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Analysis of Labor Productivity Using Marvin E. Mundel's Partial Productivity Measurement Method in Ammonia Production at PT. X

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ABSTRACT

To maintain competitiveness and efficiency in the chemical manufacturing industry, particularly in large-scale continuous ammonia production, optimal labor management is essential. This study analyzes labor productivity in the ammonia production process at PT.X, specifically in the Ammonia 1A production unit, using the partial productivity measurement method. The primary objective is to measure the contribution of labor to production output and identify the factors that cause productivity fluctuations. The method employed compares ammonia output with labor input for the period of January to December 2024. In addition, downtime analysis and a fishbone diagram were utilized to evaluate the root causes of productivity decline. The results indicate significant fluctuations in labor productivity, with the highest value recorded in November (775.8 tons/person) and the lowest in September (412.79 tons/person). The decrease in productivity is attributed to labor shortages, equipment failures, and suboptimal work procedures. The average productivity index during the observation period was 97.17%, reflecting a decline compared to the base month. These findings provide a foundation for strategic recommendations to improve workforce management and enhance operational efficiency.

Keywords: *Ammonia, efficiency, labor, Marvin e. Mundel method, productivity.*

Introduction

In an era of globalization and increasingly intense industrial competition, companies are required to continuously enhance efficiency and effectiveness across all production lines. One of the primary indicators for evaluating operational performance is the level of labor productivity. Every organization faces competition; thus, it is essential for companies to utilize their resources efficiently to generate optimal output. Labor is one of the most vital resources influencing production capacity, as the number of available workers directly determines the volume of products that can be produced [1] [2]. Productivity not only reflects the efficiency of human resource utilization, but also plays a crucial role in maintaining competitiveness and business sustainability, particularly within strategic industrial sectors such as chemical fertilizer manufacturing [3]. PT X is one of the ammonia-producing companies in Indonesia that plays a key role in supporting national food security. The company is responsible for producing 1,000 tons of liquid ammonia per day as the primary raw material for urea fertilizer production. The ammonia production process at PT X is complex, continuous, labor-intensive, and highly dependent on the performance of workers at every operational stage. Throughout its operations, the company faces challenges in maintaining consistency and increasing productivity amidst various operational dynamics.

One recurring issue is fluctuations in labor productivity, caused by several factors, including a shortage of workers in the production line. Insufficient labor results in imbalanced workloads, increased pressure on existing employees, and decreased work efficiency. In addition, factors such as low discipline, limited supervision, inadequate training, and demanding working conditions also contribute to decreased individual and team performance [4] [5]. To address these challenges and obtain an accurate understanding of labor contribution to production outcomes, an appropriate and specific measurement method is required. This study, entitled "Labor Productivity Analysis Using Partial Productivity Measurement Method in Ammonia Production at PT X," aims to measure the extent of labor contribution to ammonia production output and identify the factors contributing to productivity fluctuations. Therefore, applying this method to a large-scale, technology-intensive ammonia production process at PT X is highly relevant. The findings of this research are expected to provide strategic recommendations for improving workforce performance, optimizing operational processes, and strengthening the company's position within the national fertilizer industry.

Productivity is an approach that involves various disciplines to establish effective objectives and develop efficient methods for utilizing resources without reducing quality. In general, productivity is understood as the comparison between the output produced and the resources used. The term *"productivity"* first appeared in a scientific article written by Quesnay, a French mathematician, in 1766. However, the term did not receive a formal definition until a century later, in 1883, when another French academic, Littre, defined it as *"faculty to produce,"* meaning the ability to generate output. Although simple and concise, this definition remains widely accepted due to its clarity and ease of understanding [6]. Furthermore, productivity can be classified into three types: total productivity, total-factor productivity, and partial productivity [7]. Productivity measurement can be conducted using various methods, one of which is the productivity index approach developed by Marvin E. Mundel. In this method, the productivity index is calculated using the formula [8] :

$$Index\ Productivity = \frac{Aggregate\ Output\ in\ the\ measured\ period}{Aggregate\ Input\ in\ the\ base\ period} \times 100\% \quad (2)$$

The Summath Theory, developed in 1984, states that a formal concept known as the productivity cycle was introduced as a tool to continuously improve productivity. This cycle consists of four interconnected stages that repeat continuously [9] [10]:

1. Productivity Measurement
2. Productivity Evaluation
3. Productivity Planning
4. Productivity Improvement

The elements that influence productivity include efficiency, effectiveness, and quality. Efficiency refers to the comparison between the planned input and the actual input used in the production process. Effectiveness focuses on the level of goal achievement in terms of results, quality, and time. Meanwhile, quality reflects the extent to which the output meets technical standards and consumer expectations. These three elements support each other in creating optimal and sustainable productivity [11] [12].

