

OR IN FOOD INDUSTRY

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Abstract— With the increasing change in trend and fashion in today's world, Food has become one of the important elements used to define one's lifestyle and standards. But now, deciding 'what to eat' is a very essential part of a person's daily routine. Alongside the changing needs and wants of people, the food industry has grown tremendously.

It is becoming increasingly clear that food tech is more and more of a logistics play and requires implementation of ordering and pricing strategy. Delivering and quality controlling is a complex problem with various aspects such as cost-effective routing, cost-effective delivery and pickup nodes, perishability of food, limited transport resources and there is a need to identify feasible as well as efficient solution methods to solve them. In this research paper, we have emphasized upon various methods through which techniques of operations research have been utilized to address various problems mentioned above.

Index Terms— Transportation problem, cost minimization.

I. INTRODUCTION

Soon to be a \$200B online food delivery industry is rapidly changing the global food industry, let the hunger games begin.

The Global Revenue in the Food & Beverages segment amounts to US\$65,495m in 2019 and is expected to show an annual growth rate (CAGR 2019-2023) of 10.3%, resulting in a market volume of US\$97,087m by 2023.

User penetration is 20.8% in 2019 and is expected to hit 28.8% by 2023. The average revenue per user currently amounts to US\$42.71.

In global comparison, most revenue is generated in China (US\$22,102m in 2019).

Operations Research in an analytical method of problem solving and decision making that is useful in various industries. It breaks down problems into simple components to solve them through mathematical analysis.

In the Food Industry, OR is very helpful in solving transportation problems by finding the least expensive and the fastest route to deliver food and raw material which will further help in reducing production cost.

Transportation plays an extremely important role in the food industry, It accounts for two-

thirds of the total logistics cost and affects the level of customer service. Hence OR can be very useful in increasing the productivity of this continuously growing industry.(PLANETTOGETHER, 2018) Figuring out the optimal routes and using them can not only help increase revenue ancustomer satisfaction but also reduce wastage, the economic loss caused by food perishability and waste reached \$218 billion in the US, \$143 billion in Europe, and \$27 billion in Canada In addition to the economic impacts, food perishability also caused food safety problems in many regions. According to the WHO, about 600 million people became ill after consuming contaminated food each year. Among them 420,000 died, including 125,000 children under the age of five years. This has raised serious concern about food safety in many countries all of which can be avoided.

And with online food delivery players like Zomato, UberEats , Swiggy and Postmates building scale, the organised food business has a huge potential and a promising future which can use the OR techniques to their advantage.

II. OVERVIEW OF THE INDUSTRY

The Food Processing Industry is a mature sector that loosely tracks underlying demographic trends, such as population and income growth. Companies generate revenue from the sale of food and ingredients to a whole host of customers, ranging from supermarket chains and local bodegas to restaurants and other players further down the processing chain.

This sector is praised for its ability to deliver consistently positive investment returns.

Food, of course, is one of life's basic necessities. As such, underlying demand tends to be steady through prosperous and difficult economic times Companies endeavor to capture a greater share of household budgets through strong branding and the strategic positioning of their offerings. Trend-right products and re-formulations that are (Indian Brand Equity Foundation, 2017)easy to prepare, portable, and healthful usually gain good traction.

Success also depends on the ability to control costs and leverage fixed/near-fixed expenses. Over its history, the industry has, at times, suffered margin pressure due to severe input cost inflation in the form of higher prices for ingredients and fuel (used to power processing plants and distribute goods to the retail trade). In periods of commodity-price deflation, however, the "stickiness" of retail price hikes supports profitability.

Quality of the food products continuously changes as they move along the supply chain, which can lead to significant social, economic, and environmental consequences.

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The Indian food industry is poised for huge growth, increasing its contribution to world food trade every year. In India, the food sector has emerged as a high-growth and high-profit sector due to its immense potential for value addition, particularly within the food processing industry.

The food industry, which is currently valued at US\$ 39.71 billion! is expected to grow at a Compounded Annual Growth Rate (CAGR) of 11 per cent to US\$65.4 billion by 2018. Food and grocery account for around 31 per cent of India's consumption basket.

