IT adaptation in sugar supply chain: a study at milling level

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Abstract: The purpose of the study is to catalogue issues in the sugar supply chain at the procurement and sugar production levels. By a review of prior art and expert panel discussions, certain issues were identified for the facilitation of e-applications in the sugar production process. The relevance of the issues identified was checked by conducting a field survey. A total of 30 sugar mills in the states of Uttar Pradesh and Uttarakhand, India were targeted and 120 were collected from the mill managers to identify issues at procurement and sugar production stages. For checking the scope of IT applications, a total of 180 respondents were collected from 120 mill managers and 60 employees of IT companies who provide supply chain IT solutions. On the basis of the findings, the paper proposes certain IT solutions for solving the identified issues which will help in improving sugar cane processing at the sugar production level.

Keywords: supply chain management; sugar mills; procurement; sugar production; factor analysis; analysis of variance; ANOVA; information technology.

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1 Introduction

Sugar is one of the most demanded commodities. Everyone consumes and use sugar in their daily routine lives. In India, sugar is also closely linked to the economic, social and political environment of the country (Goel, 2014). Sugar on one side is a socially sensitive crop, but it has brought prosperity to many rural areas where sugar mills are established. As Uttar Pradesh is the largest state and also produces and consumes more sugar as compared to any other state in India (Wordpress, 2010, 2011). It becomes imperative to target Uttar Pradesh to explore the sugar industries and understand their supply chain system in a detailed manner (Yagyasena et al., 2013).

The important actors in the Indian sugar supply chain include cane farmers; transporters; millers; distributors (including brokers, wholesalers, and retailers) and lastly, consumers. The starting raw material, i.e., sugar cane comes from farmers who sell it to the millers for producing sugar and this chain ends at consumer who uses sugar in a variety of ways (Amu et al., 2013; Kadwa and Bezuidenhout, 2015; Kumar et al., 2015).

Sugar mills produce sugar from cane in four stages; firstly the cane is received from farmers. Secondly, the cane goes into crushing, thirdly processing the raw sugar, and finally packing of sugar produced. The produced sugar is stored in mill godowns and then distributed to the wholesalers on the orders made by brokers and private agents. The wholesalers, store the ordered sugar for further distribution to their area retailers and finally, the sugar is sold to the consumers. Indirect customers such as levy public distribution system (PDS), military, institutional customers (airlines, shopping malls, railways, food companies, etc.) importer countries order sugar directly from the mills or wholesalers (Kumar et al., 2012).

During the production of sugar, various by-products are obtained, namely, press mud, molasses, and bagasse. These by-products are purchased by state governments and private industries such as brick kilns, paper mills, etc. Sugar mills have different vendors who supply a variety of inputs required to produce sugar, such as chemicals; engineering parts; spare parts; miscellaneous items such as cotton waste, plywood, electrical instruments (Kumar et al., 2012, 2015).

During the procurement level, the millers communicate with the cane farmers for procuring the sugarcane. The state government has allotted respective areas, i.e., gate region (radius of 6.5 Km to 7.5 Km) and centre region (radius of 7.5 Km to 15 Km) for particular sugar mills. The area under which the farmers' sugarcane fields come will sell their cane to their respective mills. The team from the mills or employees starts surveying from the beginning of the season in April and will target the farmers to know the available quantity of cane. Further, the team starts bonding with the cane farmers' and try to convince them for supplying their cane to the respective sugar mills. When the sugarcane season starts, the millers issued two types of passes, i.e., one for the gate and other for centres. These passes are allotted to the farmers' for supplying their cane to their respective mills. This whole process of supplying cane can be operated either by centres or by farmers throughout the season by mode of transportation, namely trucks, tractors, bullock cart, etc. The mills operate the centres and act as the mediators between the farmers and millers.

In the sugar mill, the season for crushing the cane starts from October (most probably last week) to the April. The processing of sugarcane takes place with the help of heavily equipped machinery assembled in the sugar mills. There has been a steady advance in production technology at milling level. The capacity for particular mills must not exceed one crore 60 lakhs quintals for crushing the cane in one year (as interviewed with the mill managers of Uttarakhand and Uttar Pradesh, India). Further, the mill processing is strongly handled by the labours/workers under the supervision of supervisors or millers. Every sugar mill has a different work culture and labour strategy. These labours are hired from labour contractors on the contract basis to the sugar mills.

The main role of sugar mills is to target their daily cane requirement from farmers' so that they get sufficient quantity of cane for crushing. Both quantity and quality of cane matter to the sugar mills. Most of the sugar mills are using IT applications for their different departmental activities at sugar production and procurement levels. IT department of the sugar mill manages all the activities in different departments. But, still, there are many issues at procurement and sugar production levels, which require attention with the help of IT applications. Hence, it is very imperative to enhance the sugar production process at the mill level by using suitable IT tools and techniques.

1.1 Objectives of the study

The main aim of this paper is to study how IT applications can be used for solving the identified issues at the procurement and sugar production levels in the sugar supply chain. Since the body literature linking the use of IT in the sugar supply chains in India is meagre, the present study tries to bridge this gap, while at the same time unearthing the issues at procurement and sugar production levels and their suitable solution through the use of IT. The precise research objectives of the paper are to identify issues at procurement and sugar production levels. These issues were identified through secondary data collection and literature review. The validation of the identified issues is done using factor, as this provided the broad categorisation of the identified issues. Lastly, on the basis of the results of hypothesis testing certain IT solutions are prescribed for tacking these issues.

