Available at https://journalenrichment.com/index.php/jr/

Enrichment Journal of Multidisciplinary Research and Development

Enrichment: Journal of Multidisciplinary Research and Development

Minimizing Production Defects in Bolts Using The Economic Production Quantity (EPQ) Method at PT. Platindo Makmur Sentosa

Yordan Prayoga
Universitas Buddhi Dharma Tangerang, Indonesia
Email: yogaprayoga172@gmail.com

Keywords:
Product Quality; Quality Control; Product Defects; Economic Production Quantity (EPQ)

ABSTRACT

Product defects in the manufacturing industry remain a critical challenge because they affect production efficiency, operational costs, and customer satisfaction. PT. Platindo Makmur Sentosa, a bolt manufacturing company, faces challenges related to high defect rates, inefficient production planning, and difficulties in determining optimal production quantities. This study aims to identify the causes of bolt production defects, evaluate the production process, and determine the economical production quantity using the Economic Production Quantity (EPQ) method to minimize defects and improve production efficiency. This research employed a descriptive quantitative approach supported by direct observation, interviews, production data collection, and literature reviews. The analysis was conducted through defect identification, Pareto analysis, Fishbone Diagram analysis, and EPQ calculations based on production data from October to November 2023. The results showed that the main causes of defects were associated with human factors, materials, methods, machinery, and environmental conditions. The highest defect contributions were found in the FH 12×3 ZINC and TSAK 8×2.1/2 ZINC bolt types. The implementation of the EPQ method reduced production setup frequency and significantly decreased defect rates. For FH 12×3 ZINC bolts, defects decreased by 494 grams (25%), while TSAK 8×2.1/2 ZINC bolts experienced a reduction of 522 grams (45.5%). In conclusion, the EPQ method effectively optimizes production quantities, reduces defects, and improves operational efficiency. The company is recommended to implement structured production planning, conduct regular machine maintenance, and provide operator training to sustain continuous quality improvement.

INTRODUCTION

Bolt productivity is increasing due to growing domestic and international consumer demand, and many industrial companies are beginning to establish their businesses in developing countries, particularly Indonesia. Many industrial companies strive to provide products at affordable prices to meet customer needs. Additionally, companies must consider product price, production capacity, and quality. To compete effectively with rivals in the industrial sector, businesses must pay attention to these critical factors.

Bolts are commonly used as fasteners or connectors between two components and are essential elements in machinery (Christian & Wijaya, 2024). Bolt joints are widely used in bridge construction, buildings, machinery, automobile assembly, heavy vehicles, and various other industries. Bolt connections function not only as component fasteners but also as force transmission elements that integrate separate parts into a solid structure. Compared with welding or riveting processes, bolt-and-nut connection methods have the advantage of being relatively safe and easy to disassemble. However, they also have limitations, such as the possibility of loosening when subjected to external loads. Bolt joints are susceptible to two types of failure: static failure and dynamic failure. Static failure may occur due to excessive loading, over-tightening, or product defects, whereas dynamic failure occurs due to material fatigue over an extended period (Suhardjo et al., 2023).

According to Nuansa (2022), product quality is a strategic advantage that can enable companies to outperform competitors. Only companies that maintain superior product quality can grow rapidly and achieve long-term success. Therefore, improving product or service quality is an important challenge for companies seeking to compete in the international market.

Production planning involves forecasting and scheduling activities that consider costs and available resources. According to Giovana (2020), companies can implement aggregate planning to achieve cost efficiency, optimize resource utilization, and improve production planning. This method estimates demand, facility capacity, labor availability, and production inputs to support effective decision-making.

PT. Platindo Makmur Sentosa is a company operating in the metal industry that specializes in bolt production. The company currently faces several challenges, including a high number of defects in each production process, difficulties in determining optimal production quantities, and the absence of planned production quantities for each bolt type. This study is limited to the bolt production process, which is evaluated based on the physical condition of the products, with calculations performed using the Economic Production Quantity (EPQ) method. The objectives of this research are to identify the production process methods, determine the average number of defects, improve production planning, and establish economical production quantities.

Quality control is an activity closely related to the production process (Cipta et al., 2023; Mulyana & Zuliana, 2019). Quality control refers to a system used to maintain and regulate the quality of processes or products by applying appropriate tools and designing procedures according to established standards (Leuveano et al., 2023; Nobil et al., 2026). Corrective actions and inspections are continuously performed to ensure product quality (Suhartini, 2021). As a managerial and engineering function, quality control requires comparing product requirements with actual performance and implementing appropriate preventive measures to ensure that products function as intended (Nabila, 2020).

According to Ayu and Sari (2019), quality control is a strategy implemented by businesses to produce high-quality products. The proper implementation of quality control has a significant impact on the quality of final products. If a company's products do not meet predetermined specifications, they are categorized as defective, and the company must analyze the causes of defects to minimize similar occurrences in the future (Erry et al., 2019).

Yudha (2022) defines product quality as the overall characteristics of a product or service that enable it to satisfy stated and implied customer needs. Quality is a crucial factor because it influences customer perceptions and interactions with a company, as customers evaluate a company based on the quality of products or services provided (Sinta, 2023).

Product quality encompasses all aspects provided by manufacturers that are visible, functional, purchasable, and consumable by consumers according to specific requirements (Lubis, 2022).

The Economic Production Quantity (EPQ) inventory model is applied in companies where raw materials or components are produced internally rather than purchased externally (Cahyani & Mawadati, 2022; Mulyana, 2023). Unlike the Economic Order Quantity (EOQ) model, which assumes instantaneous replenishment, the EPQ model assumes that the production rate exceeds the consumption rate ($P > D$). The EPQ model is also referred to as the Fixed Production Quantity (FPQ) model because it applies a fixed and consistent production rate. This model aims to minimize inventory costs, including setup costs and holding costs (Sitohang, 2023).

Holding costs are expenses associated with maintaining inventory over a certain period, including costs related to obsolete products, warehousing, insurance, and interest expenses (Nazilatus, 2021). Setup costs refer to expenses incurred in preparing equipment or processes to fulfill production requirements, including cleaning, adjustment, and replacement of tools and equipment (Etwin, 2023). The basic formula for calculating EPQ is as follows:

$$\mathbf{Q^* = \sqrt{[2DS/H(1 - D/P)]}}$$

Description: Q^* = Optimal production quantity, D = Demand rate per year, S = Set-up cost, H = Storage cost per unit per year, P = Production rate per year.