Accounting for about 32 per cent of the country's total food market, The Government of India has been instrumental in the growth and development of the food processing industry.

The food industry deals with highly sensitive products and the quality of the food products continuously changes as they move along the supply chain, which can lead to significant social, economic, and environmental consequences. These are a few of the key reasons behind maintaining quality standards and adhering to quality requirements, which are imperative for players in the food industry. When it comes to food items, most of us tend to repeatedly buy the same brand which we perceive is of good quality and matches our expectations. Also, in the case of companies in this industry, even a small incident where the quality of products has been compromised could tarnish the brand image. Consequently, the company's profits could go crashing down the hill. This makes having appropriate quality control measures highly necessary for brands dealing in food products.

III. LITERATURE REVIEW

In food industry, the quality of the food products declines over time and should be addressed in the supply chain operations management. Managing food supply chains with operations management methods not only generates economic benefit, but also contributes to environmental and social benefits.

We concentrate on the quantitative models in this research field and classify the related articles into four categories, that is, storage problems, distribution problems, marketing problems, and food traceability and safety problems.

In the past researchers have explored the use of Operations Research in food delivery companies and how restaurants can choose between emerging food delivery companies using Transportation problems. The model used identifies the source that is the restaurant from where the quantity of food will be delivered to the destination that are the food delivery companies that want to grow their business by getting maximum amount of quantity from restaurants that can be delivered through them so that they can earn their profit and the restaurants can aim for cost minimization.

Choosing a third-party food delivery company will be more beneficial rather than the business itself starting to deliver because the cost of hiring people for delivery, managing them and arrangement of vehicles will add to the cost. The use of modeling, in this case, use of transportation problem, can be very useful for the business to determine the alternative options that the business has while deciding on the quantity of

food to be delivered by one particular food delivery company. Also, modeling saves cost compared to the costs that would incur if different alternative solutions are implemented in real life, so the manager has the option of considering all the costs offered by different food delivery companies and then determining the solution that will minimize the cost. In the past they have reviewed the operations management research on food quality and safety. Unlike other disciplines that study food quality, the Operations Research (OR) field has focused on using optimization models to capture the effects of important operational variables (e.g., inventory, routing, and pricing) on both economic and social benefits. The importance of product quality is reflected in the current research, in terms of both research contributions and the variety of the methodologies used. The future research agenda is also proposed to enrich the understanding of various kinds of operations management decisions and food quality.

There is also research undergoing as part of DEFRA sponsored feasibility study 'Resource Management and Product Traceability (e-Track)'. They address the process flow and operations management within the current food industry. It aims to improve the food production process by providing techniques for real-time resource management, product quality assessment and traceability. System integration requirements covering traceability technology and management tools will be identified to enhance monitoring, decision-making and production quality. Although the work takes into account the full picture of the future food industry, the transformation must be gradual to avoid any prohibitive costs and consequences. It should take into account the current technologies, moving gradually towards efficient, automated, adaptable, cost effective and user-friendly systems.

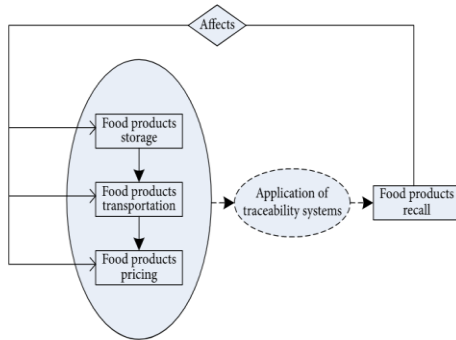
IV. ANALYSIS AND FINDINGS

Perish ability of food products

Quality of the food products continuously changes as they move along the supply chain, which can lead to significant social, economic, and environmental consequences.

Food spoilage is one of the major issues related to food safety and quality. When food products move from farms to food processors, food retailers, and end customers, spoilage cannot be avoided. Food perishability may cause huge wastes. It is estimated by the United Nations that approximately one-third of all food produced for human consumption is wasted each year.