Research Methods

This study employs a quantitative descriptive approach to analyze labor productivity in the ammonia production process at PT X. The research focuses on the Ammonia 1A production unit and uses the partial productivity measurement method developed by Marvin E. Mundel to evaluate the contribution of labor to production output. The selection of Marvin E. Mundel's productivity measurement method is based on its suitability for industrial environments that have stable production flows and clearly measurable inputs. According to Sumanth (1984), input–output–based productivity indices are effective for monitoring productivity changes over time because they are simple yet informative. Given the continuous and operation-intensive nature of ammonia production, as well as its strong dependence on workforce performance in each shift, this measurement approach becomes the most relevant and replicable for PT X, where labor input and production volume are consistently recorded and can be analyzed systematically.

Data Collection

The data used in this study consists of secondary data obtained from company production records and operational documents. The data include:

1) Monthly ammonia production output (tons)
2) Number of workers involved in the production process.
3) Downtime records and operational disruptions

The observation period covers January to December 2024. For the purpose of index calculation, January 2024 is designated as the base period because it represents the starting point of the annual operational cycle and provides a consistent benchmark for comparing monthly productivity changes throughout the year [13]. The results of this study include:

1) Productivity index trends
2) Factors contributing to productivity fluctuations
3) Strategic recommendations for workforce and operational improvements

Productivity Formula

Labor productivity is calculated using the partial productivity formula [13]:

$$Partial\ Productivity = \frac{Output}{Labor\ Input} \quad (1)$$

Productivity measurement can be conducted using various methods, one of which is the productivity index approach developed by Marvin E. Mundel. In this method, the productivity index is calculated using the formula [14] [15]:

$$Productivity\ Index = \frac{Aggregate\ Output\ in\ the\ measured\ period}{Aggregate\ Input\ in\ the\ base\ period} \times 100\% \quad (2)$$

Results and Discussion

Data Ammonia Production

Table1. presents the demand and actual production data of ammonia at PT X for the period January to December. The purpose of this analysis is to observe the alignment between market demand and actual production output, as well as to evaluate workforce productivity performance based on the accuracy in meeting production targets.

Table 1. Monthly labor and production performance

Month	Labor	Demand (TON)	Actually (TON)	Description
January	44	24.467	26.942,62	Achieved
February	44	22.701	25.879,46	Achieved
March	44	25.340	28.971,91	Achieved
April	44	24.457	28.620	Achieved
May	44	26.214	28.917,13	Achieved
June	44	25322	27167,2	Achieved
July	44	26204	27478,8	Achieved
August	40	26204	24534,1	Not Achieved
September	38	25332	15686,1	Not Achieved
October	38	26214	24902,6	Not Achieved
November	36	25331	27928,7	Achieved
December	36	26214	27116	Achieved

Employee Structure in the K1A Ammonia Unit

The Ammonia 1A Production Department consists of various positions distributed across several groups, ranging from Supervisor to Field Operator E. Each position is assigned across four separate groups: Group A, B, C, and D. Every group is composed of individuals responsible for specific duties, including Supervisors, Foremen, Senior Field Operators, as well as Panel and Field Operators. This division of tasks aims to ensure smooth operational continuity and work efficiency in each unit through clear and structured role distribution. Moreover, workers continue to receive their rights to overtime pay when working hours exceed the established limits, and the company is obligated to provide adequate rest time, implement fair shift rotations, and ensure strict supervision of occupational health and safety [16]. The table provides a comprehensive overview of the employee structure in the K1A Ammonia project and illustrates how tasks and responsibilities are organized within each group.

