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"Production Planning Control" With Special Reference to Murugappa Tool Tech Pvt Ltd, At Hosur.

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ABSTRACT:

This study analyses the production planning and control (PPC) environment of a manufacturing firm, highlighting strengths such as effective cost control and a strong focus on quality through regular checks. However, key issues include unclear communication of production targets, inefficiencies in scheduling and inventory systems, frequent production delays due to machine breakdowns, material shortages, and labour challenges. The findings also point to inconsistent training practices, suggesting the need for improved workforce development to boost productivity and reduce waste

Keywords: Production planning, Cost control, Communication gaps, Inventory management, Delays, Training, Quality checks

INTRODUCTION

Production planning and control (PPC) play a vital role in enhancing efficiency, quality, and cost-effectiveness in manufacturing. This study focuses on Murugappa Tool Tech, a leading precision tool manufacturer under Sri Ramana Vision, known for serving industries like automotive, aerospace, and heavy machinery. Despite its strong technical capabilities and commitment to quality, the company faces challenges due to its dynamic production environment. The research aims to assess the current PPC practices at Murugappa Tool Tech, highlighting strengths and identifying areas for improvement in scheduling, inventory management, resource allocation, and quality control.

RESEARCH BACKGROUND

Production planning and control (PPC) is a critical function in manufacturing that ensures the smooth coordination of production activities to achieve maximum efficiency and optimal resource utilization. It involves forecasting, scheduling, monitoring, and managing production operations to deliver the right product, in the right quantity, at the right time, and at the lowest possible cost. PPC plays a pivotal role in aligning production goals with customer demands, reducing operational waste, and streamlining workflow. The core objectives of PPC include minimizing production costs, ensuring timely delivery, maintaining consistent product quality, and improving overall productivity. This study aims to explore how effective PPC practices contribute to operational excellence and competitiveness in dynamic manufacturing environments.

IDENTIFIED PROBLEM

Murugappa Tool Tech faces several challenges in its production planning and control processes that impact efficiency and performance. These include poor inventory management, underutilized production capacity, long lead times, inaccurate demand forecasting, and inefficient resource allocation. These issues lead to delays, increased costs, and difficulty in meeting customer expectations, highlighting the need for improved planning and control strategies.

OBJECTIVES OF THE STUDY

To identify areas of improvement within the production planning process.
To analyze the current production planning and control strategies at Murugappa Tool Tech.
To evaluate how well production planning and control processes align with the company's overall business strategy.
To recommend enhancements to streamline operations and optimize resource use

NEED OF THE STUDY

The study on Production Planning and Control (PPC) at Murugappa Tool Tech is crucial due to rising complexity and competitiveness in the manufacturing sector. Despite its strong technical capabilities, the company faces issues like production delays, poor communication, inefficient

scheduling, and suboptimal resource use. This study aims to evaluate current PPC practices, assess their impact on cost, quality, and lead times, and recommend data-driven improvements

REVIEW OF LITERATURE

R. Dan Reid and Nada R. Sanders (2017) Production and Operations Management

Reid and Sanders provide a thorough foundation on production and operations management with a dedicated focus on PPC. The book outlines key PPC concepts, such as scheduling, forecasting, inventory management, and capacity planning. It emphasizes how technological advancements, like automation and ERP systems, are reshaping production planning processes. The authors also examine traditional and contemporary methods for optimizing production systems, offering a balanced approach for both theory and practical applications.

F. Robert Jacobs, Richard B. Chase, and Nicholas J. Aquilano (2020) Manufacturing Planning and Control for Supply Chain Management

This book ties PPC with the larger context of supply chain management, highlighting the strategic importance of aligning production control with overall supply chain goals. The text covers modern techniques like MRP, Just-in-Time (JIT), and ERP systems, which are critical for managing production schedules, reducing lead times, and improving flexibility. The 2020 edition explores how real-time data analytics, cloud computing, and integrated supply chain tools are enhancing the efficiency and accuracy of production planning and control.

S.N.Chary (2019) Production Planning and Control

Chary's book offers a comprehensive exploration of both the theoretical and practical aspects of PPC. It covers key PPC activities such as demand forecasting, inventory control, material requirements planning (MRP), and scheduling. What sets this book apart is its use of real-world case studies, which demonstrate how businesses implement and adapt PPC methods. The 2019 edition updates case studies with the latest industry practices and highlights the growing influence of AI and machine learning in forecasting and scheduling.

Max Muller (2021) Essentials of Inventory Management

Muller's work is essential for understanding the crucial link between inventory management and production planning. Effective inventory management is a cornerstone of PPC, and Muller delves into techniques that align production schedules with optimal inventory levels. The 2021 edition of the book discusses modern trends such as predictive analytics for inventory forecasting and automated stock replenishment systems, both of which help reduce waste and improve the responsiveness of production processes.

Jay Heizer and Barry Render (2022) Operations Management: Sustainability and Supply Chain Management

Heizer and Render's book offers a modern take on operations management, with a significant focus on sustainable practices within PPC. The authors discuss how environmental concerns are reshaping production planning, including methods for reducing waste, energy consumption, and carbon emissions. The integration of sustainability into PPC not only meets regulatory requirements but also offers competitive advantages in a market increasingly focused on eco-friendly practices. This book is a key resource for understanding how sustainability is influencing modern production control strategies.

A. T. Chan et al. (2020) Advanced Manufacturing Systems: Research and Applications edited

This edited volume presents cutting-edge research on advanced manufacturing systems and their impact on PPC. It includes discussions on Industry 4.0, cyber-physical systems (CPS), and the Internet of Things (IoT) and how these technologies are revolutionizing production control. The integration of these smart systems into PPC frameworks allows for more flexible, adaptive, and real-time production planning. This book is highly valuable for understanding how technology is shaping the future of PPC in various industries.

