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Application of Operation Research in Steel Industry

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Abstract:- In the paper, we have discussed the Application of Operation Research in the steel industry, and how its tools have helped the industry in tackling different kind of problems by creating implemental solutions to complex business challenges. Steel industry is playing an important role in Indian economy as it can steer India towards $ 5 trillion economy by 2025, as per the EY-CII report, which makes the development of the industry even more important. We have shown the existing use of Operation Research in the industry to exhibit its potential.

Keywords:- *ABC Analysis, EOQ Analysis, Decision Model, Lagrangian Relaxation, Transportation Model, Network Analysis, LPP, Monolithic Model, Integer Programming, Six Sigma, Decision Making.*

I. INTRODUCTION

Steel industry, the business of processing iron ore into steel and turning that metal into final product. The whole process revolves around different points including manufacturers, suppliers, transporters, warehouses, retailers and customers where operation research tools are used to have efficient and effective industry where the costs are minimized and profits are maximized.

The challenges that confront steel industry in the age of globalization are complex in nature, the secret in sustainable turnaround lies in how steel industry faces the challenges and develops competitive and anticipatory process. Most of the problem can be solved by adopting and modifying their operational management strategy. 50% or more of the jobs in the industry are customer service, quality assurance, production planning, scheduling, inventory management and logistics, in fact all other functional areas are inter-related to these jobs where operation research and its various tools have been proven to be effective.

Our objective is to look into and analyze the various tools and how they are used in solving different problems faced by the steel industry now-a-days. In today's world, Operation Research has proven to be really important with its in-depth application and steel industry is yet to utilize its full potential. Our aim is to promote the idea of having more research in this area.

II. LITERATURE REVIEW

According to L.tang, one of the main problems faced by the steel industry is the exorbitant inventory cost for storing the very large inventories to ensure continuity of production of the industry. Hence, a serious subject faced by most large steel industries is to find and maintain the best balance of raw material inventory, minimising the cost, which are solved by using the inventory management strategy – Economic Order Quantity (safety stock and safety lead time), Decision Model and Lagrangian Relaxation.

Y. Maheswari stated that Inventory Management is an important area for an industry like Steel. Different techniques are there to maintain a fair inventory level depending on the various factors such as supply, demand and production capacity. Operation research has been done using tools like ABC Analysis and EOQ Analysis to have better management.

According to Dharmendra Yadav, the author, concludes that a major problem faced by the industry is high transportation cost of the raw materials, which can be solved using transportation model- North West Corner method, Least Cost method, Vogel's method.

According to R.T. Askerbeyli Transportation Cost is one of the major problem in steel industry to solve this problem he suggest a tool called Transportation Model in which VAM METHOD.

According to, Atanu Das, with non-linear objective functions and linear constraints, a fixed charge capacitated transportation problem is examined. As a result, we provide a method for solving this transportation problem together with a local optimum condition for the problem. With non-linear objective functions and linear constraints, the fixed charge capacitated transportation problem is examined in this study.

According to Ville Isoherranen Production Optimisation is one of the major problem in Steel Industry which can be solved by Decision-Making tool which helps to optimize cost by taking corrective decision-making measures which lead to cost efficiency and maintaining the required level of production with proper resource allocation.

Mohammad Reza Soltany has looked into the productivity of steel industry in developing countries which are not equipped with best technology, best labor. To make their productivity better, Operation Research has been done where LP model is used to undertake Supply Chain Management in steel plant that uses blast furnace method.

Author, Matheo Biondi, felt the problem faced by the industry is the delay in production scheduling of hot rolling mill in a steel plant and its scheduling challenges, which can be solved using tools like Scheduling Algorithms and Mixed-Integer Linear Programming Formulation.

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Okwu Issac found problems in scheduling and knew effective scheduling is necessary for quality control and so a solution methodology is developed which combine a model predictive control strategy-based approach to tackle parallel process scheduling problem, rolling horizon approach to allow applying Lagrangian Relaxation algorithm to solve the model of the scheduling problem in a rolling fashion.

Hubert Hadera highlighted production delays and over the top electricity costs and took assistance from the concept of a Monolithic model to find an optimal production schedule of the steel making process, while satisfying complex production constraints and making sure the demand of electricity is constantly at par with the available supply.