Study Review

Table 1. Study Review – Relevant Previous Research

Yes	Author & Year	Research Title	Method	Results / Conclusion
1	Nazilatus Sa'idah, et al. (2021)	Analysis of Bag Raw Material Inventory Control in UD. Wijaya with EOQ and EPQ Methods	EOQ and EPQ	EOQ and EPQ result in optimal control of CCI and D300 bag fabric inventory while minimizing overall inventory costs at UD. Wijaya.
2	Hanifah Ekawati, et al. (2020)	Application of EPQ (Economic Production Quantity) Method in Laundry Raw Material Control at Android-Based Samarinda Laundry Mart	Economic Production Quantity (EPQ)	The EPQ method minimizes monthly expenses by identifying the ideal quantity and frequency of raw material production at Samarinda Laundry Mart.
3	Astri Remasari, et al. (2020)	Analysis of Raw Material Inventory Control with EOQ and EPQ Methods on Cinta Brownies in Karanganyar	EOQ and EPQ	Inventory costs with EOQ and EPQ methods are more efficient than the company's conventional methods.
4	Susanti (2022)	Analysis of the Application of the Economic Order Quantity Method as an Effort to Control Raw Material Inventory in UD. Immanuel Tompaso Baru	Qualitative Descriptive – EOQ	EOQ can determine the optimal purchase quantity, the right buyback time, and reduce the total cost of inventory compared to the company's method.
5	Waldeshan Sitohang (2023)	Analysis of Quality Control of Robusta Special Coffee	SPC and Root Cause Analysis	The dominant defects were in the form of torn plastic packaging (39%) and coarse

		Production Using Statistical Process Control and Root Cause Analysis Methods at UD Tanpak Sidikalang		coffee powder (36%); Causative factors include humans, machines, and materials.
6	Mulyana (2023)	Analysis of Production Quantity and Total Production Cost Using EPQ and EOQ Methods	EPQ and EOQ	The EPQ method produces an optimal production quantity of 43,657 units/month with a total cost of IDR 7,176,177.3, more efficient than EOQ.
7	Etwin Fibrianie, et al. (2023)	Economic Production Quantity (EPQ) Model with Continuous and Discrete Demand Synchronization in East Kalimantan River Fish Cracker Production	Economic Production Quantity (EPQ)	The ideal delivery cycle time to agents is twice per year with an average production cost of IDR 3,336,750 per period.
8	M. Rifqi (2022)	Utilizing Economic Order and Production Quantity Methods to Analyze Inventory Control and Optimize Production	EOQ and EPQ	Ideal output of dried walnut bread: 112.85 kg/cycle (2019), 108.77 kg/cycle (2020), and 111.11 kg/cycle (2021).
9	Gita Evangelista (2024)	Fresh Fruit Bunch Inventory Control with EOQ and EPQ Methods	EOQ and EPQ	EOQ and EPQ TIC are lower than corporate TIC; EOQ savings of IDR 1.14 trillion and EPQ of IDR 417.35 billion.
10	Reza Khairul Hadi (2024)	The Effect of Service Quality and Product Quality on Consumer Satisfaction at PT. Airmas Perkasa	Quantitative Associative	The quality of service and product quality have a positive and significant effect on the consumer satisfaction of PT. Airmas Perkasa.
11	Lania, Marhaendra, Beby (2023)	Decision Model and Industry Optimization in Production: A Systematic Literature Review	EOQ, EPQ, and Kanban	The EPQ method is the most efficient with a production cost efficiency of 96.56% compared to EOQ (99.02%) and Kanban (99.97%) in fried shallot producers.
12	Nuances (2022)	Fuzzy EPQ Model Considering Demand Uncertainly, Imperfect Quality, and Backorder: A Case Study in a Goat Milk SMEs	EPQ (Fuzzy)	The fuzzy EPQ model was able to reduce the total cost of powder goat's milk inventory by IDR 30,957,900 or a saving of 4.23%.
13	Giovana (2020)	Effect of Service Quality, Product Quality and Price on Customer Satisfaction	Descriptive Analysis	The 74.30% variability of consumer satisfaction can be explained by the price, product quality, and service quality at Oto Bento restaurant.
14	Thessaloniki (2022)	Analysis of Raw Material Inventory Control Using Economic Order Quantity (EOQ) for Furniture	EOQ	The use of EOQ saves the total cost of raw material inventory up to IDR 13,486,411 for furniture

		Manufacturing Company in Indonesia		manufacturing companies.
15	Almenia Lubis (2022)	Applying The Economic Order Quantity (EOQ) Method for The Control and Supply of Sheep Feed Raw Materials in PT. Eldira Fauna Asahan	EOQ	The EOQ application helps companies determine the amount of raw material requirements efficiently and makes it easier to process order data.

METHOD

Profile of PT. Platinum Makmur Sentosa

PT. Platindo Makmur Sentosa began its operations in 2002 under the management of PT. Riasarana, initially focusing on bolt finishing processes, including phosphating and plating. In 2009, the company expanded its operations by establishing a bolt manufacturing facility equipped with two heading machines and two rolling machines. Over time, the company increased its production capacity and currently operates 13 heading machines and 15 rolling machines.

PT. Platindo Makmur Sentosa operates in the metal manufacturing industry, specializing in bolt production. The company has an organizational structure consisting of Supervisors/Personnel, Head of Production, Quality Control (QC), Administration/Cashier, Head of Warehouse, Technicians, Warehouse Operators, Packing Staff, Cleaning Staff, and Security Personnel.

Data Types and Data Collection Techniques

The types of data used in this study are primary data and secondary data. Primary data was obtained directly through: (1) Survey and field observation by directly looking at the condition of the bolt production process of PT. Platindo Makmur Sentosa, including labor conditions, production machinery, spare parts replacement, and production planning; (2) Interviews with production managers or employees to verify the state of the field; (3) Discussion of issues related to the bolt production process, types of product errors, and challenges during production. Secondary data was collected through a literature review from books, research papers, theses, and scientific journals (Fita, 2021).

