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Case study article

Analysis of pipe material classification using the MUSIC-3D method in the oil and gas industry

Erwin Shafira Winoto*, Nabila Noor Qisthani

Logistics Engineering, Telkom University, Jl. DI Panjaitan No, 128, Purwokerto Sel. 53147, Jawa Tengah, Indonesia

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ABSTRACT

The oil and gas industry plays a crucial role in meeting global energy needs, significantly impacting sectors like energy, manufacturing, and transportation. Managing material inventory effectively is vital to keeping production processes running smoothly. Pipes, which are essential for transporting fluids and gases, come into various materials, sizes, and specifications, making accurate classification a must. To prioritize material needs efficiently, a thorough classification based on historical usage data is essential. This study explores how to set material priorities and develop inventory control policies using the MUSIC-3D method, which combines ABC, SDE, and FSN analyses. Our findings show that 45 materials fall into the very high-priority category, 91 are moderately high priority, and just 1 is low priority. These classifications help shape inventory policies by evaluating material criticality, procurement lead times, and usage rates. We suggest adjusting parameters like Economic Order Quantity (EOQ), Safety Stock (SS), Reorder Point (ROP), and ordering schedules to balance material availability with cost efficiency. This approach ensures that critical materials are always on hand while keeping storage costs and procurement risks to a minimum.

1. Introduction

Oil and gas processing is an industry that plays a strategic role in meeting global energy needs, especially since energy is a vital component behind nearly all human activities [1], [2]. Beyond supporting national economic growth, this industry also helps ensure global energy stability, which is essential for keeping various sectors of life running smoothly [3]. Turning crude oil into valuable products like fuels, lubricants, and petrochemicals involves complex operations that demand precision and sustainability at every step [4], [5].

The success of this production process relies heavily on efficient material management. A key part of this is managing the inventory of raw materials and supporting components, ensuring they're available when needed and in the right amounts [6]. Without a solid inventory control system, there's a real risk of production hiccups—whether from running out of materials or having too much unused stock—disrupting the entire process [7]. That's why well-planned and effective material management is crucial for keeping operations steady and boosting production efficiency.

The oil and gas industry operates on a massive scale, supporting key economic sectors like energy, manufacturing, and transportation [8]. To keep its operations running, this sector depends on a wide range of materials—everything from primary raw materials and supporting components to tools and machinery that keep each production stage flowing smoothly [9].

Inventory management is crucial for ensuring that all these materials are available when needed, not just in the upstream and downstream phases of oil and gas drilling [10], but also throughout the distribution process. This involves planning, procuring, and managing the specifications of every material used in production. Done right, good material management ensures that production needs are met on time and in the right amounts, preventing disruptions that could slow down efficiency [11]. The biggest challenge here is keeping materials available efficiently, especially with demand fluctuations and unpredictable market

*Corresponding author:
Email: eshafiraaa@student.telkomuniversity.ac.id

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dynamics [12]. By truly understanding these material needs, companies can procure smarter, cut waste, avoid operational hiccups, and make sure every material is ready whenever it's needed.

One of the key materials needed is pipes. These play a vital role in transferring products, safely and efficiently moving fluids and gases from one place to another. The wide range of functional needs has led to the use of various pipe materials to support the production process. The complexity of these materials—due to differences in types, sizes, and specifications—calls for a more accurate and comprehensive classification approach based on historical usage data [13]. Often, classification analysis only focuses on how fast or slow materials move, which doesn't fully capture the detailed priorities and needs of the materials. A more thorough classification can optimize pipe material inventory management, making operations more sustainable and effective.

That's why controlling the availability of these materials is so important. They need to be available in the right quantities and in good condition to avoid disruptions and downtime that could seriously affect production. Too much inventory (overstock) can mean high storage costs and the risk of materials going obsolete or sitting unused. On the flip side, a stockout can halt production because essential components aren't available. Either way, the result is lower productivity, delays in hitting production targets, and potentially big financial losses. By preventing both overstock and stockouts—whether it's raw materials, work-in-process, or finished goods—the company can boost customer satisfaction [14].