Goutam Dutta, in his paper believes that India, being a developing country faces many discouragements towards its path of economic growth, industrialization and having poor capacity of utilization of power plants, because of which steel industry is highly impacted mainly with the power crisis, which can be solved using the Works Planning Model from Linear Programming Models.

Patrick Alexander Philippe Carter, B.Eng.Mngt saw a problem of optimal classification of lots which can be tackled by Batch Scheduling. Scheduling include different methods which helps to reduce cost and allocates resource at optimal cost and time.

Pekka Kess in his paper believes Quality Management in steel industry is a significant part and should improve quality when needed which can be done by Six Sigma and Lean Thinking (Improvement tool). Six Sigma is a recognized approach to problem-solving that employs quality and statistical techniques to enhance fundamental processes. The Lean Thinking model facilitates improvement in patient care with available resources, meaning the same things can be achieved using fewer personnel.

Daniel C. Merten, in his research paper has showed how manufacturers of steel prefer working with auxiliary recommendation algorithms to handle the steel making scheduling processes, however, the main issue in this scenario is the lack of clarity regarding the degree of complexity that is required in these algorithms and to tackle this, the author introduces a shuffling-aided network method for evaluating the complexity of the selection patterns.

Jayant Kalagnanam's report involves matching an order book against surplus inventory as a pre-processing step towards production planning in a large steel plant using geometric and quality attributes to tackle the prescribed problems during all operations planning applications.

According to Sankarshan Basu and Goutam Dutta, this survey paper looks at various different applications of the non-Optimization techniques in Operations Research used in the steel industry particularly in the process of steel making all across the world. The most significant study, is the stochastic control of the production system. In order to assure the accurate and intended output before the existing system is altered or a new system is implemented, simulation techniques must be used.

III. FINDINGS AND ANALYSIS

- *Inventory Management*

The study is to look at the inventory management procedure and to recognise the key factors that affects inventory management practices and explore different approaches. Inventory management is an important area of the industry. If the company fails to manage inventory, it will face issues. Different inventory management techniques are there to maintain a fair inventory level in the plant.

ABC Analysis is an OR tool that determines the value of inventory items based on their importance to business. ABC ranks items based on demand, cost and risk data, and inventory mangers group items into classes. It is based on the assumption that a small number of inventory items may generally reflect the bulk monetary worth of the total materials employed in the manufacturing process. While a relatively large number of items may represent a small portion of the money value of stores used and that small number of items should be subject to the greatest degree of continuous control. ABC analysis for inventory provides better control over working capital costs. The data we get from the analysis reduces obsolete inventory and boosts the inventory turnover rate, or how often a business should replace items after their sales.

Lagrangian Relaxation is one of the most widely used and efficient methods used to solve large scale integer programming problems by performing constrained optimization. For a minimisation problem, the solution to the Lagrangian dual problem provides a lower bound, while each feasible solution provides an upper bond. LR introduces the constraints into the main problem decomposing it into a relaxed problem, making it easier to solve. It is usually performed by creating two groups, one in which number of raw materials is fixed and the ither where the raw material groups are fixed. When the number of raw material groups is fixed, it decreases the duality gap but the number of raw materials increases increasing the computation time. When the number of raw materials is fixed, the duality gap and the computational time increase as the number of raw material groups augments.

Decision model is used for determining the optimal order interval and inventory level of each group of raw materials. The objective is to minimise the total cost of manufacturers attributed with the raw material inventory. This model uses setup costs and inventory holding cost as an objective function with some constraints related to inventory, to get the solution.

EOQ is a classical approach designed to find the optimal order quantity for businesses to minimize logistics costs, warehousing space, stockouts, and overstock costs. It is the question, how much to order the quantity when inventory is replenished. If the firm buying raw materials, this is to purchase the quantity of each replenishment and if it has to

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plan for production run, it is how much production to schedule. It involves carrying cost and ordering cost. Industry like steel gets benefitted a lot through this tool since logistics costs tends to be high here which makes it important for them to keep it in check.

- *Transportation Cost*

Transportation is one of the fundamental challenges that is commonly used to decrease transportation costs for companies with many origins and destinations while meeting supply and demand requirements.

