



ISSN: 0976-3376

Available Online at <http://www.journalajst.com>

ASIAN JOURNAL OF  
SCIENCE AND TECHNOLOGY

Asian Journal of Science and Technology  
Vol. 12, Issue, 08, pp. 11804-11808, August, 2021

## RESEARCH ARTICLE

# OR MODELS: HIGH-END ANALYTICAL TOOLSTO OPTIMIZE YOUR SUPPLY CHAIN: A STUDY OF INDIAN MANUFACTURING INDUSTRY

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### ARTICLE INFO

#### Article History:

Received 24<sup>th</sup> May, 2021  
Received in revised form  
14<sup>th</sup> June, 2021  
Accepted 21<sup>st</sup> July, 2021  
Published online 30<sup>th</sup> August, 2021

#### Key words:

Demand Planning, Statistical models,  
Operation Reaserch, Forecasting,  
Supply Network Planning, Supply  
Execution.

### ABSTRACT

In the past two decades of working experience in industry, I have observed a big gap in the understanding of the utility of Operations Research (OR) models for practical decisions of the business world. While the OR academics are somewhat cut off from the higher priority problems of the real world, business executives are skeptical or completely unaware of the practical use of OR models. Some of the managerial skepticism about OR models is justified, as there are real barriers to successful implementation of such tools which need to be overcome. However, our own experience of the past six years of developing and applying these models for real world supply chain problems of a variety of industries has convinced us and our customers about their use. This article aims to lift the veil of secrecy about OR models by responding to common apprehensions and providing examples of organizations that have broken the barriers to successful implementation and reaped direct business gains. The examples are drawn from our first-hand experience.

**Citation:** Sanjay Tripathi and Dr. Rajesh Jain, 2021. "OR models: High-end Analytical Toolsto Optimize your Supply Chain: A Study of Indian Manufacturing Industry", *Asian Journal of Science and Technology*, 12, (08), 11804-11808.

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## INTRODUCTION

OR models are based on an advanced set of mathematical optimization techniques called Operations Research. They are useful in analyzing and recommending decisions in complex situations where data is available but simpler approaches like managerial judgment or spreadsheet tools do not capture all factors relevant for complete analysis. For example, the planning and execution decisions of logistics, distribution, production and procurement in businesses with large scale and geographical coverage are complex. These problems have tens of thousands or more variables and constraints. Even when the data is available in well maintained IT/ERP systems, complete and correct analysis of these supply chain problems is often not possible with simpler approaches. This is where OR models become indispensable tools for support managerial decisions. Experience with majority of successful real-world applications of OR models to supply chain problems has demonstrated the gains of cost, contribution and service level in the range of 2-30%.

**Ways in Which OR models Could be Useful for Business:**  
OR models could support strategy, planning and execution in each of the major stages in a supply chain:

**Network Footprint Design:** Location and sizing of production, storage and distribution facilities, for both major overhaul and minor tweaks.

- **Network Allocation Planning:** Allocation of products and transport modes between facilities of suppliers, production, warehouses and customers, on monthly as well as daily basis.
- **Inventory Replenishments:** Safety stocks and reorder points for both finished products and procured items.
- **Fleet Planning:** Fleet sizing at plants and warehouses, for both outbound dispatches and inbound deliveries.
- **Route Planning and Order Assignments:** Daily planning of routes (direct and milk-run deliveries) and assignment of orders to vehicles, for both outbound dispatches and inbound deliveries.
- **Production Planning and Scheduling:** Product mix, size and sequence of batches on major production resources, on monthly as well as daily basis.

While supporting optimal plans and execution schedules in the above-mentioned supply chain areas, OR models can help to achieve total optimization of the supply chain. Optimization can be achieved on the relevant KPIs – contribution margin, cost to serve, time to serve, product fill rate and utilization of assets.

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A FMCG firm with 42 plants and 67 depots realized that primary outbound logistics is a high impact stage and network allocation is a corresponding high impact OR problem.

An automobile manufacturer identified production and procurement as higher impact stages.

For a steel maker, diversifying from B2B into B2C business, setting up outbound warehouses distribution network was a

A large automobile firm tested an OR tool for outbound route planning and estimated transport cost reduction of 5-24% under varying serviceability targets.