Steve M. Dobson (2020) Production Planning & Control for Semiconductor Manufacturing

Focused on semiconductor manufacturing, Dobson's book provides a detailed look at the specialized PPC techniques used in high-tech industries. The book covers areas such as batch production scheduling, lot tracking, and capacity management in an environment where production processes are often highly complex and time-sensitive. It offers practical insights into the challenges of balancing precision with efficiency, especially in industries with long lead times and strict quality standards.

A. T. Chan and K. W. Chau (2021) The New Manufacturing Engineer: Shaping the Future of Industrial Operations

Chan and Chau's book explores the role of engineers in shaping modern manufacturing systems. A key theme is the integration of digital technologies such as machine learning, artificial intelligence, and digital twins into PPC. These technologies are increasingly used to improve decision-making, reduce downtime, and optimize production schedules. The authors also address how the changing landscape of manufacturing demands new skills and approaches to production planning, making this book vital for engineers involved in PPC.

Peter Jones (2021) Strategic Operations Management

Jones offers a strategic perspective on PPC by linking it directly to long-term business goals such as profitability, competitiveness, and market expansion. The book explores decision-making frameworks in production planning, focusing on how capacity planning, scheduling, and resource allocation align with broader organizational objectives. It provides insight into balancing short-term operational demands with long-term strategic goals, an increasingly important consideration in PPC.

William M. Feld (2021) Lean Manufacturing: A Step-by-Step Guide to Implementation

Feld's book is an essential resource for understanding the principles of Lean manufacturing, which are closely tied to production planning. Lean techniques like Just-in-Time (JIT), Kaizen, and value stream mapping are all critical components of PPC in reducing waste and improving production flow. The book provides a practical, step-by-step guide on how to implement Lean practices into existing PPC systems to enhance efficiency and responsiveness.

Eliyahu M. Goldratt (2021) The Theory of Constraints: A Systems Approach to Continuous Improvement

Goldratt's Theory of Constraints (TOC) continues to be a foundational work in PPC. TOC emphasizes the importance of identifying bottlenecks within production systems and focusing resources on alleviating these constraints. This approach helps ensure that production flow is maximized. Goldratt's methods are particularly relevant in complex manufacturing environments where capacity is limited, and optimizing flow is crucial for improving efficiency and meeting customer demand

John G. Van Maanen (2019) Managing the Production Flow: Optimizing the Manufacturing Process

Van Maanen's book focuses on managing production flow, a key aspect of PPC. The author discusses methods for optimizing resource allocation, scheduling, and minimizing delays in production processes. The book includes modern approaches to enhancing production flow, such as real-time monitoring systems and simulation-based forecasting. The use of these advanced techniques in PPC systems allows companies to adapt more swiftly to changing market conditions.

James B. Ayers (2020) The Complete Guide to Supply Chain Management

Ayers provides a thorough overview of supply chain management, with significant attention to the role of PPC within this larger system. He examines how effective PPC can streamline the entire supply chain, reduce inventory costs, and ensure timely delivery of goods. The 2020 edition discusses the integration of digital tools and analytics into PPC to enhance the visibility and efficiency of supply chain operations, making it an essential resource for modern PPC practices.

Andrew P. Sage (2020) Industrial Engineering and Operations Research

Sage's book focuses on the intersection of industrial engineering, operations research, and PPC. It presents optimization models and decision-making tools used in PPC, such as linear programming and simulation techniques. The book provides a detailed explanation of how mathematical modeling can be used to solve complex PPC problems, improving overall production efficiency and decision-making.

steven nahmias. (2021) Production and Operations Analytics

This book explores the role of advanced analytics in production and operations management, including PPC. It covers techniques such as predictive modeling, optimization algorithms, and machine learning, demonstrating how these technologies can be applied to improve decision-making and production efficiency. The book discusses how data-driven approaches can enhance demand forecasting, production scheduling, and inventory management in modern

John Mangan (2020) Global Supply Chain Management and International Logistics

Mangan's book connects global supply chain management with PPC, addressing the challenges that arise when coordinating production processes across different regions. Topics include lead time management, international inventory control, and demand uncertainty. This book is crucial for understanding the complexities of PPC in a globalized production environment where supply chains are often stretched across continents.

David A. Collier and James R. Evans (2022) Operations Management: A Supply Chain Approach

This text offers a comprehensive overview of operations management, with particular attention to how PPC integrates with supply chain decisions. It examines how modern PPC systems help businesses optimize production schedules, reduce waste, and manage resource utilization. The authors explore the role of technology in enhancing PPC effectiveness, making the book an essential resource for understanding the intersection of PPC and supply chain management.

RESEARCH GAP

Despite extensive research on Production Planning and Control (PPC), there is a notable lack of studies focusing on mid-sized, emerging manufacturers like Murugappa Tool Tech, especially in dynamic industrial regions such as Hosur. Existing literature predominantly addresses large corporations or theoretical frameworks without practical validation. This study addresses key gaps, including the limited exploration of PPC in Indian SMEs, the contextual effectiveness of tools like MRP and JIT in custom tooling environments, and the impact of training and maintenance on performance. Uniquely, it also incorporates employee perspectives, offering a holistic, case-based analysis to enhance PPC understanding in similar manufacturing contexts.

RESEARCH METHODOLOGY

This study adopted a structured mixed-methods approach, combining both qualitative and quantitative techniques to examine key aspects of Production Planning and Control (PPC) at Murugappa Tool Tech. Primary data was gathered through structured questionnaires and interviews across departments, supported by secondary data from records and literature. The study focused on areas like inventory control, scheduling, quality management, automation, and training, enabling a holistic understanding of PPC practices.

Sampling and Data Handling A sample of 80 respondents was selected using a combination of Richard B. Chase (2022) Supply Chain and Operations Management: A Decision-Oriented Introduction

Chase's book provides a decision-oriented approach to supply chain and operations management, with a significant focus on PPC. It highlights the key decisions that must be made in production planning, such as capacity planning, scheduling, and inventory management. The 2022 edition integrates modern technologies like real-time data analytics and machine learning, showing how they can optimize production processes and enhance decision-making.