The transportation models or problems are primarily concerned with the best possible way in which raw materials can be supplied at various factories or plants from the source of raw materials can be transported to a number of sides of raw materials according to plant demand known as demand destinations. The problem of minimizing the total transportation cost is generally considered as a single source linear transportation model.

Transportation model is used for optimization of the cost for transportation of supply of the raw materials from the source to the destination by the help of the truck vehicles by road. One of the most important utilization of the method of solving the transportation problem to reducing or minimizing the transportation cost of the transportation. The simple algorithm method can be used to solve any linear programming problem but this method is called laborious. The model is classified into two parts: routes of roads from source to the destination and vehicle condition and optimises manpower. The model is solved using three methods: North-west Corner, Least Cost, and Vogel's method.

Due to the fixed charge, the non-linear capacitated transportation issue does not have a global optimal solution. This problem's intriguing feature is that there may be more solutions than there are origins plus destinations, multiplied by one. These kinds of issues are applicable to several industries, trading firms, etc.

- *Production Optimisation*

The decision-Making tool helped to optimize cost by taking corrective decision-making measures which lead to cost efficiency and maintaining the required level of production with proper resource allocation.

These challenges include the continuous pressure and new demands placed by customers and the need to drive costs down, to improve all operations for better agility, and to manage the company in meeting its needs.

Production planning is the most common approach for solving the production optimization challenge is the "push production" approach in which demand is predicted and goods are produced before customer order and the second approach is pull production in which the manufacturing of products or parts is to meet only the actual immediate demand.

MRP is another idea of this system is to have stock when needed and to have none when it is not needed. The focus is not just to look at the reorder point for the items but on identifying the size and timing requirements from the master production schedule.

- *Supply Chain Management*

Major problems faced by steel industries in developing countries majorly include severe lack of technology, low productivity of labor, low potential utilization of resources which makes it even more important for them to minimize their production cost and maximize their profit through something else.

Linear programming model is used to undertake the Supply Chain Management (SCM) in steel industries that use blast furnace (BF). Objective functions used in the model are purchasing and providing principal raw materials (iron ore and coke) for a steel company, transforming them into various types of steel products, and transporting them to different destinations to minimize the total cost. Constraints applied to this model include constraints on resources, production and selling the steel products. Main features of the model consisted forming a relation among decision variables and considering diversity and amount of provided ore from different mines, consumed coke and diversity among steel products. Since end product pricing is not in control of manufacturers, if we plan supplying, manufacturing and distribution according to the model result, cost reduction can be achieved.

- *Effective Scheduling*

Steel industry being one of the most complicated industries as recognised production scheduling as a difficult industrial scheduling problem. Different approaches recognise this problem differently and are there to give positive outcomes.

Okwu Issac found that when the charges and casts in scheduling are defined through lot planning, the plant has to determine when and where (on which device) each charge should be processed at each production stage. Model-based predictive control (MPC) describes a set of advanced control methods, which make use of a process model to predict the future behaviour of the controlled system. Here, Rolling Horizon approach handles the disturbances in the dynamic environment and Lagrangian relaxation embedded into the rolling horizon strategy tackles scheduling problems. The observation showed that it yielded significantly better result with good improvement compared to a different method in Operation Research, passive adjustment method.

Scheduling Algorithm helps in processing efficient, effective and feasible algorithms on the hot rolling mills which majorly consists of a set of production campaigns or as called rolling programs which comprise of a finite number of slabs. It includes majorly two steps: building a rolling program and sequencing the built rolling program. To optimally compose the program, the minimal cost flow is used. The challenge is formulated as a MILP problem with due date and production mix limitations. Since orders might

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be delayed for several weeks, the scheduling department acquires a better understanding of the order book and the additional material required to fill gaps in the order portfolio. A hot rolling mill production planning approach that generates optimum hot rolling programmes and schedules. The optimum manufacturing schedule is established by building and sequencing hot rolling programmes.

