A Study on Data Analysis for Production Schedule Adherence: Root Cause Investigation

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ABSTRACT

Production Schedule Adherence (PSA) plays a significant role in achieving the efficiency of operations and on time delivery of products in the manufacturing industries. Effective scheduling ensures optimum utilization of the available resources, minimization of delays and increase of productivity of the organization. Machine failure, unavailability of raw materials, shortage of manpower, inefficient planning and improper quality control may delay and disrupt the production. This study focuses on identifying the key factors of Production Schedule Adherence using quantitative research. Data from 150 respondents were collected using structured questionnaire on a 5-point Likert scale. Reliability analysis, descriptive statistics, normality test, Spearman's Rank Correlation, Multiple regression analysis, Pareto analysis and Five Whys analysis were used to analyze the effect of the various factors on PSA.

Keywords: Production Schedule Adherence, Manufacturing Efficiency, Machine Breakdown, Preventive Maintenance, Production Planning, Quality Management.

INTRODUCTION

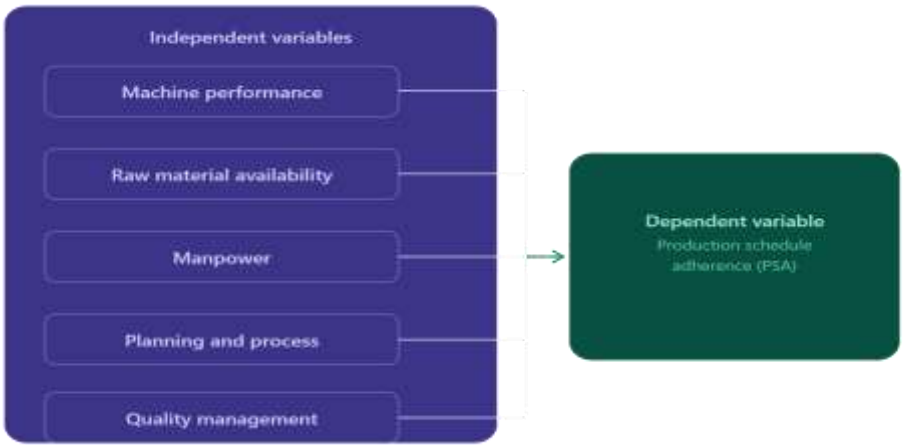
Production scheduling is a fundamental task within a manufacturing company because it keeps the production process in a steady flow. A schedule leads to effective coordination of all operations including machines, resources and labor activities to accomplish the production goals on time. The delays occurring in production may cause losses in productivity, in additional operating costs and in commitments to product delivery. A few internal variables such as equipment breakdown, lack of raw material, labor problems and process deficiency can cause the normal flow of production. An organization needs to cope with these problems to sustain operational effectiveness and performance. In a manufacturing environment, organizations try to eliminate

production interruptions by enhancing production planning, maintenance system and resource usage. Careful monitoring and control of the production process led to elimination of waste and better product quality. Examining the causes of the production delay help organizations in taking appropriate decisions for the production process and so analysis of factors causing production delays becomes very important to achieve the desired level of operational efficiency and stability.

INDUSTRY PROFILE

The manufacturing industry is important for industrial and economic development, creating employment, generating economic growth, and contributing to new technological developments. In this sector raw materials are processed into new finished goods using machinery, employees and processing. All manufacturing organizations function in a competitive environment where the ability to produce efficient, high quality, and timely products leads to the success of the organization. Industries in this sector are automotive manufacturing, engineering manufacturing, electrical engineering, textiles, chemical industry, consumer goods and so on. In this sector, consistent production flow, and adequate management of all the resources available are necessary for performing operations, meeting customer demands, increasing productivity and diminishing manufacturing disruptions. Modern manufacturing industries depend on technology to manage sophisticated machines and processes, use automation systems, apply modern quality practices and effective planning maintenance activities. The key role of this industry is to increase production efficiency, reduce waste production and achieve overall productivity for enduring growth.

