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Production Quantity Estimation Method in Continuous Line Flow and Discontinuous Line Flow Systems with Barchart Simulation

Mohd Razif Idris, Andri Hermawan
Universiti Kuala Lumpur, UniKL MIDI. Email: mrazif@unikl.edu.my
Universitas Muhammadiyah Cirebon University, West Java, Indonesia. Email andri.hermawan@umc.ac.id
Corresponding Author Email: mrazif@unikl.edu.my

Abstract
Background. Production quantity forecasting is a crucial element in the planning and control of manufacturing systems, as it directly affects operational efficiency and capacity utilization. Production systems are generally classified into continuous and discontinuous line flow, which differ in process flow characteristics and levels of variability.
Aims. This study aims to examine production quantity forecasting methods for both systems using a Barchart simulation approach as a visualization and process time analysis tool.
Methods. The research method used is a systematic literature review and conceptual modeling based on production time, cycle time, setup time, and waiting time.
Conclusion. The results of the study indicate that Barchart simulation is effective in representing the stability of production flow in continuous line flow systems and identifying process variability and irregularity in discontinuous line flow systems.
Implementation. Thus, the Barchart simulation can be used as a simple yet informative tool to support production quantity forecasting based on manufacturing system characteristics.

Keywords: production forecasting, continuous line flow, discontinuous line flow, Barchart simulation, production planning.

INTRODUCTION

Production forecasting is a crucial part of operations planning because it impacts manufacturing system efficiency (Heizer et al., 2020; Slack et al., 2022). It serves as the basis for capacity planning, production scheduling, and resource control decisions. Accurate production forecasting impacts a company's operational performance, particularly in terms of cost efficiency, on-time delivery, and production facility utilization. Conversely, errors in production forecasting can lead to problems such as excess inventory, increased work-in-process, order delays, and lower overall system productivity.

In manufacturing practice, production systems can generally be classified into two main categories: continuous and discontinuous line flow systems. Continuous line flow systems are characterized by continuous process flow, a fixed sequence of operations, and relatively low product variation. This system is widely applied in industries with high production volumes and standardized products, such as the automotive, electronics, and chemical processing industries. These characteristics allow a deterministic approach to estimating production quantities, as cycle times and production line capacity tend to be stable.

In contrast, a discontinuous line flow system is characterized by discontinuous production, varied process routes, and high product variation and processing time. This system is commonly used in job shops and batch-production environments, where changes in product types, setup times, and workstation queues are frequent. These conditions create greater uncertainty, making production quantity forecasting more complex and requiring an approach that accommodates process variability.

The fundamental differences between these two production systems require a forecasting method appropriate to the characteristics of each workflow. An approach that is effective in a continuous line flow system may not necessarily produce accurate results when applied to a discontinuous line flow system. Therefore, an analytical approach is needed that is not only quantitative but also able to provide a visual depiction of the time dynamics and sequence of the production process.

One relatively high-analytical-value yet straightforward approach is the Barchart simulation. Barchart simulation visualizes production activities along the time dimension, enabling direct observation of the relationships among process time, idle time, setup time, and activity overlap between workstations. In the context of production forecasting, Barcharts can be used to identify adequate system capacity, potential bottlenecks, and differences in workflow patterns between continuous and discontinuous systems.

Although discrete-event simulation and specialized software have been widely used in production system analysis, their implementation often requires complex data and high technical expertise. In contrast, Barchart simulation offers a more straightforward, understandable approach, making it suitable as an initial tool in the production planning process, particularly at the production quantity estimation stage.

Based on this background, this study aims to describe and compare production quantity estimation methods for continuous and discontinuous line flow systems using Barchart simulation. This research is expected to provide theoretical contributions to the development of production estimation methods and practical contributions to industry practitioners by helping them select an estimation approach appropriate to the characteristics of their production systems.

Research on production planning and estimation has evolved significantly as manufacturing systems have become increasingly complex. Previous studies have shown that production quantity estimation methods for continuous line flow systems generally rely on deterministic approaches based on line capacity, cycle time, and line balancing. This approach is considered adequate in production environments with low levels of variation and stable process flows. Meanwhile, in discontinuous line flow systems, research has focused more on stochastic models, queuing theory, and discrete-event simulation to capture uncertainty arising from variations in process and setup times and production routes.

In recent years, simulation approaches have become increasingly dominant in production system analysis, particularly with the use of advanced simulation software. However, most of this research focuses on numerical accuracy and system optimization, at the expense of relatively high modeling complexity. On the other hand, simple visual approaches such as Bar Charts or Gantt charts are more frequently used for operational scheduling and have rarely been studied in depth as quantitative analysis tools for production forecasting, particularly for comparing continuous and discontinuous line flow systems. This opens up research opportunities to re-explore the role of Barchart simulation as a more straightforward yet more informative analytical method.