The paper is organised as follows. The first part focuses on identification of relevant issues at the procurement and the sugar production levels via primary data collection from the expert panel (mill managers) and through secondary sources. The second part focuses on the analytical methods applied for framing a model to facilitate e-Applications for the identified issues at both levels and analysis of variance (ANOVA) is used for testing the hypothesis. Thirdly, suitable IT solutions are suggested for dealing with the issues which may provide optimum profits for millers. To conclude, conclusions and limitations of the present study follow.

2 Literature review

Sugar supply chains in Australia, Brazil, Greece, Indonesia, and in the USA have received extensive research coverage from the academia. However, studies on the Indian sugar supply chain system are meagre. A review of studies conducted in other countries has provided valuable insights into sugar supply chain at procurement level and production levels.

Gaucher et al. (2003) presented a supply chain model of the sugar industry. They used two components modelling framework using strategic and logistical approaches. The strategic model describes the impact of stakeholder's technical interfaces on total sugar production where the logistical model shows the feasibility of strategic scenarios regarding task capacities and daily management of sugar cane flows. Semenzato (1995) and Barnes et al. (1998, 2000) have pointed out that some of the sugar industries have already implemented the logistic model in their supply chain system which helps to find out the reason in harvesting to the delays occur during the crushing period.

Gaucher et al. (1998, 2003) pointed out the impact of bottlenecks on the supply chain system of the sugar industry. A French island called La Réunion has followed the associated methodology to evaluate the results regarding the mixture of changes occur in the way of transportation. When the complete supply chain system was occupied by strategic model, then the logistic chain was provided on a daily basis gets motivated resulting the left out organisation equally. Therefore, the transportation of sugarcane from the cane fields to the sugar mills through the trans-loading centre.

Gaucher et al. (2003) have described the structure of the logistic model of the flow of sugarcane from three types of modules, namely, cane growers; the trans-loading centre and sugar mill-yard. Transportation facilities link these modules from one point to another. With the use of a logistic model with the combination of strategic model solutions for various issues can be addressed. Many issues can be solved by using the logistic model. The strategic model consists of two sub-modules, i.e., supply planning and operation, and cane processing. The model is a three-level representation of the supply area, includes the mill, intermediate operations like haulers (Bezuidenhout et al., 2013) and trans-loading centres, and production units (Pus), and simulates a crushing season on a weekly basis. Lejars et al. (2003) and Guilleman et al. (2003) have reported the application of the strategic model in La Réunion and South Africa for addressing the alternative supply chain management of sugar mill and variations that occur in cane quality within the mill supply area (Ndoro et al., 2015). The use of bagasse plays an important role in power generation in South African sugar industries and helps in reducing greenhouse gas emissions (Mashoko et al., 2013). Le Gal et al. (2003) have developed a computer program (MAGI) for framing this model by using simulation process so that all users get the benefit of it. Neungmatcha et al. (2013) have used an adaptive genetic algorithm (AGA) for solving the sugarcane loading station problems from the grower's fields to the trans-loading centres to the sugar mills.

Higgins et al. (2004) studied the methods developed for identifying opportunities to increase harvesting and transport efficiencies and process to facilitate proper implementation for sugar production. They have mentioned main components like reducing costs of production, development of the modelling framework identifying the key drivers and linkages, and an application to improve the efficiency of the system. They have used operations research techniques, financial modelling and simulation method for framing the system. Higgins et al. (2007) has mentioned the difficulty faced by mill traffic officers while managing the road transports due to a large number of harvesters coming from different locations to transport their cane to the mill. Hence, it is required to address such issue by implementing and developing the mixed integer programming model for managing the road transport operations.

Purcell (1981) has examined the relationship between business and government in the sugar industry in Mexico. Most of the private sugar mills and their owners are bound by the government rules and regulations to benefit the lower class, i.e., cane farmers and constitute an effective business-government relationship. The author has also attempted for assessing the autonomy of the state for providing interests to the business and lower class during the policymaking process. Thus, the mechanisms and behaviours of such relative autonomy were conserved and improved.

Drummond (1996) has reported conditions of unsustainability in the Australian sugar industry. Drummond (1996) has highlighted a realistic approach and regulation theory to develop a conceptual and a new framework for solving the sustainability issues. Everingham et al. (2002) have reported about the uncertainty associated with variable climatic conditions for sugarcane industries. This variation produces impact across an integrated supply chain comprising of cane growing, harvesting, transportation, milling, and marketing. A comprehensive systems approach for using seasonal climate forecast system will improve risk management and decision making capability of the entire supply chain. Rao (2007) also mentioned the role of ICT (Kukreja and Chakrabarti, 2013) in such a scenario could provide timely information, increased choice, reduce transaction cost so that efficiency of decision making can be improved. López-Milán and Plà-Aragonés (2014) also presented the decision support system for planning the sugarcane operations in Cuba on a daily basis at mill level which further may help in reducing the transportation cost.

Murty et al. (2006) have reported on the environmental regulation, productive efficiency, and cost of pollution abatement for the Indian sugar industry.