The combination of material classification methods with a three-dimensional inventory approach can help companies figure out the best priorities and policies for inventory control. The MUSIC-3D method is a technique that analyzes product categories across three dimensions, making it easier and faster for stakeholders to manage inventory [15]. This approach can pair up with other categorization techniques—like ABC-SDE-FSN or ABC-FSN-XYZ—to cut inventory costs even further. So, using a multi-dimensional method like MUSIC-3D gives a fuller picture of inventory dynamics, leading to smarter management practices compared to the usual ABC analysis.

In this study, we'll use the ABC, SDE, and FSN classification methods to group items based on usage value, consumption rate, and lead time for material procurement [16]. The ABC method helps companies prioritize inventory control and plan effectively by looking at usage levels and monetary value [17]. The SDE method (Scarce, Difficult, Easy) sorts materials by how hard they are to get [18], while the FSN method (Fast, Slow, Non-moving) tracks how often materials are used each year [19], [20]. Combining these three methods leads to more precise inventory management, planning, and control [21], giving the company a solid foundation for shaping material inventory strategies [22].

2. Material and method

2.1. Research flow

The research flow consists of a series of systematic steps designed to meet the study's objectives. It acts as a roadmap for the research process, guiding us from the starting point to the finish line, with each step logically and purposefully linked. This study includes several well-organized stages to ensure that data is collected, analyzed, and classified accurately, supporting smart inventory management decisions.

The first step is data collection and processing, which lays the groundwork for analysis and decision-making. We gather data through methods like interviews, observations, and secondary sources to capture all the relevant details. This data becomes the main input for the classification process that follows. Once the data is ready, the next step is mapping it based on key parameters for classification analysis. These include total order value to gauge a material's economic impact, order quantity to spot demand patterns, lead time to figure out procurement timelines, order frequency to see how often a material is requested, and usage frequency to track its consumption rate in production. This mapping lets us evaluate each material systematically based on its traits, paving the way for a structured, data-driven classification.

After that, we analyze the data using three core classification methods: ABC, SDE, and FSN. ABC analysis sorts materials by usage volume and investment value, SDE analysis groups them by procurement lead time, and FSN analysis categorizes them based on usage rate. When the classification is done, we pull the results from each method into a single summary for a clearer, more complete picture. Then, we calculate the MUSIC-3D score, which combines the ABC, SDE, and FSN analyses. This score acts as a guide to prioritize materials in inventory management. By using this method, companies can fine-tune their inventory strategies, balancing economic value, availability, and usage rates effectively.

2.2. Inventory control

Inventory or stock is raw materials or finished goods that are stored to be ready for use in the future [23]. According to Taylor and Russel in [24], inventory is the stock of goods kept by a company, institution, or organization to meet customer demand, both internal and external. Inventory is used to ensure the smooth operation of the company's processes, making inventory an important aspect for any company or organization [25]. Inventory control is a series of activities that must be carried out by every company to monitor the inventory it possesses so that no issues related to inventory occur [26], [27]. Material inventory control becomes a very important aspect to pay attention to because it encompasses 20% to 40% of the total assets owned by the company, especially those engaged in the manufacturing sector [28]. The goal of

inventory control is to prevent the company from experiencing shortages or excesses in the stock of materials used in the production process or other company operations, which could eventually lead to the cessation of the company's production or operations [16]. Additionally, inventory control is also carried out to maintain the quantity of inventory so that the costs related to inventory can be optimized [18], [29].

2.3. *Multi Unit Spares Inventory Control-Three Dimensional (MUSIC-3D)*

MUSIC-3D is a method for grouping materials or spare parts required in the production process, evaluated from multiple perspectives based on a company's specific needs [30], [31]. Research by Sharda and Gorana [32] highlights several approaches within this method, which align with various inventory analysis techniques designed to manage materials efficiently.

These techniques include ABC analysis, which groups items by their economic contribution based on value usage; HML (High, Medium, Low) analysis, which distinguishes materials by their unit price, separating costly from inexpensive ones; and VED (Vital, Essential, Desirable) analysis, which prioritizes materials according to their criticality to operations. Similarly, SDE (Scarce, Difficult, Easy) analysis identifies materials that are rare or challenging to procure based on the procurement process, while GOLF (Government, Ordinary, Local, Foreign) analysis assesses payment terms depending on supplier locations, such as government, local, or foreign sources. Additionally, SOS (Seasonal, Off-Season) analysis differentiates materials needed seasonally, and FSN (Fast, Slow, Non-Moving) analysis categorizes them by consumption rate, distinguishing between fast-moving and slow or non-moving items.