The economic loss caused by food perishability and waste reached \$218 billion in the US, \$143 billion in Europe, and \$27 billion in Canada. In addition to the economic impacts, food perishability also caused food safety problems in many regions. According to the WHO, about 600 million people became ill after consuming contaminated food each year. Among them 420,000 died, including 125,000 children under the age of five years. This has raised serious concern about food safety in many countries.



The goal is to present the latest research development in this field and to identify future research opportunities.

In order to identify the progress and gaps in the existing literature on food quality and operations management models, a conceptual framework is constructed to understand the key decisions. The framework helps us understand the achievements, challenges, and opportunities in the research on food quality and operations management models.

V. TRANSPORTATION PROBLEM IN FOOD SUPPLY CHAIN

We discuss the transportation planning in food supply chains considering food quality degradation. In economy, transportation plays an important role, which accounts for two-thirds of the total logistics cost and affects the level of customer service. In reality, food supply chains stretch from upstream agricultural farms to downstream consumers, with intermediate manufacturers, foodservice providers, and sellers in the middle. Along the distribution process, food products may perish and temperature control becomes crucial for supply chain partners to reduce wastes and enhance food quality and food safety. To enhance the profitability and competitiveness, many enterprises strive to handle the issue of product perishability so as to maintain the value of their products.

The transportation planning problems are mainly concerned with the optimization of delivery routes, delivery quantities, and delivery time. Transportation modes, such as flights, cargo vessels, or trains, should also be considered. Although great progress has been made in this direction in terms of considering product perishability properties, challenges still exist.

Transportation planning mainly deals with vehicle routing problems (VRP). When considering product perishability, more factors should be reconsidered in this research area. First, food safety is a main concern when enterprises distribute the food products from manufacturer to retailers and customers.

Second, different types of perishable products should be stored in different conditions during transportation. Because the storage temperatures for chilled meat and fresh vegetable are different, a vehicle may be divided up into multiple compartments with different temperature controls. This makes the transportation planning more complex and more challenging. Third, distribution planning of the food products is often linked to customers' preferences and satisfactions. In real life, the fresher the products, the higher the price. Shorter delivery time helps to maintain the freshness, yet it increases the total transportation cost.

• Transportation Planning Considering Various Factors:

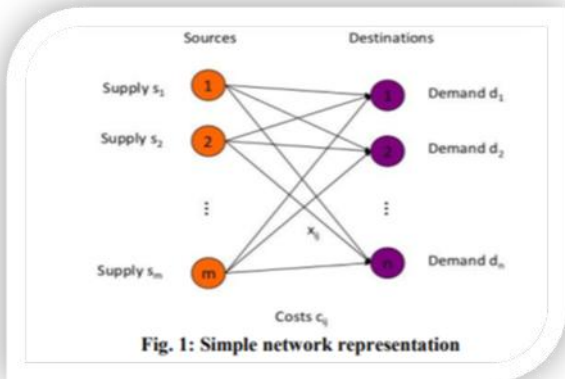
During the transportation of perishable products, factors like the product quality, the product safety, the transportation mode, the preservation conditions, or multifirms' coordination all have significant impacts on optimal decisions.

Riegersberg developed a simulation model of the distribution chain of fresh-cut iceberg lettuce under the consideration of quality and safety during distribution stage. The main purpose was to study the impacts of product life cycle, customer purchasing behaviors, and distribution lead time reduction on distribution strategies.

