

Managing Sugarcane Supply Chain-A Key Challenges

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Abstract: Sugarcane holds importance as a cash crop with the sugar industry playing a crucial role, in various economies globally. It is essential to manage the supply chain to ensure a flow of sugarcane from farms to sugar mills and ultimately to consumers. This review paper explores key challenges to manage sugarcane supply chain in the field of seasonal variability, quality control, procurement and pricing, logistics and transportation, sustainability and environmental concerns, supply chain coordination and price fluctuations faced by the sugarcane supply chain Management, highlighting the complexities and obstacles that impact its efficiency and sustainability. The examination covers challenges related to sourcing, transportation, processing and distribution, within the supply chain. Furthermore, it explores solutions and strategies aimed at tackling these obstacles to enhance management of the sugarcane supply chain.

Key words: Sugarcane, Sugarcane Management, Supply Chain Management, Challenges

I. Introduction: The sugarcane (*Saccharum officinarum*) is, a giant grass, member of the Gramineae family, which also includes three species that do not bear sugar: *Saccharum robustum*, *Saccharum spontaneum* and *Saccharum edule* and three species that do: *Saccharum officinarum* (Noble Cane), *Saccharum sinense* and *Saccharum barberi*. In the 1880s, agronomists began breeding sugarcane with other species (Priya and Nataraj, 2024). These crosses are the ancestors of all modern forms. Sugar's history started in India, on the island of Papua New Guinea. From there, it travelled over the Pacific Ocean to reach the Indus Valley, Oceania, Southern Asia and Southern China (De Matos et al., 2020). After Brazil, India is the world's second-largest producer of sugar. In India, sugarcane production occupies 21% of the country's agricultural land. Approximately 22% of the world's sugarcane is produced in this nation. India planted 4.85 million hectares of sugarcane in 2020–21; this resulted in a production of 399.25 million tons and a productivity rate of 82.20 tons per hectare. India's sugarcane production was projected to reach over 84 metric tons per acre in the 2022 fiscal year. Comparing this to the previous year, there was a rise (Anonymous, 2024). According to Priya and Nataraj (2024), Maharashtra is the biggest producer in India, followed by Uttar Pradesh and Karnataka in second and third place, respectively. Maharashtra produced 123.97 lakh tons (123.97 million metric tonnes) of sugarcane in 2022–2023 on 19.46 lakh hectares of planted land, with a productivity rate of 98.8 tons per hectare. The state's principal sugarcane-producing regions are Kolhapur, Pune, Satara, Solapur and Ahmednagar (Anonymous, 2024).

One of the most popular business strategies in the industry is supply chain management, which integrates suppliers, manufacturers, distributors, retailers and customers in order to maximize efficiency and minimize overall costs (raw material, transportation, storage, production, labor, etc.) and product distribution to consumers. SCM closes the communication gap between functional departments to avoid quality problems and delivery delays. It formulates product as the main business and unifies the industry-specific product range. Growing, harvesting, shipping and processing sugarcane all take place within a completely integrated supply chain. Sugarcane ripens for 12 to 24 months of the year due to the climate and ability to ward against pests and diseases. After that, green sugarcane is chopped or burned before being gathered. Using laborers in the field, harvesting (manual or conventional) entails cutting and stacking the sugarcane. Sugarcane that has been bilted, chopped and placed onto a trailer is part of an automated harvesting system. The amount of sugarcane, the haulage truck type, the weather, the distance to the mill and the quantity of sugarcane all affect how long it takes to convey the crop. The cars are weighed when they get to the mill and the sugarcane is either thrown directly into the mill speller or placed in a stockpile. Ultimately, the mill turns the sugarcane into sugar and molasses by refining and processing it (Rossetto, et al., 2022). In the sugar producing industry, the four main stakeholder groups are growers, harvesters, hauliers and millers. They are an essential part of more efficient corporate processes that lessen disparities in the supply chain. Finding out how much sugar can be produced from each tonne of crushed sugarcane is the miller's objective. While the haulier's objective is to load and transport sugarcane while ensuring a consistent supply for the mill at the lowest feasible cost, the grower's purpose is to reduce production expenses. Despite the fact that each link in the supply chain frequently operates separately, it functions as a cohesive whole. Many parties involved in the supply chain can collaborate to make choices that could increase income. Most agricultural supply chains aim to minimize expenses in order to maximize net revenue (Teixeira et al., 2023).

From farmers and sugar mills to consumers and logistics companies, the sugarcane supply chain is a complicated web of relationships. Numerous obstacles affect the sustainability and overall effectiveness of this complex system. In this paper, we explore the main issues that arise in the management of the sugarcane supply chain and look at possible ways to improve its effectiveness.

Challenges in Sugarcane Supply Chain Management: The all challenges in sugarcane supply chain management in term of seasonal variability, quality control, procurement and pricing, logistics and transportation, sustainability and environmental concerns, supply chain coordination and price fluctuations is shown in fig. 1 and described in detail as,



Fig. 1: Key Challenges in Sugarcane Supply Chain Management.

