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Optimization Of Supply Chain By Theory Of Constraints In A Manufacturing Industry

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Abstract
Supply chain management is one of the governing factors contributing to the firm's productivity and profitability. This supply chain performance is adversely affected with the presence of constraints or obstacles. As a result, the firm's efficiency will reduce and the profitability decreases. Theory of Constraints is a systematic approach to identify and eliminate these constraints by using various methodologies and tools which help in the process of continuous improvement. This paper entails a detailed empirical analysis carried out to show the association between supply chain performance and theory of constraints. The study adopted a self-administered questionnaire to collect inputs from 42 medium scale manufacturing industries in Bangalore. Regression model was used to test the derived research hypothesis. The primary constraints present in the supply chain division of a manufacturing company, namely suppliers, production, finance, and customers, were identified using thinking process tools. Extended lead times for raw material procurement, decrease in overall equipment efficiency, price negotiation with customers and high production expenses beyond the budget were the main identified constraints. Drum Buffer Rope, Bottleneck analysis and Throughput accounting were among the few solutions suggested, pertaining to the identified constraints. By applying these techniques, the company could increase their overall productivity.
Keywords: *Theory of Constraints, Supply Chain Management, Manufacturing Industry, Undesirable Effects, Current Reality Tree.*

INTRODUCTION

The Theory of Constraints (TOC), a process optimisation methodology created by Dr. Eliyahu Goldratt, focuses on locating and resolving bottlenecks or limitations in a system (Goldratt E. M. et al., 1984). By taking advantage of these limitations, companies can meet their financial goals while ensuring on-time deliveries, cutting lead times, and preventing stock-outs in the supply chain. Since each task in a complicated system has constraints that must be met, TOC's development approach is methodical. It provides a five-step method called the Process of On-Going Improvement (POOGI) to recognise and address obstacles. Finding the constraint, using it, subordinating everything to it, elevating it when necessary, and continuously avoiding new restrictions are the processes(T M Sanjika, 2010).

TOC uses a variety of thinking-process (TP) techniques to pinpoint the underlying causes of problems and create effective solutions. The Current Reality Tree (CRT), the Evaporating Cloud (EC), the Future Reality Tree (FRT), the Negative Branch Reservation (NBR), the Prerequisite Tree (PRT), and the Transition Tree (TRT) are some of the more well-known TP tools (Fredendall et al., 2002). Supply chain management seeks to reduce waste and increase efficiency by streamlining the movement of products and services from suppliers to customers. To efficiently meet client requests and establish a competitive edge, it entails coordinating multiple phases, including suppliers, manufacturers, distributors, retailers, and end users.

This study focused on improving the supply chain of a prominent manufacturing industry located in Bengaluru, India. The company employed 500 workers and received a significant portion of orders requiring high levels of customization. Until 2022, despite being a market leader, the company experienced only small incremental growth in revenue and profits. Both domestic and international competitors were catching up in terms of distribution. Production faced several challenges, including a decrease in Overall Equipment Efficiency (OEE), frequent equipment breakdowns, high rejection rates,

and difficulties in procuring raw materials (Harish U.C, 2019). These issues resulted in insufficient raw materials according to the monthly production schedule (MPS) (Viera Sukalova et al., 2015).
To address these problems and enhance productivity, we adopted the TOC's 5 focusing steps. By utilizing the CRT, we identified the root causes and sub-causes of the constraints. Additionally, conducting bottleneck analysis (Reinaldo Fagundes et al., 2010) allowed us to pinpoint the areas causing constraints and reduce rejection rates during production. Implementing the TOC approach and proposed solutions can result in a complete turnaround in the supply chain performance. The alignment and integration of the entire enterprise, including suppliers, production, finance, and distribution, at all levels, using the principles of TOC, enables the company to sustain improved performance over an extended period.

LITERATURE REVIEW

As detailed by Karthik Modi et al., (2018), throughput accounting, drum buffer rope, replenishment solutions were suggested to synchronize the whole production and finance state of the godrej Locks. CRT diagrams were constructed for various sectors of the supply chain to identify the constraints and solutions were provided. Roberto Panizzolo et al., (2016), conducted a survey to collect data from various European firms which had implemented TOC. ANOVA and regression models were used to test the hypotheses. José Antonio Valle Antunes Junior et al., (2020) revealed that on time delivery and high speed were the main competitive aspects that TOC elements use. It also provided a clearer understanding of the extensive overlaps between different TOC parts and their concurrent impact on operational performance. The total effects of applying TOC to supply chain management was measured using throughput accounting.
In accordance with Brijesh Ainapur et al., (2011), analysis of constraints with the help of various TOC tools like Ishikawa fishbone diagram, survey responses etc. helped in upgrading the other aspects of overall Supply Chain execution from 63.17%-71.03%. According to Ken Mathu (2014), TOC helped to minimize the supply chain constraints present in the coal-mining industry for the sake of increase in operational effectiveness, efficiency, and profitability (throughput). To verify the authenticity and dependability of the data, samples were gathered, examined, and the triangulation method was applied. In the study carried out by Emin Gundogar et al., (2016), System models were used to identify close to ideal options. Results showed that two buffer stocks and capacity improvements of about 46% boosted production on average by 88.8%. The daily manufacturing output grew with each additional unit of the Spring Knitting station's capacity, and as a result, the bottleneck shifted to the Gluing station.