Bolling and Suarez (2001) have studied recent developments in the Brazilian sugar industry. Brazil produces both sugar and ethanol from sugarcane; and it is one of the few nations that can adjust sugar production rapidly to potential world sugar shortfalls and high international prices (Jena and Poggi, 2013). Kinoshita (1991) discussed the cogeneration process in the Hawaiian sugar industry. This industry has produced steam and electricity through their cogeneration plant to supply power to its factories and irrigation pumps. It strengthens the economic viability of the industry and also generated good revenue from their traditional products like sugar and molasses. Singh et al. (2007) also emphasised on the sugarcane milling waste utilisation for hydrogen production in India by using mainly bagasse. The benefit of this waste was genetically useful for efficient generation of energy.

Masuku and Kirsten (2004) have emphasised the role of trust in the performance of the supply chain system of the sugar industry in Swaziland. They report that the role of trust between the farmers and millers helps in enhancing the performance of the sugar supply chain by providing sufficient and good quality of cane to the mills. It leads to increase in production of sugarcane and generate some good revenue to the mills. They have also highlighted that honesty, fairness, and absence of opportunistic behaviour between farmers and millers are required for maintaining mutual respect that the relationship for improving the whole sugar supply chain performance. Singh (2006) also measured the performance of the sugar mills in Uttar Pradesh by their ownership, size, and location. He has highlighted that most sugar mills required to improve their efficiency and productivity because of various stakeholders are highly dependent on the industry performance. He has also mentioned that almost, every sugar mill was found highly underutilised regarding labour and energy inputs, but this could be improved by adjusting their mill operation to the target point as determined by the efficient mills.

A proper supply chain planning is the need of the sugar industry and management of supply chain partners is highly sought after. It can be achieved only by building trust among the supply chain partners, such as farmers, millers, and distributors. Further exploration through conferences, seminars and workshops with 'The Sugar Technologists' Association of India (STAI)' and 'Confederation of Indian Industry (CII)' revealed various issues at the procurement and sugar production levels. Some of the problems found were related to delay in payment to the farmers by millers (Tripathi, 2012), targeting daily requirement of the cane for crushing, manually checking the quality of cane, mills not being operational during the season which directly affects the production of sugar and other by-products. Black marketing increases the prices of sugar in the market. Government taking action against millers for not paying money to farmers, lack of trust among farmers and millers, the cane quantity issues, the involvement of indirect customers like Jaggery (Gur)/Khandsari Units, open market, etc. and many more.

3 Research methodology

On the basis of secondary data collected, and the literature review done through online databases like EBSCOS, Pro-Quest, Google Scholar; certain relevant issues were identified at procurement and sugar production levels of the sugar supply chain. Therefore, following are the relevant issues at the procurement and sugar production levels:

3.1 Issues at procurement level

1. limited sharing of benefits between farmers and millers
2. lack of trust
3. logistics
4. maintaining personal records of farmers and mill employees
5. managing slips information to benefit farmers and cane society
6. weighing cane quantity
7. checking the quality of cane
8. delay in payments
9. monitoring middleman, i.e., cane society and centres
10. lack of achieving the daily requirement of sugarcane for crushing.

3.2 Issues at sugar production level

1 lack of information regarding the status of work
2 no proper monitoring of conversion process
3 black marketing
4 less use of automation
5 no such aggregate planning in sugar mills for maintaining level strategy for labour
6 no records of daily wise production of sugar and by-products in the sugar mill are maintained
7 low level of technology absorption in sugar production process.

Thus, the two research questions arise,

- 'Do the identified issues have a relationship with one another, which will facilitate the use of e-applications at the sugar production level?'
- 'Do the identified issues have significant differences by using IT Application at the sugar production level?'

3.3 Development of survey questionnaire

A structured questionnaire was developed to get the responses of the millers on the identified issues. The questionnaire was used to collect responses from the mill managers and IT companies. A total of 120 responses were collected from the mill managers by visiting their mills.

Since the inclusion of IT companies is necessary to check the suitability of using IT applications for solving the identified issues at the sugar production level. A survey questionnaire was also circulated in 60 IT companies (supply chain solutions provider) through email. This yielded 60 responses from different departments with their response rates as per their job positions, such as, director (1.66%), assistant director (3.33%), business analyst (6.66%), senior software engineers (23.33%), software engineers (18.33%), consultants (13.33%), system analyst (11.67%), team leader (16.67%), and software architect (5%).

The questionnaire was designed in English for collecting the responses from sugar mills and IT companies in India. The respondents were asked to rate the issues to check the scope of IT applications for the identified issues at the sugar production level. The rating was obtained on a five-point Likert scale (1 = *not at all relevant*, 2 = *not relevant*, 3 = *neutral*, 4 = *relevant*, and 5 = *highly relevant*).

4 Analysis

The following sub-sections present the analysis of data collected.

4.1 Validity test using factor analysis

Factor analysis was conducted to ensure the validity of the scales employed (Burton and Mazerolle, 2011; Floyd and Widaman, 1995). This method is used for developing valid relations among the number of issues and reduce them into a few (Hair et al., 1995). The present study has employed factor analysis to validate the construct, i.e., issues at the sugar production level.