Based on a review of previous research, several research gaps can be identified. First, most studies discuss production quantity estimation methods separately for continuous and discontinuous line flow systems, without conducting a systematic comparative analysis of the two within a common methodological framework. Second, widely used simulation approaches tend to focus on complex software-based discrete-event simulations, making them less applicable to practitioners who need a quick, easy-to-understand analysis tool in the early stages of production planning. Third, the use of Barchart simulation for production quantity estimation remains limited and is often treated as a scheduling visualization tool rather than an instrument for analyzing production capacity and flow.

Therefore, there is still a need for research examining production quantity estimation methods using a more straightforward approach that adequately represents production system characteristics and allows clear comparisons between continuous and discontinuous line flow systems. This study seeks to fill this gap by integrating Barchart simulation as an analytical tool in the production quantity estimation process.

This research aims to:

1. Examine production quantity estimation methods for continuous and discontinuous line flow systems based on their respective process flow characteristics.
2. Analyze the use of the Barchart simulation as a tool in estimating production quantities.
3. Compare production flow patterns and adequate capacity between continuous and discontinuous line flow systems using a Barchart simulation approach.

The expected contributions of this research include:

1. A theoretical contribution, namely, enriching the operations management literature related to production quantity estimation methods using a visual, time-based approach.
2. A methodological contribution, namely, utilizing Barchart simulation as a more straightforward alternative analysis method compared to discrete event simulation.
3. A practical contribution, namely, providing guidance for industry practitioners in selecting a production quantity estimation method that suits the characteristics of their production system.

LITERATURE REVIEW

Production Quantity Estimation Concept

Production quantity estimation is the process of determining the output quantity a production system can produce within a specific time period, accounting for resource limitations, process times, and workflow patterns. In operations management, production estimation serves as the basis for capacity planning, scheduling, and production control. Forecast accuracy is greatly influenced by system stability and the level of uncertainty within the production process.

Continuous Line Flow Production System

A continuous line flow system is a production system with a standardized and continuous workflow, where each workstation is arranged according to a fixed process sequence. Continuous line flow systems are characterized by stable process flow and low time variation, thus enabling the use of a deterministic approach in production estimation (Hopp & Spearman, 2011; Groover, 2020). The main characteristics of this system include high production volume, low product variation, and relatively constant cycle times. These conditions allow the use of deterministic models in calculating production capacity and quantity. In this system, the main constraints usually lie in line balancing and bottleneck control.

Discontinuous Line Flow Production System

In contrast, discontinuous line flow systems have a high degree of variability due to differences in routes and setup times (Nahmias & Olsen, 2015). Products can pass through workstations in different sequences, depending on process requirements. Variations in setup times, processing times, and queues lead to significant uncertainty. Therefore, production quantity estimation methods in this system often utilize probabilistic and simulation approaches to obtain more realistic estimates.

Barchart Simulation in Production Systems

Barchart simulation is a method for visualizing production activities along the time dimension, where each activity is represented by a bar chart showing its duration and sequence. In production systems, Bar Charts can be used to analyze machine utilization, idle time, and process activity overlap. Although relatively simple, the Barchart simulation can provide a clear picture of workflow patterns and system capacity, making it a potentially helpful tool for production forecasting.

METHODS

Research Design

This research uses a descriptive-comparative approach with time-based modeling and simulation methods. This approach was chosen to analyze and compare production quantity estimation methods in continuous and discontinuous line flow systems through Barchart simulation. The research is conceptual-quantitative, focusing on the analysis of production flow, process time, and system capacity.

Research Objectives and Scope

The research objectives are manufacturing production systems classified into two types:

1. Continuous line flow systems, with sequential process flow and relatively constant cycle times.
2. Discontinuous line flow systems, with variable process flow, varying process times, and setup times.

The scope of the research is limited to:

1. Production time analysis (processing time, setup time, waiting time)
2. Estimation of production quantity within a specific time period
3. Use of Barchart simulation as a visualization and analysis tool

Research Variables

The variables used in this study include:

Input Variables

1. Available production time (AvailableT)
2. Cycle time (for continuous systems)
3. Processing time per workstation
4. Setup time (specifically for discontinuous line flow)
5. Waiting/queue time

Process Variables

1. Production flow pattern
2. Operation sequence
3. Time interaction between workstations

Output Variables

1. Product quantity that can be produced
2. Effective system capacity
3. Bottleneck identification

Data Collection Method

The data used in this study are secondary and simulated, obtained through:

1. Literature review of reputable textbooks and scientific journals.
2. Hypothetical data compiled based on the general characteristics of continuous and discontinuous line flow systems for Barchart simulation purposes.
3. The time parameter is assumed to be constant for continuous systems and variable for discontinuous systems.

This approach is commonly used in methodological research and conceptual simulations in the field of operations management.