Table 2. Job and task allocation table

No	Job	A	B	C	D
1	SPV	S.1	S.2	S.3	S.4
2	FRM	F.1	F.2	F.3	F.4
3	Senior Lap	SL.1	SL.2	SL.3	SL.4
4	Opt. Pan A	OPA.1	OPA.2	OPA.3	OPA.4
5	Opt. Pan B	OPB.1	OPB.2	OPB.3	OPB.4
6	Opt. Pan C	OPC.1	OPC.2	OPC.3	OPC.4
7	Opt. Lap A	OPLA.1	OPLA.2	OPLA.3	OPLA.4
8	Opt. Lap B	OPLB.1	OPLB.2	OPLB.3	OPLB.4
9	Opt. Lap C	OPLC.1	OPLC.2	OPLC.3	OPLC.4
10	Opt. Lap D	OPLD.1	OPLD.2	OPLD.3	OPLD.4
11	Opt. Lap E	OPLE.1	OPLE.2	OPLE.3	OPLE.4

Each group has clearly defined assignments and responsibilities. However, there are vacancies in several positions, as indicated in each group, resulting in incomplete staffing for certain roles. These vacancies are caused by several factors, such as employees transferring to other departments, retirement, and official duty assignments. As a result, the number of employees listed in this table ranges between 36 and 44 people, depending on the month and the respective group. From June to July, the workforce was still fully staffed with approximately 44 employees. However, in October, the number of employees decreased by eight, resulting in a total of 36 employees. Despite this, the work distribution remains structured to ensure smooth operations and efficiency, while considering the effective management of available human resources.

The following presents the monthly calculation details (as a sample calculation) based on the output and input data of PT X:

1) January

$$Partial\ Productivity\ = \frac{Output}{Labor\ Input} = \frac{26{,}942}{44} = 612{,}3 \quad (3)$$

$$Productivity\ Index = \frac{612{,}3}{612{,}3} \times 100\% = 100\%\ \text{(Base)} \quad (4)$$

2) February

$$Partial\ Productivity\ = \frac{Output}{Labor\ Input} = \frac{25{,}879}{44} = 588 \quad (5)$$

$$Productivity\ Index = \frac{588}{612{,}3} \times 100\% = 96.03\% \quad (6)$$

Table 3. Monthly productivity recapitulation

No	Month	Labor	Output	AOMP	IP (%)
1	January	44	26.942,62	612,33	100
2	February	44	25.879,46	588,17	96,03
3	March	44	28.971,91	658,45	107,56
4	April	44	28.620,78	650,47	106,23
5	May	44	28.917,13	657,21	107,33
6	June	44	27.167	617,44	100,83
7	July	44	27.479	624,52	101,98
8	August	40	24.534	613,35	91,08
9	September	38	15.686	412,79	58,22
10	October	38	24.902	655,33	92,44
11	November	36	27.928	775,8	103,65
12	December	36	27.116	753,22	100,64
Total & Average			**314.145**	**6,349,233**	**9,716,583**

Based on the recap of labor productivity data over one year, the AOMP (Average Output per Manpower) and IP (Productivity Index) indicators show fluctuations in productivity from month to month. The productivity index uses a base year value of 100, meaning that an index value above 100 indicates an increase compared to the base period, whereas an index value below 100 indicates a decrease in productivity [17] [18]. The highest AOMP value occurred in November, reaching 775.80 tons per person, followed by December with 753.22 tons per person, reflecting highly optimal work efficiency toward the end of the year.

Meanwhile, the lowest AOMP value was observed in September at 412.79 tons per person, which also coincided with the lowest IP value of 58.22%, indicating a significant productivity decline compared to the base month (January). The highest IP values were recorded in March (107.56%), May (107.33%), and April (106.23%), showing improvements relative to the base period. On the other hand, the lowest IP value, as noted earlier, occurred in September (58.22%), indicating a sharp drop in labor productivity. Overall, the annual average IP stood at 97.17%. Since the base index value is set at 100, this average suggests that productivity experienced a slight decline over the year. Although the decrease is not highly significant, it indicates that the company has not yet consistently maintained productivity improvement throughout each month.

