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Production Planning Models (Approaches) from the Perspective of Mathematical Sciences

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Abstract:

Introduction: This study aims to provide a mathematical description of the production planning model (method). There will occasionally be restrictions on the raw material availability for production activities due to this element of uncertainty.

Objectives: The researcher will outline and analyze the various perspectives, arguments, and opinions that exist in the literature, and look for relationships between them

Methods: This research was compiled using qualitative research methods and descriptive and analytical journal literature review approaches. Most of the data used are secondary data.

Result: Deterministic and stochastic mathematical models are the two broad categories into which production planning mathematical models fall. In deterministic models, the data is assumed to be confident at this point. In the meantime, the stochastic model uses data that reflects the "best prediction" of unknown values. These deterministic methods finally address average or worst-case value issues even though many human judgment and quantitative models have been developed to anticipate variables with this uncertainty. Even though they have been studied extensively in the literature, deterministic production planning models are generally not helpful when uncertainty is considered. There are two types of manufacturing-related uncertainties: system uncertainty and manufacturing environment uncertainty. The second category consists of supply and demand uncertainties and other uncertainties outside the purview of production process management.

Conclusion: Even though they have been studied extensively in the literature, deterministic production planning models are generally not helpful when uncertainty is considered. There are two types of manufacturing-related uncertainties: system uncertainty and manufacturing environment uncertainty. Uncertainties like supply and demand issues outside the purview of industrial process management are included in the second category.

Keywords: Production Planning, mathematics science, deterministic model, stochastic model

1. Introduction

According to Pochet & Wolsey [1], production planning is the process of organizing the usage of resources and raw materials as well as the production tasks necessary to transform inputs into finished goods. It is shown that doing all of this will satisfy customer demand in the most economical way possible that is, by lowering overall costs. Therefore, making decisions on production levels for each period within the planning horizon is necessary to solve production planning difficulties [2,3,4]. Choosing how much to invest in the final product, how many workers to hire, how much raw material to buy, and other relevant factors may also be part of the process of solving this challenge. Planning is essential to the success of any activity or business and is necessary to ensure its sustainability. Maintaining the production cycle is the aim [5,6]. Gaining clarity in their work can boost individuals' motivation at work. The company will benefit from increased production efficiency and improved product quality, enabling the entire amount spent on production capital to be used efficiently.

If this cycle continues, there will be a positive impact felt by employees. One of the benefits is: 1) Employees get work targets [7]. By implementing production planning, employees will have targets at work, so there will be motivation to do the work; 2) Increase Motivation and Teamwork [8]. If production planning can be done well, it will affect workers' certainty and increase team collaboration. Because they have a target to aim for and avoid uncertainty; 3) Ensure Efficiency in Resource Utilization [9]. Make a good plan, you can find out the details of the appropriate use of raw materials. With this implementation, the impact can be to reduce costs by the company; 4) Reduce employee workload [10, 11]. Making proper planning can help reduce employee workload. Because the division of work is more even and scheduled according to portions.

Reporting from research [12] regarding Penerapan Perencanaan Produksi untuk Meningkatkan Efisiensi dan Efektivitas Produksi di Era New Normal pada Home Industry Ar Bakery Nganjuk (Implementation of Production Planning to Increase Production Efficiency and Effectiveness in the New Normal Era in the Ar Bakery Nganjuk Home Industry). A fact was obtained from the researched field data, in the form of the impact and influence of implementing production planning. Where in this research, there are differences in the impact for companies and workers on production planning. For example, the level method has a labor efficiency of 0%, cost efficiency of 34.2%, time efficiency of 0.49%, and effectiveness of 0.28%; the chase hire and layoff strategy have a cost efficiency of 50.2%, cost efficiency of 45.3%, time efficiency of 20%, and effectiveness of 0.22%; the mix overtime strategy has a cost efficiency of 40.2%, time efficiency of less than 5.15%, and effectiveness of 0.30%, and energy efficiency. From the results of this research, the impact of implementing each production plan is known, which has a different impact on a company. Determining the production planning used also depends on the type and type of business being run by each company [13]. This also determines the impact on employees, if they can choose the right production planning, namely the distribution of workload to each employee, which can be spread evenly. Thus reducing stress levels and increasing company productivity. This also directly impacts the continuity of job security for employees.