RESEARCH METHODOLOGY

This research paper follows a deductive approach and aims to investigate the application of the TOC within the supply chain of manufacturing industries. The primary objective was to explore the extent to which TOC principles were being utilized in these industries and to understand their relevance in relation to supply chain performance. Various facets of the research approach are presented in the ensuing subsections.

Designing The Questionnaire

To achieve the set objectives, a survey was conducted, and a self-administered closed-format questionnaire was designed as the data collection instrument. The questionnaire was carefully crafted by doing a thorough examination of the literature on TOC and supply chain, as well as in consultation with experts, to ensure that the questions were straightforward and simple, facilitating ease of response for the participants. Before collecting data, the questionnaire underwent a thorough review by experts. Their main objective was to evaluate its structure, clarity, and completeness to ensure its quality. By incorporating the feedback provided by these experts, the questionnaire was optimized to better align with the research objectives and facilitate effective data collection. The questionnaire covered areas such as Throughput Accounting, Strategic planning, Drum Buffer Rope system, Flexibility to adapt to changes, Product mix decisions. To evaluate the reliability of the questions, a pilot study was conducted with a small sample, and questions with values less than 0.7 were eliminated from the questionnaire to ensure its reliability (Ramesh KT et al., 2020). This process contributed to the refinement of the questionnaire, enhancing its validity for the main study.

Data Collection

Data collection was done by a quantitative approach, which included detailed market research for potential manufacturing companies which were aware of the TOC methodologies. For this research, the data was collected from manufacturing plants across Bengaluru. The plants belong to one of the following

industries: electronic, mechanical, machinery, automobile, electrical and chemical industry. In each plant, the level of their understanding and feasibility regarding TOC practices and its applications were evaluated. After the validation, the final questionnaire was sent to a group of 400 companies out of which 42 responses were received leading to a response rate of 10.5% which falls in the acceptable range of 9 to 13% (Melnyk et al., 2012). G* Power analysis was used to calculate the minimum sample size which was found to be 55 and allowed us to validate our sample size requirement (Hair et al., 2014).

Data Analysis

The study analyzes the collected data by using a statistical software namely Statistical Package for the Social Sciences (SPSS). The base software includes functions for statistical analysis, data management and data documentation. In order to conduct the quantitative analysis, Reliability test and Validity tests were performed. Cronbach's alpha was employed to measure the reliability of the survey carried out and Cronbach's value was found to be 0.707 which suggested that the set of items in the questionnaire or survey are moderately consistent with each other and hence is in the acceptable range indicating the questionnaire to be reliable.

A validity test is a type of assessment or evaluation designed to determine whether a particular measure or test is accurately measuring what it is intended to measure. Factor analysis was conducted to verify the construct validity of the questionnaire. It was used to group related questionnaire questions into factors. The Principal Component Analysis method was used to decide how many components to extract, and this method necessitates that all factors have eigenvalues greater than 1. Varimax rotation with Kaiser Normalisation was used because an orthogonal solution, or factors that are not significantly connected with one another, was required. The KMO test value of 0.709 indicates that factors in the factor analysis have a relatively reasonable level of common variance and are suitable for carrying out the analysis. The factor loadings obtained were greater than the threshold value of 0.7 which indicates that all the items in the questionnaire are valid pertaining to the hypothesis stated.

Pearson Correlation Coefficient evaluates the strength and direction of the linear link between two variables and was used to validate the questionnaire. By comparing the obtained results of correlation coefficient against the critical value for n-2 degrees of freedom, the value was found to be 0.304, which is lesser than the calculated values seen in the output. Hence the set of items present were proven to be valid.

Hypothesis testing was done to check the association between the two variables namely: Theory of Constraints (Independent variable) and Supply chain performance (Dependent variable). Linear Regression was used to validate the derived hypothesis. The hypothesis drawn for this study were:

H0: There is no significant association between the Theory of Constraints and Supply Chain Performance.

H1: There is a significant association between the Theory of Constraints and Supply Chain Performance.

The R-squared value of 0.618 indicated a moderate-to-high level of explanatory power. It demonstrated that up to 61.8% of the variance in the dependent variable may be accounted for by the independent variables in the regression model. The p-value obtained in the regression analysis was 0.002 which was lesser than the significance level of 0.05. This provided the evidence to reject the null hypothesis and hence accept the alternative hypothesis.