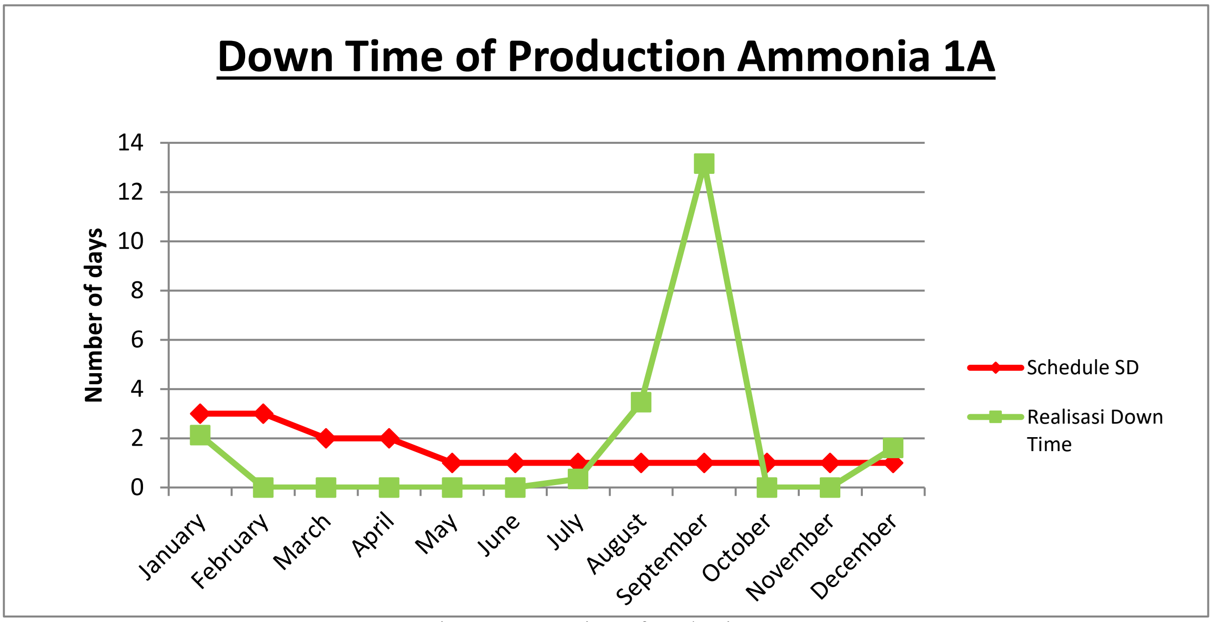

Figure 1. Downtime of production

The graph above illustrates a comparison between the Production Shutdown Work Plan (RKAP SSD) and actual downtime from January to December 2024. The planned shutdown (RKAP SSD), shown in red, is stable at one day per month, except in October and November where no planned shutdown occurred, indicating effective preventive maintenance planning. Meanwhile, the actual downtime, shown in green, fluctuated significantly and had a direct impact on ammonia production performance at PT X.

A major increase in downtime occurred in August (3.46 days) and peaked in September (13.15 days), caused by severe vibration issues in compressor units and start-up failures. These disruptions resulted in extended production stoppages far beyond the planned shutdown schedule. In contrast, June, July, October, November, and December experienced minimal downtime, showing that operations ran smoothly during those months. The downtime data table confirms these fluctuations. Minor disruptions occurred in July (0.34 days), followed by critical shutdowns in August and September due to high vibration failures in compressor systems. No shutdowns occurred in February, March, April, May, October, and November, representing stable operating conditions. In December, downtime reached 1.6 days due to a tube leak requiring repair until early January 2025.

To analyze the root causes of productivity decline, a fishbone diagram was used, categorizing the causes into four main factors: Machine, Manpower, Material, and Method [19] [20]. The dominant cause of extended downtime was machine-related issues, especially compressor vibration problems that led to repeated shutdowns and unplanned operational interruptions.

