration (days)
1	250	27	118	395	2798	20
2	190	36	128	354	2932	30
3	181	25	130	336	2785	23
4	135	29	127	291	2747	26
5	137	24	138	299	2800	13
6	91	21	139	251	2641	7
7	115	6	165	286	2748	4
8	147	0	120	267	2067	2



The most important aspect of this WITNESS presentation is that it shows that carriers go round a closed circuit system, while tons of cane moves through an open circuit system. In fact, carriers are created at the farm groups when the harvesting season begins and do not leave the system until the end of the harvesting season.

#### 4. MODEL VALIDATION

Validation is necessary to enhance confidence in the model. It is concerned with determining whether the conceptual simulation model is a sufficiently accurate representation of the system under study. The approach used to validate the model in this case study consists of comparing its output data with theoretical data of the modeled system by constructing the 90% confidence interval of the differences between the simulated results and the observed data. The results of simulation were compared with theoretical data for:

1. Optimum combination of numbers of transportation carriers for each program.
2. The crushing duration of each program

**Table 4: Comparison of simulated results with theoretical data.**

Harvesting Program No.	Optimum fleet size			Crushing duration		
	Theoretical data	Simulated results	Deviation (%)	Theoretical data	Simulated results	Deviation (%)
1	370	395	6.75	21	20	-4.76
2	328	354	7.92	33	30	-9.09
3	318	336	5.66	24	23	-4.16
4	289	291	0.69	26	26	0
5	275	299	8.72	14	13	-7.14
6	247	251	1.61	7	7	0
7	262	286	9.16	4	4	0
8	255	267	4.70	2	2	0

Using these data, model validation showed a great agreement between theoretical and simulated number of carriers required to deliver the sugar cane to the mill and crushing duration. Thus the percentage deviation between theoretical and simulated results shoes 90% confidence interval. Therefore, it is assumed that the differences are acceptable and the model valid.

## 5. RESULTS AND DISCUSSIONS

### 5.1 Optimum Fleet Size and its Allocation Plans

The optimum fleet size for each program is given in table no 3. These values of optimum fleet size were obtained from iteration performed for each program. The maximum numbers of bullock carts required are 250 for 1<sup>st</sup> program, 36 tractor trailers for 2<sup>nd</sup> program and 165 trucks for 7<sup>th</sup> program. This number of each carrier type is varying in each program as per availability of sugarcane in the concerned farm group. So, these maximum numbers of bullock carts, tractor trailers and trucks should be registered in the factory to deliver the sugarcane from farm group to the Mill in 2010-11 crushing season. Therefore, the optimum fleet size is

$$250 \text{ bullock carts} + 36 \text{ tractor trailers} + 165 \text{ trucks} = 451$$

Thus, the fleet size is reduced by 179 number of that currently used 630 carriers that means 28.41% of fleet size is reduced after simulation results.

Table 5 gives the effective allocation of these sugarcane carriers between different farm groups.

**Table 5 Allocation plans of sugar cane carriers**

Sr. No.	Farm Group	Harvesting Program Number							
		1	2	3	4	5	6	7	8
1	Faizpur	26	34	20	21	14	13	16	55
2	Bamnod	113	48	59	19	20	28	13	0
3	Hingona	90	74	67	50	58	13	0	0
4	Savda	13	25	13	25	23	33	67	91
5	Khiroda	8	9	22	20	21	4	19	0
6	Maskavad	3	4	3	5	5	4	3	0
7	Padlse	3	5	2	3	1	3	0	0
8	Nimbhora	1	2	1	1	5	2	0	0
9	Kathora	4	3	3	5	2	4	0	0
10	Yawal	1	3	3	4	1	1	0	0
11	Duskheda	1	4	2	2	2	4	3	0
12	Kolwad	6	7	5	5	4	1	0	0
13	Satod	8	8	6	4	4	2	0	0
14	Korpavli	13	9	11	9	2	0	0	0
15	Dahigaon	20	18	9	7	1	0	0	0
16	Vadri	10	11	11	8	2	4	3	0
17	Raver	1	1	1	3	1	5	0	0
18	Mohrale	11	10	12	11	2	0	0	0
19	Savkeda	15	13	9	6	5	4	0	0
20	Kehrala	1	3	1	3	8	11	5	8
21	Kingaon	12	6	9	15	8	8	3	0
22	Naygaon	12	7	15	11	6	3	0	0
23	Varangaon	5	14	11	14	24	10	5	0
24	Nashirabad	4	7	8	8	6	6	0	0