Research Stages

The research stages are carried out systematically and organized, including: (1) identification of defect problems in bolt production; (2) collection of production and reject data in the field; (3) analysis of the causes of rejection using the Fishbone Diagram; (4) data processing using the Economic Production Quantity (EPQ) method; (5) implementation and evaluation of EPQ calculation results; and (6) preparation of conclusions and recommendations for improvement. The study was conducted for 8 weeks, from the first week of October to the last week of November 2023.

RESULTS AND DISCUSSION

Observation Data and Product Type

The data obtained in the observation is in the form of the number of production products and defects from the bolt production process. Observations were carried out directly to the field with production operator PT. Platinum Prosperous Sentosa. PT. Platindo Makmur

Sentosa produces four main types of bolts that are the object of the study, presented in Table 2.

Table 2. Bolt Product Types of PT. Platinum Makmur Sentosa

Yes	Bolt Name	Code/Dimension (Example)	Main Uses
1	Hexagonal Bolts	FH 6×1/2 ZINC, FH 8×1/2 ZINC-H, FH 12×3 ZINC, FH 6×1 ZINC	Common fasteners in the construction, machinery, and assembly of heavy vehicles; hexagonal head.
2	Car Bolts	PAB 6×1 ZINC+, DW 6×3/4 GRY-H, DW 6×2 GRY-H, DW 6×1.1/2 GRY-H	Used in steel and bridge construction joints; has a rounded head with a square-shaped neck.
3	Machine Bolt	TSAT M4×8 Zinc-H, TSAK 8×2.1/2 ZINC, TSAK 10×3 ZINC, TSAK 8×38 ZINC	Precision machine bolts for assembly of machine components, industrial equipment, and automotive.
4	Screw Bolts / JP	FHS 6×1 (−) Polos, JP M3×9 ZINC, JP M4×8 ZINC, JP M6×30 ZINC	Bolts with head grooves for screwdrivers; used in panel assembly, electronics, and light equipment.

Bolt Production Operating Process Map (PPO)

The Operation Process Map (PPO) is an overview of the flow of the bolt production process in order from start to finish. The bolt production process at PT. Platindo Makmur Sentosa consists of 13 stages which can be described as follows:

Table 3. Operation Process Map (PPO) of PT. Platinum Makmur Sentosa

Yes	Process Stages	Activity Description
1	Production Warrant	The production department issues a warrant containing product specifications, manufacturing procedures, facilities used, and production period to the relevant departments.
2	Raw Material Inspection	Verify the suitability of raw materials in the warehouse with production planning, including the adequacy of quantities and the fulfillment of the company's steel wire quality standards.
3	Machine Tools Inspection	Check the completeness of machine tools before production: Thread Rolling Dies (thread former), Cutting Dies (wire cutter), and Heading Dies (bolt head former).
4	Creation of Check Sheets	Engineers make test bolt samples which are sent to customers for approval before mass production begins.
5	Heading Process	The wire is cut from the coil to the specified size, then the bolt head is formed using Trim Dies and Cutting Dies on the Heading machine.
6	Quality Control Heading	Checking the bolt dimensions of the Heading process uses sigmats (calipers) to ensure conformity with the specification standards.
7	Slotting Process	Formation of a gap or circular cavity in the center of the bolt head for screw bolt type.
8	Rolling Process	The bolts from the Heading process are transferred to the Rolling machine for thread formation (drat) on the bolt body using Rolling Dies.
9	Quality Control Rolling	Rolling quality check using a scale to ensure the suitability of the weight and dimensions of the bolt thread.
10	Hardening Process	The bolts are heated to an austenitization temperature, held for a specified time, and then cooled to increase the hardness of the steel material.

11	Quality Control Hardening	Hardening hardness testing of bolts using a press machine to verify the achievement of the specified hardness specifications.
12	Drying Process	Drying of bolts from residual coolant (coolant) that is inherent during the production process.
13	Packing Process	The bolts are weighed to the specified weight, wrapped in plastic, and then packed in cardboard as a ready-to-ship product to be shipped to customers.

Production Data of Heading Process per Week

Based on observations on the Heading production process obtained in the data for the first week of October to the last week of November 2023, production data per week is presented in Table 4. The unit of production used is kilogram (kg).

Table 4. Production Data Process Heading per Week (kg)

Yes	Bolt Type	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
1	FH 6x1/2 ZINC	37,20	126,37	256,24	253,95	247,11	127,53	0,00	15,25
2	FH 6x1 ZINC	108,88	0,00	0,00	0,00	0,00	0,00	0,00	0,00
3	FH 8x1/2 ZINC-H	0,00	50,78	163,27	100,64	0,00	0,00	0,00	0,00
4	FH 12x3 ZINC	536,70	0,00	976,60	1.214,60	251,20	0,00	477,60	0,00
5	DW 6x3/4 GRY-H	0,00	125,04	232,57	197,43	227,72	26,93	0,00	0,00
6	DW 6x2 GRY-H	440,75	534,12	512,80	374,41	0,00	0,00	0,00	0,00
7	FHS 6x1 (-) Polo Shirts	0,00	0,00	0,00	23,01	325,82	140,64	0,00	0,00
8	PAB 6x1 ZINC+	241,38	0,00	121,29	294,33	305,18	210,43	0,00	0,00
9	TSAT M4x8 Zinc-H	242,79	257,02	232,73	246,51	160,31	0,00	0,00	0,00
10	STEEL 8x2.1/2 ZINC	193,60	806,50	717,77	149,55	0,00	0,00	81,10	512,04
11	TSAK 8x1.1/4 ZINC	77,10	0,00	0,00	0,00	0,00	0,00	0,00	0,00
12	TSAK	474,80	632,30	600,80	132,60	0,00	0,00	0,00	0,00