IDENTIFICATION OF CONSTRAINTS

Identifying constraints in the manufacturing company involves referencing the observed Undesirable Effects (UDEs) in their supply chain. By pinpointing specific challenges, tailored solutions can be developed to enhance efficiency and productivity. The UDEs observed in the supply chain serve as a basis for comparison and analysis. Addressing these constraints will optimize supply chain operations.

CRT For Suppliers

This subsection demonstrates how the non-availability of raw materials with respect to purchasing is resulting in longer replenishment lead times and exceeded budgeted expenses caused by cost overruns. Since purchasing was initially evaluated on extended lead time (1), it was highly affected by three main factors: inaccurate demand forecasting (2), lack of communication between the company and the supplier (6) and ineffective logistics and transportation problems (4). It usually occurs due to vehicle breakdown, longer distances and also when there is poor coordination with logistics providers and delays in shipping process (7). Insufficient response rate from the suppliers (3) was the main reason for (2). It is due to factors like time zone difference, language, availability of suppliers, longer distance etc. Inadequate methods for

anticipating and analyzing past data (5) leading to (2), which in turn leads to inappropriate buying of raw materials with respect to quantity, cost, right grade etc. As a result, (5) & (6) collectively reflect another UDE namely, "Not enough raw materials available according to monthly production schedule (MPS)" (10). As suppliers were unable to deliver raw materials according to the production plan (8) because suppliers have capacity constraint, inventory shortages, prior orders which still have to be fulfilled. Whereas even suppliers will be not able to supply raw materials at every point needed and also due to inefficient procurement process (9), this phase happens due to complex & inflexible procurement policies, difference in communication etc. Unable to deliver raw materials according to production plan are having two causes: one is suppliers struggle to fulfill the shifting demands (12); reasons for this may be fluctuating customer requirements, requirements for new products and economic factors and the other being, on the basis of provisional orders, suppliers begin manufacturing (11). Because suppliers have a tendency of anticipating demands, production lead time, they should have an estimate about capacity to be manufactured and prepare a plan accordingly. Since on the basis of provisional orders suppliers begin manufacturing (11), it takes suppliers a long time to generate the needed items (17) due to constraints in production capacity, complex manufacturing procedures, availability of raw materials. And also based on sales predictions there is a need to make certain tentative orders with the suppliers (18) where again availability of RM's will be a problem in future. In such cases, the company will pre-order a few expected raw materials required in future and keep it as a buffer stock. Orders fluctuate regularly as sales projections vary (13) because budgeted expenses are exceeded by cost overruns brought on by changes in supplier's prices (19). This happens when there are no proper supplier pricing policies and also for long period contractual agreements where suppliers may change prices as there are no specified price protection mechanisms. Budgeted expenses are exceeded due to two main causes; one is inadequate supplier price negotiation/contract management (15) which happens due to lack of competitive bidding and contract terms and another cause is market volatility and economic factors (16) where we can observe varying raw materials price and exchange rates which results in supply demand imbalances.

CRT For Suppliers

This subsection demonstrates the limitations which are affecting overall equipment efficiency (OEE). These limitations affect the overall productivity and output estimated from the equipment. Firstly, frequent equipment downtime (1) is one of the major UDE that affects the business by causing interruptions in process flow. Downtime occurs due to two main factors one is machine breakdown happening abruptly (2) due to various factors pertaining to it like frequent power failure (4) which drops down the efficiency of the machine because it will take time to readapt to the process which had been initiated, and another main reason for machine breakdown is lack of maintenance planningand scheduling (3) resulting in production interventions and impeding operational effectiveness. Unexpected breakdowns can occur as a result of neglected equipment maintenance problems like component wear, lubrication concerns, and performance deterioration. Another factor affecting equipment downtime (1) is non availability of spare parts (5); having the required spare parts on hand is essential for minimizing downtime and quickly restarting operations when a piece of equipment breaks down or needs repairs. However, machine downtime can be prolonged if spare parts are not easily accessible or due to delays in deliveries of spare parts (9), which can lead to loss in production and leading to higher expenses. The other main factor impacting equipment downtime is inefficient changeover and setup (6) which demands a lot of time and work to transition between various configurations or items. Long changeover durations lead to more equipment downtime (1) and a decrease in production capacity. The skill gap among operators is further exacerbated by improper automation practices (8). When used correctly, automation technology can improve productivity, streamline processes, and eliminate insufficient training and skill gaps among operators (7).