A large cement firm, while using an OR model for logistics network allocation, initially found large deviation between optimal plan and actual execution, but steadily reduced the gap by aligning KPIs to model result and changing relevant processes. Delivered cost reduction increased from 2% to 14% over one year.

A medium transformer cores manufacturer used an OR model to optimize slitting plans, leading to 3-9% reduction in unused material which implied big cost saving.

A large snacks FMCG firm reduced average inventory levels by half at the same fill rates after six months of implementing a replenishment tool for distributors. This was driven as a change management project by the senior managers, and involved participation of personnel from logistics, sales, depots and distributors.

A firm having SAP ERP has installed an OR tool at its central server for all India production and logistics allocation planning. The master and transaction data which are well maintained in ERP are automatically uploaded into OR tool every Monday. As logistics planning is conducted at the regional level, the regional planning teams upload certain specific data in standard spreadsheets. Certain data consistency checks and validations are automated, and errors automatically pointed out to logistics teams for corrective action. Periodic model run and reports generation is automated too. Executives in different functions – corporate, logistics, plant, sales – get different sets of reports. Certain reports, like KPIs, are displayed to everyone.

Furthermore, if the business and operational requirements are modeled right, this optimization can be achieved under all relevant constraints, thereby yielding optimal yet practically feasible solutions.

In addition to recommending optimal plans, the same OR models can be used to regularly provide valuable insights to the senior management, such as:

- **Compliance Analysis:** Overall compliance index which measures the deviation of actual execution from optimal plan, and the key factors causing this deviation.
- **Bottlenecks Identification and Prioritization:** Identification of those few operational constraints whose relaxation could result in large gains to the business.
- **Budget Planning:** Yearly allocations of budgets and targets for various sales units, regions, warehouses and plants.
- **Barriers to implementation of these tools, and conditions for their success.**

Despite the tangible gains offered by OR models, their active use in the industry remains scant. Only a few enlightened businesses have been able to break free of the following barriers and derive full benefits of OR implementation. These barriers could also be viewed as factors about which special care needs to be taken to ensure effective implementation of OR models.

**Mapping ‘high impact’ supply chain stages on to ‘high impact’ OR problems:** Lack of clear notion about which are high impact stages in a particular industry’s supply chain leads to incorrect problem prioritization/diagnosis. Lack of clear notion about which decision problems and objectives could be most visibly impacted by OR models yields incorrect prescription. Identifying the two and mapping them for one’s own industry is the first strategic step a senior management could take towards setting the agenda for OR led systemic improvement.

**Capturing all relevant constraints and objectives of business and operations:** Any major decision problem cuts across several functions like logistics, sales, production, procurement, strategy. Therefore, detailed business and operational requirements for scoping the problem should draw inputs from all these functions. Not doing so would likely result in incomplete scoping, hence less effective configuration and tailoring of OR models. On the contrary, by incorporating all relevant requirements, the OR models will generate outputs which are optimal yet practically feasible to implement. Moreover, those outputs will have easier buy in of internal stakeholders as their concerns would have already been reflected.

**Using OR model for complete decision and improvement cycle, i.e. planning, execution, compliance tracking of KPIs, and bottlenecks identification/removal:** An optimal plan is merely an immediate output of an OR model. Quite often, such a plan might be for a short period and based on certain forecasted input parameters. Actual decisions are likely to deviate from such a plan as several parameters turn out to be different from forecasts (leading some to believe that such forecast based optimization is not useful). Therefore, a longer period optimal plan needs to be followed up with shorter period or real time optimal schedules generated from the same OR model applied with additional micro level constraints and more accurate estimates of parameters. Subsequently, post-facto analysis could be carried out with the same OR model to quantify the factors contributing to the deviations from optimal

plan to optimal schedule to actual execution. This analysis could point to the few major factors which need to be controlled in the future – sort of KPIs to track and assess performance of various functions. Furthermore, different operational constraints of the model can be relaxed to identify the few crucial constraints (bottlenecks) which the senior managers ought to remove in order to accrue maximum business gains.