MUSIC-3D is a combination of several categories above to classify the company's material inventory by considering several aspects according to the company's needs and conditions [16]. Each classification result from each category will be assigned a value according to its priority level, where 3 means highly prioritized, 2 means moderately prioritized, and 1 means can be ignored under certain conditions [33].

Table 1.
MUSIC-3D classification category

No	MUSIC-3D Score	Criteria
1	≥7	Very high priority
2	≤6	Moderate priority
3	≤3	Can be ignored

Table 2.
SDE analysis category

Category	Lead Time
Scarce (S)	>180 days
Difficult to Get (D)	≤180 days
Easy (E)	<30 days

Each value from the classification will be summed up and will produce a score for the MUSIC-3D classification as shown in Table 1.

2.4. *ABC analysis*

According to Ginting in [16], ABC analysis is one of the classification or grouping methods of materials based on the value of material usage per time (price per unit multiplied by the volume of material usage in a certain period). The ABC classification method uses the Pareto concept, which states that approximately 80% of the total value of material inventory is represented by 20% of the inventory materials [26], [34]. In this method, materials are classified into three categories as follows [30].

2.5. *SDE analysis*

SDE analysis is a method of classifying inventory materials based on the lead time of procurement from the managed inventory [30]. There are three categories in SDE analysis, as shown in Table 2.

2.6. *FSN Analysis*

FSN analysis is a method of classifying materials based on the consumption rate or usage of a material [16]. This method is carried out by identifying the rate of material usage or how many times the material is used within a period (usually one year) [30], [35]. The categories in this method are divided into three: Fast, Slow, and Non-Moving.

3. Results and discussions

3.1. *Identification of inventory*

The inventory data in this study includes pipe material data consisting of various items identified by material number. Each material item has its own specifications, ranging from order quantity, total usage, price per unit, to lead time. The identification of the inventory data is shown in Table 3.

It is known that there are 137 pipe materials in the inventory data managed by the inventory department. In addition, an attachment detailing the material usage and purchase data is also required in this analysis to determine the usage frequency and purchase frequency of each material item.

3.2. *Inventory classification using ABC analysis*

The ABC Analysis method is an inventory classification method based on usage value. In this study, the usage value of material items over the past four years was calculated. The aspects considered in the calculation are total material usage, quantity ordered, total order value, value per unit, value usage, and percentage usage.

Table 3.
ABC analysis results

Material		Usage	Value/unit (IDR)	Value (IDR)	%	Cum.	Category
Code	Description						
H560500187	PIPE,CS,A106,B,SML,BE,40,6IN,6M	731	5,864,428	4,286,896,790	14.75	14.75	A
H560504921	PIPE:LN,SS,A312,TP316L,SML,BE,40,8IN,6M	37	58,190,211	2,153,037,816	7.41	22.16	A
H560500184	PIPE,CS,A106,B,SML,BE,40,4IN,6M	576	2,970,480	1,710,996,276	5.89	28.05	A
…	…	…	…	…	…	…	…
H560902347	PIPE,SS,A312,TP316,SML,PE,40S,3/4IN,6M	0	4,563,000	-	0.00	100.00	C

Table 4.
SDE analysis results

Material Number	Material Desc.	Lead Time (day)	Freq. (time)	Avg. Lead Time (day)	Category
H560500170	PIPE,CS,A106,B,SML,BE,40,1.1/2IN,6M	567	3	189	S
H560500171	PIPE,CS,A106,B,SML,BE,80,1.1/2IN,6M	201	1	201	S
H560500187	PIPE,CS,A106,B,SML,BE,40,6IN,6M	2596	10	260	S
…	…	…	…	…	…
H560920422	PIPE,6"S,40,SML,5592MM,A335,P5,13MM,22ST	0	0	0	E

Table 5.
FSN analysis results

Material Number	Material Desc.	Freq. (times)	Freq. per Year	Category
H560500167	PIPE,CS,A106,B,SML,PE,80,1IN,6M	6	2	F
H560500171	PIPE,CS,A106,B,SML,BE,80,1.1/2IN,6M	6	2	F
H560500173	PIPE,CS,A106,B,SML,BE,40,2IN,6M	11	3	F
…	…	…	…	…
H560902347	PIPE,SS,A312,TP316,SML,PE,40S,3/4IN,6M	0	0	N