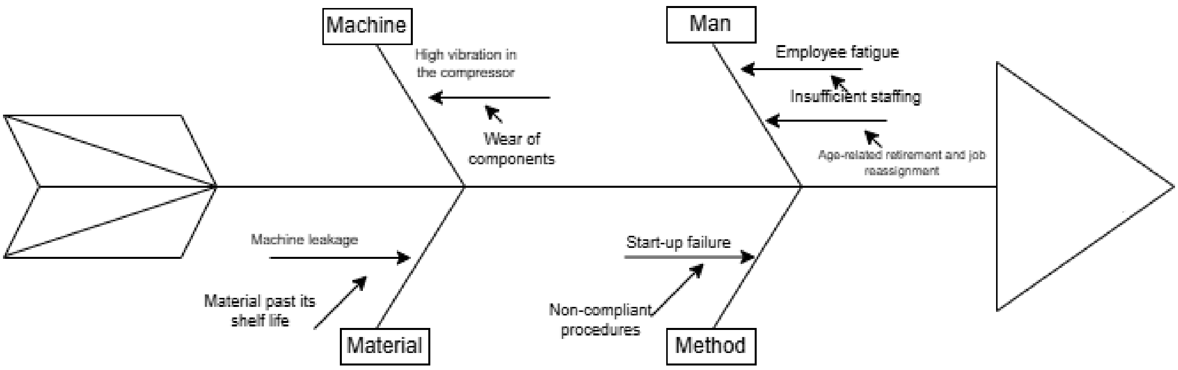

Figure 2. Fishbone diagram of productivity decline

Figure 2 illustrates the key factors causing productivity decline in ammonia production at PT X, classified into four categories: Machine, Manpower, Material, and Method**.** The primary issue under *Machine* is high vibration in compressor units (105-J, 101-J, and 103-J), which frequently triggered system trips and caused extended downtime. In the *Manpower* category, insufficient skilled workers during certain shifts led to unbalanced workloads and reduced operational efficiency. *Material* issues include component leaks, such as tube 1114-CA, requiring production shutdowns for repairs. Meanwhile, *Method* problems involve inadequate operational procedures and preventive maintenance, contributing to equipment failures. Overall, these factors collectively disrupted operations and lowered productivity. Improving machine maintenance, workforce competency, material reliability, and operating procedures is essential to reduce downtime and enhance production performance.

Suggested Action Plan Summary

Based on the analysis of production data, employee structure, partial labor productivity calculations, and downtime in the Ammonia 1A production unit at PT X throughout 2024, it can be concluded that labor productivity experienced considerable fluctuations. Although several months, such as March, April, and May, showed productivity improvements compared to the base month (January), the overall average annual productivity index was 97.17%, indicating a decline in productivity. The most significant decrease occurred in September, coinciding with the longest downtime recorded at 13.15 days, caused by severe technical disruptions to production machinery, particularly the radial compressors.

Table 4. Table of action plan

Factor	Issue	Why It Occurs	Improvement Plan
Machine	Compressor trips due to high vibration	Delayed maintenance, insufficient monitoring	Increase maintenance frequency; install better vibration sensors
Manpower	Lack of skilled personnel on some shifts	Uneven manpower allocation; limited training	Conduct operator training; rebalance shift assignments
Material	Leaks in gaskets and pipes	Aging or damaged components	Regular material inspection; replace aging parts proactively
Method	Suboptimal operating & maintenance procedures	Outdated SOPs; limited evaluation	Update SOPs; conduct regular performance reviews

Additionally, productivity was affected by a reduction in workforce due to rotation, retirement, or external assignments, which led to vacant positions in several groups. Furthermore, based on the fishbone analysis, the decline in productivity was influenced by machine-related issues (damage and high vibration), labor constraints (insufficient personnel), material quality concerns (supporting materials), and suboptimal operational and maintenance methods.

Conclusion

The analysis of labor productivity in the Ammonia Production 1A unit reveals notable fluctuations throughout the January–December 2024 observation period. The partial productivity assessment indicates that productivity peaked in November at 775.8, while the lowest value occurred in September at 412.78, reflecting substantial month-to-month variability. Rather than displaying a consistent upward or downward pattern, productivity showed irregular oscillations driven by operational instability. The Productivity Index (PI) further reinforces this condition, with several months performing below the January 2024 baseline, most notably August (91.08%) and September (58.22%) while later months such as November and December demonstrated recovery through improved index values.

These variations stem from several contributing factors identified through the Fishbone Diagram analysis, including machinery performance, workforce capability, material readiness, and operational methods. Recommended improvement efforts therefore include increasing the frequency of routine maintenance (Machine), enhancing operator training and adjusting labor allocation (Man), ensuring timely replacement of components and supporting materials (Material), and standardizing as well as periodically reviewing operating procedures (Methods).

Collectively, these findings confirm that labor productivity in ammonia production is highly influenced by operational conditions and resource management. Consequently, the study successfully achieves its objectives of measuring the contribution of labor to ammonia output through productivity indices and identifying the underlying causes of productivity fluctuations.

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