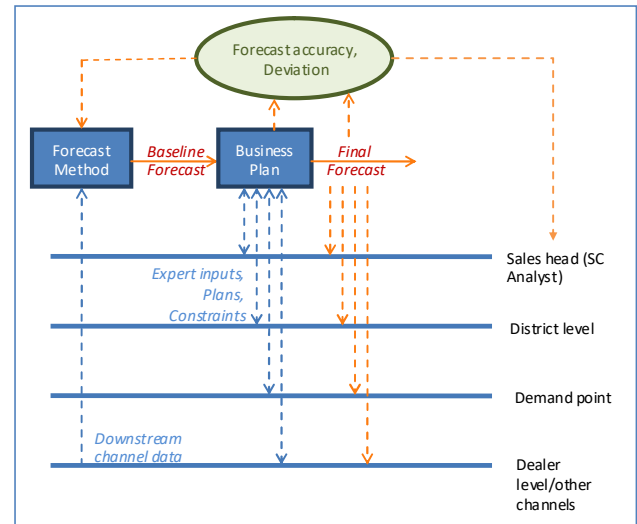
*Daily route planning at a firm supplying spares to channel partners involved business objectives of delivery time commitment, transport cost reduction, and reliable quality transportation; and operational constraints of availability of certain vehicle sizes, different vehicle speeds on different types of roads, and entry time restriction in cities for larger vehicles.*

*Inter-plant and outbound logistics of a cement firm had to consider operational constraint of high utilization of limited number of rakes.*

**Identifying data sources, integrating with existing IT/ERP systems, and building data validation interfaces:** If certain input data required for an OR model needs to be entered manually or some of the data has errors, the process of operating the model could be frustrating. While the OR model should ideally be integrated with data sources like existing IT/ERP systems, full input automation will often require additional work of developing standard templates and data maintenance for those parameters which are not reliably stored in the ERP. In addition, some of the data stored in the ERP might be incorrect or inconsistent. Therefore, appropriate data validation rules need to be automated in the form of interfaces which promptly highlight any problems with the data.

**Making a time-phased roadmap of implementing OR models and necessary changes in processes and organization:** Finally, an absence of a complete perspective of the supply chain and of the different OR modeling pieces which could solve the whole jigsaw puzzle could create conflicting views and difficulty in building consensus. Also, any significant OR model implementation may not be fully successful if it is not accompanied with facilitating changes in certain operational and organizational processes (which are reflected in new standard operating procedures). Therefore, preparing a roadmap of implementing various OR models which provides total vision of the improvement, reflects the priority of ‘high impact’ supply chain stages and decision problems, and incorporates necessary changes in organizational and operational processes, is a crucial step towards desirable change management.

**Getting started with implementation:** As must be obvious from the previous discussion of barriers, the best way to get started with optimization enabled supply chain improvement is to first identify the combinations of ‘high impact’ supply chain stages and OR decision problems; then prepare an implementation roadmap of relevant OR models and accompanying process changes; and subsequently scope each model and delineate input data, data sources, validations, output reports, and IT integration aspects. Preparation of this blueprint will go a long way to assure right implementation of OR tools and consequent gains for the business. Crucial part of any OR model implementation is data sanity and consistency. Data fetched from ERP system or the manually uploaded data and as explained in the previous section that data has to be error free.



To maintain the data consistency and building the validation rule we can categorized data in two part (i) setup of a supply chain structure in the OR based application; called as static data or Master data and the update frequency is very low to that data. New data element will be appended as and when they are part of supply chain of company. (ii) Planning data which is nature of transactional for each planning horizon. Data validation process will be dependent on the Master data and transactional data. Any supply chain model is driven by demand of the product at the granular level. As we called OR model are demand driven model the most crucial data for OR model is Demand data. There are some process and tool required to generate the demand for nay market – product combination. Next section describe the detail on the demand planning.

*Production planning for individual plant and planning for entire supply chain with multiple resources with different capacity can be performed using generic planning tools with generic linear programming (LP) and mixed integer programming (MILP) packages such as CPLEX (GAMS). The developed optimization tool using GAMS/CPLEX is prepared with the specific formulation and build the appropriate data interface and integration with existing legacy system of the organization. In the constraint scenario of the production where the many resources are shared among the different production schedule and various products. Build optimization engine can handle all such production constraint of shared resources, raw material availability, MoQ, and utilization of resources.*

**Demand Planning & Collaborative Process:** Demand generation process is based on the statistical Time Series forecasting, Support vector Machine or using the high end models based on the artificial Intelligence like Machine Learning techniques, Deep Learning Techniques etc.