2. CONCEPTUAL FRAMEWORK OF THE RESEARCH



Source: Author's own conceptual model

REVIEW OF LITERATURE

The problem of Production Schedule Adherence (PSA) is becoming increasingly crucial in manufacturing industries as it directly affects the operational efficiency and performance of production. From the literature review conducted, it can be inferred that earlier research works focused on machine performance, manpower, raw material supply, and process optimization as key contributors to maintain the flow of production. Predictive maintenance, preventive maintenance, and IoT based maintenance have become a common strategy used by companies to reduce the breakdown time of machines and improve the productivity of the production system (Lee & Park, 2022). Research also suggests that workforce planning, workforce training, and labor optimization are effective in improving productivity and decreasing disruptions within the system (Lopez et al., 2023). Also, inventory management, supplier scheduling and real time tracking are important for smooth supply of raw materials and reducing the production disruptions (Smith, 2023). Process optimization algorithms, reduction in set up times and lean manufacturing techniques are effective in scheduling and improving the overall operational performance (Zhou et al., 2024). It can be stated from the conducted

literature that AI and data driven techniques help in improving the performance and control of the manufacturing organizations. The studies also conclude that good production management leads to improving PSA and the overall performance of the system.

RESEARCH GAP

The review of literature indicates that the issues related to production schedule adherence are dominant in manufacturing sector due to effect of number of operational factors. Most of the research related to factors effect on PSA were mainly carried out on the parameters, such as machine break down, manpower, material shortage and inefficiency of processes. The research works mostly analyzed the effect of parameters one by one but rarely combined parameters. Research focuses more on predicting and controlling technologies, less effort has been placed on identifying the cause behind the time delay in production and deviation from schedule. In the research conducted on higher technologies (AI, IoT, ML), focuses are made more on the automation and predicting aspect rather than finding out the reasons for actual operational problems. Lack of research on actual plant information and real industrial problems can also be seen. Lack of study on real plant environment (model and simulation) may lead to discrepancy with actual production. Also, small and medium enterprises are suffering from resource constraints, hence study conducted for this segment is lesser than those for larger organizations. Finally, research is missing to consider the effects on workers' factors such as workers fatigue, workers' skills, and workers' decisions. So, there is a need for a more practical and integrative approach

RESEARCH QUESTIONS:

1. Machine breakdowns occur frequently?
2. Delays in raw material availability frequently disrupt the production schedule?
3. Production operations suffer from insufficient manpower?
4. Communication between departments is poor?
5. Rework and product rejection cause delays in production?

PRIMARY OBJECTIVE:

To investigate and study the factors affecting Production Schedule Adherence of a manufacturing concern.

SECONDARY OBJECTIVES:

- To observe the impact of machine efficiency over production schedule adherence.
- To evaluate the impact of raw material availability on scheduling process efficiency.
- To find out the impact of manpower factors on productivity and stability of the schedule.
- To identify the role of planning and process control to enhance the schedule adherence.
- To examine the contribution of quality practices toward productivity.
- To find out the main causes of production delays through R.C.A (Root Cause Analysis).

HYPOTHESIS OF THE STUDY

1. Reliability Analysis (Cronbach's Alpha)

H0: There is an acceptable internal consistency reliability of items in the scale (Cronbach's Alpha >0.70).

H1: There is an unacceptable internal consistency reliability of items in the scale (Cronbach's Alpha <0.70).

2. Normality test

H0: There is a normality of data.

H1: There is not a normality of data.

3. Spearman's rank correlation test

H0: No significant relationship between Production Schedule Adherence and production factors.

H1: There is a significant relationship between Production Schedule Adherence and production factors.

4. Multiple regression analysis

H0: Machine performance, raw material availability, manpower, planning & process, and quality management do not have a significant effect on Production Schedule Adherence.

H1: At least one of machine performance, raw material availability, manpower, planning & process, and quality management has a significant effect on Production Schedule Adherence.

RESEARCH METHODOLOGY:

The research used a descriptive research design with quantitative approach to investigate the factors affecting Production Schedule Adherence (PSA) in a manufacturing industry. In the present study, primary data was collected using a structured questionnaire which was administered to the employees from various departments and different job positions involved in the production and operational functions. The questionnaire comprises of items on various dimensions such as production planning effectiveness, material availability, machine utilization, work force efficiency, and production monitoring systems. A convenience sampling technique was used for collection of primary data, and a total of 150 responses were obtained for the study. Secondary data was also collected from journals, articles, industry reports and on-line. Data analysis was conducted using Microsoft Excel and IBM SPSS statistics software. The techniques of analysis were descriptive statistics (percentages and mean), Cronbach's Alpha as reliability analysis, testing for normality of data, Spearman's Rank Correlation, Multiple Regression analysis, Pareto analysis and the Five Why's to identify major problems and root cause analyses affecting PSA.