Barchart Simulation Procedure

Simulation is a commonly used approach to analyze production systems with high levels of uncertainty (Banks et al., 2010; Law, 2015). Time-based visualizations, such as Bar Charts, can help identify bottlenecks and idle time in production systems (Goldratt & Cox, 2004; Li et al., 2009). Simulation and visual scheduling approaches have been widely used in the analysis and scheduling of production systems (Banks et al., 2010; Hartmann & Briskorn, 2010; Robinson, 2014). Barchart simulation is performed through the following stages:

Stage 1: Identification of Production Processes

Determine the number of workstations and the sequence of production processes for each system:

1. Continuous line flow system: The process sequence is fixed (e.g., S1 → S2 → S3).
2. Discontinuous line flow system: The process sequence varies depending on the product type.

Step 2: Determining Time Parameters

Determine the time duration for each activity:

1. Processing time per workstation
2. Setup time (if any)
3. Waiting time between processes

Stage 3: Barchart Development

Each production activity is represented by a horizontal bar showing:

1. Process start time

2. Activity duration
3. Activity sequence and overlap

Stage 4: Production Capacity and Flow Analysis

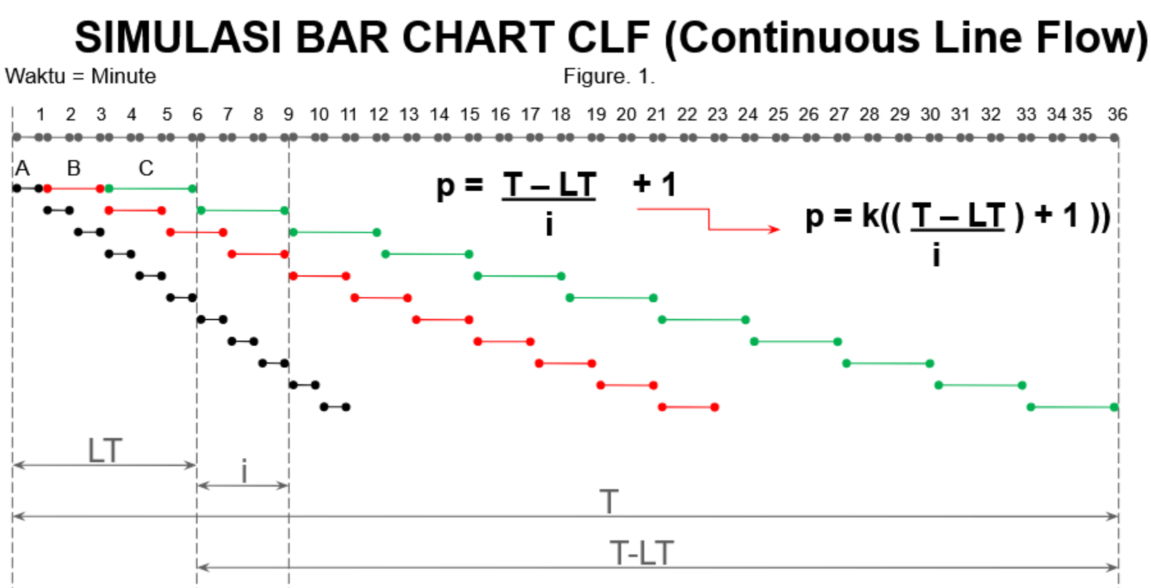
From the resulting barchart, analyze:

1. Total production time used
2. Idle time
3. Bottleneck points
4. Number of units that can be produced in a given time period

Simulation Results and Discussion

Continuous Line Flow System Simulation Results

The Barchart simulation of the continuous line flow system, shown in Figure 1, was conducted assuming sequential production flow and relatively constant processing times at each workstation. Based on the time parameters established in the methodology phase, the Barchart shows a regular and repetitive pattern of production activity. Each workstation begins a process immediately after the previous station completes its work, so there is no significant waiting time between processes.



The simulation results in Figure 1 show that the total system cycle time is the sum of the processing times of all workstations. With fixed available production time, the number of units that can be produced in a period can be calculated directly using a deterministic approach. The bar chart for this system also shows a relatively high and stable machine utilization rate, as well as minimal idle time.

From these results, it can be concluded that the bar chart simulation is able to represent the main characteristics of a continuous line flow system, namely stable production flow and consistent cycle time. This simplifies the process of estimating production quantities and supports the use of line capacity-based estimation models.

Figure 1 above presents the following situation: If a product is produced through Processes A, B, and C with Cycle Times A = 1', B = 2', C = 3', and each product is represented by one product per process.

To calculate the number of products, the following mathematical model can be used:

CONTINUOUS LINE FLOW FORMULA:

$$p = k\left(\frac{T - LT}{i} + 1\right)$$

Note:

- i = Interval, the time interval between product production
- LT = Lead Time, the time required to produce a product
- p = Number of products produced in one period
- T = Time, the specified time period in hours or minutes, starting from the start of the
    - production process until the specified time
- k = Constant, the number of production lines

For example: On a production line, the calculated time for SK 1 is 3.5 seconds, SK 2 is 2.2 seconds, SK 3 is 1 second, and SK 4 is 4 seconds. What will be the total production volume one hour later?