Any Demand forecasting model has some limitation and accuracy involved in that. To make demand more accurate we have to put some process to align the demand with the business aspiration and Targets. The Expert input and bottom channel input are most crucial input to finalize the demand. Based on finalized demand the OR based supply chain optimization tool generate the different plan to serve the demand and basis on the demand we can define the Production plan, procurement plan and inbound as well as outbound logistics plan. Based on the industry type and Finished Goods (FG) configuration, we need to make the Bill of Material for each Finished Goods (FG) and based on the FG demand we can derive the raw material requirement plan (MRP) for each FG. We can optimize the procurement planning basis on demand of FG.

### Procurement Planning

**BOM Mapping & Material Requirement Planning:** Bill Of Material (BOM) mapping is essential to generate the procurement plan. Procurement is process which required certain lead time to reach material at the production line. We need to make the procurement plan on rolling basis (3 to 6 months or more rolling plan). To minimize the total landing cost of raw material and the fulfill the supplier business commitment we need a OR based optimization engine which will factor the lead time, logistics cost, the supplier capacity and cost of material supplied.

**Supplier Collaboration and Share of Business:** We can build as supplier collaboration module to have the interactive plat form for supplier to put their capacity and supply constraint. Each supplier Share of Business (SOB) to be defined and the OR model should adhere the SOB and minimize the total landing cost of Raw material. Each vendor and their material supplied to mapped in system and accordingly capacity has to be defined in supplier capacity data

$$\text{Total Landing cost of Material} = \sum (\text{Cost of Material} + \text{Logistics Cost}) * \text{SOB}$$

**Inbound Logistics Planning:** Logistics link with all modes available has to defined in the system and

**Production Planning:** Production planning is key driver for On time in Full (OTIF) delivery, if organization don't know about the stock level of finished goods and Raw materials, resource availability, or the job schedules implies that the organization inefficiency about the production planning and production control, this may cause the excess inventory or the loss sale due to improper inventory of finished goods.

**Goldon B. Carson:** "Production planning and control involves generally the organization and planning of the manufacturing process. Specifically, it consists of the planning of the routing, scheduling, dispatching and inspection, co-ordination and the control of materials, methods, machines, tooling and operating times. The ultimate objective is the organization of the supply and movement of materials and labour, machine utilization and related activities, in order to bring about the desired manufacturing results in terms of quantity, time and place."

**James L. Lundy:** "Basically, the production control function involves the co-ordination and integration of the factors of production for optimum efficiency. Overall sales orders or plans must be translated into specific schedules and assigned so as to occupy all work centres but overload none. The job can be done formally in which case elaborate charting and filing techniques are used ; or it can be done informally, with individuals' thoughts and retention there of supplanting tangible aids."

**Charles A. Koepke:** "Production planning and control is the coordination of a series of functions according to a plan which will economically utilize the plant facilities and regulate the orderly movement of goods through the entire manufacturing cycle, from the procurement of all materials to the shipping of finished goods at a predetermined rate." Production planning is a process of planning of raw materials, workforce, production resources (equipment/workstations) to fulfil the manufacturing orders on time and in full. Aoptimal production plan makes the best use of available resources to deliver orders on time and in full. Production planning is a process which involves a number of steps such as deciding what to produce, how to produce, when to produce, etc., these are the part of production planning. The whole process should be carried out in optimal way and at the lowest cost. This is a control function and has to be carried as meticulously as planning.