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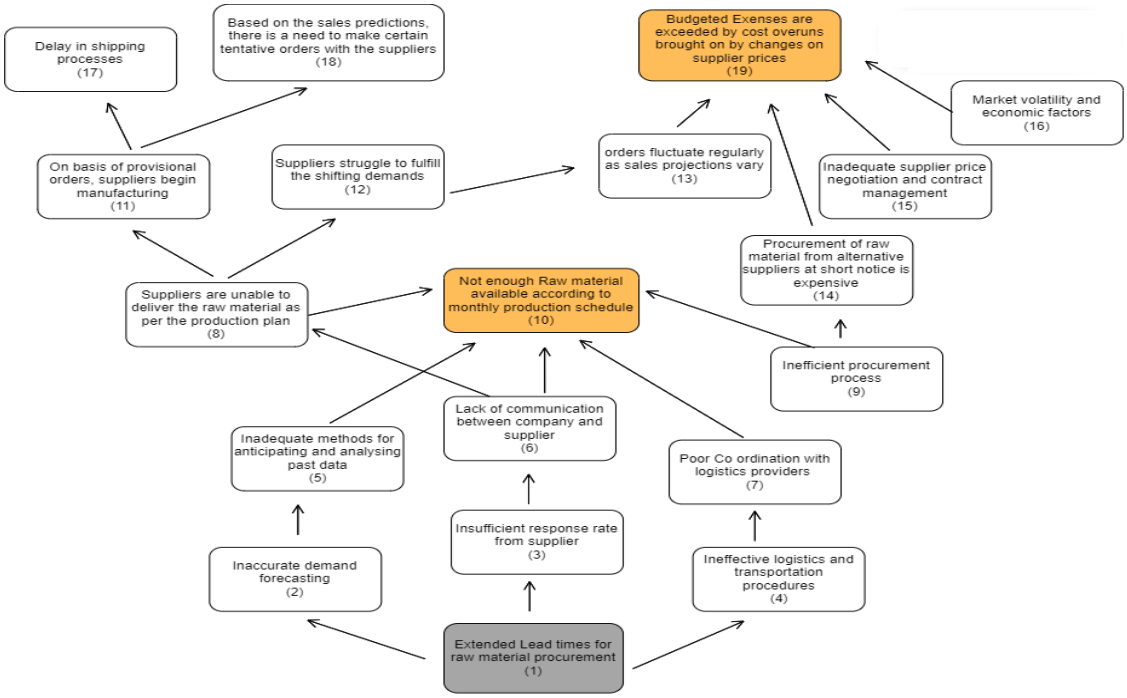

Figure 1. CRT for Suppliers

Another UDE constraining the production process is higher rates of rejection (10) which has various factors affecting the rejection rates. Products are rejected when they are deemed unfit for use or sale due to not meeting the required quality requirements (11). This may happen as a result of inconsistent quality of the raw material (12). It is challenging to consistently generate high-quality products because inconsistent material quality introduces variability and uncertainty into the production process. Another factor influencing rejections is failure in adopting new technologies (13) which is mainly due to capital constraint and unskilled labor. Both these factors of not adopting new technologies (13) and insufficient material quality (12) results in the root cause of decrease in OEE (19). Another main UDE for decreasing OEE is non availability of raw materials (14). Lack of production-related raw materials is the outcome of import delivery delays (15) brought on by logistical, shipping, or supplier-related challenges. Additionally, difficulties with customs clearance (16), such as complicated processes or mistakes in the documentation, might increase the time required to access imported supplies. These causes interfere with manufacturing plans and add to the scarcity of raw materials. Other factors influencing non availability of raw materials (14) are scarcity of critical materials that can occur when the planning of raw material procurement is poor and improper (17), such as faulty demand forecasting or ineffective inventory management. Unpredictable and erratic changes in client orders (18), such as abrupt shifts in demand, changes in preferences, or unforeseen order cancellations or revisions, further exacerbate this deficit. Due to these variances, it is difficult to keep up with changing customer expectations and the planning process for purchasing. Due to the non-availability of raw materials (14), manufacturing is delayed, orders are put on hold, and customers may become dissatisfied and also make a huge impact on frequent equipment downtime (1).

CRT For Distribution/Customer

The CRT for Distribution/Customer is shown in the fig. 8.3. This CRT shows how the problem of price negotiation with the customers was arising from frequently fluctuating raw material prices and ineffective logistics management.

The major UDE identified was the ineffective logistics management process (1) which was caused due to increased transportation costs (2) and the imbalance in supply and demand (3). The carrier selection for transportation is very crucial as evaluation of various carriers based on their deliveries and price has to be done else it leads to ineffective carrier selection and negotiation (4). A poor selection of carrier has an impact on the deliveries of the products and also inadequate coordination between the suppliers, carriers and customers (7) which together constitute delayed deliveries (5) and hence is another contributing factor towards ineffective logistics management (1). The delay in delivery of products was caused by the main factor namely, inaccurate forecasting and planning (8) which has to be done sooner because of the variation in lead times stated by the different vendors for raw material procurement (17). The supply

demand imbalance (3) is seen frequently in the company which is resulting due to the fluctuating marketing conditions (6) which is in turn due to the influence of economic factors which vary (9) and the market disruptions caused due to the introduction of a new product (10). These all lead to the main root cause, which is the difficulty in price negotiation with the customers (16). The supply demand imbalance (3) occurs because of another contributing factor namely the lead time variations from different suppliers or vendors (17) by which, the raw materials are not delivered in the right time and the customers should wait for their respective orders. The problem of price negotiation (16) also emerges due to the presence of multiple purchasing options (15) available with the customer until and unless there is a monopoly of the required material or product. Since the customer wishes for high quality requirements in the product (12) the raw material price fluctuates (11) based on this requirement. There is an increase in the quality costs (13) due to the investments that are been made for quality control and testing measures (14) taken to ensure that the material is of the standard quality as quoted by the suppliers. These all factors contribute to the difficulties occurring in negotiating the price with the customers. It is also noted that if the customer relationship with the company is not for longer years then there is a risk of losing the customer while negotiating with the prices.