This study investigated the impact of storage temperature and duration on the fate of *Escherichia coli* O157:H7 (An important food- and waterborne pathogen that causes diarrhea, hemorrhagic colitis, and hemolytic-uremic syndrome (HUS) in humans.) on commercially packaged lettuce salads, and on product quality. Fresh-cut Romaine and Iceberg lettuce salads of different commercial brands were obtained from both retail and wholesale stores. The packages were cut open at one end, the lettuce salad inoculated with *E. coli* O157:H7 via a fine mist spray, and resealed with or without an initial N₂ flush to match the original package atmospheric levels. The products were stored at 5 and 12 °C until their labeled "Best If Used By" dates, and the microbial counts and product quality were monitored periodically. The results indicate that storage at 5 °C allowed *E. coli* O157:H7 to survive, but limited its growth, whereas storage at 12 °C facilitated the proliferation of *E. coli* O157:H7. There was more than 2.0 logCFU/g increase in *E. coli* O157:H7 populations on lettuce when held at 12 °C for 3 d, followed by additional growth during the remainder of the storage period. Although there was eventually a significant decline in visual quality of lettuce held at 12 °C, the quality of this lettuce was still fully acceptable when *E. coli* O157:H7 growth reached a statistically significant level. Therefore, maintaining fresh-cut products at 5 °C or below is critical for reducing the food safety risks as *E. coli* O157:H7 grows at a rapid, temperature-dependent rate prior to significant quality deterioration. (E.Narkhedec, 2019) Specific information regarding the effect of temperature on pathogen growth on leafy greens is needed to develop science-based food safety guidelines and practices by the regulatory agencies and produce industry. Temperature control is commonly thought to promote quality of leafy greens, not safety, based at least partially on a theory that product quality deterioration precedes pathogen growth at elevated temperatures. This prevalent attitude results in temperature abuse incidents being frequently overlooked in the supply chain. This study demonstrates that human pathogens, such as *E. coli* O157:H7, can grow significantly on commercially packaged lettuce salads while the product's visual quality is fully acceptable. Packaged fresh-cut salads are marketed as "ready-to-eat" while lacking an effective pathogen kill step during their preparation. Thus, maintaining storage temperature at 5 °C or below is critical to prevent pathogen proliferation and mitigate food safety risks should pathogen contamination inadvertently occur during crop growth or postharvest fresh-cut processing.

VI. OR IN FOOD DELIVERY

With the increasing change in trend and fashion in today's world, Food has become one of the important elements used to define one's lifestyle and standards. But now, deciding 'what to eat' is a very essential part of a person's daily routine. Alongside the changing needs and wants of people, the food industry has grown tremendously. Every city has multiple food joints, cafes, and restaurants which offer a variety of menu to serve their customers. Cuisines from all over the world are being served at a single place. The presentation of food also matters while the quality of food is now a big challenge to the food industry with a growing awareness of health and fitness.



All of this has led to immense competition among the food producers. Producers are competing by price cutting, cost-cutting, improvement in quality, better ambiance and better service. Price Cutting is essential to increase demand of a particular product over its competitor's product. Cost cutting is done through the efficient use of raw material and decreasing production cost and transportation cost. Need for better service has led to the formation of a new service industry known as food delivery.

"It is becoming increasingly clear that food tech is more and more of a logistics play, restaurant discovery is not a deep competitive advantage. There are clear trends on customer and seller satisfaction supported by the better delivery speed and compliance that vouch for the superiority of the captive delivery model in the Indian market," said Anil Kumar, founder, and chief executive officer, Red Seer.

Food delivery and rescuing is a complex problem with various aspects such as cost-effective routing, cost-effective delivery and pickup nodes, perishability of food, limited transport resources and there is a need to identify feasible as well as efficient solution methods to solve them.

How can operations research be used in the food industry in solving the following problems:

(i) Transportation problem: We will be using the model building to understand how transportation cost can be minimized while delivering food from the restaurant's kitchen to the customer. It will also help us derive the route to be chosen for the delivery so as to decrease the delivery time.

(ii) LPP: we will discuss how linear programming can be used to arrive at the maximum profit. By deciding how much to produce. This can be determined through ISO Proffer and ISO Cost lines.

The transportation problem is a special type of linear programming problem where the objective is to minimize the cost of distributing a product from a number of sources or origins to a number of destinations". (Vishal Pandey) The structure of transportation problem allows a complex problem with many constraints and variables to be solved faster and with a more economical algorithm. The transportation problem deals with the transportation of the goods to different markets on the basis of the requirement of the markets (demand) and quantity that the business can send to the market (supply). "A typical transportation problem is like this: A matrix is given where sources are given row wise, destinations are indicated column wise and unit cost of transportation from each source and demand at every market". (Vohra, 2010) Transportation problems are solved only if the supply is equal to demand, that is that they are balanced, if it isn't balanced the problem can't be solved and to solve it a dummy source or destination will have to be added. We will be using a transportation problem to understand how restaurants can choose between different delivery companies to minimize their cost and deliver the food to the customers.