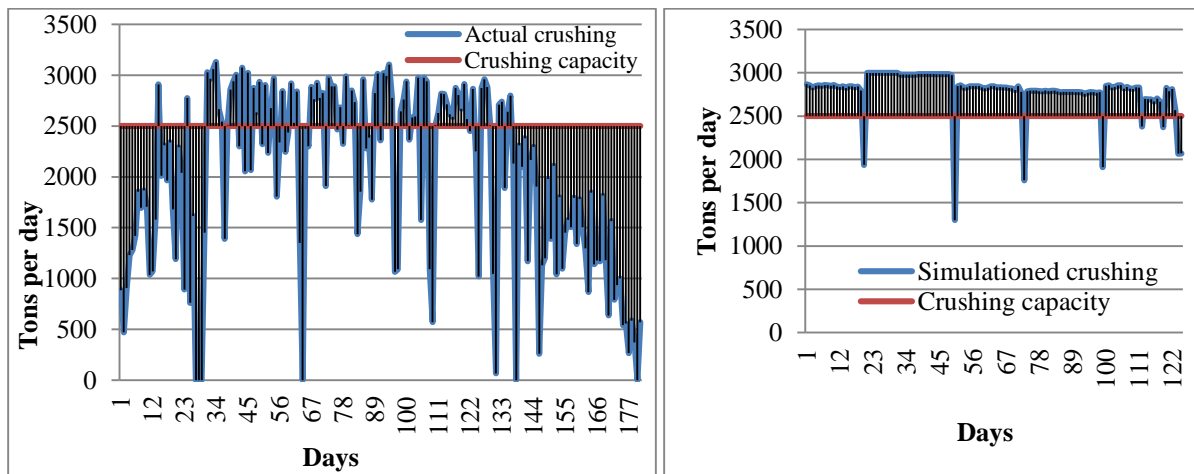
25	Muktainagar	1	5	5	7	19	14	5	2
26	Idgaon	4	6	6	10	6	3	6	5
27	Kinod	0	2	0	0	0	0	0	0
28	Paldhi	2	3	4	7	19	22	1	0
29	Kurha	0	0	1	0	1	14	58	0
30	Harsoda	1	2	3	0	3	20	44	70
31	Takarkheda	0	0	0	0	1	6	26	3
32	Bhadgaon	4	5	3	1	1	1	0	0
33	Parola	0	1	1	2	5	5	0	7
34	Erandol	2	2	6	3	13	3	9	0
35	Salva	0	1	3	1	5	0	0	0
36	Shirpur	0	2	1	1	0	0	0	0

### 5.2 Optimum Crushing Duration

On the basis of simulated results, the crushing of all available sugarcane is completed in 125 days assuming no rain and no factory breakdowns and maintenance. But, this crushing duration was 181 days prior to simulation of the system including stoppage. That means the crushing duration is reduced to 125 days, but considering the contingencies, factory breakdowns and maintenance period, the period of 125 days is converted into 140 days for computing costs in the cost analysis.

### 5.3 Capacity Utilization

The percentage capacity utilization is improved to 95.60 which was 74.15 prior to simulated results. The comparison of simulated results and actual daily sugarcane delivery to the mill. The sugarcane delivery to the factory is less than capacity or demand during the entire season whereas, in the simulated delivery of sugarcane in the entire season is almost uniform



**Fig 2 Comparison of simulated results and actual daily sugarcane delivery to the mill**

#### 5.4 Net Profit Enhancement

Prior to the results based on simulation, the total cost was Rs. 9164.03 lakhs which was 98.60 % of the selling price and the net profit percentage was 1.40, after simulation of the system the total cost is found Rs. 8317.41 lakhs which is 89.52 % of the total selling price i.e. the net profit percentage is 10.48 of the selling price.

After simulation there is saving of Rs. 846.62 lakhs in the total cost, consequently the amount of net profit is increased to 975.68 lakhs. It means the percentage of net profit was 1.40 % of selling price is increased to 10.48 % of selling price.

#### 6. CONCLUSION

The use of simulation techniques to investigate methods for determining the optimal fleet size, dispatching strategy of vehicles schedules was successful. The simulation technique made it possible to model this very complex system, which could not have been represented using analytical techniques such as linear programming or only the theory of queues. Another advantage of using simulation is the integration of the main components of the system, in order to take into account the interests of both growers and millers

Model validation using the 2010-11 harvesting season data showed a good agreement between simulated and observed actual results. Simulated results of the model gave the optimal fleet size and dispatching strategy, reducing the number of sugarcane carriers by 28.41% of that currently used.

The simulation model developed is not M.S.S.K. Ltd., Faizpur (India) specific. It can be used for planning purposes at any of the sugarcane mills that use a road transport system exclusively. Being designed as an interactive model, it allows changes to the resource characteristics. The model developed can easily be applied at other sugar factories which are located in the India having similar problems. It can also be applied to the mills, which uses a completely mechanized harvesting system.

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