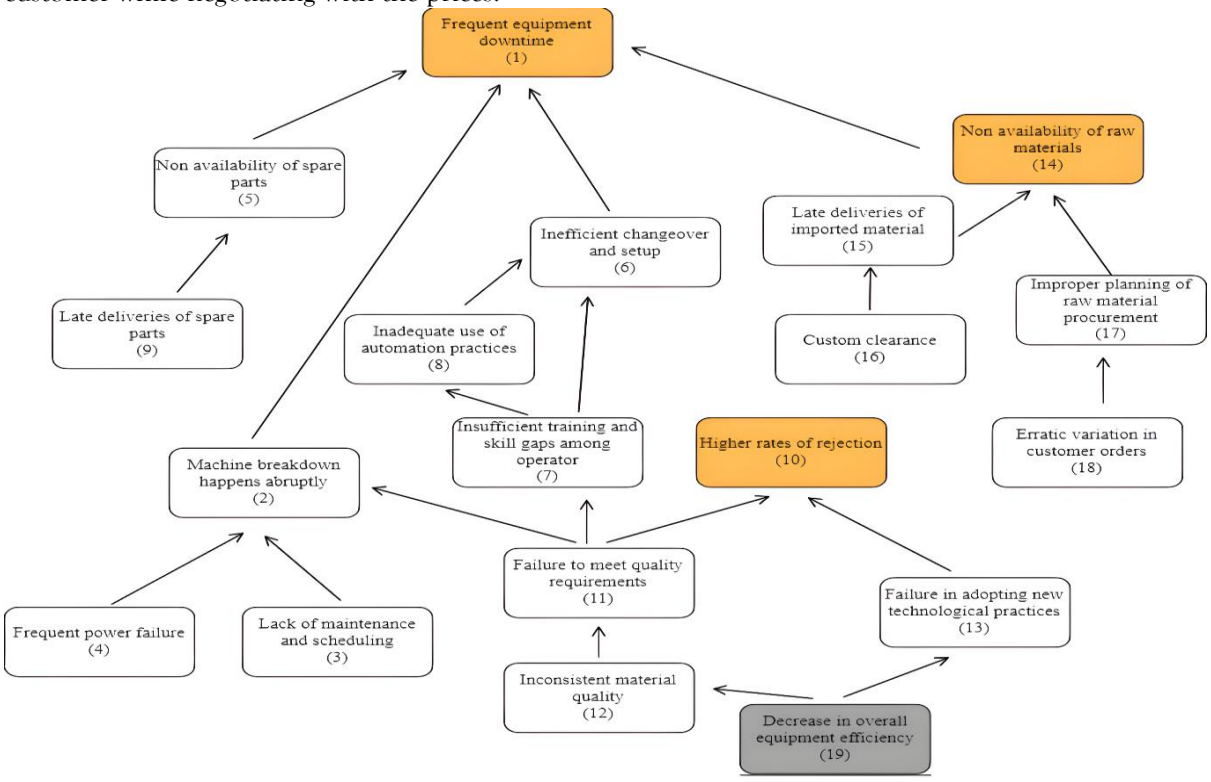

Figure 2. CRT for Production

CRT For Finance

The subsection demonstrates how the constraints affect the people, organizations or government while managing their financial resources. These limitations may influence the decisions made about investments, capital allocation and funding strategies among other financial issues. Firstly, high production expenses which go beyond allocated budget (1) is one of the major UDE that affects the gross and net profit of the industry and this is caused by three main effects of which one being, unskilled labor (2) where the hired man power is not capable of doing the assigned work or lack in knowledge about the equipment being used which automatically lowers the output of the industry. Another one being, lower equipment efficiency (3), where industry is bordered on not using high specifications equipment due to capital constraints which will limit their production rate. Due to their process of cost cutting, the company will still be using older equipment (5) which will affect overall equipment efficiency over a long period of time and the other parameters affecting will be unstable cash flow, where industries experience cash flow and withdrawals that are irregular and unpredictable. This may cause financial instability and make it challenging to successfully prepare for and manage finances. Unstable cash flow gives rise to two main UDEs which will in turn affect the supply chain. One of the major UDE is, COGS exceeding the set range (6) which directly affects the gross profit and net profit and various causes for it are increased

employee cost (8), hiring unskilled laborers (2) in large number and giving salaries for their lower efficiency output, results in increase of COGS.