Alan Rushton (2020) The Handbook of Logistics and Distribution Management

Rushton's handbook addresses logistics and distribution, which are integral components of PPC. The book explores how efficient PPC can optimize the distribution of materials and goods throughout the supply chain. Topics such as transportation scheduling, warehousing, and inventory management are covered, providing valuable insights into how PPC interacts with other supply chain functions.

convenience, stratified, and purposive sampling methods to ensure cross-functional representation Data collection occurred over 21 days using paper surveys, online forms, and interviews. Post-collection, data was digitized, cleaned, coded, and processed using Excel and SPSS, enabling the development of charts, frequency tables, and correlation matrices for deeper analysis**.**Design and Analysis Tools The research followed a cross-sectional, quantitative, and analytical design, guided by theoretical frameworks such as Lean Manufacturing, TOC, and ERP principles. Analytical tools included descriptive statistics, chi-square tests, ANOVA, correlation, and regression (if applicable). Visualization techniques like bar charts, heatmaps, and box plots were used to interpret results, offering actionable insights for improving PPC efficiency within the company.

LIMITATION OF THE STUDY

This study on Production Planning and Control (PPC) is subject to certain limitations, including its focus on a specific industry, limiting broader applicability—especially to service sectors. The sample size is relatively small, which may not reflect wider industry trends. Due to time constraints, the research captures only a short-term view, potentially missing long-term patterns. It also relies partially on secondary data, which may affect result accuracy. Additionally, the study may not fully account for the influence of rapidly evolving technologies like AI and IoT on PPC practices.

4.1 DATA ANALYSIS AND INTERPRETATION

TABLE NO: 4.1
GENDER OF RESPONDENTS

Gender	No. of Respondents	Percentage (%)
Male	57	71.25%
Female	23	28.75%
Total	80	100%

INTERPRETATION:

Out of 80 respondents, 57 are male (71.25%) and 23 are female (28.75%), indicating a male-dominated workforce in the surveyed population. This skew in gender distribution may reflect industry norms or recruitment practices favouring male participation in production-related role

CHART NO 4.1

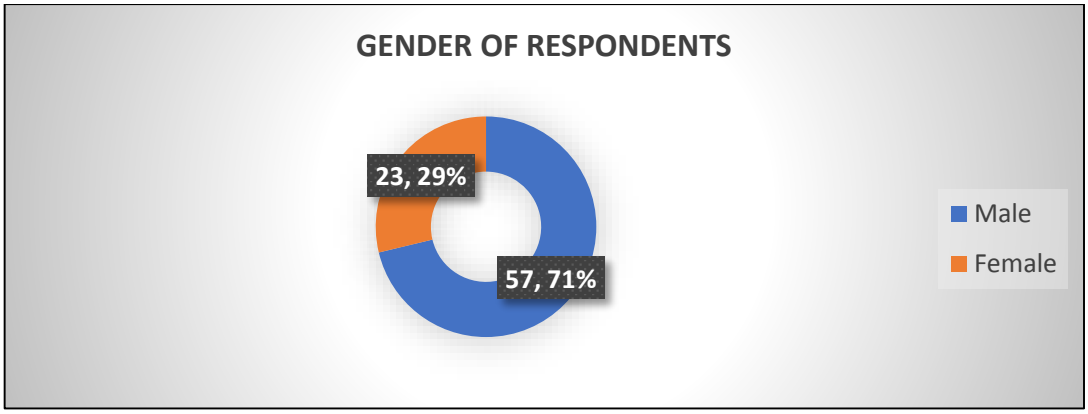


TABLE NO: 4.2
AGE OF RESPONDENTS

Response	No. of Respondents	Percentage (%)
18-25	26	32.5%
46 and above	19	23.8%
26-35	18	22.5%

36-45	17	21.2%
Total	80	100.0%

INTERPRETATION:

The above table shows the age distribution of respondents. The majority (32.5%) fall within the 18-25 age group, followed by 23.8% in the 46 and above category. The 26-35 age group comprises 22.5%, while the 36-45 age group accounts for 21.2% of respondents. This indicates that younger individuals make up the largest proportion of respondents.

CHART NO 4.2

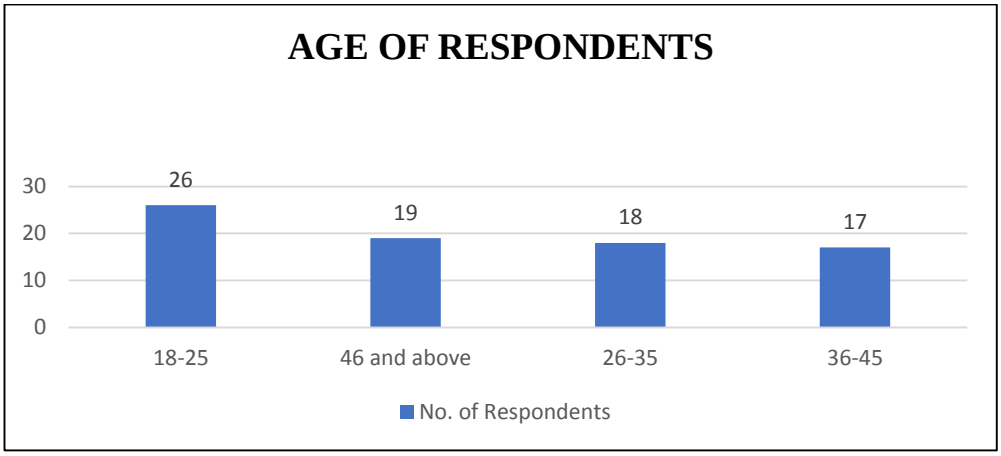


TABLE NO: 4.3

HIGHEST QUALIFICATION

Response	No. of Respondents	Percentage (%)
Diploma	24	30.0%
PG	23	28.7%
Others	18	22.5%
UG	15	18.8%
Total	80	100.0%

INTERPRETATION:

The table illustrates the highest qualifications of respondents. A significant portion (30.0%) hold a diploma, while 28.7% have a postgraduate (PG) qualification. Undergraduate (UG) qualifications account for 18.8%, and 22.5% belong to the "Others" category. This suggests that most respondents have a higher educational background.