Harjunkoski and Grossmann (2001) also introduced the general precedence scheduling model for the stainless-steel plant. Harjunkoski and Sand (2008) introduced more flexible formulation having stages and multiple machines. The scheduling part of the model uses assignment and precedence binaries following equations from Hadera and Harjunkoski (2013). The scheduling model is based on the precedence variables and assignment variables that suggests which of the parallel machines on each stage shall process a given heat. This production schedule also helps in defining the demand of electricity so that the supply can be monitored side by side

➢ *Power Crisis*

Industry like steel needs huge amount of energy, which makes it difficult if the industry is working in a developing economy. A developing economy tends to have poor utilization of power plants and fluctuations in power supply happens generally, which makes it important for steel industry to give its best power management as possible and here, operation research comes into picture.

The product mix part of the model called the 'Works Planning Model' was implemented by running the linear programming model at the targeted level of hot metal, liquid steel and sale able steel production and the market demand and commitment for the month.

The output of the model was the optimal production targets of different mills, steel melting shops and blast furnaces. The model was run successively with a objective of maximisation of production and contribution to the same profit maximization objective and the difference in the value of objective was observed.

As the availability of the power is decreased, the processors go out of the optimal product mix. The guiding principle is that if processor goes out of the optimal product mix first, it should be the first processor to be shut down. Henceforth, the model changed the relative importance of different processors in the case of a power crisis.

The proposed formulation describes a power intensive steel making process that produces a set of products on a specified set of units, while also satisfying various operational constraints. The plant is assumed to deliver a fixed number of products that are already known. The power consumption is both unit and product specific. Electricity purchase includes different options and is subject to hourly price-variations as well. The optimization should determine the optimal amounts to be transferred to/from the electricity sources at any given time interval. (Fig:1: Optimization of steel production scheduling with complex time-sensitive electricity cost; Hubert Hadera). However, it must be kept in mind the distribution of the costs among the elements of the objective function might differ.

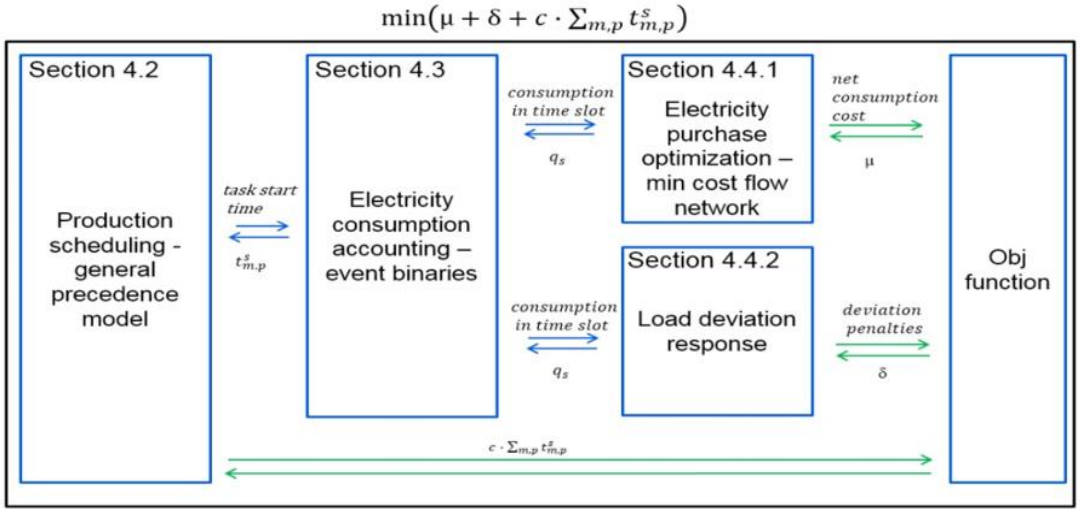

Fig 1:- Optimization of steel production scheduling with complex time-sensitive electricity cost; Hubert Hadera

➢ *Classification of Lots*

Scheduling includes different methods which help to reduce cost and allocates resource at optimal cost and time. The author describes 13 classifications of batch scheduling problems. Any one particular problem can have any combination of these thirteen classifications. The classifications include process topology, equipment assignment, equipment connectivity, inventory storage policy, material transfer, batch size, batch processing time, demand patterns, changeovers, resource constraints, time constraints, costs, and degree of uncertainty. (Fig:2: Planning and Scheduling Optimization in Integrated Steel Production; Patrick Alexander Philippe Carter).