Production costs are crucial for industrial businesses since they determine how much it will cost to manufacture the goods the company needs to make [14]. Production costs are critical for industrial enterprises since they are a primary factor in determining the cost of goods sold (COGS) that the business will produce [15]. The selling price of a product is determined by taking into account the overall costs incurred by the company during the production of products or services, or COGS [16]. Managers can make better decisions about product selling pricing, marketing tactics, and resource allocation by thoroughly understanding manufacturing costs [17]. Businesses can establish profitable selling prices while maintaining market competitiveness by knowing their production costs. A company's profitability is directly impacted by its production expenses. Businesses can boost their profit margins by managing their production expenses. Production cost analysis aids businesses in assessing operational effectiveness and pinpointing areas in need of development. Comprehending production costs enables organizations to enhance their cost control and management strategies. This entails identifying wasteful spending, improving production process efficiency, and using available resources better.

Production costs are the basis for determining product selling prices [18]. By knowing production costs accurately, companies can set selling prices that allow them to achieve profit goals and remain attractive to customers. Knowledge of production costs allows companies to plan production more effectively. This includes setting production targets, setting production budgets, and appropriate resource allocation to meet market demand. Production costs are also used as an indicator of company performance. By comparing actual production costs to budget or standard costs, companies can evaluate their operational performance and identify opportunities to improve efficiency and productivity.

By understanding the importance of production costs, industrial companies can manage their resources more efficiently, increase profitability, and remain competitive in an increasingly competitive marketplace. In the end, production costs determine the profits that the company will obtain in the future. Professional management is needed to manage large companies with many complex activities so that the vision, mission, and business goals can be achieved. Managing costs, especially production costs, is something that must be done by professional management so that the business can run efficiently and effectively during operations so that the company can obtain a high level of profit and reduce production costs. To achieve this, company management must plan well when creating a production cost budget. Every company needs to have good budget planning to determine what actions must be taken.

Budgets are very important in the business world because they can provide information about all business activities, which include various types of operational and technical activities that are interconnected and have an impact on one another [19, 20]. To plan all short-term and long-term actions, management needs a budget. In production planning, material flow equations and investment balances in time-indexed capital are usually taken into account using time discretization, such as years, months, or weeks [4]. Linear Programming (LP), Mixed Integer Linear Programming, and Mixed Integer Nonlinear Programming (MINLP) models are often used and successfully solve these types of problems with objective functions that describe profits, costs, total sales, total production, etc. Therefore, this research intends to describe the production planning model (approach) from a mathematical perspective.

The approach used to compile this research uses descriptive and analytical techniques of journal literature reviews with qualitative research methods. The data used is mostly secondary data, sourced from various references related to the subject and questions at hand. This secondary data includes documents, archives, notes, journals, and official reports related to this research. This study is also connected to several other studies, such as a study [21] that demonstrates that UKM Fahmi Mandiri's production is optimal based on calculations made with Windows V3 QM tools and the simplex linear programming method. Producing 40,025 packs of Vsang brand banana chips, 20,000 packs of Bintang Rasa brand, and 16,500 packs of Pak Ben's will yield an optimal profit level of Rp 426,800,000. The production optimization model's computation results demonstrate that UKM Fahmi Mandiri's utilization of production inputs is optimal. When using the simplex approach, the production optimization model calculation findings indicate that UKM Fahmi Mandiri had a 16532,000 IDR increase in earnings.

Additionally, research [22] that demonstrates how the fuzzy concept is applied to the desired outcomes in the form of a fuzzy membership function. The challenge lies in scheduling production in a business when several goals are to be achieved, such as revenue, labor expenses, and raw material costs. The outcomes come in the form of a model with many goals that may be created using fuzzy goal programming (FGP), which can then be solved using linear programming (LP) to plan a company's production. A study in [23] states that the company needs to manufacture 20 units of closets, 31 units of chairs, and 1 unit of bed with a profit of IDR 91,950,000 to maximize production with maximum profits.