CHART NO 4.3

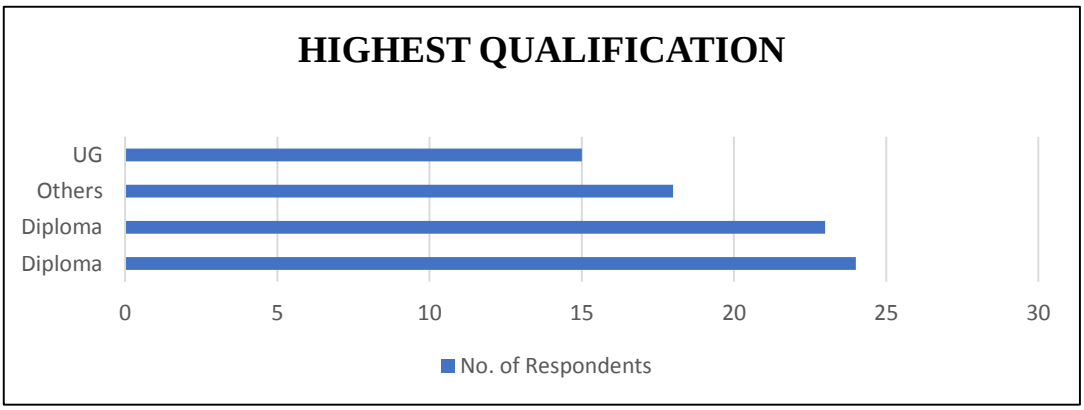


TABLE NO: 4.4

YEARS OF EXPERIENCE

Response	No. of Respondents	Percentage (%)
3-5	28	35.0%
10+	25	31.2%

0-2	14	17.5%
6-10	13	16.2%
Total	80	100.0%

INTERPRETATION:
The data indicates that the majority of respondents (35.0%) have 3-5 years of experience, followed by 31.2% with over 10 years of experience. A smaller portion (17.5%) have 0-2 years of experience, while 16.2% have 6-10 years. This suggests a well-balanced mix of experience levels among respondents.

CHART NO 4.4

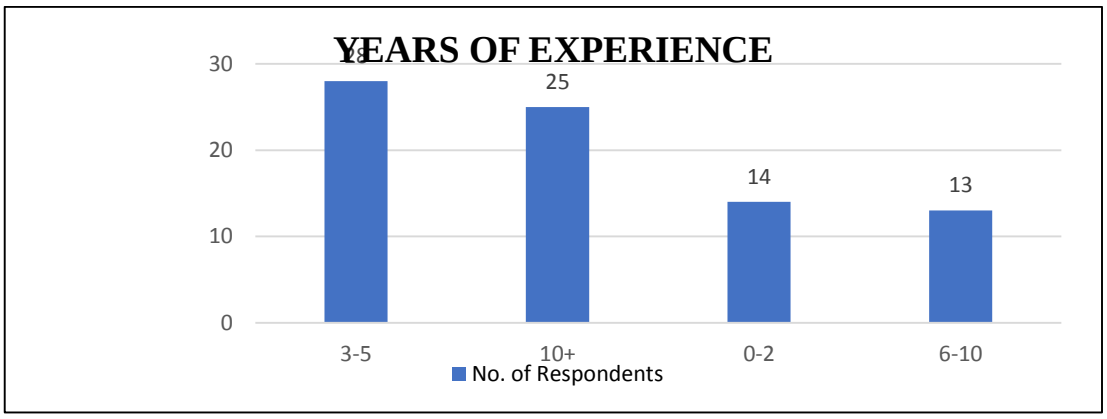


TABLE NO: 4.5
ROLE IN COMPANY

Response	**No. Of Respondents**	**Percentage (%)**
Production Manager	22	27.5%
Supervisor	20	25.0%
Worker	20	25.0%
Other	18	22.5%
Total	80	100.0%

INTERPRETATION:
The table represents the roles of respondents in their respective companies. The highest proportion (27.5%) are Production Managers, followed closely by Supervisors and Workers at 25.0% each. The remaining 22.5% fall into the "Other" category. This distribution shows a mix of leadership and operational roles among respondents.

CHART NO 4.5

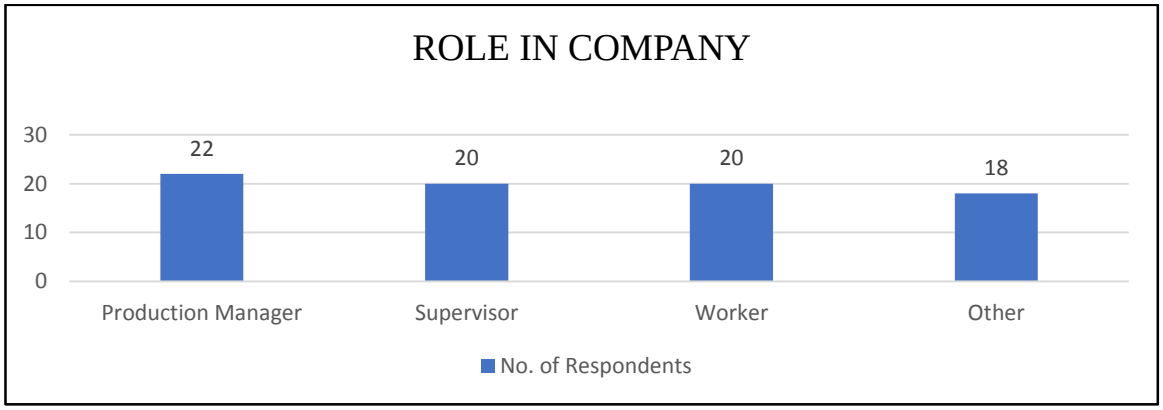


TABLE NO: 4.6
FREQUENCY OF PRODUCTION PLAN REVISION

Response	**No. of Respondents**	**Percentage (%)**
Daily	24	30.0%
Weekly	22	27.5%

Monthly	20	25.0%
Quarterly	14	17.5%
Total	80	100.0%

INTERPRETATION:

The results reveal that production plans are most frequently revised on a daily basis (30.0%), followed by weekly revisions (27.5%). Monthly revisions account for 25.0%, while quarterly revisions are the least common at 17.5%. This suggests that many companies prefer frequent updates to their production plans.