Table 1 Descriptive statistics for issues at sugar production level

Notations	*Issues*	*Mean*	*S.D.*
S1	Providing mutual benefits between farmers and sugar mills	3.82	0.63
S2	Building trust between the farmers and millers	4.35	0.76
S3	Logistics	4.11	0.54
S4	Maintaining personal records of the farmers by cane society and sugar mill	4.53	0.54
S5	Managing slip generation and distribution by sugar mills and centres to the farmers and cane society	4.46	0.66
S6	Weighing the quantity of material/sugarcane	4.30	0.63
S7	Checking the quality of material/sugarcane	4.23	0.73
S8	Improving money circulation to farmers and cane society by sugar mills	4.58	0.60
S9	Managing the middleman for procurement process	4.19	0.73
S10	Applying just in time (JIT) principles in ensuring the proper supply to sugar mill as well as maximum yield from sugarcane to produce sugar	4.18	0.70
S11	Helps in deciding the sufficient allowances for targeting the daily requirement of sugarcane for the procurement of crushing	4.12	0.66
S12	Online updating the information regarding status of work at sugar mill	4.22	0.64
S13	Better monitoring of conversion process	4.40	0.76
S14	Better monitoring in the inventory level of sugar and by-products at the warehouse/mill godowns to prevent black marketing	4.52	0.61
S15	Helps in upgrading the automated packaging plant which boost the capacity to produce more amount of sugar and improves processing efficiency	4.16	0.70
S16	For aggregate planning in sugar mills for maintaining level strategy for labour	3.93	0.69
S17	Managing the records of the employees of sugar mill	4.34	0.60
S18	Maintaining the records of the daily wise production of sugar and by-products in the sugar mill	4.56	0.55
S19	Enables the adoption of new technologies in sugar production	4.41	0.52

Table 2 Pearson correlation with significant two-tailed test for issues at sugar production level

Iss.		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19
S1	Pea Cor Sig. (2-tail)	1																		
S2	Pea Cor Sig. (2-tail)	.451**	1																	
		.000																		
S3	Pea Cor Sig. (2-tail)	.548**	.022	1																
		.000	.795																	
S4	Pea Cor Sig. (2-tail)	.212*	.083	.465**	1															
		.011	.322	.000																
S5	Pea Cor Sig. (2-tail)	.228**	.139	.415**	.707**	1														
		.006	.097	.000	.000															
S6	Pea Cor Sig. (2-tail)	.026	–.091	.206*	.573**	.689**	1													
		.754	.278	.014	.000	.000														
S7	Pea Cor Sig. (2-tail)	.178*	–.284**	.373**	.484**	.549**	.687**	1												
		.034	.001	.000	.000	.000	.000													
S8	Pea Cor Sig. (2-tail)	.137	.157	.269**	.531**	.502**	.452**	.482**	1											
		.102	.061	.001	.000	.000	.000	.000												
S9	Pea Cor Sig. (2-tail)	.211*	–.050	.402**	.693**	.529**	.429**	.527**	.484**	1										
		.011	.553	.000	.000	.000	.000	.000	.000											
S10	Pea Cor Sig. (2-tail)	.377**	.544**	.202*	–.025	.035	.045	–.098	–.143	–.195*	1									
		.000	.000	.015	.767	.676	.592	.243	.089	.019										
S11	Pea Cor Sig. (2-tail)	.535**	.173*	.443**	.533**	.433**	.306**	.325**	.354**	.623**	.129	1								
		.000	.039	.000	.000	.000	.000	.000	.000	.000	.125									
S12	Pea Cor Sig. (2-tail)	.339**	.209*	.570**	.343**	.245**	.212*	.335**	.456**	.324**	.000	.391**	1							
		.000	.012	.000	.000	.003	.011	.000	.000	.000	.994	.000								
S13	Pea Cor Sig. (2-tail)	.222**	.004	.263**	.498**	.412**	.427**	.458**	.566**	.612**	–.263**	.644**	.531**	1						
		.008	.964	.002	.000	.000	.000	.000	.000	.000	.002	.000	.000							
S14	Pea Cor Sig. (2-tail)	–.107	.199*	–.092	.109	.289**	.348**	.042	.253**	.161	.046	–.008	.128	.279**	1					
		.204	.017	.273	.196	.000	.000	.620	.002	.055	.582	.929	.126	.001						
S15	Pea Cor Sig. (2-tail)	.221**	.401**	.026	.088	.152	–.092	.009	.304**	.223**	–.090	.180*	.106	.204*	.096	1				
		.008	.000	.758	.298	.070	.275	.912	.000	.007	.286	.032	.209	.014	.254					
S16	Pea Cor Sig. (2-tail)	.537**	.255**	.502**	.108	–.088	–.084	.001	–.063	.204*	.270**	.275**	.441**	.168*	–.038	.107	1			
		.000	.002	.000	.198	.298	.319	.990	.456	.015	.001	.001	.000	.044	.656	.205				
S17	Pea Cor Sig. (2-tail)	.527**	.442**	.263**	.244**	.200**	.217**	.117	.284**	.193*	.174*	.358**	.554**	.512**	.297**	.097	.319**	1		
		.000	.000	.001	.003	.016	.009	.164	.001	.021	.037	.000	.000	.000	.000	.247	.000			
S18	Pea Cor Sig. (2-tail)	.327**	.487**	–.025	–.001	.039	–.007	–.341**	–.021	.020	.304**	.187*	.156	.170*	.156	.144	.278**	.456**	1	
		.000	.000	.768	.989	.643	.933	.000	.801	.814	.000	.025	.062	.042	.062	.087	.001	.000		
S19	Pea Cor Sig. (2-tail)	.007	.211*	.035	.041	.189*	.027	–.249**	.039	–.194*	.247**	.032	–.193*	–.229**	–.196*	–.047	–.044	–.103	.382**	1
		.936	.011	.681	.627	.024	.753	.003	.645	.020	.003	.707	.021	.006	.019	.574	.598	.222	.000	

Note: *Correlation is significant at the 0.05 level (2-tailed), and **correlation is significant at the 0.01 level (2-tailed).