Then:

LT = SK1+SK2+SK3+SK4
= 3.5 + 2.2 + 1 + 4
= 10.7 Seconds

T = 1 Hour = 60 Minutes = 3600 Seconds

i = 4 Seconds (the longest among the SK)

So:

$$p = k\left(\frac{T - LT}{i} + 1\right)$$

$$= (1)\left(\frac{(3600)-(10.7)}{4} + 1\right)$$

$$= (1)\left(\frac{(3589.3)}{4} + 1\right)$$

= (1) (897.325 +1)
= (1) (898.325)
= 898.325

Likewise, the longest SK time is in first place as in the following Barchart simulation in Figure 2 below:

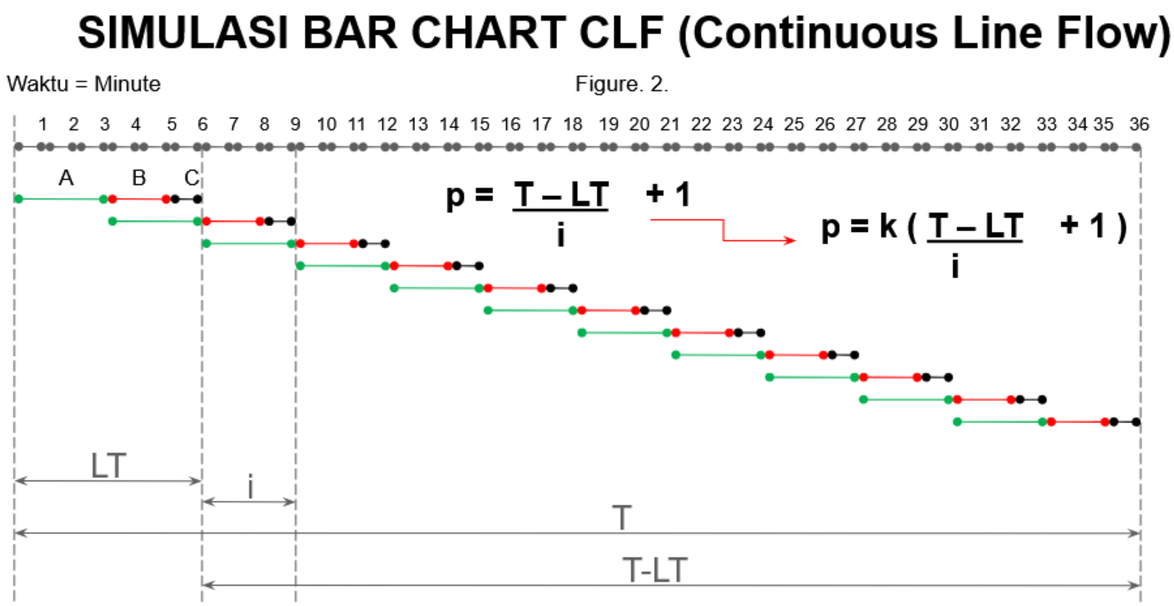


Figure 2 above presents the following situation: If a product is produced through Processes A, B, and C with Cycle Times A = 3', B = 2', and C = 1', and each product is represented by one product per process.

To calculate the number of products, you can use the mathematical model above.

For example, on a production line, the calculated time for SK A is 4 seconds, SK B is 3.5 seconds, SK C is 2.2 seconds, and SK D is 1 second. What will be the total production volume after one hour?

Then:

LT = SKA+SKB+SKC+SKD
= 4 + 3.5 + 2.2 + 1
= 10.7 Detik
T = 1 Hour = 60 Minutes = 3600 Seconds
i = 4 Seconds (the longest among the SK)
So:

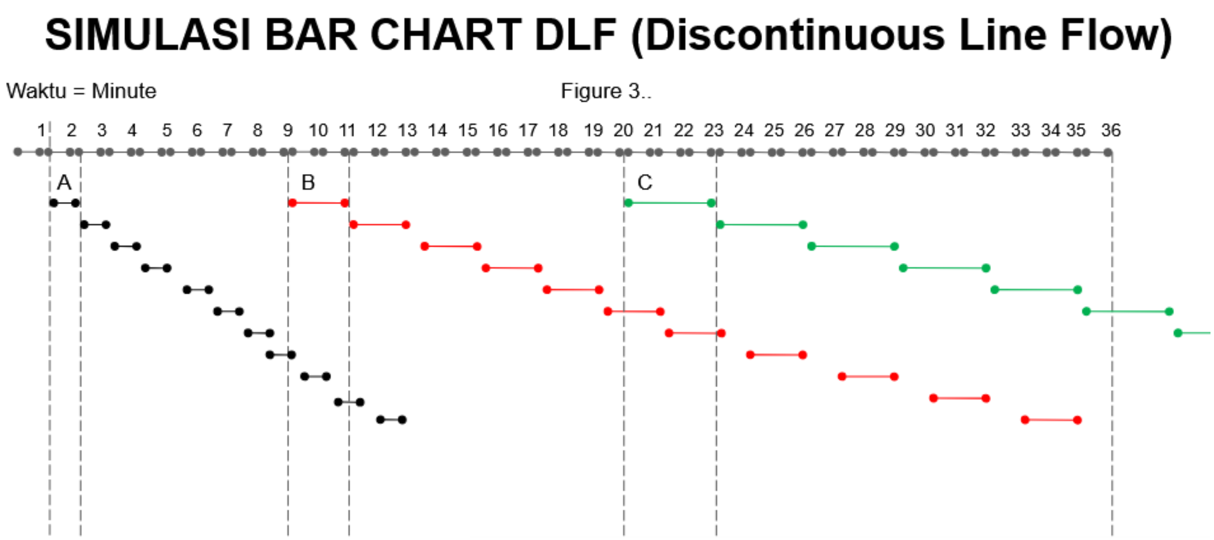
$$p = k\left(\frac{T - LT}{i} + 1\right)$$

$$= (1)\left(\frac{(3600)-(10.7)}{4} + 1\right)$$

$$= (1)\left(\frac{(3589.3)}{4} + 1\right)$$
$$= (1)(897.325 + 1)$$
$$= (1)(898.325)$$
$$= 898.325$$

Discontinuous Line Flow System Simulation Results

In contrast to the continuous system, the Barchart simulation results for the discontinuous line flow system show a discontinuous production flow pattern, hindered by delays or pauses. As shown in Figure 3 below:



Variations in setup, processing, and waiting times cause the bar lengths in the bar chart to be inconsistent across activities. Furthermore, there are significant time gaps between processes, representing queues and changes in production sequences.

Simulation results also show that some of the available production time is spent on non-productive activities, such as setup and waiting for process turns. This results in the system's adequate capacity being lower than its theoretical capacity. Therefore, production estimates in a discontinuous line flow system cannot be based solely on average processing times; they must consider all time components shown in the bar chart.

Bar chart simulations of this system provide a clear visual depiction of sources of production inefficiency, such as high setup times and bottlenecks at specific workstations. This information is handy in evaluating and improving the production system.

Figure 3 above presents the following situation: If a product is produced through Processes A, B, and C with Cycle Times A=1', B=2', and C=3', and each process represents one product, with Delay Times D1=7' and D2=9', then the following mathematical model can be used to calculate the number of products:

Model Formula A. (See Figure 3)

$$\mathbf{p = k\left(\frac{T - (LT + D_T)}{ilg} + 1\right)}$$

Note:

- LT = Lead Time, the time required to produce a product (CT(A) + CT(B) + CT(C) + CT(n))
- P = Number of products produced
- DT = Delay Time, the total delay time (D1 + D2 + D3…..Dn)
- k = Constant, the number of production process lines
- ilg = The Longest Interval/Interval in the longest process
- T = Time required to produce a product

For example: On a production line, the calculated time for SK A is 1 second, the distance to SK B with a delay of D1 is 3 seconds, SK B is 2.2 seconds, the distance to SK C with a delay of D2 is 4 seconds, SK C is 3.5 seconds, the distance to SK D with a delay of D3 is 5 seconds, and SK D is 4 seconds. What is the total production volume after 2 hours?

Then:

LT = SKA+SKB+SKC+SKD
= 1 + 2.2 + 3.5 + 4
= 10.7 Detik
T = 2 Jam = 120 Menit =7.200 Detik
i = 4 Detik (yang paling lama diantara SK)
D = D1+D2+D3
= 3 + 4 + 5
= 12
Jadi :

$$\mathbf{p = k\left(\frac{T - (LT + D_T)}{ilg} + 1\right)}$$

$$= (1)\left(\frac{(7200)-(10.7+12)}{4} + 1\right)$$

$$= (1)\left(\frac{(7200)-(22.7)}{4} + 1\right)$$

$$= (1)\left(\frac{7.1777,3}{4} + 1\right)$$

$$= (1)\left(1784,325 + 1\right)$$

= (1) (1795.325)
= 1795,325
= 1795 Unit
It is different if the SK with the longest duration is in the first order as in Figure 4 below:

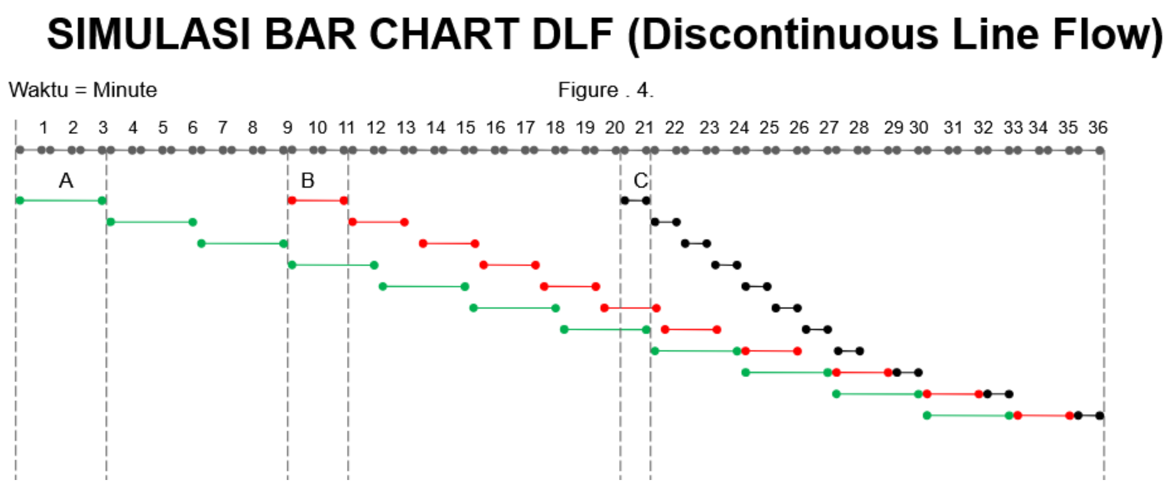


Figure 4 presents the following conditions: If a product is produced through processes A, B, and C with cycle times A = 3', B = 2', and C = 1', and each process represents one product with a delay time.

There will be an intersection between the longest SK and the smallest one below it. Therefore, the formula used with the following mathematical model is:

Model B Formula.

$$\mathbf{Pc = \frac{(LT + D_T)}{ilg}}$$

$$\mathbf{Pn = \frac{T-(LT + D_T)}{ilg}}$$

$$P = k\,((Pc + Pn)-1)$$

Note:

T = Time required to produce a product
LT = Lead Time, time required to produce a product (CT(A) + CT(B) + CT(C))
Pc = Number of products produced (LT + DT)
Pn = Number of products produced after time T - (LT + DT)
P = Total Number of Products during T
DT = Delay Time, total delay time (D1 + D2)
k = Constant, number of production process lines
ilg = The Longest Interval / Interval in the longest process

For example: On a production line, the calculated time for SK A is 4 seconds, the distance to SK B with a delay of D1 is 3 seconds, SK B with a time of 3.5 seconds, the distance to SK C with a delay of D2 is 4 seconds, SK C with a time of 2.2 seconds, the distance to SK D with a delay of D3 is 5 seconds, and SK D with a time of 1 second. What is the total production volume after 2 hours?

Then:

LT = SKA+SKB+SKC+SKD
= 4 + 3.5 + 2.2 + 1
= 10.7 Seconds

T = 2 Hours = 120 Minutes = 7,200 Seconds

i = 4 Seconds (the longest among SK)

D = D1+D2+D3
= 3 + 4 + 5
= 12

So:

Model B Formula.

$$\mathbf{Pc = \frac{(LT + D_T)}{ilg}}$$

$$= \frac{((10.7) + (12))}{(4)}$$

$$= \frac{22.7}{4}$$

$$= 5.675$$

$$= 5$$

$$\mathbf{Pn = \frac{T-(LT + D_T)}{Ilg}}$$

$$= \frac{7200 - ((10.7 + (12))}{4}$$

$$= \frac{7200 - 22.7}{4}$$

$$= \frac{7177.3}{4}$$

$$= 1794$$

$$\mathbf{P = k\ ((Pc + Pn)\text{-}1)}$$

$$= (1)\ .\ ((5 + 1794)\text{-}1)$$

$$= 1798$$

Mathematical Model for Calculating Estimated Production Time Considering Setup Time, Learning Curve, and Rest Time

Estimated production time in a manufacturing system is influenced not only by the main process time but also by various supporting factors that significantly impact production line performance. In this study, a mathematical model for estimating production time was developed, accounting for three main components: setup time, the learning curve effect, and operator rest time. This approach aims to produce more realistic production time estimates that approximate actual operational conditions.

Setup Time

Setup time is the time required to set up a machine, piece of equipment, or production line before the production process begins or when a product type changeover occurs. In continuous line flow systems, setup time is generally relatively small. It occurs infrequently, whereas in discontinuous line flow systems, setup time can be a dominant time component due to the high frequency of product changes.

Process Time with a Learning Curve

The learning curve phenomenon illustrates the decrease in process time per unit as operator experience or production process stability increases. In other words, as more units are produced, the time required to produce the next unit tends to decrease until a steady state is reached.