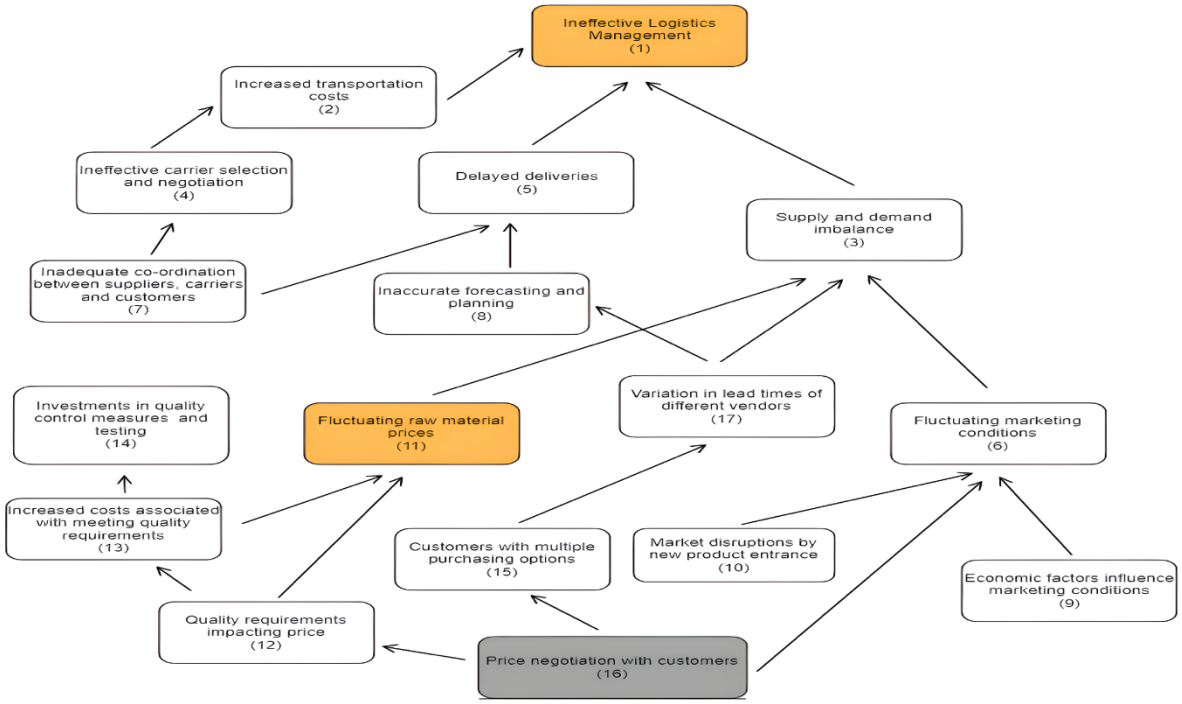

Figure 3. CRT for Distribution/Customer

Inaccurate costing on finished goods (9) also leads to increase in COGS and also results in increased cost of procuring raw materials, increased employee cost, increased overhead cost (10). Overhead costs refer to additional costs that a business incurs that are not a direct result of the creation of goods or services. Rent, utilities, insurance, non-production employee pay, office supplies, and maintenance expenditures are examples of overhead costs. The profitability and financial stability of a corporation may suffer if these costs increase which results in rising utilities (15) relating to rising expenses for utilities that a business needs to run its premises, including power, water, gas, and other services. These charges may result in higher overhead costs and have an adverse effect on a company's profitability. The other main UDE under unstable cash flow (4) is unproductive accounts receivable and delayed payment (7). This parameter highly affects inflow of cash to the industry. Unstable A/R narrowed the company's performance as there was no capital to invest for production and to fulfill customer demands. There are various causes pertaining to (7), one of them is delayed overseas client payment (11). Orders received from other countries need a longer period of time to export. For overseas customers there will be a specified credit period to complete their payment i.e. if a product is being exported to an overseas customer with a specified credit period of thirty days but docking of the products to the customer needs forty-five days. Company suffers fifteen days of extra credit days which is a loss to the firm, this is due to a longer docking time period (16). Another parameter causing (7) is delayed payment from government orders. As there is no specified credit period for government orders, companies cannot expect payment for goods and services provided on a fixed date, which will still be a delay of payment to the firm till they obtain their receivables. All delayed payments happen due to lack of follow up on payments (13). Industry must keep up regular track on payments which are yet to be received else delayed payment results in unproductive A/R (7) and also unstable cash flow (4).