From Table 4, we can see that factor analysis grouped the individual 19 issues into six factors. All the factors extracted have eigen values greater than 1, and this indicates that all the factors are significant (Nath et al., 2017). The total variance explained by this factor solution is 77.019%. These issues were grouped by factor loading pattern. The cut-off point for all loading is +/– 0.40 based on the sample size, which is 180. Table 4 shows that all the loadings for each issue, which are more than 0.40. It is to be noted that the rotated factor solution for the issues S1, S3, S4, S5, S6, S7, S8, S9 and S11 loads significantly on FS1; S16 and S17 loads on FS2; S12, S18 and S19 loads on FS3; S14 loads on issue FS4; S10 and S13 loads on FS5; and S2 and S15 load on FS6.Since none of the items were deleted, it means that all the issues identified are valid.

Descriptive statistics for various issues at the sugar production level are shown in Table 1. There should be a sufficient trace of correlation to justify the application of factor analysis (Gupta and Gupta, 2011). The Pearson correlation with the significant two-tailed test is employed to test the statistical significance of these issues (S1 to S19). Table 2 shows the correlation matrix for the 19 issues at sugar production level. The table indicates that all these issues are correlated to each other and have no evidence of multicollinearity among them. According to Hair et al. (1995), the criterion of multicollinearity is generally 0.9 and above. This table also indicates that 112 out of the 171 correlations (65.50%) are significant at 0.01 and 0.05 levels. It provides a sufficient base to perform factor analysis (Gupta and Gupta, 2011). The value of Kaiser-Meyer-Olkin measure of sampling adequacy (MSA value) is 0.520 (Table 3) which exceeds the minimum MSA level of 0.45 and easily comes in the acceptable range. The chi-square statistic for Barlette's test of sphericity is 1.889 at 171 degrees of freedom at a statistical significance level of 0.000, which is well below the minimum level of 0.05.

For the construct (issues at procurement and sugar production levels), 19 issues, i.e., from S1 to S19 (see Table 4) were reduced to six factors (see Table 4) namely,

- managing the process to benefit supply chain partners (FS1)
- maintaining level strategy and records (FS2)
- adopting new technologies in sugar production (FS3)
- avoiding wrong practices (FS4)
- just in time (JIT) principles and conversion process (FS5)
- automated plant (FS6).

Table 3 KMO and Bartlett's test for issues at sugar production level

Kaiser-Meyer-Olkin measure of sampling adequacy.	.520
Bartlett's test of sphericity approx. chi-square	1.889E3
df	171
Sig.	.000

Table 4 VARIMAX-rotated component analysis factor matrix for issues at sugar production level

Issues	*Component factors*						*Communalities*
	FS1	*FS2*	*FS3*	*FS4*	*FS5*	*FS6*	
S1	*.767*	.145	.125	–.046	.268	.228	.750
S2	–.046	.273	.390	.324	.473	*.551*	.861
S3	*.692*	.431	–.127	–.234	.153	–.075	.765
S4	*.820*	.204	.071	–.026	–.078	.044	.728
S5	*.884*	.003	.100	.090	.150	.082	.829
S6	*.809*	–.072	–.035	.305	.093	–.263	.832
S7	*.736*	.145	–.457	.014	–.050	–.133	.792
S8	*.667*	.060	–.014	.222	–.183	.327	.638
S9	*.680*	.288	–.058	–.010	–.369	.163	.711
S10	–.030	.283	.211	.085	*.824*	–.038	.814
S11	*.532*	.530	.235	–.078	–.199	.134	.682
S12	.268	–.088	*.672*	.300	–.181	.017	.654
S13	.521	.363	.070	.355	*–.564*	.086	.860
S14	.196	–.148	–.044	*.823*	.071	.071	.749
S15	.089	.061	–.007	.022	–.079	*.924*	.872
S16	–.111	*.808*	.030	–.023	.084	.023	.675
S17	.131	*.596*	.239	.578	–.046	.033	.767
S18	–.103	.275	*.801*	.308	.027	.081	.829
S19	.140	–.183	*.760*	–.336	.281	–.051	.825
							TOTAL
Sum of squares (eigen values)	4.500	3.361	1.803	1.785	1.699	1.486	*14.634*
Percentage of trace	23.684	17.689	9.490	9.392	8.940	7.823	*77.019*

Table 5 Descriptive statistics for reduced factors or issues at sugar production level

Notations	*Issues*	*Mean*	*Std. dev.*	*N*
FS1	Managing the process to benefit the supply chain partners like farmers, society, centres and millers	4.26	0.452	180
FS2	Maintaining level strategy for labour and records of employees	4.14	0.529	180
FS3	Maintaining records and adoption of new technology helps in the production of sugar and by-products	4.40	0.363	180
FS4	Avoid wrong practices	4.52	0.614	180
FS5	JIT principles and monitoring the conversion process	4.29	0.444	180
FS6	Automated plant and trust building	4.25	0.616	180

4.2 Hypothesis testing

The testing of the hypothesis was done with the help of one-way ANOVA. This test is employed on the reduced issues. FS1 is the dependent variable, while FS2 to FS6 are the independent variables. Therefore, the following null hypothesis is proposed:

H_0 Use of e-application in the procurement process (issues FS2, FS3, FS4, FS5, and FS6), does not affect FS1 (process management).