CHART NO 4.6

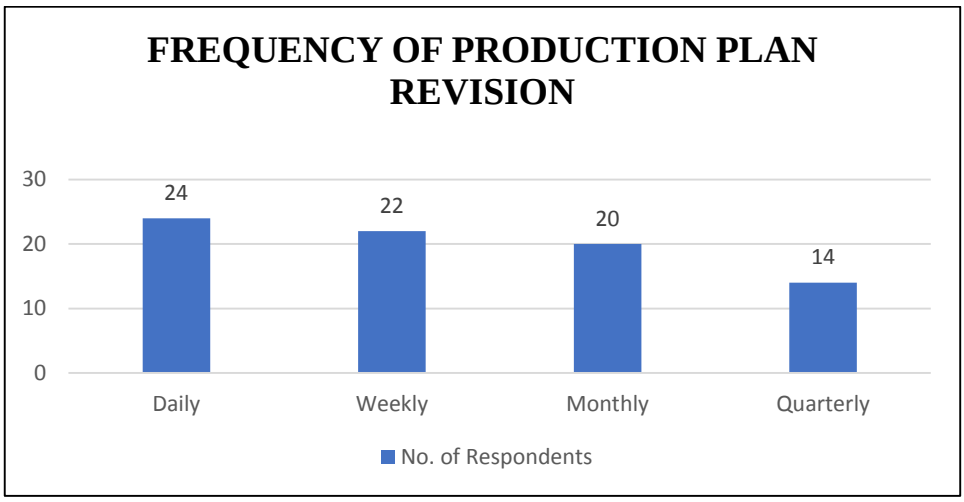


TABLE NO: 4.7

PRODUCTION TARGETS CLEARLY COMMUNICATED

Response	**No. of Respondents**	**Percentage (%)**
No	44	55.0%
Yes	36	45.0%
Total	80	100.0%

INTERPRETATION:

The table shows that a majority of respondents (55.0%) feel that production targets are not clearly communicated, while 45.0% believe they are. This indicates a potential gap in communication regarding production goals within organizations.

CHART NO 4.7

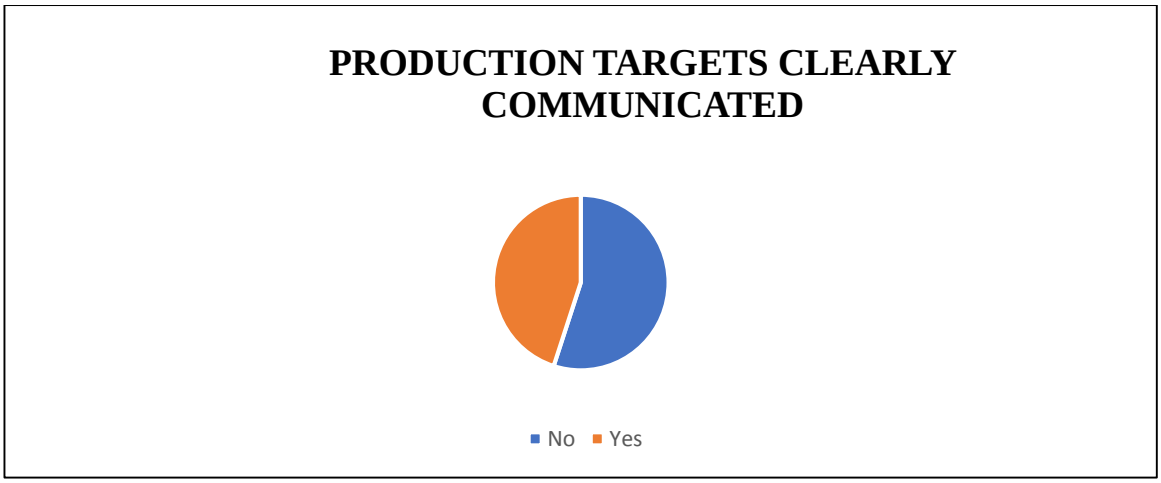


TABLE NO: 4.8
EFFECTIVENESS OF PRODUCTION SCHEDULING SYSTEM

Response	No. of Respondents	Percentage (%)
Ineffective	21	26.2%
Effective	18	22.5%
Very Effective	16	20.0%
Neutral	13	16.2%
Very Ineffective	12	15.0%
Total	80	100.0%

INTERPRETATION:

The table suggests that opinions on production scheduling systems vary. While 26.2% of respondents find them ineffective, only 22.5% consider them effective. A smaller percentage (20.0%) find them very effective, while 16.2% remain neutral, and 15.0% consider them very ineffective. This implies that production scheduling could be improved in many organizations.