	8x1.3/4 ZINC								
13	TSAK 8x38 ZINC	0,00	0,00	0,00	278,08	0,00	0,00	331,56	1.496,20
14	ZINC 8x3 STEEL	0,00	0,00	0,00	0,00	45,90	0,00	58,80	382,81
15	ZINC 8x2 STEEL	0,00	0,00	0,00	0,00	0,00	0,00	0,00	101,27
16	ZINC 10x3 STEEL	0,00	0,00	0,00	0,00	708,10	1.065,80	126,10	0,00
17	JP M3x9 ZINC	0,00	0,00	0,00	0,00	0,00	80,44	111,23	77,07
18	JP M4x8 ZINC	0,00	0,00	0,00	0,00	0,00	0,00	76,02	54,10
19	JP M4x12 ZINC	0,00	0,00	203,72	14,11	0,00	0,00	0,00	0,00
20	JP M6x30 ZINC	0,00	0,00	0,00	292,38	0,00	0,00	0,00	0,00
21	Pin Plug 80x28 Nickel	852,83	530,70	0,00	0,00	0,00	0,00	0,00	0,00
TOTAL		**3.206,03**	**3.062,83**	**4.017,79**	**3.571,60**	**2.271,34**	**1.651,77**	**1.262,41**	**2.638,74**

Rolling Process Production Data per Week

Based on observations on the rolling production process obtained in the data for the first week of October to the last week of November 2023, production data per week is presented in Table 5. The unit of production used is kilogram (kg).

Table 5. Rolling Process Production Data per Week (kg)

Yes	Bolt Type	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
1	DW 6x3/4 GRY-H	226,69	54,67	105,29	246,28	448,00	133,43	0,00	0,00
2	DW 6x2 GRY-H	698,14	888,96	537,40	597,49	0,00	0,00	0,00	0,00
3	DW 6x1.1/2 GRY-H	22,09	67,40	0,00	0,00	0,00	0,00	0,00	0,00
4	FH	81,96	40,04	189,86	214,93	197,72	153,02	58,19	0,00

	6x1/2 ZINC								
5	FH 8x1/2 ZINC-H	0,00	0,00	18,35	245,49	52,28	0,00	0,00	0,00
6	TSAT M4x8 Zinc-H	81,96	67,90	97,89	91,84	73,23	65,96	73,89	66,64
7	STEEL 8x2.1/2 ZINC	0,00	588,60	818,08	63,10	226,10	0,00	0,00	469,80
8	TSAK 8x1.3/4 ZINC	0,00	60,80	890,90	491,20	0,00	0,00	0,00	131,60
9	TSAK 8x38 ZINC	0,00	0,00	0,00	215,90	0,00	0,00	209,13	1.099,80
10	ZINC 8x3 STEEL	0,00	0,00	0,00	0,00	0,00	0,00	0,00	272,10
11	ZINC 8x2 STEEL	0,00	0,00	0,00	0,00	0,00	0,00	0,00	106,21
12	ZINC 10x3 STEEL	0,00	0,00	0,00	0,00	712,40	1.054,90	245,90	0,00
13	FH 12x3 ZINC	566,30	14,31	0,00	1.771,30	601,40	0,00	476,10	0,00
14	FH 8x2.1/2 ZINC	0,00	0,00	0,00	0,00	459,20	0,00	0,00	0,00
15	FHS 6x1 (-) Polo Shirts	0,00	0,00	0,00	0,00	0,00	174,67	250,90	0,00
16	PAB 6x1 ZINC+	368,93	361,04	269,33	215,24	224,74	333,29	7,84	0,00
17	PH 6x3/8 ZINC-H	0,00	0,00	0,00	0,00	0,00	0,00	39,11	93,80
18	FH 6x1 ZINC	188,74	0,00	0,00	11,61	32,42	3,11	0,00	0,00
19	JP M3x9 ZINC	0,00	0,00	0,00	0,00	0,00	52,30	47,50	58,75
20	JP M4x8 ZINC	0,00	0,00	0,00	0,00	0,00	0,00	40,23	56,61
21	JP M4x12	0,00	0,00	152,76	46,74	0,00	0,00	0,00	0,00

	ZINC								
22	JP M6x30 ZINC	0,00	0,00	0,00	294,30	0,00	0,00	0,00	0,00
23	Pin Plug 80x28 Nickel	802,50	568,50	0,00	0,00	0,00	0,00	0,00	0,00
TOTAL		**3.037,31**	**2.712,22**	**3.079,86**	**4.505,42**	**3.027,49**	**1.970,68**	**1.448,79**	**2.355,31**

Total Production and Reject Analysis

Based on the results of data processing during 8 weeks of observation, an analysis was carried out using the Pareto Chart to determine the most influential causes that must be resolved to reduce reject. The results of the analysis show that there are 21 types of bolts produced with a total Heading production of 21,682.51 kg and a total reject of 218.20 kg during the October-November 2023 period. A summary of total production and rejection for the Heading process is presented in Table 6.

Table 6. Total Production Output and Rejection Heading Process – October to November 2023

Yes	Bolt Type	Total Production (kg)	Total Reject (kg)	Percentage Reject (%)	BS/Item	Remarks
1	FH 6x1/2 ZINC	1.063,65	10,13	0,95	0,29–2,19	Production is quite stable
2	FH 6x1 ZINC	108,88	0,84	0,77	0,84	Production only 1 week
3	FH 8x1/2 ZINC-H	314,69	2,66	0,85	0,44–1,38	Production is not weekly
4	FH 12x3 ZINC	3.456,70	36,31	1,05	4,13–11,58	Highest reject (need attention)
5	DW 6x3/4 GRY-H	809,69	7,16	0,88	0,45–2,02	Fluctuates between weeks
6	DW 6x2 GRY-H	1.862,08	15,49	0,83	3,12–4,64	First 4 weeks of production
7	FHS 6x1 (-) Polo Shirts	489,47	5,43	1,11	0,19–2,88	Last 5 weeks of production
8	PAB 6x1 ZINC+	1.172,61	11,56	0,99	1,02–3,52	Quite consistent
9	TSAT M4x8 Zinc-H	1.139,36	9,54	0,84	1,42–2,23	Stable and consistent
10	STEEL 8x2.1/2 ZINC	2.460,56	22,60	0,92	1,25–7,00	Large and fluctuating production
11	TSAK 8x1.1/4 ZINC	77,10	0,59	0,77	0,59	Production only 1 week
12	TSAK 8x1.3/4 ZINC	1.840,50	15,32	0,83	1,11–5,49	Stable production 4

						weeks
13	TSAK 8x38 ZINC	2.105,84	24,48	1,16	2,32–14,12	Reject increases in the final week
14	ZINC 8x3 STEEL	487,51	5,44	1,12	0,41–3,61	Last 4 weeks of production
15	ZINC 8x2 STEEL	101,27	0,96	0,95	0,96	Limited production
16	ZINC 10x3 STEEL	1.900,00	27,13	1,43	3,06–17,81	Very high reject (need attention)
17	JP M3x9 ZINC	268,74	4,77	1,77	0,73–2,70	Last 4 weeks of production
18	JP M4x8 ZINC	130,12	2,35	1,81	0,51–1,84	Limited production
19	JP M4x12 ZINC	217,83	1,84	0,84	0,12–1,72	3 weeks production
20	JP M6x30 ZINC	292,38	2,44	0,83	2,44	Production only 4 weeks
21	Pin Plug 80x28 Nickel	1.383,53	11,18	0,81	4,61–6,57	First 2 weeks of production
	TOTAL	**21.682,51**	**218,20**	**1,00**	–	