- *Dependent variable:*
  1 Process management (FS1)
- *Independent variables:*
  1 maintaining level strategy (FS2)
  2 managing production (FS3)
  3 avoid wrong practices (FS4)
  4 monitoring conversion process (FS5)
  5 automated plant (FS6).

Table 6 Correlations for reduced factors or issues at sugar production level

Issues	*FS1*	*FS2*	*FS3*	*FS4*	*FS5*	*FS6*
FS1	1					
FS2	.352	1				
FS3	.295	.540	1			
FS4	.161	.146	.061	1		
FS5	.593	.565	.462	.276	1	
FS6	.154	.333	.356	.178	.328	1

Table 7 ANOVA for issues at sugar production level

Issues		*Sum of squares*	*df*	*Mean square*	*F*	*Sig.*
FS2	Between groups	23.156	13	1.781	13.796	.000
	Within groups	16.655	129	.129		
	Total	39.811	142			
FS3	Between groups	6.373	13	.490	5.092	.000
	Within groups	12.418	129	.096		
	Total	18.791	142			
FS4	Between groups	15.026	13	1.156	3.859	.000
	Within groups	38.638	129	.300		
	Total	53.664	142			
FS5	Between groups	17.437	13	1.341	16.198	.000
	Within groups	10.682	129	.083		
	Total	28.119	142			
FS6	Between groups	11.757	13	.904	2.766	.002
	Within groups	42.170	129	.327		
	Total	53.927	142			

Table 7 shows the results of the ANOVA between these issues. The value of F ratio for FS2 is 1.781/0.129 = 13.796 with 13 and 129 degrees of freedom, resulting in a probability (p) of 0.000. Similarly, for FS3 F-ratio is F (13, 129) = 5.092 at p = 0.000; FS4 is F (13, 129) = 3.859 at p = 0.000; FS5 is F (13, 129) = 16.198 at p = 0.000; and FS6 is F (13, 129) = 2.766 at p = 0.002. The values of p for all these issues are well below the minimum significance level of 0.05. Hence, the null hypothesis is rejected because the mean scores for all the issues, i.e., FS1, FS2, FS3, FS4, FS5 and FS6 with the values of 4.26, 4.14, 4.40, 4.52, 4.29 and 4.25 respectively (see Table 5) are significant. This results in accepting the alternate hypothesis that there are significant differences among these issues. Hence, the sugar production level can be improved by overcoming with these issues like procurement process, level strategy for labour, sugar production records, the inventory level of sugar, conversion process and automated plant with the use of IT Applications. In this way, the farmers, society, centres and millers get benefits of IT Applications by avoiding the wrong practices and bringing transparency to the production process.

5 Results and discussion

From the results of the hypothesis testing, it is clear that FS1 is being affected by FS2, FS3, FS4, FS5, and FS6. Therefore, the issues related to the management of the sugar production process (FS1) can be addressed by managing the procurement process with the help of IT applications (FS2, FS3, FS4, FS5, and FS6) at the sugar production level. Therefore, all these issues can be managed by different IT applications. By detailed literature review, the following suitable IT solutions are proposed for tackling these issues:

Logistics information systems (LIS) LIS is a technology that can be used for solving the problems related to transportation, inventory, and warehousing management (Bookbinder and Dilts, 1989; Closs and Kefeng, 2000; Christopher, 2005; Gurung, 2006). GPS technology is used to manage the status of the vehicles, network communications, and real-time mapping which avoid delays in delivering the cane from centres to factories (Vanajakshi et al., 2009). It enables JIT delivery of raw material to the factories which maximise the yield of fresh cane to produce more sugar. In U.P., no sugar industry is using such technology for logistics management. Further, there could be more integrated technology which may take place to manage such issue like automatic vehicle locator (AVL). It improves the delivery efficiency by guiding cane-loaded trucks to avoid gaps (Johnson and Alvarez, 2004; Vanajakshi et al., 2009).

Electronic data interchange (EDI) is an IT application (Gurung, 2006; Kumbhar, 2011) which helps in providing the online information and sharing the data of farmers and millers. It helps in managing the time of millers for surveying farmers' field, and all information can be gathered from cane society and farmers by millers in an electronic way. Thus, it brings transparency among these supply chain partners and would help in building trust among them.

Sugar mills can use software like Oracle, MySQL database, etc. for managing and maintaining the personal records of the farmers and cane society. These records are used for targeting them to deliver their cane to the mills. To benefit the farmers is that the records of the mills like cane price per quintal, distance of the mill from their villages, etc. can also be maintained and farmers can access it. But the problem to do so is a lack of computer literacy rate among the farmers. This can be overcome by opening several training centres or call centres from where they get such information about any mills.

The Uttar Pradesh Government has taken the initiative for a novel e-governance project to support cane farmers and is trying to establish a good relationship between farmers and millers. The sugarcane information system (SIS) is the largest rural information technology platform currently being used for solving the various problems of cane farmers (Tripathi, 2012). Problems such as delay in payments, surveying the cane field, correct and timely measurement of sugarcane, on-time selling of their cane to mills, etc. are currently being addressed. This system bridges the communication gap between farmers and sugar mills via the use of short messaging service (SMS), interactive voice response system (IVRS); and a model website was also developed for this project. 116 sugar mills have already adopted this website in Uttar Pradesh and around 29 lakh farmers' details are being protected with a password protected webpage (India Governance, 2012). This concept is very useful because farmers have mobile phones and can access such technology with the telecom services in the rural and remote areas of the nations (Kumar et al., 2013b).