CHART NO 4.8

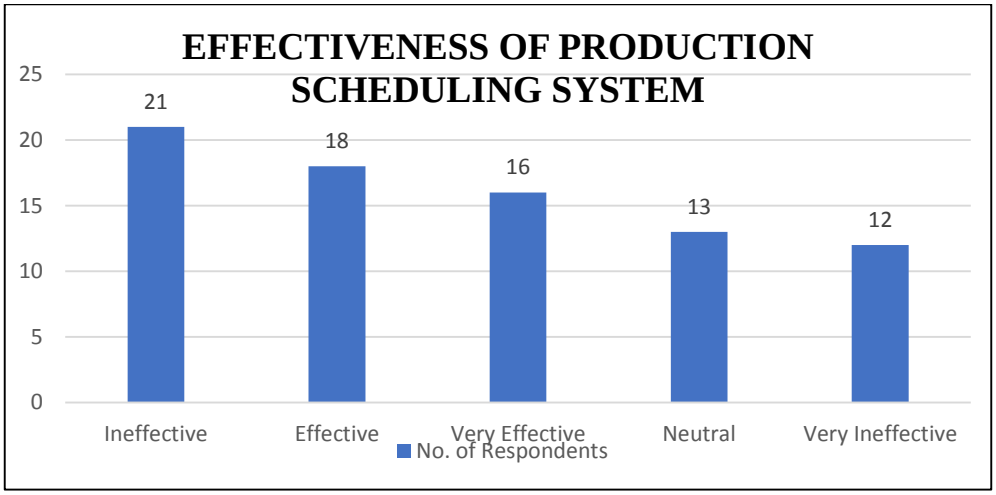


TABLE NO: 4.9
FREQUENCY OF PRODUCTION DELAYS

Response	No. of Respondents	Percentage (%)
Sometimes	21	26.2%
Never	20	25.0%
Often	18	22.5%
Rarely	11	13.8%
Always	10	12.5%
Total	80	100.0%

INTERPRETATION:

The results indicate that production delays occur sometimes (26.2%) or never (25.0%) in most cases. However, 22.5% report frequent delays, 13.8% rarely experience them, and 12.5% always face production delays. This suggests that while some companies manage to avoid delays, others struggle with frequent disruptions.

CHART NO 4.9

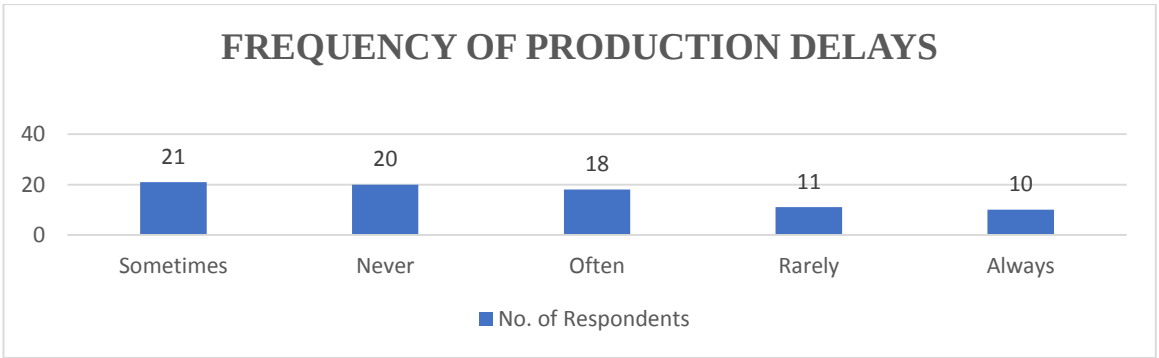


Table No: 4.10
PRIMARY REASON FOR PRODUCTION DELAYS

Response	No. of Respondents	Percentage (%)
Machine Breakdown	22	27.5%
Labor Issues	16	20.0%
Material Shortage	16	20.0%
Poor Planning	15	18.8%
Others	11	13.8%
Total	80	100.0%

INTERPRETATION:

Machine breakdown (27.5%) is the leading cause of production delays, followed by labor issues and material shortages (20.0% each). Poor planning accounts for 18.8%, while 13.8% of delays stem from other factors. These findings highlight the need for better equipment maintenance and workforce management.

CHART NO 4.10

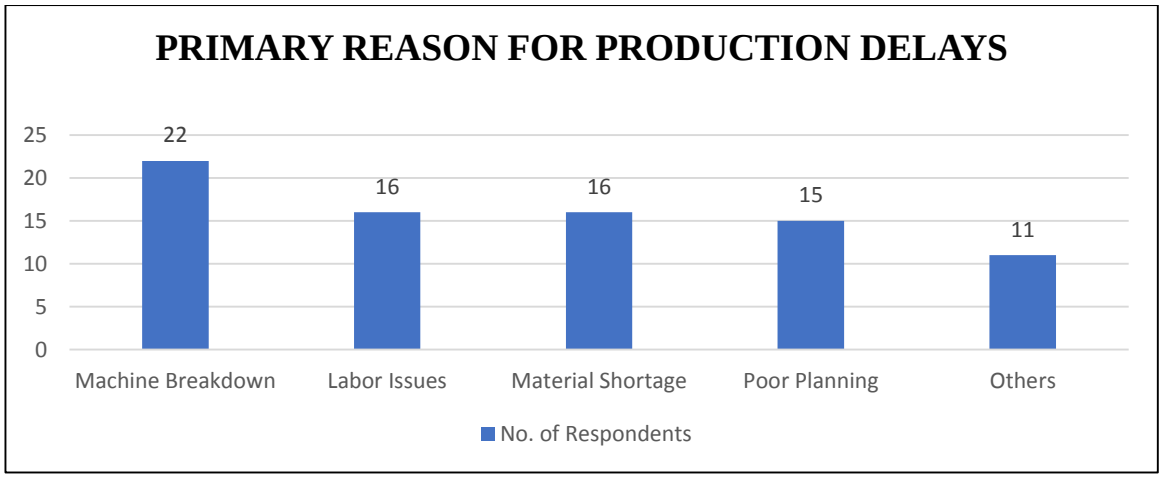


TABLE NO: 4.11
SATISFACTION WITH RESOURCE ALLOCATION

Response	No. of Respondents	Percentage (%)
Dissatisfied	18	22.5%
Satisfied	18	22.5%
Highly Dissatisfied	16	20.0%
Neutral	16	20.0%
Highly Satisfied	12	15.0%
Total	80	100.0%

INTERPRETATION:

The responses show a varied level of satisfaction with resource allocation. While 22.5% of respondents are satisfied, an equal percentage are dissatisfied. Meanwhile, 20.0% are highly dissatisfied, another 20.0% are neutral, and 15.0% are highly satisfied. This suggests that organizations need to enhance their resource distribution strategies.