DATA ANALYSIS & INTERPRETATION

TABLE 1: SHOWING CORRELATION

Variable	PSASCORE	MESCORE	RMSCORE	MPSCORE	PPSCORE	QSCORE
PSASCORE	1	-0.772	-0.714	-0.522	-0.632	-0.651
MESCORE	-0.772	1	0.726	0.595	0.636	0.665
RMSCORE	-0.714	0.726	1	0.608	0.635	0.684
MPSCORE	-0.522	0.595	0.608	1	0.468	0.486
PPSCORE	-0.632	0.636	0.635	0.468	1	0.471
QSCORE	-0.651	0.665	0.684	0.486	0.471	1

Interpretation

Spearman's rho correlation was used to evaluate relationship between Production Schedule Adherence and Production related factors among 150 respondents. It is observed that all variables have a high significant level of relationship with the Production Schedule Adherence at 0.01 level ($p<0.01$). Machines ($r=-0.772$, $p<0.01$)

and Raw material (r=-0.714, p<0.01) show strong negative relationship with Production Schedule Adherence, meaning that an increase in machine related problems and factors affecting raw materials will reduce production schedule adherence. Quality (r=-0.651), Planning & Process (r=-0.632) and Manpower (r=-0.522) shows a moderate relationship with Production Schedule Adherence.

TABLE 2: SHOWING MULTIPLE REGRESSION

Model	R	R Square	Adjusted R Square	Std. Error of Estimate
1	0.828	0.686	0.675	0.44974

Model	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Regression	63.522	5	12.704	62.811	<.001
Residual	29.126	144	0.202		
Total	92.648	149			

Model	**B**	**Std. Error**	**Beta**	**t**	**Sig.**	**Zero-order**	**Partial**	**Part**	**Tolerance**	**VIF**
(Constant)	6.544	0.21		31.123	<.001					
RMSCORE	-0.236	0.089	-0.213	-2.643	0.009	-0.729	-0.215	-0.123	0.337	2.965
MPSCORE	-0.058	0.078	-0.046	-0.744	0.458	-0.561	-0.062	-0.035	0.573	1.745
PPSCORE	-0.179	0.081	-0.142	-2.199	0.029	-0.635	-0.18	-0.103	0.526	1.9
QSCORE	-0.188	0.08	-0.166	-2.354	0.02	-0.681	-0.192	-0.11	0.439	2.28
MESCORE	-0.391	0.077	-0.39	-5.062	<.001	-0.773	-0.389	-0.237	0.367	2.725

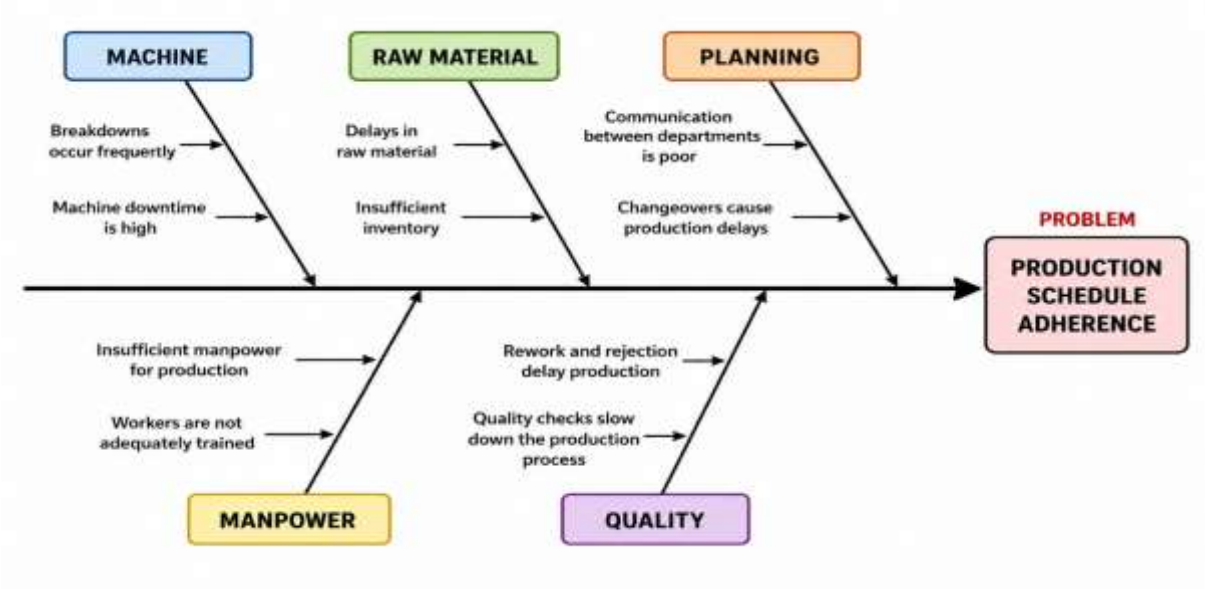
Interpretation:

To determine the effects of Machine (MESCORE), Raw material (RMSCORE), Manpower (MPSCORE), planning and process (PPSCORE) and Quality (QSCORE) on Production schedule adherence (PSASCORE), a multiple regression was carried out. The R value (0.828) of the model summary indicates that there is a strong relationship between the predictors and the response, and the R 2 (0.690) shows that 69% of the variation in Production Schedule Adherence is attributed to Machine, Raw material, Manpower, planning and process, Quality and Planning and Process. This adjusted R 2 of 0.670 suggests that 67% of the variation in production schedule adherence is accounted for by the five predictors and gives a relatively good fit with respect to number of variables, while the prediction error (standard error of estimate: 0.45) appears to be rather low. The ANOVA results revealed a significant regression model F=62.81 p<.001, which signifies that the model accurately predicts the production schedule adherence. The coefficient results demonstrate that Machine (=-0.39, p<.001) had the strongest influence and negatively on production schedule adherence and was statistically significant. Other variables which had significant but rather negative impacts on production schedule adherence were raw material (=-0.21, p=0.01), planning and process (=-0.14, p=0.03) and quality (=-0.17, p=0.02). However, Manpower (=-0.05, p=0.46) did not have any significant influence. The results from the collinearity check

showed that all the variables are within the limit where multicollinearity is not considered to be an issue in this model as the tolerance levels are > 0.1 and the VIF levels are < 5. In summary the results concluded that Machine had the strongest positive impact on production schedule adherence, followed by Raw material, quality and planning and process, while Manpower does not have any significance.

ROOT CAUSE ANALYSIS (RCA)

1. FISHBONE DIAGRAM



2. PARETO ANALYSIS

Factor	Absolute β	Percentage	Cumulative %
Machine	0.39	40.6%	40.6%
Raw material	0.21	21.9%	62.5%
Quality	0.17	17.7%	80.2%
Planning & Process	0.14	14.6%	94.8%
Manpower	0.05	5.2%	100.0%

Interpretation:

The first factor influencing the adherence to the production schedule is the performance of the machine, which is the main contributor in roughly 40% of the problems - the biggest single one by far. The second largest contributor is raw material at about 22%, which together with the first one gives a cumulated 62%. These two parameters represent more than two-thirds of the problem. The quality management contributes with 18%, which means a cumulated value of 80%. At this point it is a major finding to discover that 80% of the problem can be attributed to three parameters, (Machine, raw material, and Quality), the classic 80/20. Planning and process accounts for about 15% with a cumulated value of 95% and finally manpower has the minimum influence with 5%.

3. 5 WHY ANALYSIS

Why Step	Question	Answer
1	Why are the machines failing?	Production must halt any time machines are down during operation.
2	Why are the machines down?	They are experiencing many spontaneous breakdowns and taking a long time to be repaired.
3	Why are the machines experiencing more breakdowns and taking more time to be repaired?	There are no routine checks of equipment health or no preemptive maintenance carried out on the equipment before the break down
4	Why are there no routine checks of the equipment or no preemptive maintenance carried out?	There is no standardized system of preventative maintenance, maintenance schedule
5	Why is there no standardized system of preventative maintenance?	Maintenance has not been given as a strategic objective, and the organization has a tendency to react to meet immediate production pressures.

CAUSE OF THE PROBLEM

Absence of an organized preventive maintenance and reliability management system due to the lack of a high enough level of organizational priority being placed upon the maintenance planning process.

FINDINGS OF THE STUDY

- This research concludes that PSA in manufacturing is controlled by five key operational factors namely machine availability, raw material availability, manpower, planning & process and quality management.
- All the five factors are found to have a significant negative correlation with PSA at the 0.01 level with Spearman's correlation analysis thus concluding that the decay in any of the factors causes a decrease in the PSA.
- Machine availability (r=-0.772) shows a negative correlation with PSA and thus implies equipment related failure as the most important and principal cause of disruptions of PSA,
- The next significant factor contributing negatively is raw material availability (r=-0.714), concluding that the fluctuation and delays in raw material procurements are major obstacles for the company.
- The R value for the multiple regression model is found to be 0.690, thus concluding that the five predictors account for nearly 69% of the variation in PSA, and the fit of the model is very reliable and significant.
- The regression coefficient for machine availability is the highest (= -0.39) indicating it as the major independent predictor and Manpower (= -0.05, p=0.46) indicates it to have no independent effect on PSA.
- The combined contribution of machine availability, raw material availability and quality management contribute to nearly 80% of the total disruptions in production, this follows the 80/20 principle where focus on fewer problem areas can lead to significant changes.
- Root cause analysis using the five- why shows that repeated failure of machines is due to lack of proper planned maintenance, organization's practice is more reactive rather than planned maintenance.
- The contribution of planning & process control and quality management also indicate a negative relationship with PSA.