Based on the results of the Pareto Chart analysis, the two types of bolts with the most rejections are FH 12x3 ZINC type bolts (BS/Item: 36.31 kg) and TSAK 10x3 ZINC (BS/Item: 27.13 kg), so that these two types are the focus of improvement analysis using the Fishbone Diagram.

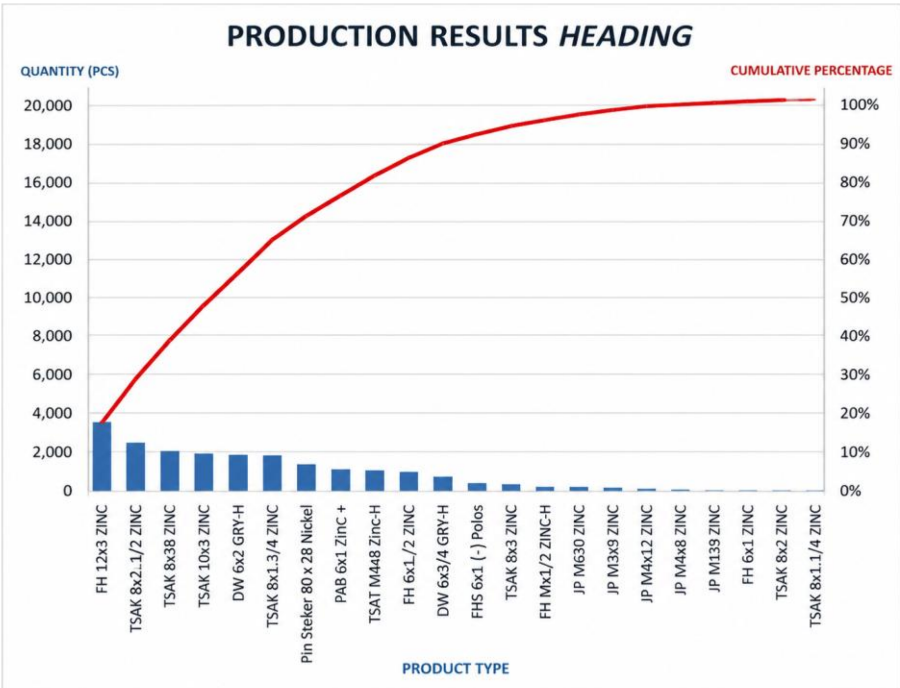

Figure 1. Heading Production Pareto Chart and BS Heading Production Pareto Chart

Fishbone Analysis Diagram

The analysis of the causes of defects in bolt production was carried out using the Fishbone Diagram. Based on the results of field observations, the cause of bolt production defects was identified through 5 main factors (5M) as follows:

(1) Man: Operator negligence in scheduling irregular Mold Dies changes, clogged Water Coolant (coolant), and warehouses that provide non-standard or imitation parts to technicians.

(2) Material: Poor quality wire material causes breakage during bolt head formation and cutting. The use of cheap Water Coolant accelerates the wear of dies and cutting.

(3) Method: The operator is not meticulous in the order of the production process, the replacement of spare parts and dies is not according to the specified time, and the production planning is irregular.

(4) Engine: The condition of the engine that is too old causes the performance to be not optimal. Until 2023, the machines at PT. Platindo Makmur Sentosa is classified as no longer suitable for operation, resulting in frequent errors that damage other parts.

(5) Environment: The condition of the dark, noisy, and hot place makes the operator not focus on paying attention to the production results, aggravated by the operator who is not always on standby in the production room.

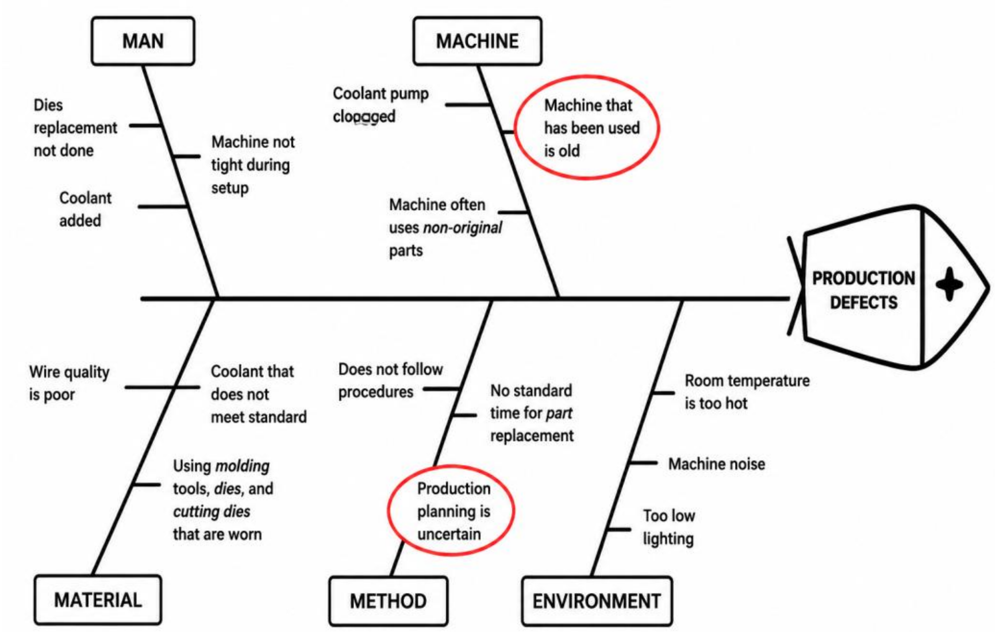

Figure 2. Fishbone Diagram Analysis of Causes of Bolt Production Defects

Data Processing with EPQ Method

Based on observations in the field, defect quality control on FH 12x3 ZINC and TSAK 8x2.1/2 ZINC type bolts is only carried out by weighing once a week. Further analysis using EPQ (Economic Production Quantity) is needed to make it easier to find the highest cause of defects and conduct a repair analysis.