According to research [24], businesses that utilize decision variables see their production costs increase to IDR 149,425,025,077. In contrast, businesses that use accurate production planning see their production costs decrease to IDR 187,489,966,259. By implementing a dynamic program, a corporation can save IDR 38,064,941,182 or 20%. Thus, by conducting this research, we can determine how to optimize production capacity so that the company may employ it according to its needs. Similarly, the research [25] indicates that the FA technique may identify the best ways for production planning, including labor costs, production costs, and procurement costs that satisfy the constraints on production quantity, worker count, and procurement quantity

2. Objectives

In using analytical techniques, the author involves a deeper evaluation and understanding of the literature reviewed. The focus is to identify patterns, themes, concepts, or theories that emerge from the literature. The researcher will outline and analyse the various perspectives, arguments, and opinions that exist in the literature, and look for relationships between them. In qualitative research, analytical techniques help researchers to understand emerging concepts, differences in approaches, and the potential contribution of literature to an in-depth understanding of the research topic.

3. Methods

The approach used to compile this research uses descriptive and analytical techniques of journal literature reviews with qualitative research methods. The data used is mostly secondary data, sourced from various references related to the subject and questions at hand. This secondary data includes documents, archives, notes, journals, and official reports related to this research. In using analytical techniques, the author involves a deeper evaluation and understanding of the literature reviewed. The focus is to identify patterns, themes, concepts, or theories that emerge from the literature. The researcher will outline and analyze the various perspectives, arguments, and opinions that exist in the literature, and look for relationships between them. In qualitative research, analytical techniques help researchers to understand emerging concepts, differences in approaches, and the potential contribution of literature to an in-depth understanding of the research topic.

4. Results

4.1 Harris and Wilson's EOQ Production Planning Completion Model

The production planning completion model using the Economic Order Quantity (EOQ) method is one of the analytical tools used in supply chain management to determine the optimal number of orders that must be made by the company. This method helps companies optimize inventory costs by considering storage costs, ordering costs, and inventory shortage costs. There are several models that can be used to complete production planning using EOQ, including the Harris and Wilson models. F. W. Harris created the Economic Order Quantity (EOQ) model in 1913, which marked the start of research and development into production planning and scheduling models [26]. The EOQ model's goal is to estimate the order quantity that minimizes total storage and ordering expenses. Furthermore, R. H. Wilson created the Harris model to identify the reorder point in 1934 [27], with the goal of keeping raw materials from running out of inventory while emphasizing the importance of buffer stock. In 1940, Wilson coupled his technique with Harris's EOQ, resulting in the Wilson EOQ technique or Wilson Formula. This model has been used for inventory control for nearly four decades [28]. The EOQ model uses the following formula:

$$Q = \sqrt{\frac{2 \times D \times S}{H \times C}} \qquad 4.1$$

Where:
Q: EOQ order quantity, D: Annual Product Demand, S: Ordering Costs, H: Storage Costs, and C: Cost Per Unit

4.2 Wagner and Whitin's Dynamic Lot Sizing Model

Furthermore, another important contribution was made by H. Wagner and T. Whitin. They proposed the dynamic lot size model in 1958 as a generalized version of the EOQ model, considering demand as a parameter that changes with time. Next, the proposal of the Material Requirement Planning (MRP) system in the 1970s was a step forward in standardization and production planning control systems [1]. The Wagner-Whitin Dynamic Lot Size Model is a dynamic algorithm used to determine the optimal production lot size in a production system with demand that varies over time. The Wagner-Whitin algorithm attempts to find the most economical production pattern by considering storage costs and ordering costs in a certain time period [29]. The basic principle behind this model is to determine a production schedule that optimizes total inventory costs, including holding costs, ordering costs, and stockout costs. The main advantage of the Wagner-Whitin Dynamic Lot Sizing Model is its ability to generate optimal production schedules by considering fluctuations in demand over time. However, this model is quite computationally intensive because it involves calculating total costs for many possible combinations of lot sizes and production times. Therefore, this model is more suitable for relatively complex and large production systems.