➢ *Quality Management*

Six Sigma is a recognized approach to problem-solving that employs quality and statistical techniques to enhance fundamental processes. Six Sigma is now universally

recognized as a highly effective method for eliminating flaws in a business's quality system. A set of statistical tools used in quality management to provide a framework for process improvement is known as Six Sigma which has a great contribution to the steel industry.

The Lean Thinking model is a process to facilitate improvement in patient care with existing resources, meaning the same things can be achieved using fewer people which will impact the steel industry positively.

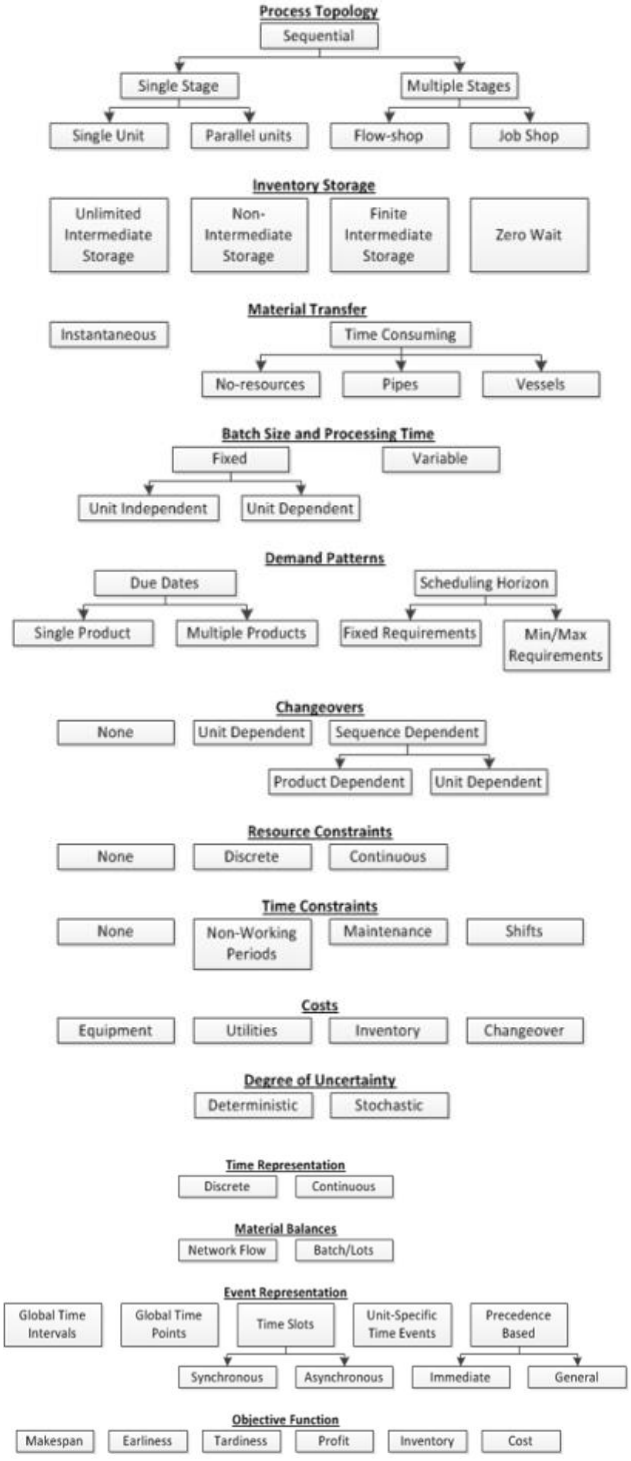

Fig 2:- Planning and Scheduling Optimization in Integrated Steel Production; Patrick Alexander Philippe Carter

➢ *Basic Procedure Planning*

The objective is to make use of O.R techniques like the shuffling-aided network to evaluate the complexity of the selection patterns established by a human expert during the steel manufacturing process.

The significance of various planning parameters in the context of steel production planning have been determined by applying a mixture of association rules and complex network methods. Our outcomes largely coincide with common knowledge about the interplay of different chemistry-related factors – with the exception that, in our dataset, elements except carbon are largely disregarded in the manual selection process. Our findings contradicts the existing knowledge about steel production planning constraints, as the exact chemical composition of consecutive steel grades technically affects the steel quality.