CHART NO 4.11

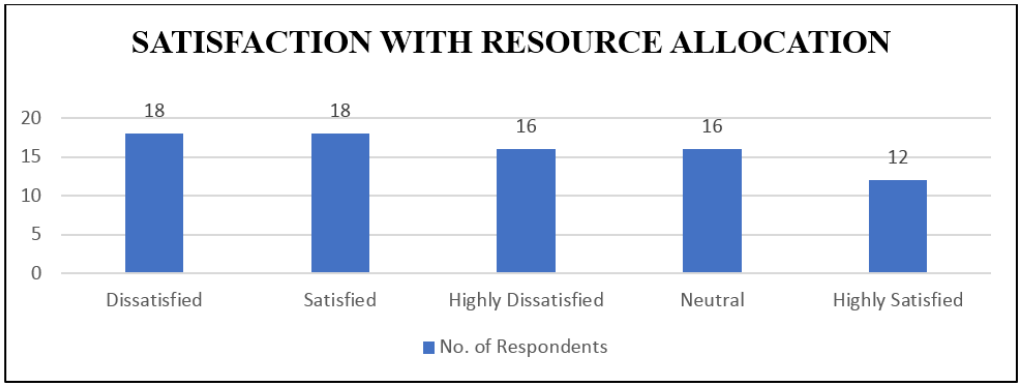


TABLE NO: 4.12
FREQUENCY OF QUALITY CHECKS

Response	No. of Respondents	Percentage (%)
Hourly	23	28.7%
Daily	22	27.5%
Weekly	18	22.5%
Monthly	17	21.2%
Total	80	100.0%

INTERPRETATION:
The table reveals that quality checks occur hourly in 28.7% of cases, daily in 27.5%, weekly in 22.5%, and monthly in 21.2%. This indicates that most organizations implement frequent quality control measures to ensure production standards.

CHART NO 4.12

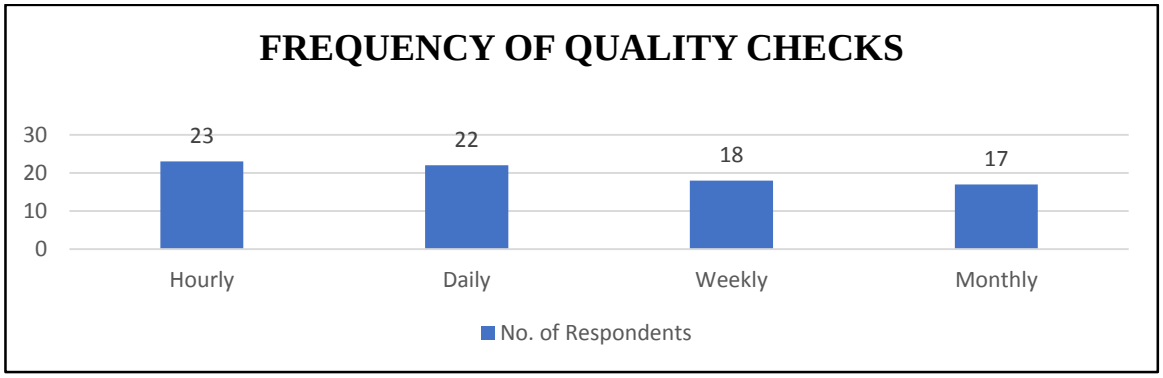


TABLE NO: 4.13
USE OF AUTOMATION TOOLS IN PRODUCTION CONTROL

Response	No. of Respondents	Percentage (%)
Yes	43	53.8%
No	37	46.2%
Total	80	100.0%

INTERPRETATION:
A majority (53.8%) of respondents confirm the use of automation tools in production control, whereas 46.2% do not. This suggests that while automation is widely adopted, there is still room for increased integration.