Seasonal variability: The challenges in managing the sugarcane supply chain largely revolve around the seasonal fluctuations that are natural to the crop's production. These variations have widespread effects on different stages of the supply chain including production, processing, transportation, coordination and market dynamics. Factors like the timing of harvests and unpredictable weather conditions impact the production phase, whereas processing is hindered by issues such as the capacity of mills and variations in sugarcane quality. Transportation encounters congestion and strained infrastructure, especially during peak seasons. Coordinating activities among stakeholders becomes more complex and effective inventory management becomes essential for mills. Market challenges such as price volatility and access issues further complicate the situation. Overcoming these hurdles requires careful planning, operational flexibility, adoption of technology and collaborative efforts among all involved parties (Vasantha et al., 2021; Sallam et al., 2023; Jayasinghe et al., 2024).

Quality control: Quality control plays a crucial role in the sugarcane supply chain to uphold standards and enhance sugar extraction efficiency. It begins with meticulous seed selection and cultivation practices, covering harvesting, transportation, processing, storage and adherence to regulations. Key practices involve choosing superior seeds, timely harvesting, careful handling, efficient transportation, rigorous quality checks at mills, optimized processing techniques, proper storage conditions, hygiene upkeep and compliance with certification and traceability norms. These measures ensure top-notch sugarcane and derived products, meeting consumer demands and bolstering market competitiveness. Consistent monitoring, optimization and commitment to standards are essential for sustained quality and environmental stewardship in the industry (Kim et al., 2021; Kremsa, 2021; Misra et al., 2022).

Procurement and pricing: Procurement and pricing are pivotal elements in managing the sugarcane supply chain, influencing the dynamic between growers and mills and the industry's overall sustainability. Procurement encompasses contract farming, spot purchases and ensuring adherence to quality standards, while pricing mechanisms involve formulas, government-mandated fair prices and models for revenue sharing. To address uncertainties in pricing and production, risk management strategies are employed, while contractual agreements delineate terms and conditions for both parties involved. Government policies play a role in regulating prices and maintaining quality standards. By implementing transparent pricing, equitable contracts and strategies for risk mitigation, effective procurement and pricing practices promote efficient supply chain relationships, sustainability and resilience (Kombo, 2023; Koshuma et al., 2022; Voora et al., 2023)

Logistics and transportation: Logistics and transportation are crucial elements in the sugarcane supply chain, facilitating the movement of raw sugarcane from farms to processing facilities and the distribution of sugar and its by-products to consumers. Successful coordination during harvesting and efficient handling during collection are essential. Various transportation modes, such as road and rail, play significant roles. Adequate storage facilities, both temporary and at processing plants, are vital for preserving cane quality. Effective logistics management involves optimizing routes and utilizing real-time tracking, while maintaining infrastructure ensures operational efficiency. Compliance with transport and environmental regulations is imperative. Efficient management practices improve supply chain optimization, reduce costs and ensure timely delivery, ultimately promoting sustainability and operational excellence (Laird and Venables, 2017; Johnson et al., 2018; Sharma et al., 2022).

Sustainability and environmental concerns: Sustainability and environmental concerns within the sugarcane supply chain involve addressing various issues including land use, water management, climate change and social impacts. These encompass challenges like deforestation, habitat fragmentation, soil degradation, water consumption and pollution, greenhouse gas emissions, labor rights and community engagement. Certification programs and regulatory adherence are vital in fostering sustainable practices, alongside circular economy endeavors like waste valorization and optimizing resource usage. Prioritizing sustainability allows stakeholders to bolster ecosystem resilience, safeguard natural resources and foster community welfare while ensuring the industry's longevity. Collaboration among diverse stakeholders is paramount for instigating positive transformations and realizing sustainable development objectives (Manasa and Mehta, 2020; Singh et al., 2021; Zhang et al., 2023).

Supply chain coordination: In sugarcane management, supply chain coordination involves bringing together growers, mills, transporters and distributors to improve efficiency and cut costs. This involves activities like setting up contract farming agreements, providing support to growers, scheduling harvests, planning transportation routes, managing production, ensuring quality control, forecasting market demand, managing distribution channels, sharing information, integrating technology and planning for risks and contingencies. Effective coordination cultivates collaboration, transparency and trust among stakeholders, resulting in better resource utilization, cost reduction and sustainable development (Asrol et al., 2021; Czinkota et al., 2021; Park and Singh, 2023).

Price fluctuations: Price fluctuations in the sugarcane supply chain significantly impact stakeholders throughout the industry. Influenced by factors like weather, demand, policies and global trends, these fluctuations complicate planning efforts. Farmers bear the brunt, experiencing income instability and potential financial hardship. Supply chain disruptions emerge, impacting transportation, processing and distribution. Processors encounter financial risks, struggling with profit margins during low-price periods and strained working capital during spikes. Uncertainty impedes long-term planning and investments for both farmers and processors. Government policies can exacerbate market distortions. Essential risk management strategies include diversification, forward contracting and collaboration. Addressing these challenges necessitates cooperation among government, industry and farmers to foster resilience (McKay et al., 2016; Singh and Dewan, 2020; Gulati et al., 2021).