Our results facilitate steel production planning by explaining which planning goals or constraints cannot be relaxed if the schedule preparation appears infeasible. Consequently, if a human expert planner is absent, less experienced planners could benefit from our work and build on the expert planner's know-how. On top of that, our method helps in any situation where an order suggestion algorithm has to be configured based on implicit selection criteria that derive from fundamental technological production principles. We advocate for a good focus on network-aided planning and scheduling methods as they provide an intuitive representation of the problem circumstances.

➢ *Production Planning*

The objective is to tackle the potential occurrences of unwanted production of surplus inventory of steel using O.R concepts like- Integer programming to provide an instant analysis comparing the performance of the provided heuristic solutions against optimal solutions. This inventory management problem can arise in certain situations like- when orders placed are cancelled at the last minute or when quality of acquired products is not up to standard.

The order book has a list of orders from different customers. Each order has a target weight- (Ot) that needs to be delivered, along with a target weight that specifies the minimum (Omin) and maximum weight (Omax) acceptable at delivery as well. Over and above the total weight (per order), there are additional restrictions regarding the size and number of units on the basis of which the order can be factorized at delivery.

In the whole process, minimum and maximum weight for the entire process is specified such that, the produced units need to be within the maximum- minimum limit along with the weight intervals.

To fulfil an order, the production units size and quantities need to be specified such that- Minimum production weight >= Specified production size x Specified production quantity <= Maximum production weight.

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The solutions described here have been deployed in a steel plant and are now used in daily mill operations. The surplus inventory matching problem requires that we maximize the total weight of applied orders while minimizing the unused portion of the applied slabs, subject to the prescribed constraints.

- *Tackling Queues*

Queues are inherent in all multistage-manufacturing systems. Queuing models have also been used to perform capacity calculations for various sections of a steel plant. All systems for multistage manufacturing have queues by nature. They mostly happen in the primary mills and finishing mills. They come to the conclusion that this issue is much diminished if the infrastructure and machinery of steel plants and primary rolling mills are arranged in a direct line.

The steel industry is no different when it comes to the importance of simulation, especially given the high start-up costs and lengthy development times associated with putting up a plant or even changing the configuration of an existing facility. To assure the accurate and intended output before the existing system is altered or a new system is implemented, simulation techniques must be used.

IV. CONCLUSION

The research helped us in knowing the importance and use of Operation Research in Steel Industry. The application proved that Operation Research can be used to optimize most of the work in steel industry. We looked at how Supply chain management was solved by Linear Programming Model; Inventory Management solved through ABC Analysis, EOQ Analysis, Decision Model and Lagrangian Relaxation Model; Production Optimization using Decision Making; Optimal classification of lots using Batch Scheduling; Quality management using Six Sigma and Lean thinking; Transportation cost using Transportation model; Effective Scheduling using tools like Model Predictive Control and Lagrangian Relaxation, etc. and Power crisis using Works Planning Model. All these OR tools helped us in knowing how it minimized the cost and maximized the profits.

By using computational techniques, artificial intelligence (AI) is the study of mental processes. The significant advancements in information systems technology have made really useful applications conceivable. One of the most encouraging advancements to date originated in the steel sector, where operator guidance for the intricate primary end processes has been the most common application area. AI is anticipated to carry out the following fundamental tasks: Knowledge visualisation. search tactics. planning, deduction, heuristics, and strategic reasoning. Applications in each of the phases of integrated steel are described in this section.

V. LIMITATIONS

The studies, conclusions must be seen in the light of following limitations

- The data is only taken from existing research paper and no primary data collection has been done.
- Steel industry which has been considered in different papers didn't include modern steel plants which might be using some different operation research tools to solve other problems.
- Even in the areas covered here, there is a narrow choice of topics and uncritical use of existing methodologies.
- The review shows that OR studies in developing countries have not always addressed the specific problem environment of the developing economies with respect to issues of equity, management, technology, distribution and infra-structure. Even in the areas covered there is a narrow choice of topics and uncritical use of existing methodologies.

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