4.3 MILP Model for Production Planning

If production planning is to be applied in a more sophisticated way to a more complex manufacturing system, usually this application is made using the Mixed Integer Linear Programming (MILP) model. This is owing to the inclusion of decision variable elements in the problem, such as preparation costs and timings, process start costs and durations, machine assignment decisions, ordering costs and times, and so on. These costs and times are fixed and not proportionate to manufacturing volume. Therefore, binary or integer variables are required in the model [1, 30]. Several contributions to the development of production planning models using MILP are discussed below. The worker in the study [31] created a continuous time model for production planning and scheduling, which is utilized in companies that manufacture huge quantities of products. Initially, the model proposed was MINLP, and then after linearization, the MILP form was obtained. The model aims to maximize profits obtained from production with constraints related to machine assignment, limited operating time, and machine preparation and scheduling periods. The researcher in his work [32] presents a combined MILP and Constraint Programming model for production planning in the chemical process industry to minimize process costs, holding costs, and buffer inventory costs.

4.4 Production Planning with Deterministic Demand

Classical deterministic production planning problems have gained significant acceptance in the optimization literature. The basic mathematical model of production planning with deterministic demand for many problems can be formulated as follows:

1. Parameter:

Symbol	Understanding
$f(t)$	production costs for period t
$C_p(t)$	production costs per unit for period t
$C_h(t)$	storage costs for period t
C	production capacity
$D(t)$	product demand for period t

2. Decision Variables:

Symbol	Understanding
$P(t)$	production amount for period t
$I(t)$	production costs per unit for period t
$y(t)$	if production occurs in period t, 0 otherwise

3. Deterministic Product Planning Model or Lot Sizing

$$min \sum^{n} C_p P_{t=1}(t) + \sum_{t=1} nf(t)y(t) + \sum_{t=1} nCh(t)I(t) \qquad 4.2$$

with obstacles:

Supply

$$I(t-1) + P(t) = D(t) + I(t);\ \forall t = 1, \dots, n \qquad 4.3$$

Capacity Constraints

$$P(t) \leq C_y; \forall t = 1, \dots, n \qquad 4.4$$

Non-negative Constraints and Integers

$$P(t) \geq 0, y(t) \in \{0,1\};\ \forall t = 1, \dots, n \qquad 4.5$$

4.5 Mixed Integer Non-linear Programming (MINLP)

Mixed Integer Non-Linear Programming (MINLP) is an optimization problem where several variables have constraints to obtain integer values with an objective function and a feasible region indicated by the non-linear function. Mixed Integer Non-Linear Programming (MINLP) can be expressed as follows:

$$minz = C^T y + f(x) \quad 4.6$$

with constraints:

$$h(x) \leq 0 \quad 4.7$$

$$g(x) + b(y) \leq 0 \quad 4.8$$

$$x \in X \subseteq R_+^n , y \in R^n \subseteq R_+^n \quad 4.9$$

The researchers [33] describe the problem (P) of the non-convex MINLP class with the formulation:

$$min_{x,y} C^T y + f_1(x) \quad 4.10$$

with constraints:

$$g_1(x) + B_{1y} \leq 0 \quad 4.11$$

$$g_2(x) + B_{2y} \leq 0 \quad 4.12$$

$$x \in X \subset R_+^n \quad 4.13$$

$$y \in Y = \{0,1\}^q \quad 4.14$$

Where $f: X \rightarrow R$ dan $g_1: Y \rightarrow R^{n1}$ is a continuous but non-convex function and $g_2: Y \rightarrow R^{n2}$ is an ordered convex function and a convex collection defined by $X = \{x: x \in R^n, D_1 x \leq c_2\}$, B_1, B_2, D_1 is a matrix and c_1, c_2 is a vector with corresponding dimensions.

4.6 Production Planning Stochastic Program Model

In the work [34] workers suggested a linear stochastic programming approach for hierarchical production planning under variable demand. They demonstrate that the shape of the distribution reflecting demand is an essential consideration in decision-making. Then, in [35] created a stochastic programming model that explicitly incorporates uncertainty in the form of discrete demand scenarios for textile production planning. The researchers in their work [36] developed a linear stochastic programming model for production planning in which the price coefficient and right-hand side terms were unpredictable. Decisions about production levels are made in two stages.