Considering a restaurant for our analysis as XYZ Ltd, XYZ Ltd. is a restaurant with 5 branches in Mumbai, which don't have the option of food delivery. But with the growing demand of customers to have food at their own convenience and at home so the business decided to start food delivery through food delivery companies. Each branch has the option to send deliveries out through different available third-party delivery companies that charge a price to the business and carry out the task of transporting the food at the customer's chosen address.

Each branch cannot exceed the set supply as other food items are only available at the restaurant for dine-in purpose or takeaway. The second assumption is that each food delivery company has set targets from each branch. They can only deliver a fixed quantity of food from each branch to customers. This will be the demand for food delivery companies.

The other assumptions with respect to the model of transportation can be made:

To find the most cost-effective and profitable route, only one restaurant is compared to the available food delivery applications

- The restaurant must have one or multiple outlets/franchises
- More than one food delivery method must be available to the given restaurant.
- The outlets/ franchises of restaurants must be widespread.
- Outlets of close proximity also should be included.

Using Transportation Problem, the most effective cost problems can be solved.

Table 1: Marix

	Swiggy	Zomato	Uber Eats	Food Panda	Supply (Availability)
Branch 1	C11	C12	C13	C14	a1
Branch 2	C21	C22	C23	C24	a2
Branch 3	C31	C32	C33	C34	a3
Branch 4	C41	C42	C43	C44	a4
Branch 5	C51	C52	C53	C54	a5
Demand (Requirement)	b1	b2	b3	b4	$\sum a_i = \sum b_j$ Demand=Supply Balanced

Now the business after deciding the food delivery

companies will have to see how much quantity each branch (source) will send to each company (destinations) depending upon the unit cost of transporting from each source to each destination.

Finding the initial solution through Vogel's Approximation Method (VAM). "VAM is an iterative procedure calculated to find out the initial feasible solution of the transportation problem". (Business Jargons) VAM considers the opportunity cost between the two least cost and allocations are then made

Use of modeling and using this method will help the business determine the least cost and act accordingly rather than choosing only one food delivery company which may have higher cost or which may not be able to deliver the set target of deliveries that the business wants per day. Therefore, through the use of transportation problem, it will be easier for XYZ Ltd. to choose between different suppliers and likewise the food delivery companies can make use of transportation problems to choose between the many different restaurants that want to delivery through their company and then charge prices for delivery and quantities to be delivered accordingly.

- Integrated production and distribution planning in the fast moving consumer goods industry: a block planning application

In the fast moving consumer goods industry there is an ongoing trend towards an increased product variety and shorter replenishment cycle times. Hence, manufacturers seek a better coordination of production and distribution activities. In this paper, a so-called block planning approach is presented which establishes cyclical production patterns based on the definition of setup families. For the delivery of final goods from the plants to distribution centers two transportation modes are considered, full truckload and less than truckload. The proposed mixed-integer linear optimization model minimizes total production and transportation costs.

In particular, a rigid and a flexible block planning approach are compared which differ by their degree of flexibility in the scheduling of the production lots.

VII. PROBLEMS AND ITS SOLUTION

Today many industries are faced with the customers' desire for an increased variety of product variants. Specifically, in the fast moving consumer goods industry, e.g. in the food and beverage industry, the number of packaging sizes, customized package

Prints and labels, composition of ingredients and flavors, as well as the number of new products has considerably increased. As a result, manufacturers changed their policy from producing large batches with only a small number of setups to a policy with short production cycles for product types (product families) and frequent changeovers between prod(Yadav, 2018)uct variants within the same product family. Typically, production lines are set up for a specific family requiring a major setup or cleaning operation such that the changeover between the individual product variants can be accomplished with only a minor setup operation. At the same time, retailers which are often organized in nation-wide

supply chains are seeking faster replenishment and shortened cycle times in order to reduce their inventories. To respond to these recent developments, operational planning and scheduling systems in the fast moving consumer goods industry have to meet the following challenges.

- A closer coordination of production and distribution activities is required in order to avoid excessive inventories at the manufacturers' warehouses.

- Setup families comprising product variants which can be produced with the same basic setup of the manufacturing equipment need to be identified.