Most mills have already implemented different IT applications in their procurement process, but still, proper supply chain planning is necessary with the involvement of mill owners for upgrading their software according to their mill requirement. The biggest issue that most of the farmer's face is a delay in payment by millers. This issue needs to get addressed which is possible only with the involvement of government bodies. Hence, it is recommended to use IT applications for maintaining live records or data of the farmers during the crushing season which must be observed and managed by the government organisations at regular intervals of time. It helps in bringing transparency to the system. Therefore the government can take immediate action against those mills who delay in paying the farmers and cane society. It results in improving the on-time money circulation by millers to the farmers and generates trust between them.

IT-enabled solutions like weighbridge (Kumbhar, 2011; Chandraju et al., 2012) are used for weighing the quantity of raw material and by-products. It also maintains the data related to procurement of cane and sugar produced and helps in generating several useful reports. The information on the daily crushing of cane is also managed with the help of weighbridge. This technology is also used to evaluate all the types of bills like dues, advances, etc. of the cane farmers, society, and centres. Another IT-enabled solution like cane billing system (Kumbhar, 2011) is also used for managing the bill details of cane farmers, cane transporters, and cane society. Many sugar mills already adopt these IT solutions in U.P and Uttarakhand.

A suitable IT-enabled solution is required to transfer money to the farmers by the sugar mills. A technology like SAP or Oracle (Chandraju et al., 2012) can be integrated with the weighbridge and cane billing system in such a way so that the farmers receive on-time payment by the millers of their delivered cane into their bank account. This account should be opened for farmers and organised by the millers under the supervision of the government. It would help the farmers and cane societies in getting immediate payment for their delivered cane, and if any delay occurs, then the government may take immediate action against that sugar mill. This type of concept brings visibility to the cane prices and improves the payment system.

Mills always want good quality (juicier) cane for crushing and processing. It results in the fulfilment of their needs by crushing more cane to produce more sugar on a daily basis through which mills can generate some good revenues. Sometimes, bad or mixed quality of the cane comes to the mill for crushing. It is highly recommended to use some suitable IT system through which the centres and millers will be able to check the quality of sugarcane. In Australia, near infrared technology and cane analysis system (Johnson, 2000; Johnson and Alvarez, 2004; Sugar Technology, 2010) are used to perform on-line analysis of the prepared cane of the farmers. It helps in evaluating their quality of cane and pays them accordingly. No such application is in operation in the mills in U.P. because the millers manually check the quality of the cane. Collan et al. (2014) have also advocated for the use of IT applications in supply chains to avoid bull-whip effect.

As suggested by Kumbhar (2011), IT applications such as hardware (printers, scanners, client-server system, etc.) and software (DBMS-Oracle and MySQL) are used for generating slips to distribute to farmers and cane society, maintaining records of-permanent and seasonal permanent employees or labourers; daily-wise production; inventory; warehouse; centre's; transporters; cane society; and farmers, and monitoring sales and distribution of products and other by-products. All these activities are managed by using SAP and ERP systems. This technology brings transparency to the complete system from procuring cane to packaging and distribution of finished goods. Almost every sugar mill in U.P. is using this application to do their work. But still, there is a lack of transparency at different levels due to low absorption of technology at farmer and distribution level.

Most mills are already using IT applications in the sugar production process, but the problem still exists. The problem like mills are increasing their crushing capacity from time to time for crushing more cane, but still, mills are unable to target their daily wise production of cane. It makes some sense that it is not necessary to increase their capacity only, but also to solve problems like the higher involvement of various indirect customers like Jaggery (Gur)/Khandsari units and delay in supply of cane due to ineffective supply chain planning. Hence, it is necessary to apply JIT principles to get maximum yield from cane for producing sugar and provide the best prices on cane to farmers by lowering the supply levels to indirect customers.

Another problem is black marketing of sugar at mill godowns which must be prevented by monitoring the inventory level of sugar and by-products with the use of IT applications like RFID and bar coding (Vijayaraman and Osyk, 2006; Attaran, 2007). In this way, the unwanted delivery of sugar bags can be handled and helps in avoiding such wrong practices.

Sugar mills need to upgrade their plant by adopting automation techniques. A fully automated plant brings transparency to the conversion process through which any breakdown can be handled easily. This breakdown would disrupt the whole process very effectively, which results in less production of sugar. To minimise the maintenance time, it is required to connect the factory machinery with the computer systems. This technique increases the capacity of the plant to produce more amount of sugar in less time, and further improves the processing efficiency.

Change in climatic conditions brings some moisture to the product like sugar, which results in decreasing the value of sugar. It is caused due to the improper safety of products at mill godowns. This issue can be solved by using suitable technology through which the temperature of the mill godowns can be maintained. Computerised control systems are used to control and monitor the sugar mill operations (Johnson and Alvarez, 2004). This system is not yet completely adopted by sugar mills in U.P. Therefore, to get better output, it is necessary to integrate such system in the mills.

Lee et al. (2012) have also suggested the use of IT in developing algorithm such as fuzzy AHP to select partners in the green supply chain. Similarly, sugar mills can also customise these results for the selection of various vendors in their supply chain.

Hence, the adoption of IT application is necessary for solving various issues at the procurement and sugar production process levels.