Operator Rest Time (Take a Rest)

In industrial practice, operators cannot work continuously without breaks. Physical and mental fatigue factors require scheduled rest periods to maintain workplace safety and product quality. Therefore, rest periods are explicitly included in the mathematical model.

Total Production Time Model

By combining all these components, the mathematical model for total production time is formulated as shown in the following figure:

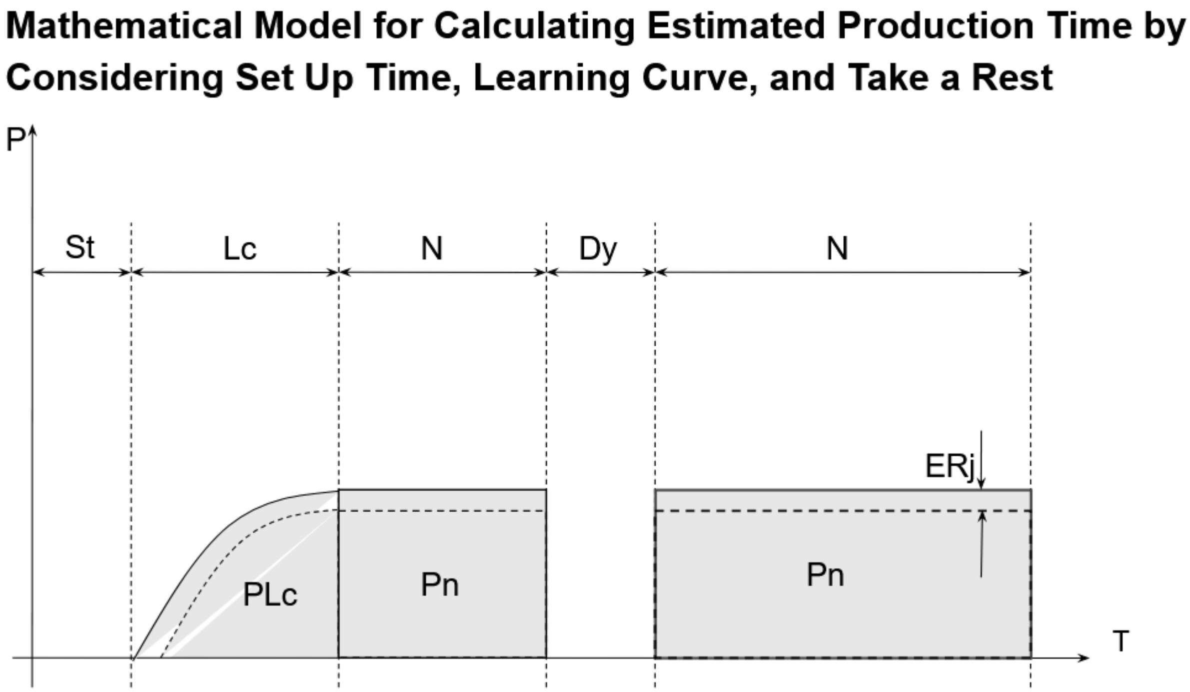


Figure. 5. Mathematical Model for Calculating Estimated Production Time by Considering Set Up Time, Learning Curve, and Take Rest Time

In Figure 5 above are the basic materials for creating a mathematical model formula to calculate the Estimated Production Quantity as shown below:

$$T = St + Lc + N + Dy$$

$$N = T - (St + Lc + Dy)$$

$$Pn = \frac{T - (St + Lc + Dy)}{Ct}$$

$$EP = Pn + PLc - ERj$$

Where:
P = Daily Production Amount
T = Time Required to Complete an Order
St = Machine Setup Time
Lc = Learning Time
N = Normal Time
Dy = Delay Time
Ct = Cycle Time
Pn = Normal Production Amount
PLc = Learning Process Production Amount
ERj = Estimated Number of Defects
EP = Estimated Production

For example:

A shirt manufacturing industry requires one hour of setup time each morning before starting work, with working hours from 8 a.m. to 5 p.m. With a one-hour learning period for employees, the estimated production is only 50 shirts per hour, and a one-hour break from 12:00 to 1:00 p.m. The estimated failure rate is only 1%. The product cycle time is 1 minute. What is the estimated number of shirts produced per day?

Therefore:
St = 1 Hour = 60 Minutes
Lc = 50 Pcs/1 Hour
Dy = 1 Hour = 60 Minutes
ERj = 1%
Ct = 1 Minute
Question: What is the estimated number of shirts produced per day?