Set-Up Costs

Set-up costs are the cost of preparing equipment and facilities so that they can be used to produce certain products or components. The calculation of set-up costs consists of three components:

Electricity Consumption (Setting Time = 30 seconds, Electrical Energy = 1.1 kWh, Price/kWh = Rp 1,114.74):

$$= 1.1 \text{ kWh} \times \text{IDR } 1{,}114.74 \times 0.5 \text{ hours} = \text{IDR } 613.11$$

Operator Salary (Salary/day = IDR 75,000, Working Hours/month = 173 hours, Setting Time = 30 minutes):

$$= (\text{IDR } 75{,}000 / 173) \times 0.5 \text{ hours} = \text{IDR } 216.76$$

Raw Materials (Weight 1 Pcs = 9.88 grams, Raw Material Price/kg = Rp 17,000):

$$= (9.88 / 1{,}000) \times \text{IDR } 17{,}000 = \text{IDR } 1{,}679.60$$

Total Set-Up Cost = IDR 613.11 + IDR 216.76 + IDR 1,679.60 = **IDR 2,509.47**

EPQ Calculation Input Data

The data used for the EPQ calculation was taken from production data for the October–November 2023 period for the two bolt types with the most rejections, presented in Table 7.

Table 7. Economic Production Quantity (EPQ) Calculation Input Data

Product Name	D (kg/year)	P (kg/year)	S (Set-Up Fee, Rp)	H (Storage Fee/year, Rp)
FH 12x3 ZINC	17.283,5	59.754,2	2.509,4	2.098,2
STEEL 8x2.1/2 ZINC	12.302,8	31.570,5	2.509,4	2.450,8

EPQ Calculation of Type FH 12x3 ZINC

Known: D = 17.283.5 kg/year; P = 59,754.2 kg/year; d = 72 kg/day; p = 248.9 kg/day; S = IDR 2,509.4; H = IDR 2,098.2. Calculation:

$$Q^* = \sqrt{[2 \times 17{,}283.5 \times 2{,}509.4 / 2{,}098.2 \times (1 - 17{,}283.5 / 59{,}754.2)]} = 241.2 \text{ kg}$$

$$t \text{ (time between set-ups)} = Q^*/D = 241.2 / 17{,}283.5 = 0.012 \text{ years} = 2.9 \text{ days} \approx 3 \text{ days}$$

$$tp \text{ (production cycle time)} = Q^*/P = 241.2 / 59{,}755.2 = 0.004 \text{ years} = 0.9 \text{ days}$$

$$Imax = (P - D) \times tp = (59{,}755.2 - 17{,}283.5) \times 0.01 = 424.7 \text{ kg}$$

$$TC0 = \sqrt{[2H \times (1 - D/P) \times D \times S]} = \sqrt{[2 \times 2{,}098.2 \times (1 - 17{,}283.5/59{,}755.2) \times 17{,}283.5 \times 2{,}509.4]} = \text{Rp } 359{,}667.5/\text{Year}$$

Results: With the EPQ method, FH 12x3 ZINC type bolts only took 7 days to produce a monthly demand of 1,728.4 kg with a production reject of 646 grams, more efficient than without EPQ which required 16 days with a reject of 1,581 grams.

Calculation of 8x2.1/2 ZINC Type Blank EPQ

Known: D = 12,302.8 kg/year; P = 31,570.5 kg/year; d = 51 kg/day; p = 131.5 kg/day; S = IDR 2,509.47; H = IDR 2,450.77. Calculation:

$$Q^* = \sqrt{[2 \times 12{,}240 \times 2{,}509.47 / 2{,}450.77 \times (1 - 12{,}240/31{,}570)]} = 202.33 \text{ kg}$$

$$t \text{ (time between set-ups)} = 202.3 / 12{,}240 = 0.02 \text{ years} = 4.9 \text{ days} \approx 5 \text{ days}$$

$$TP \text{ (Production Cycle Time)} = 202.3 / 31{,}570.5 = 0.006 \text{ years} = 1.4 \text{ days}$$
$$Imax = 202.3 \times (1 - 12{,}240/31{,}570) = 123.9 \text{ kg}$$
$$TC0 = \sqrt{[2 \times 2{,}450.77 \times (1 - 12{,}302.8/31{,}570) \times 12{,}302.8 \times 2{,}509.47]} = \text{Rp } 381{,}350/\text{year}$$

Results: With the EPQ method, the TSAK 8x2.1/2 ZINC type bolt only took 4.8 days to produce a monthly demand of 1,230.28 kg with a production reject of 248 grams, more efficient than without EPQ which required 21 days with a reject of 1,096 grams.

Calculation Simulation – Comparison of Results

The simulation was carried out to compare production results using the company's method (before EPQ) and the EPQ method (after EPQ) using the same data from the October-November 2023 period. A comparison of results is presented in Table 8.

Table 8. Comparison of Production Results Before and After the Implementation of the EPQ Method

Remarks	Company Method (Before EPQ)			EPQ Method (After EPQ)		
	Total Production (kg)	Jml. Set-Up	Total Defect (gr)	Total Production (kg)	Jml. Set-Up	Total Defect (gr)
FH 12x3 ZINC	3.456,70	20 times	1.976	3.618,00	15 times	1.482
STEEL 8x2.1/2 ZINC	2.460,60	22 times	1.148	2.427,00	12 times	626

Based on Table 8, the set-up efficiency achieved is: (1) FH Type 12x3 ZINC: reduced from 20 to 15 set-up times (efficiency of 5 set-ups), with production yields close to previous (–161.3 kg or almost equivalent); (2) TSAK Type 8x2.1/2 ZINC: reduced from 22 to 12 set-ups (efficiency of 10 set-ups) with an increase in production output (difference +33.6 kg).