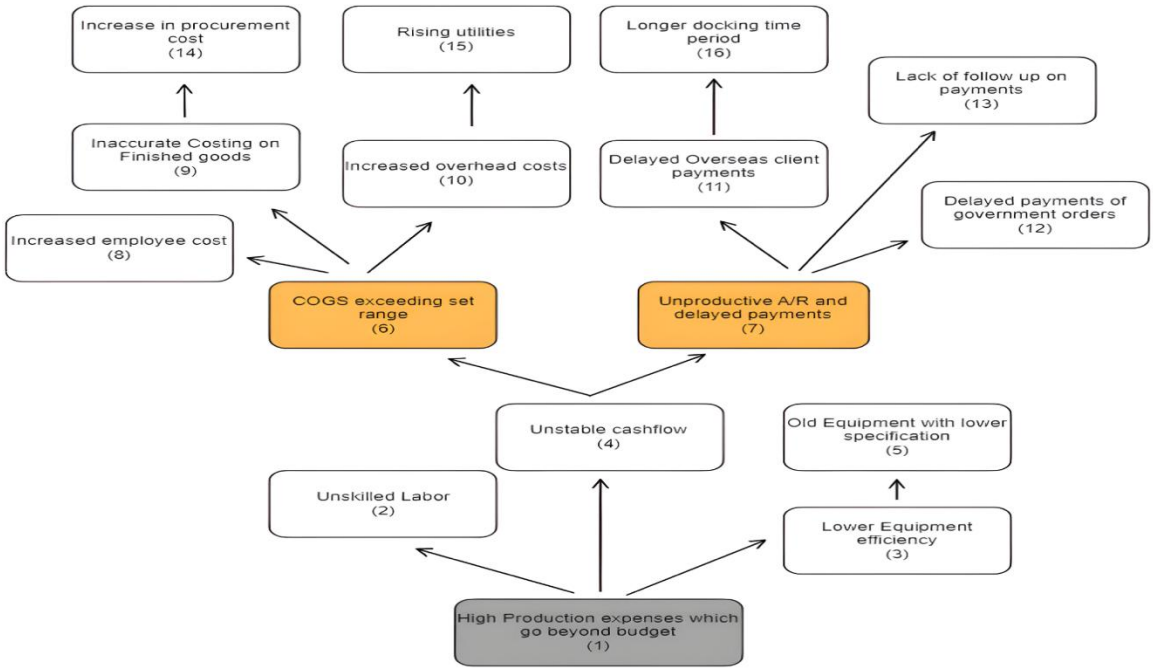

Figure 4. CRT for Finance

Developing Solutions

Solutions For Suppliers

The manufacturing industry encountered a significant challenge with nearly 90% of their projects facing extended lead times for raw material procurement, primarily due to high customization requirements and large order quantities. To mitigate this constraint, the industry was advised to enhance their forecasting capabilities, allowing project teams to estimate future customer projects and plan procurement in advance, thus reducing lead times. Additionally, implementing buffer stock for standard parts was suggested to prevent delays caused by immediate procurement needs for urgent orders. To ensure a steady supply of raw materials and enhance supply chain flexibility, maintaining multiple ISO verified vendor lists was recommended. Moreover, the adoption of effective Customer Relationship Management (CRM) and Supplier Relationship Management (SRM) systems, along with regular supplier interactions, aimed to enhance operational efficiency (Chijioke E Nwachukwu et at., 2021). Lastly, the industry was encouraged to focus on accurate costing and revise costing practices to control expenses and address budget overruns stemming from supplier changes. These proposed solutions aimed to streamline processes, improve responsiveness to customer demands, and foster sustainable growth in a fiercely competitive market.

Solutions For Production

To address decreased Overall Equipment Efficiency (OEE), the application of Theory of Constraints (TOC) tools proved valuable in resolving undesirable effects (UDEs). The company was advised to follow the Five Focusing Steps, a systematic approach, to effectively reduce equipment downtime. This involved identifying and optimizing disruptive machinery while considering necessary upgrades. To tackle higher rejection rates, bottleneck analysis was recommended as a crucial step. Through this process, bottleneck areas in production can be identified, allowing for the implementation of corrective actions, such as equipment maintenance, operator training, and quality control improvements. In handling non-availability of raw materials, the Drum-Buffer-Rope (DBR) approach was proposed. By ensuring a steady supply of materials and optimizing production scheduling, this strategy aimed to address and mitigate disruptions caused by raw material shortages (Fei Qiao et al., 2013). By adopting these TOC tools and methodologies, the company can achieve significant improvements in OEE, enhance overall production efficiency, and minimize operational disruptions.

Solutions For Finance

The finance and accounts department of the manufacturing industry faced a critical challenge with production budgets consistently going beyond the set limits due to volatile raw material costs in the market. To address this issue, we proposed the implementation of the Theory of Constraints (TOC) five focusing steps, which involved identifying and optimizing the manufacturing process bottleneck,

minimizing downtime, and synchronizing other operations accordingly. By investing in enhancing the bottleneck's capacity and efficiency through process improvements and skill development, the organization could control and minimize production costs effectively, aligning them with the financial constraints. Additionally, billing strategies based on the invoice date was suggested and introducing minimum order quantities was advised for overseas customers to tackle the constraint of unproductive accounts receivables and delayed payments. Furthermore, we proposed throughput accounting principles which will allow the company to strategically manage operations, maximize throughput, and eliminate bottlenecks, thus reducing the impact of excess costs of goods sold (COGS) on gross and net profits (Hatem Karim Kadhim et al., 2020). Through continuous improvement initiatives and efficient time-based decision making, the company could further optimize production processes and achieve cost reduction objectives successfully.