- According to the similarity of the individual recipes or processing conditions of the product variants within a setup family, the definition of fixed setup sequences is a further challenge. In practice, these production sequences are determined by the quality requirements of the individual products.

- In order to facilitate the coordination of production and distribution activities and to allow a quick response to customer enquiries for short-term deliveries, production schedules are preferred which show a regular pattern, i.e. which follow the same basic cycle time at least for high-runner products while low-runner products with low and varying demand volumes are scheduled less frequently.

While traditionally minimizing production costs has been considered as the major objective, attention has shifted towards faster replenishment and improved logistical performance. Thus, finished product inventories are merely regarded as buffers between the manufacturing and the distribution stage of the supply chain. As a result, distribution costs have to be included in the overall objective function.

VIII. ORDERING AND PRICING STRATEGIES FOR FRESH PRODUCTS WITH MULTIPLE QUALITY LEVELS CONSIDERING CONSUMER UTILITY:

Considering a scenario in which there are two quality levels of fresh products and introduction of consumer utility function, we studied the optimal ordering and pricing strategies under certain quantity. Our results showed that, facing the two quality levels of fresh products, retailers would not benefit from sales of lower quality of fresh products with the deterministic demand. In the pursuit of profit maximization, the initial order quantity is smaller than the potential demand for market.(Riaz, 2007) Given the technological advancements and logistical capabilities over the last seven decades or so, perishables have become a large part of supermarket retailing sales. For instance, a report by FMI (2009) indicates that of the \$430 billion plus in US supermarket sales registered for the year 2008, 81% or over \$348 billion are due to sales of groceries directly related to foods and beverages (F & B). And there is no doubt that fresh foods have played a dramatically important role in china. Motivated by the common practice, retailers usually divide fresh products, which may decay or deteriorate during the sale process, into different quality levels, and sell them in a separate way. In this paper, considering a scenario in which there are two quality levels of fresh products and introduction of consumer utility function, we studied the optimal ordering

and pricing strategies under certain quantity. Then, we discussed how environmental factors, such as demand volatility and ordering costs, affected retailers' decision. By considering consumer utility to study the optimal ordering and pricing decisions of multi-quality fresh products, we found corresponding answers of the above questions, and gave the management suggestions.

Ferguson and Koenigsberg (2007) have presented a two-period model where the quality of the leftover inventory is often perceived to be lower by customers, and the firm can decide to carry all, some, or none of the leftover inventory to the next period [9]. This is also a model involving quality drop and quantity change.

IX. LIMITATIONS

- Due to lack of accurate primary data, secondary sources of information used as a medium to collect information thus findings may be influenced by conclusions of previous research papers.

- Since secondary resources are being used, the authenticity of information on the internet is questionable. Consideration of resources chosen is thus imperative.
- While factual figures or representation of certain documents may be reliable, different sources may present varying information on the same topic.
- The analysis is done using assumptions and the mathematical model prepared is not with actual data thus the scope of the research paper is limited.
- Chances of attribution, exaggeration in prior research studies.
- Biases played into the conclusions of previous research papers forming our source for data.
- The use of transportation problem is based on certain assumptions like fixed quantities and only a few parties involved which may not hold true in real life thus making the decision making and the problem more complex.

X. CONCLUSION:

There is a rise in demand of food being delivered at the doorstep of consumers and looking at this opportunity many businesses are tapping this market at different terminals of value chain may it be supplying raw materials, providing logistics solution or processing food and thus many companies are emerging and eventually the competition between them is increasing. Increased competition means that these companies try to offer minimum cost and more benefits to the consumers so that the customers choose them over their competitor.

From the above analysis and research, we can conclude that operations research can be used by the business to determine how they can decide between different alternatives to minimize the cost and earn greater profit margins and how food delivery companies can compete by offering low cost per unit to get maximum food delivered through their company. The use of modeling saves cost compared to the

costs that would incur if different alternative solutions are implemented in real life. So the manager has the option of considering all the costs offered by different food delivery companies and then determining the solution that will minimize the cost and if the food delivery company changes the cost or the quantities are changed so rather than disrupting the whole system, use of transportation problem can help in determining the other best solution for the business.

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