The defect comparison that can be simulated is the defect of the engine setting result (Set-Up), where each machine setting has a maximum of 10 pcs of defect bolts. The defect efficiency is presented in Table 9.

Table 9. Defect Efficiency Before and After the Implementation of the EPQ Method

Bolt Type	Defect Before EPQ (gr)	Defect After EPQ (gr)	Defect Efficiency (gr)	Efficiency Percentage (%)
FH 12x3 ZINC	1.976	1.482	494	25,00
STEEL 8x2.1/2 ZINC	1.148	626	522	45,50

From Table 9, it can be seen that the EPQ method was able to reduce defects in FH 12x3 ZINC type bolts by 494 grams (25%) and TSAK 8x2.1/2 ZINC type bolts by 522 grams (45.5%). This proves that the implementation of EPQ can significantly minimize defects in the bolt production process at PT. Platinum Prosperous Sentosa.

Production Area Layout Improvements

Layout is one of the key decisions that determine long-term operational efficiency and has strategic implications in capacity, process, flexibility, cost, and quality of work. Layout conditions before repairs at PT. Platindo Makmur Sentosa shows several inefficiencies: (1) 1 operator manages 1 production machine; (2) The QC room is not near the production area; (3) Irregular arrangement of machines, making it difficult for operators to do work.

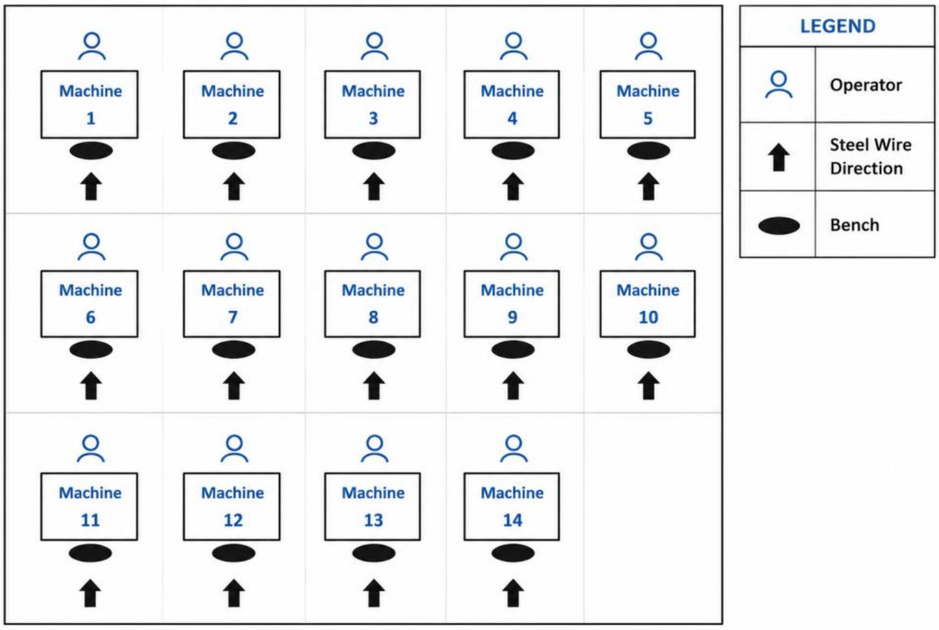

Figure 3. Production Area Layout Before Repair

After the layout improvement (referring to Figure 4), the changes made include: (1) 1 operator holding 2 production machines, improving labor efficiency; (2) QC rooms are placed in the production area to speed up quality checking; (3) Face-to-face machine arrangement, making it easier for operators to monitor the ongoing production process; (4) M6 Type machines are integrated with a more structured steel wire arrangement to optimize the production flow.

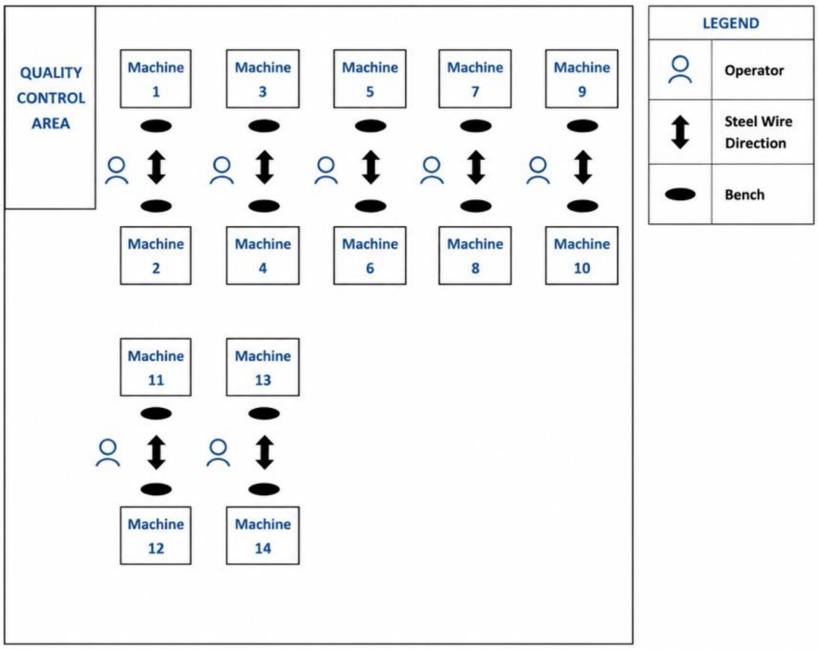

Figure 4. Production Area Layout After Repair

CONCLUSION

Based on the results of the research and data processing conducted at PT. Platindo Makmur Sentosa, it can be concluded that the bolt production process begins with a 6 mm wire raw material that is processed through a Heading machine for bolt head formation using Trim Dies and Cutting Dies. The process continues with a Rolling machine for thread formation using Rolling Dies and proceeds through a series of quality control, hardening, drying, and packing processes. The number of bolt production defects during the eight observation weeks from October to November 2023 averaged 12.5% of the total production output. These defects were caused by man factors (operator and warehouse negligence), material factors (low-quality wire and water coolant), method factors (irregular production planning), machine factors (aging machine conditions), and environmental factors (less supportive workplace conditions). The application of the Economic Production Quantity (EPQ) method has proven effective in minimizing defects. For FH 12x3 ZINC-type bolts, the set-up frequency was reduced from 20 to 15 times, resulting in a defect reduction efficiency of 25% (494 grams). Meanwhile, for TSAK 8x2.1/2 ZINC-type bolts, the set-up frequency was reduced from 22 to 12 times, resulting in a defect reduction efficiency of 45.5% (522 grams). The application of the EPQ method also resulted in more economical production quantities by optimizing machine utilization. As a recommendation, companies are advised to conduct regular inspections based on standard operating procedures for each component, replace original machine parts periodically, initiate repair actions through structured planning stages, and provide regular retraining for operators to ensure that production processes run smoothly and comply with the established production schedules.