While in work [37] which expressed the problem of production planning with additional controls, such as selecting plant site preferences. Regarding the uncertain demand data, a stochastic programming approach is proposed so that it can determine the optimal plan for medium-term production loading. Also, [38] proposed an integer stochastic programming approach for fish production planning. Uncertainty in their model arises from the availability of fish raw materials. Also in the model, the short shelf life of fish raw materials is taken into account. Stochastic programming in fish production planning was also discussed by [39, 40].

The Production planning stochastic program model is a mathematical approach to production planning that considers uncertainty in demand and market conditions [41]. In this model, statistical assumptions are used to model the probability distribution of factors that influence demand, such as trends, seasonality, and random fluctuations. Demand is considered a random variable that follows a certain probability distribution. Stochastic demand models can include different types of probability distributions, such as normal distribution, exponential distribution, or poisson distribution, depending on the characteristics of product demand. This model considers production capacity, production cycle time, and inventory policies. The goal is to find a production schedule that minimizes production costs and inventory costs while meeting customer demand at the desired service level [42, 43].

5. Discussion

In [44] examined the evolution of the MILP technique for short-term scheduling systems. The suggested model is divided into temporal, discrete, and continuous representations, and many methods for speeding up the solution process are described. They examined more specific choice factors utilized for task assignments (binary) and the amount produced, materials consumed, and available (continuous) over time intervals. Others [45] presented the MILP model for optimizing production planning and design decisions in multi-product manufacturing over several time periods. The model assumes deterministic seasonal fluctuation in costs, prices, demand, and supply. The goal is to increase the net present value of profits. The models put forward are MILP deterministic models.

The main advantage of the stochastic programming Model is its ability to overcome uncertainty in production and inventory planning. By taking into account the probability distribution of demand, companies can make better decisions and be more responsive to market fluctuations. However, these models also require accurate historical data and a deep understanding of the factors influencing demand to provide reliable results.

Inventory policies, such as overall inventory levels or customer service levels, are determined based on company preferences and goals. This allows companies to adjust their inventory levels according to acceptable risks and expected profits. Stochastic Program Models use mathematical optimization techniques, such as dynamic programming or linear programming, to find optimal solutions based on given assumptions and constraints [46, 47]. Decisions are taken taking into account risks and uncertainties in demand. Sensitivity analysis is used to evaluate the sensitivity of an optimal solution to changes in important parameters, such as price, production costs, or customer service levels. This helps companies understand the potential impact of changes in market conditions or internal policies.

6. Conclusion

Planning the manufacturing process for a specific item to meet consumer demand while minimizing production costs by considering economic, environmental, and social factors is the primary goal of the problem of sustainable production planning. Numerous challenges were encountered during production, including raw material shortages, labor availability under specific conditions, production capacity, environmental preservation, and more. The challenge of optimizing sustainable production planning applies the 3Ps (profit, planet, people) as the embodiment of economic, environmental, and social factors, respectively, to minimize overall production costs or increase profits. In this production planning activity, there is an element of uncertainty inherent in the required data such as demand and availability of raw materials, namely processed products, availability of labor and the evolution of time for the future. With this element of uncertainty, there will be limitations on the availability of raw materials for production activities from time to time. In connection with this optimization problem, production planning is needed that is oriented towards optimization problems. Mathematical models in production planning problems are roughly divided into two types: deterministic and stochastic models. Deterministic models assume that data is certain at this time. Meanwhile, the stochastic model employs data that represents the "best prediction" of unknown values. These deterministic methods finally address average or worst-case value issues, even though many human judgment and quantitative models have been developed to anticipate variables with this uncertainty. There is always a chance that solving this issue will result in serious mistakes and a costly resolution procedure. Even though they have been studied extensively in the literature, deterministic production planning models are generally not helpful when uncertainty is considered. There are two types of manufacturing-related uncertainties: system uncertainty and manufacturing environment uncertainty. Uncertainties like supply and demand issues outside the purview of industrial process management are included in the second category.

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