Solutions and Strategies:

The solutions & strategies for above mentioned different challenges in the sugarcane supply chain management in terms of technological integration, sustainable farming practices, infrastructure development, price stabilization mechanisms, collaborative supply chain models and government policies are shown in fig. 2 and described in detail as follows,



Fig. 2: Solution and Strategies for Challenges in Sugarcane Supply Chain Management

Technological integration: It offers solutions to key challenges in sugarcane supply chain management. Smart farming practices, precision agriculture and supply chain visibility through blockchain enhance efficiency and transparency. Predictive analytics and mobile applications empower informed decision-making for farmers. Inventory management systems optimize operations, while energy-efficient technologies and collaborative platforms promote sustainability and communication. Quality assurance systems ensure compliance and product quality. Continuous improvement fosters adaptation to emerging challenges. Overall, integrating these technological solutions enhances efficiency, sustainability and profitability in the sugarcane supply chain (Manobharathi and Anandaraja, 2021; Gopikrishnan et al., 2022).

Sustainable farming practices: It offer comprehensive solutions to issues within the sugarcane supply chain. They bolster resilience to climate variations, optimize resource usage and improve soil quality, alongside encouraging crop diversification and adding value. Community involvement empowers farmers, facilitating joint efforts and access to markets. Certification programs grant access to premium markets, while supportive policies encourage sustainability. In essence, sustainable farming practices ensure environmental sustainability, social inclusivity and economic stability for all involved in the sugarcane supply chain. (Srivastav et al., 2021; Ghaffar et al., 2022).

Infrastructure development: It is essential for overcoming challenges in the sugarcane supply chain. Enhancing road and transportation networks, improving rail and waterway connectivity and building storage facilities can alleviate bottlenecks and minimize delays. Upgrading processing plants, establishing logistics hubs and advancing ICT infrastructure facilitate smoother coordination and greater efficiency. Moreover, guaranteeing dependable power supply, investing in research facilities and enacting supportive regulatory frameworks foster private sector investment and sustainability. Prioritizing sustainable practices ensures that infrastructure development promotes environmental responsibility and long-term viability in the sugarcane industry (Balakrishnan, 2019; Birru et al., 2019).

Price stabilization mechanisms: They are essential for addressing the challenges posed by price fluctuations in the sugarcane supply chain, which can have adverse effects on farmers' income and the sustainability of the industry. These mechanisms encompass a range of strategies aimed at stabilizing prices and ensuring fair returns for farmers in term of Contract Farming, Price

Guarantees, Futures Contracts and Price Forecasting, Buffer Stock Management, Market Diversification, Price Information Systems, Risk Management Strategies, Cooperative Marketing, Policy Interventions, etc. These measures, when implemented collectively, mitigate risks and uncertainties, ensure fair returns for farmers and contribute to the sustainability and resilience of the sugarcane industry.

Collaborative supply chain models: They are effective in addressing challenges in sugarcane supply chain management by facilitating cooperation, coordination and information sharing among stakeholders. These models offer several benefits in term of transparency and information sharing, efficient inventory management, risk sharing and mitigation, value chain optimization, sustainability and social responsibility, market access and value addition, policy advocacy and influence, etc. Overall, collaborative supply chain models foster trust, transparency and cooperation, leading to innovation, growth and shared value creation in the sugarcane industry (James et al., 2020).

Government policies: It play a crucial role in addressing challenges in the sugarcane supply chain management. Strategies include implementing price support mechanisms, providing subsidies and incentives to ensure fair prices and reduce production costs for farmers. Access to credit, research support and infrastructure development are also essential. Market regulation, export promotion and environmental regulations promote fair trade, market diversification and sustainability. Strengthening extension services and fostering policy coordination further support sustainable development. Overall, government policies play a crucial role in enhancing the resilience and competitiveness of the sugarcane sector (Gulati et al., 2018; Jayne et al., 2021).

Other Problems: In addition to technological integration, infrastructure development, price stabilization mechanisms and government policies, there are other challenges in sugarcane supply chain management that require specific solutions and strategies in term of water management, labour shortages, land degradation, pest and disease management, climate change resilience, market volatility, quality control and standards compliance, smallholder empowerment, supply chain traceability, community engagement and social responsibility, etc. By addressing these challenges with specific strategies, the sugarcane supply chain can become more resilient, sustainable and competitive.

II. Conclusion:

The supply chain for sugarcane has numerous obstacles that affect its sustainability and efficiency. Seasonality, quality assurance, cost, shipping, sustainability, cooperation and price swings are all included in these difficulties. However, these challenges may be overcome and the sugarcane supply chain may function more efficiently by putting technology solutions into place, encouraging sustainable practices, investing in infrastructure, stabilizing pricing and encouraging cooperation. In order to protect the livelihoods of millions of farmers globally and ensure the sugar industry's long-term viability and success, it is imperative that these difficulties be addressed.

Compliance with Ethical Standards:

Conflict of interest: The authors declare that they have no conflicts of interest.

Informed consent: Informed consent was obtained from all individual participants included in the study.

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