REFERENCES

Ayu A., & Sari, M. S. (2019). Quality Control of Arabica Coffee Production Process at UD. Cipta Lestari in Pujungan Village Using the Six Sigma Method. Journal of Engineering, Vol. 8, No. 4.

Cahyani, C. I., & Mawadati, A. (2022). Analysis of Raw Material Inventory Control Using Economic Order Quantity (EOQ) for Furniture Manufacturing Company in Indonesia. *ICSET: International Conference on Sustainable Engineering and Technology*, *1*(1), 28–33.

Christian, C., & Wijaya, E. (2024). The Effect of Brand Awareness, Brand Image, and Product Quality on Consumer Satisfaction of Oppo Smartphone Users in Pekanbaru. *Nexus Synergy: A Business Perspective*, *1*(4), 207–219.

Cipta, H., Aprilia, R., & Kurniawan, H. (2023). Material requirements planning method for controlling inventory of raw materials. *Jurnal Teknik Informatika CIT Medicom*, *15*(1), 1–8.

Erry R., Beny D., & Faizin, M. N. (2019). Analysis of Quality Control to Reduce Defect Products in Steel K-015 Cable Using DMAIC Method at PT. Sucaco, Tbk. International Journal of Innovative Science and Research Technology, Vol. 4, No. 8.

Etwin F., Dwi C., & Andi F. H. (2023). Economic Production Quantity (EPQ) Model with Continuous Demand and Discrete Demand Synchronization in East Kalimantan River Fish Cracker Production. Journal of Applied Science, Vol. 4, No. 1, 36–58.

Evangelista G. (2024). Control of Fresh Fruit Bunch Inventory with Economic Order Quantity and Economic Production Quantity Methods. Scientific Journal of Mathematics, Vol. 13, No. 3, 23–35.

Fita A. (2021). The Contribution of Sharia Marketing Ethics During the Pandemic in Increasing Family Income. Sultan Maulana Hasanuddin State Islamic University, Banten.

Hadi, R. K. (2024). The Effect of Service Quality and Product Quality on Consumer Satisfaction at PT. Airmas Perkasa. Journal of Science, Vol. 7, No. 2, 89–101.

Hanifah E., Pitrasacha A., & Yunita. (2020). Application of the EPQ (Economic Production Quantity) Method in the Control of Laundry Raw Materials at Samarinda Laundry Mart Based on Android. ISSN Journal, Vol. 22, No. 1.

Lania, M., Marhaendra, & Beby. (2023). Decision Model and Industry Optimization in Production: A Systematic Literature Review. Medan International Conference on Economics and Business, Vol. 1, 67–80.

Leuveano, R. A. C., Asih, H. M., Ridho, M. I., & Darmawan, D. A. (2023). Balancing inventory management: Genetic algorithm optimization for a novel dynamic lot sizing model in perishable product manufacturing. *Journal of Robotics and Control (JRC)*, *4*(6), 878–895.

Lubis, A. (2022). Applying The Economic Order Quantity (EOQ) Method for The Control and Supply of Sheep Feed Raw Materials in PT. Eldira Fauna Asahan. International Journal of Innovative Science and Research Technology, Vol. 3, No. 3, 657–664.

Mulyana, A. E., & Zuliana, I. (2019). Economic order quantity method approach in raw material inventory control for a small medium enterprise. *International Conference On Applied Science and Technology 2019-Social Sciences Track (ICASTSS 2019)*, 129–133.

Nabila, K. (2020). Quality control analysis using Six Sigma and improvement methods with Kaizen. Journal of Industrial and Technology Management, Vol. 01.

Nazilatus S., Muhammad Z. F., & Hidayat. (2021). Analysis of Bag Raw Material Inventory Control at UD. Wijaya with EOQ and EPQ Methods. ISSN Journal, Vol. 8, No. 4, 1–15.

Nobil, A. H., Afshar Sedigh, A. H., Cárdenas-Barrón, L. E., Nobil, E., Céspedes-Mota, A., & Treviño-Garza, G. (2026). A review paper on the economic lot scheduling problem with the common cycle approach. *RAIRO-Operations Research*, *60*(3), 1325–1355.

Nuances. (2022). Fuzzy EPQ Model Considering Demand Uncertainly, Imperfect Quality, and Backorder: A Case Study in a Goat Milk SMEs. P-ISSN 1693-2102, Vol. 15, No. 2.

Rifqi, M. (2022). Utilizing the Economic Order and Production Quantity Method to Analyze Inventory Control and Optimize Production. I-Tabaos, Vol. 2, No. 2, 57–94.

Sitohang, W. (2023). Analysis of Quality Control of Robusta Special Coffee Production Using Statistical Process Control and Root Cause Analysis Methods at UD. Tanpak Sidikalang. ARTI Journal, Vol. 18, 55–78.

Suhardjo, S., Renaldo, N., Sevendy, T., Wahid, N., & Cecilia, C. (2023). Customer Satisfaction with Online Food Delivery Services. *Luxury: Landscape of Business Administration*, *1*(2), 90–101.

Suhartini. (2021). Analysis of Production Quality Control to Reduce Defects in Shoe Products Using Six Sigma and Kaizen Methods. Journal of Industrial Management & Engineering, Vol. XXI.

Susanti. (2022). Analysis of the Application of the Economic Order Quantity Method as an Effort to Control Raw Material Inventory in UD. Immanuel Tompaso Baru. Journal of Scientific Horizons, Vol. 1, No. 4, 23–44.