- Hypothesis found true where unreliability in machines and raw material availability combined with ineffective process planning led to low PSA.

PRACTICAL IMPLICATIONS

- A systematic equipment maintenance strategy consisting of planned maintenance, preventative services, and condition-based monitoring should be adopted and enforced, because uncontrolled machine breakdowns were the largest operational barrier to maintaining the production schedule adherence.
- The significant negative effects of insufficient raw materials on schedule adherence necessitate the transformation of procurement practices through developing strong supplier relationships, adopting calculable levels of safety stocks, and implementing real-time monitoring systems that initiate reorder well before critical stock-out levels occur.
- The transition from manual production planning approaches to the usage of a digital planning support system in which the uncertainty, resource constraints, and communication among various departments are incorporated into schedules is crucial for production planning teams to create an operationally accurate schedule which can be executed in practice.
- Quality-related events, such as reprocessing or product rejections, had a significantly negative impact on the performance of the schedule, and organizations should consider building defect prevention procedures and the standardization of the production processes at every level, rather than only on an inspection at the end of the process.
- The practice of using some sort of problem prioritization methodology is crucial in guiding corrective efforts and organizational resources towards the issues that have the largest effects on schedule adherence. This can be facilitated by using the Pareto principle to maximize the benefits gained from the continuous improvement efforts in schedule performance recovery.
- Formalizing and adopting problem-solving tools such as the "5 Why" in regular production review meetings helps frontline managers and production engineers to identify and remove root causes of the frequent delays rather than attempting to find solutions to the symptoms of the problem.
- The operational perspective gained in this study will serve as an actionable diagnostic checklist for operations managers, industrial engineers and operations consultants to analyze the causes of schedule deviations and design customized solutions according to their real situations.

SUGGESTIONS

- Establish an effective preventive maintenance schedule/standardized procedures to eliminate unintended machine downtime and increase equipment dependability.
- Implement a real time tracking and alert system to monitor raw material levels and supplier lead times so that material can be ordered in time before it is completely depleted and impact the production.
- Deploy an advanced production planning system that combines machine availability, workforce available and the readiness of material to form the schedule.
- Implement dedicated quality assurance at all major stages to trace and eliminate defects at the root of the production process, hence reducing rework and unintended production stops.
- Introduce cross functional workforce training to develop multi-skill workers so that it does not create problem to the production schedule if a worker is absent or not skilled.
- Conduct Pareto-based operation review meetings regularly among production supervisor, maintenance engineer, quality officer and supply chain officers to check the disruption trend and re-channel the improvement efforts.
- Promote a continuous improvement culture through the application of root cause analysis techniques to frontline staff and supervisors on regular basis, such that the problem underlying causes of production delays are solved permanently, not just superficially.

CONCLUSION

This study addressed the key operational determinants that lead to Production Schedule Adherence in the manufacturing industries through the well-defined quantitative study with 150 respondents. Five different operational dimensions i.e. Machine, material, manpower, planning and process and quality control are analysed based on independent and collective impacts on the ability of the manufacturing industries to meet their targeted plans on scheduled basis.

The results of the investigation show that machine has been the highest impact operational determinant for schedule adherence followed by material, quality control and planning and process. Based on multiple regression it was found that all five dimensions collectively contributes 69% for the fluctuation in Production Schedule Adherence, it proves the fact that all the elements are interdependent and complex with relation to schedule adherence in industrial environment. Pareti based disruption analysis revealed that 80% of all production disruptions are caused due to machine, material and quality control and therefore all organizations must address all three factors on priority to focus the corrective investment.

The root cause of frequent machine breakdown found through Five Why analysis is that lack of organized preventive maintenance system together with tendency of the organization to solve machines break down reactively instead of preventively, clearly shows that improvement on process and technology will not show the fruitful results without consistent and organizational will and commitment for future actions.

In the concluding part it can be said that continuous Production Schedule Adherence is possible only by disciplined effort and management of machines reliability, material supply, quality management and planning, as four operational aspects which organization must maintain on daily priority and strive for continuous improvement. With these three dimensions, companies will reduce the production loss and enhance their efficiency in meeting customer’s requirements and achieve competitive advantage over long term.

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