Key driver for the production planning is the right demand forecast for the finished product at the appropriate geography level. Multi location production required the utmost accurate demand forecasting for the location associated with the production units. A Optimal plan to server the demand in full, will define the production for each production units. Production for small unit can be handle using excel spreadsheet but for the large organization and multi-production facilities the complexity increased exponentially. Production planning helps organization to plan the raw materials procurement, resources requirement, workforce requirement, based on the demand of the finished goods to be produced. It has an impact of inventory levels of raw materials, cash flow, finished product inventory, sales, and distribution

**There are few levers to manage the production planning and improve the efficiency:**

**Demand Forecasting:** To begin production planning the initial step to be take is forecasting demand of your finished product at highest level of accuracy. The forecasted demand give us the estimates of our consumption of finished goods and based on this production planning tool will allocate the resources. The basic data element is required for the forecasting is the historical sales data, market trends, growth of the industry and segment and some other key demand driver which will impact the demand for the future planning horizons. Preparing the proper forecast will ensure the good production planning for the quantity and the raw material procurement planning and energy and non-energy workforce requirements.

**Inventory management:** Inventory planning is very crucial and important aspect of the supply chain, organization cannot build the desired product if there are shortage of raw material and vice versa organization will help with space/storage area constraint and large capital blockage in case of high inventory

stored. Another aspect of inventory management is that organization should store the appropriate raw material inventory at the optimal level of inventory. This will be derived based on the proper and accurate forecast of the finished product. Organization should know that when to build, how much to build and where to build the Raw material inventory. This will help to control the cost of production and timely production of required products.

**Plan – Do – Check – Adapt:** The elementary and important aspect of planning is that, organization should plan for everything and for everyone. This means that, often when organization build the production plan, few item like equipment or the resources or the workforce are unaccounted. Organization should plan for the available resource and maintenance schedule. Hence organization should plan for all the resources, rawmaterial, and work force. Once the production plan is finalized and rolled out for implementation and production process begins. Since then organization should build the mechanism to monitor each and every planed item for production using IoT devices or with supervisors for the efficient production and ensuring the plans are properly implemented. Organization should build the mechanism to record the deviation and inefficiency in the process and use for the future course correction. Despite of the proper planning, some steps are the things may go wrong at the time of execution, which is recorded in the deviation summary build at the monitoring steps starting from the supplier in efficiency of rawmaterial, energy breakdown, machine breakdown or workforce unavailability. It is very essential to adopt the changes quickly and act so that the planned quantities can be delivered on time and in full.

**KPI's to be tracked for the Production planning:** To ensure that the production planning and operation or at the right pace and track, organization should track few Key Performance Indicators:

**Production Cost:** This element impact in the monetary term of the products and impact on the overall supply chain cost. Being the biggest shareholder of any product supply chain. Organization should track the production cost. This includes the raw material cost (including sourcing and logistics cost), energy and non-energy resource cost, workforce wages, capital cost interest etc.

**Capacity Utilization Ratio:** The ratio of actual performance vs maximum possible or the best rated production output. Optimal use of the machine and workforce will help to track and control the cost of production. Low utilization of resource may cause the high fixed cost element of EBIDTA of the organization

**Planned vs Actual:** This KPI gives what you have planned and what you achieved in the defined planning horizons. The deviation in plan vs actual will guide organization to do the course correction for the future. The cost of deviation should be highlighted to the workforce and take necessary corrective measure to avoid in future. Major pitfalls of the production are:

- Raw material stock out due to wrong raw material planning or long lead time of procurement, hence organization should maintain the optimal level of inventory at each production unit and define the proper reorder point
- Proper maintenance schedule of equipment to be build and maintenance has to be done based on the schedule to avoids the breakdown at the production time.
- Equipment Bottleneck: Bottleneck can be at any stage, for example if packing unit has bottleneck then it may cause the bottleneck at the storage and the production of the other products in the production line and it may cause the deviation in plan.

#### **Outbound Logistics Planning**

- Primary logistics
- Secondary logistics
- Loading, Unloading & Other cost
- Logistics constraint

#### **Inventory Planning**

- Opening Stock
- Desired Closing Stock

#### **Constraint Management**

- Dispatch Constraint
- Production Constraint
- Raw Material Availability constraint
- Logistics Flow Constraint
- Direct and Stock movement constraint
- Other Operational Constraint

#### **Last mile Delivery**

- Full Truck Load
- Milk run route
- Less than Truck Load
- Service Area and serviceability constraint

#### **Compliance and Monitoring KPI's**

- Deviation and Compliance analysis
- Variance Analysis

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