N= T- (St + Lc + Dy)

$$= 9-(1+1+1)$$
$$= 6$$

$$\mathbf{Pn = \frac{T- (St + Lc + Dy)}{Ct}}$$

$$= \frac{6 \text{ hour}}{1 \text{ Minutes}}$$

$$= \frac{6 \times (60 \text{ minutes})}{1 \text{ Minutes}}$$

$$= 360 \text{ Pcs}$$

EP = Pn + PLc - ERj

$$= 360 + 50 - (1\% \times 360)$$
$$= 410 - 3.6$$
$$= 406.4$$

Relationship to Barchart Simulation

In the manufacturing industry, the concept of balanced time plays a strategic role as a basis for formulating operational policies and production planning. Balanced time is a condition in which the workload across workstations or production activities is aligned so that there are no bottlenecks or significant idle time. Therefore, the balance time value represents the most stable and efficient operational capacity of a production system.

In this research, balance time is treated as cycle time, which serves as the primary reference for calculating production time estimates. This approach aligns with industrial policy that establishes cycle time as a key parameter in determining output targets, capacity planning, and evaluating production line performance. By using balance time as the cycle time, the developed mathematical model can reflect desired operating conditions rather than merely theoretical or ideal conditions.

Mathematically, the cycle time (CT) in this study is determined from the equilibrium time value obtained from the Barchart simulation analysis, which reflects the most stable average process duration after accounting for setup time variability, learning curve effects, and operator rest time policies. Therefore, cycle time is not assumed to be a constant value, but rather the result of the overall production system balancing process.

The integration of equilibrium time as cycle time in the Mathematical Model for Calculating Estimated Production Time by Considering Set-Up Time, Learning Curve, and Take a Rest allows the model to serve as an industrial policy tool. This cycle time value is used as the basis for:

1. Determining production target quantities per period,
2. Determining labor requirements and machine allocation,
3. Evaluating the efficiency of continuous and discontinuous line flow systems,
4. Decision-making related to process improvement and production time control.

With this approach, the resulting production time estimates are not only analytical but also applicable and relevant to industry needs. Determining equilibrium time as cycle time bridges the gap between mathematical models and operational policy practices, allowing the results of this study to be directly used as a reference in planning and controlling production systems based on Barchart simulations.

DISCUSSION

The simulation results indicate that the Barchart simulation not only serves as a visualization tool for production schedules but can also be used as an analytical tool for estimating production quantities. In continuous line flow systems, Barcharts help confirm cycle time stability and the appropriateness of using a deterministic approach. Meanwhile, in discontinuous line flow systems, Barcharts help uncover process variability and non-productive factors that affect the system's adequate capacity.

These findings align with the basic concept of operations management, which states that systems with low variation are better suited to deterministic models. At the same time, those with high uncertainty require a more flexible approach. The main advantage of Barchart simulation in this study is its ability to present complex information in a simple, easy-to-understand format, making it suitable for both practitioners and academics.

However, Barchart simulations also have limitations, particularly in representing the dynamics of highly complex and stochastic production systems. Therefore, Barcharts are more appropriately positioned as initial or complementary analysis tools rather than as a complete replacement for software-based discrete-event simulations.

Implications of Research Results

Based on the simulation results and discussion, this study has several implications, namely:

1. Practical implications: Barchart simulations can be used as a rapid tool for estimating production volumes and identifying bottlenecks.
2. Methodological implications: Barcharts can be developed as an alternative approach in production system analysis, particularly in the early planning stages.
3. Academic implications: This study strengthens the understanding of the relationship between production system characteristics and production volume estimation methods.

CONCLUSIONS

This study discusses production quantity estimation methods in continuous and discontinuous line flow systems using a Barchart simulation approach. Based on the simulation results and discussion, it can be concluded that production flow characteristics significantly influence the selection of an appropriate production quantity estimation method.

In continuous line flow systems, Barchart simulations demonstrate a stable and repeatable production flow pattern, with relatively low process time variations. These conditions allow for the use of a deterministic approach-based production quantity estimation method, where production quantity can be calculated directly based on cycle time and line capacity. Barchart simulations serve as a visual verification tool that strengthens the accuracy of production estimation in these systems.

In contrast, in the discontinuous line flow system, Barchart simulation results show significant variation in process times, setup times, and waiting times between activities. This variability causes the system's effective capacity to be lower than its theoretical capacity. Therefore, estimating production volumes in this system requires approaches that account for uncertainty, such as probabilistic models and simulations, to produce more realistic estimates.

Overall, this study demonstrates that Barchart simulation can be used as a simple yet effective analytical tool to support production volume forecasting, particularly as an initial approach in production planning and workflow evaluation in manufacturing systems.

Recommendations

1. Based on the research results and conclusions, several recommendations can be made as follows:
2. For industry practitioners, Barchart simulations are recommended as an initial tool in production planning to identify effective capacity and potential bottlenecks, especially before implementing more complex simulations.
3. For production managers, the choice of production quantity estimation method should be tailored to the characteristics of the production system being used, taking into account the level of process variation and uncertainty.
4. For future researchers, it is recommended to expand this research by incorporating empirical data from real industry sources and comparing the results of Barchart simulations with discrete-event simulations or data-driven approaches.

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