Table 8 summarises the above discussion on the use of IT solutions for managing the identified issues at procurement and sugar production level.

Table 8 IT solutions for various issues at procurement and sugar production level

S. no.	*Issues*	*IT solutions*
1	• Transportation logistics management • Warehousing management • Inventory management	• Logistics information systems (LIS)
2	• Applying JIT principles in ensuring the proper supply to sugar mills as well as maximum yield from cane to produce sugar	• GPS technology
	• Transportation logistics management	• Automatic vehicle locator (AVL)
3	• Maintaining personal records and other related information of the farmers and millers	• Electronic data interchange (EDI)
	• Building trust among farmers and millers	• Advanced computer system
	• Delay in payment to farmers and cane society	• Sugarcane information system (SIS) • SAP or Oracle integrated with weighbridge and cane billing system
4	• Providing mutual benefits between the farmers and millers	• Databases like Oracle and MySQL
	• Maintaining personal records and other related information of the farmers, mill employees or labourers, daily production, warehouse, inventory, transporters, centre, and cane society	• Software like SAP, ERP system, MS Office and Novell Netware
	• Managing slip generation and distribution to the farmers and cane society	• Operating systems like Windows and DOS
	• Monitoring sales and distribution	• Hardware like printers, scanners, client-server, UPS system, etc.
5	• Weighing the quantity of material/sugarcane	• Weighbridge
	• Providing information on daily wise crushing cane	• Cane billing system
	• Managing bill details of farmers, society, and transporters	

Source: Compiled from literature review done by the authors (see results and discussion for the citations of the same)

Table 8 IT solutions for various issues at procurement and sugar production level (continued)

S. no.	*Issues*	*IT solutions*
6	• Checking the quality of material/sugarcane	• Near infrared technology
	• Decision on the sufficient allowances for targeting the daily requirement of sugarcane for the procurement of crushing	• Cane analysis system
7	• Monitoring of the inventory level of sugar and by-products at mill godowns to prevent black marketing	• RFID • Bar coding
8	• Up gradation of the plant	• Automation technique
	• Better monitoring of conversion process	• Computerised control systems
	• Online updating of the information regarding status of work at sugar mill	• SAP

Source: Compiled from literature review done by the authors (see results and discussion for the citations of the same)

6 Conclusions, limitations and scope for future work

With increasing competitiveness in manufacturing and production, the key to success is proper management of supply chains (Wei et al., 2018). Supply chain capabilities play an important role in the improvement of business performance (Tham and Chiadamrong, 2016).

Use of IT applications in the supply chain system help in improving and managing the flow of products, funds, and information. With effective implementation of IT at procurement and sugar production levels, it is foreseen that it would help in increasing the overall surplus and brings transparency to the supply chain system of the sugar industry. The collaboration between supply chain partners is essential for the efficiency of any supply chain, and often such collaborations are characterised by complex interactions comprising various inter-organisational interfaces (Allmayer and Winkler, 2014). In sugar industry, every supply chain partner is highly dependent on each other. Without developing strong relationships among them, no supply chain partners work effectively. Here, it was found that farmers-millers relationship is highly important to make a better flow of raw material for production as well as to establish trust among them. Therefore, it is necessary to create a software or IT application which must have the same platform at both farmers and mill ends. This kind of IT implementation brings transparency among them and improves the income of both. It also solves the farmers' payment problems, and millers get sugarcane timely to their mills for processing. Future studies concerning the sugar industry should explore inventory management and warehousing models such as the one proposed by Shaikh (2017), Shah and Khanzode (2017).

Policy makers and industry actors must take corrective actions to overcome these issues to help supply chain partners, i.e., farmers, millers, distributors, and other stakeholders of the sugar industry in supporting their activities. Deeply involvement of government bodies may reduce the burden of the supply chain partners, especially for cane farmers and distributors by using new government policies and provide support in implementing IT application to them.

The present study focuses only on the states of Uttar Pradesh and Uttarakhand, India. The future studies can further target to collect the samples from other sugar producing states in India. There is not much literature available concerning this field of research. Therefore, it takes more time to understand the existing supply chain system, policies, work culture and various issues of the sugar industry in India. The overview of the results must be viewed by considering the perspective of rural and urban areas in Uttar Pradesh and Uttarakhand, India.

The results and limitations of this study are a good starting point for future research regarding the use of IT applications in the supply chain system of the sugar industry. Relevant issues should also be identified at the distribution level for managing activities like vendor, inventory, transportation, and distribution. It can be done by targeting the different supply chain partners, namely, farmers, millers, and distributors include brokers, wholesalers, and retailers for collecting relevant information or data. Later, certain IT solutions can also be proposed for the issues at all these levels.

By taking cues from this study, e-commerce architectures (Kumar et al., 2010) can be developed by showing the usefulness of IT at different levels of the sugar supply chain. The proposed architecture may be adopted by various government and private organisations to facilitate better communication among the supply chain partners. In the foreseeable future, the sugar industry may increase its competitiveness as compared to the other industries by using IT applications (Kumar et al., 2013a, 2014). Currently used business methods may be replaced with new and updated technologies which hold a good scope of research and development. A broader study is thus required to grasp the issues in all three sectors of the sugar industry, i.e., private, public, and cooperative sugar mills for a better implementation of IT applications. Further studies can target more sugar mills in the country in equal proportions from all three sectors to get better and more valuable results. Comparison of the issues of the sugar mills of different sectors can also be done.

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