CHART NO 4.13

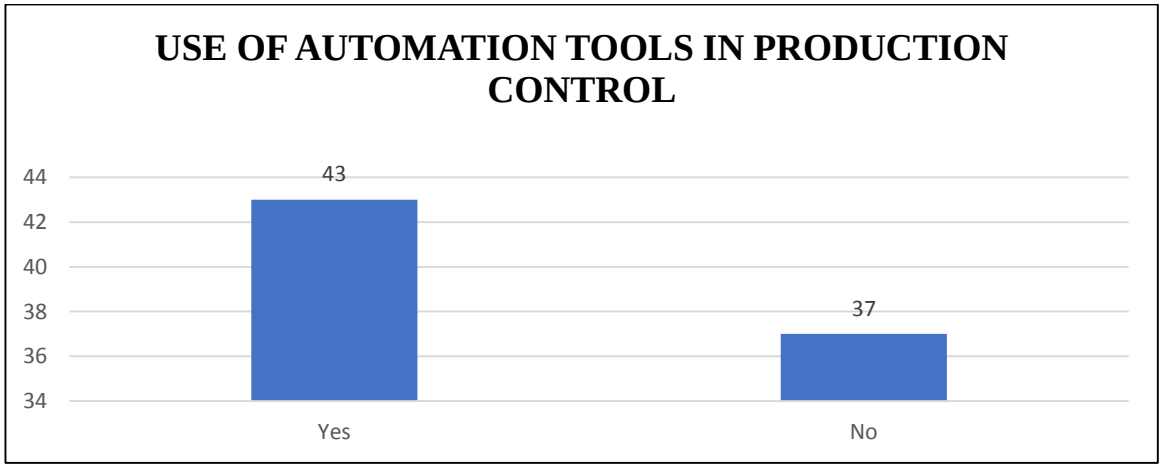


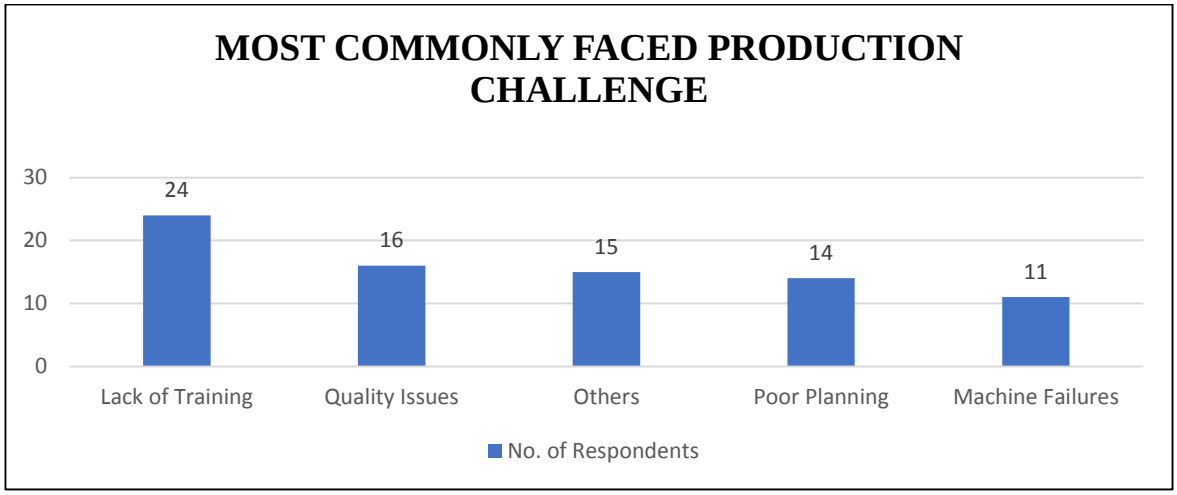
TABLE NO: 4.14
MOST COMMONLY FACED PRODUCTION CHALLENGE

Response	No. of Respondents	Percentage (%)
Lack of Training	24	30.0%
Quality Issues	16	20.0%
Others	15	18.8%

Poor Planning	14	17.5%
Machine Failures	11	13.8%
Total	80	100.0%

INTERPRETATION:
The data shows that lack of training (30.0%) is the most prevalent challenge in production. Quality issues (20.0%), poor planning (17.5%), and machine failures (13.8%) are also significant concerns. Addressing training deficiencies could enhance overall production efficiency.

CHART NO 4.14



SUMMARY OF FINDINGS

1. Gender Distribution: The majority of the respondents (71.25%) were male, indicating a male-dominated workforce in the production sector.
2. Age of Respondents: A significant portion of respondents (32.5%) were aged between 18 and 25 years, suggesting a relatively young demographic in the workforce.
3. Educational Qualification: Most respondents possessed a Diploma (30%), followed closely by those with Postgraduate degrees (28.7%), reflecting a technically qualified respondent base.
4. Years of Professional Experience: The largest segment of respondents (35%) reported having 3–5 years of experience, followed by 31.2% with more than 10 years of experience, indicating a balanced mix of early-career and experienced professionals.
5. Designation within the Organization: Respondents were fairly distributed across job roles, with 27.5% being Production Managers, and 25% each serving as Supervisors and Workers.
6. Frequency of Production Plan Revisions: Daily revision of production plans was reported by 30% of respondents, showing a dynamic and frequently updated planning environment.
7. Communication of Production Targets: A majority (55%) indicated that production targets were not clearly communicated, suggesting a communication gap within organizations.
8. Effectiveness of Scheduling Systems: Scheduling systems were perceived as ineffective by 26.2% of respondents, while only 20% found them very effective, highlighting the need for improvement.
9. Incidence of Production Delays: Production delays were commonly reported, with 26.2% experiencing them sometimes and 22.5% often, indicating prevalent operational inefficiencies.
10. Primary Causes of Delays: Machine breakdowns were identified as the primary cause of delays (27.5%), followed by labor issues and material shortages (20% each).
11. Satisfaction with Resource Allocation: Satisfaction levels were mixed; 22.5% were satisfied, while an equal proportion were dissatisfied, and 20% were highly dissatisfied.
12. Frequency of Quality Checks: Frequent quality monitoring was evident, with 28.7% of respondents indicating hourly checks and 27.5% daily checks.
13. Adoption of Automation Tools: A majority (53.8%) confirmed the use of automation tools in production control, while 46.2% did not, revealing room for increased technological integration.
14. Common Production Challenges: Lack of training (30%) was the most cited challenge, followed by quality issues (20%) and poor planning (17.5%).

SUGGESTION

An integrated digital platform can significantly enhance PPC at Murugappa Tool Tech by improving communication, scheduling, monitoring, and decision-making. It addresses the issue of unclear production targets by centralizing information through real-time dashboards, notifications, and calendars. Advanced scheduling tools optimize production plans by factoring in constraints like labor, machines, and materials. Real-time monitoring

enables early detection of delays and bottlenecks, supporting timely interventions. Additionally, the platform aids in efficient resource allocation by highlighting utilization patterns and supports data-driven decisions through analytics on performance and cost metrics, fostering continuous operational improvement.

CONCLUSION

The study concludes that while companies show strengths in quality control and cost management, they face persistent challenges in communication, scheduling, and inventory management. Issues like production delays, limited training, and inefficient resource allocation hinder overall performance. The findings highlight the need for more integrated and data-driven approaches, improved communication, proactive maintenance, and employee-focused strategies to enhance the effectiveness of production planning and control systems.

DIRECTIONS FOR FUTURE RESEARCH Future research on PPC could explore longitudinal studies to assess long-term impacts of implemented changes, and comparative sectoral analyses to identify industry-specific best practices. Investigating the integration of emerging technologies like AI, IoT, and ERP systems in PPC, along with workforce-centric factors such as training and employee engagement, would offer valuable insights. Additionally, conducting cost-benefit analyses and incorporating environmental sustainability metrics into PPC evaluation can help organizations align operational efficiency with financial and ecological goals.

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