CONCLUSION

This study presents a comprehensive roadmap for the integration of Theory of Constraints (TOC) into real-world supply chains. Its primary objectives were to demonstrate the importance of TOC in manufacturing industries and to identify constraints within the supply chain to enhance output efficiency. Through empirical analysis, a strong association between TOC and improved Supply Chain Performance was established, underscoring the necessity of applying TOC methodologies to manufacturing industries. Subsequently, the study implemented the CRT tool, an iterative process, to identify UDEs and root causes across collaborative departments such as suppliers, production, distribution/customer, and finance. By developing tailored solutions for these UDEs, the supply chain's performance and efficiency will significantly be improved. The study's findings highlight the substantial benefits of employing Theory of Constraints as a valuable methodology to optimize supply chain performance. By pinpointing critical issues and providing viable solutions, TOC can effectively enhance overall productivity and profitability for manufacturing firms.

REFERENCES

[1.] Ainapur A, Brijesh B, Singh RK, Vittal PR. TOC approach for supply chain performance enhancement. Saarbrücken: LAP LAMBERT Academic Publishing; 2015.
[2.] Al Amin M, Rahman A, Shahriar A. Application of Theory of Constraints in Supply Chain Management. J Eng. 2019;10(1):67–76.
[3.] Duncan C. Fundamental Statistics for Social Research. London: Routledge; 1997.
[4.] Hair JF Jr, Sarstedt M, Hopkins L, Kuppelwieser VG. Partial Least Squares Structural Equation Modeling (PLS-SEM). Eur Bus Rev. 2014;26(2):106–21. https://doi.org/10.1108/ebr-10-2013-0128
[5.] Fredendall LD, Patterson JW, Lenhartz C, Mitchell BC. What should be changed. Qual Prog. 2002;35(1):50–9.
[6.] Goldratt E. The Goal: A Process of Ongoing Improvement. Croton-on-Hudson: North River Press; 2012.
[7.] Gundogar E, Sari M, Kokcam AH. Dynamic Bottleneck Elimination in Mattress Manufacturing Line Using Theory of Constraints. SpringerPlus. 2016;5(1). https://doi.org/10.1186/s40064-016-2947-1
[8.] Harish U. Implementation of Theory of Constraints (TOC) in a Manufacturing Plant. Int J Adv Sci Res Manag. 2019;4(8):228–32.
[9.] Pacheco DAJ, Antunes Junior JAV, de Matos CAA. The Constraints of Theory: What Is the Impact of the Theory of Constraints on Operations Strategy? Int J Prod Econ. 2020;235:107955. https://doi.org/10.1016/j.ijpe.2020.107955
[10.] Kadhim KH, Najm KJ, Kadhim HN. Using Throughput Accounting for Cost Management and Performance Assessment: Constraint Theory Approach. TEM J. 2020;9(2):763–9. https://doi.org/10.18421/tem92-45
[11.] Ramesh KT, Sarmah SP. Impact of Supply Risk Management on Firm Performance: A Case of the Indian Electronics Industry. Int J Product Perform Manag. 2020;70(6):1419–45. https://doi.org/10.1108/ijppm-04-2019-0205
[12.] Mathu K. Applying the theory of constraints in the South African coal supply chain. Mediterr J Soc Sci. 2014;5(9):131.
[13.] Melnyk SA, Page TJ, Wu SJ, Burns LA. Would You Mind Completing This Survey: Assessing the State of Survey Research in Supply Chain Management. J Purch Supply Manag. 2012;18(1):35–45. https://doi.org/10.1016/j.pursup.2011.12.002
[14.] Modi K, Lowalekar H, Bhatta NMK. Revolutionizing Supply Chain Management the Theory of Constraints Way: A Case Study. Int J Prod Res. 2018;57(11):3335–61. https://doi.org/10.1080/00207543.2018.1523579
[15.] Nwachukwu C, Hieu V. Assessing Supplier-Customer Relationship Management Practice and Business Performance. In: Proceedings of the First International Conference on Computing, Communication and Control System, I3CAC 2021; 2021 Jun 7–8; Bharath University, Chennai, India.
[16.] Qiao F, Wu Q. Layered Drum-Buffer-Rope-Based Scheduling of Reentrant Manufacturing Systems. IEEE Trans Semicond Manuf. 2013;26(2):178–87. https://doi.org/10.1109/tsm.2013.2248763
[17.] Sanjika T. An overview of the Theory of Constraints and related literature [dissertation]. Durban: University of KwaZulu-Natal; 2010.
[18.] Šukalová V, Ceniga P. Application of the Theory of Constraints Instrument in the Enterprise Distribution System. Procedia Econ Finance. 2015;23:134–9. https://doi.org/10.1016/s2212-5671(15)00445-1