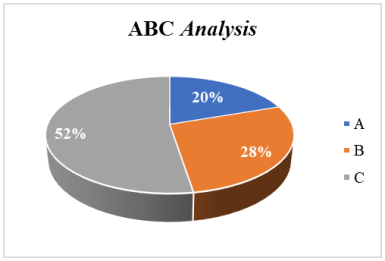

Figure 1. ABC analysis percentage diagram

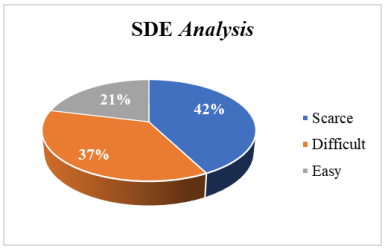

Figure 2. SDE analysis percentage diagram

Based on the results of material classification using ABC Analysis, it is known that 27 materials fall into category A, 38 materials fall into category B, and 72 materials fall into category C with the following percentage ratios. See Fig. 1. It is known that out of the total material items, 20% are in category A, 28% are in category B, and 52% are in category C.

3.3. *Inventory classification using SDE analysis*

The SDE classification method is used to group materials based on the lead time of each material's order. In inventory management, there are situations where the purchase of materials is made more than once in a single period. Therefore, it is important to calculate the average lead time to optimize the procurement process. The SDE classification division is as follows: materials with a lead time of more than 180 days fall into the Scarce (S) category, lead time less than or equal to 180 days falls into the Difficult (D) category, and lead time of less than a month falls into the Easy (E) category. The results of the SDE classification calculation are shown in Tabe 4.

Based on the results of material classification with SDE Analysis, it is known that there are 58 materials in the Scarce category, 50 materials in the Difficult category, and 29 materials in the Easy category. The percentage ratio of material classification is shown in Fig. 2. It is known that 42% of the materials are materials with a long lead time or more than 180 days, thus falling into the category of scarce materials. Then, 37% of the materials are materials with a medium lead time, thus falling into the category of difficult materials to procure. Meanwhile, 21% of the materials fall into the category of easily obtainable materials because they have a short lead time.

3.4. *Inventory classification using FSN analysis*

The FSN classification method is carried out based on the rate of material usage over a certain period. The goal is to identify items that are frequently or even rarely used, so that their control methods can be adjusted accordingly. The results are shown in Fig. 5.

Table 6.
MUSIC-3D classification results

Material Number	Material Desc.	ABC	SDE	FSN	Total	Classification	Criteria
H560500187	PIPE,CS,A106,B,SML,BE,40,6IN,6M	A	S	F	9	ASF	Very high priority
H560504921	PIPE:LN,SS,A312,TP316L,SML,BE,40,8IN,6M	A	S	S	8	ASS	Very high priority
H560500184	PIPE,CS,A106,B,SML,BE,40,4IN,6M	A	D	F	8	ADF	Very high priority
…	…	…	…	…	…	…	…
H560500310	PIPE,SS,A312,TP304,SML,PE,80,1/2IN,6M	C	E	N	3	CEN	Can be ignored

Table 7.
The results of MUSIC-3D classification criteria

No.	Classification	Score	Criteria	Amount
1	ASF	9	Very high priority	1
2	ASS	8		9
3	ADF	8		7
4	BSF	8		2
5	ADS	7		4
6	BSS	7		12
7	BDF	7		8
8	CSF	7		2
9	AES	6	Moderate priority	6
10	BDS	6		9
11	CSS	6		22
12	CDF	6		4
13	BES	5		7
14	CSN	5		10
15	CDS	5		15
16	CDN	4		3
17	CES	4		15
18	CEN	3	Can be ignored	1

In this case, the classification is reviewed based on the frequency of material usage, where materials with a usage frequency of more than once a year fall into the Fast Moving (F) category. Then, materials with a usage frequency of once-a-year fall into the Slow Moving (S) category, and materials with no usage (0) in a year fall into the Non-Moving category (N).

From the results of the material classification using FSN Analysis, it was found that 24 materials fall into the Fast-Moving category because they have a usage frequency of more than once a year. Then, 99 materials fall into the Slow-Moving category because they have a usage frequency once a year. Meanwhile, 14 materials fell into the Non-Moving category because there has been no usage in the last four years. Here is the percentage ratio of the pipe material inventory over the past four years based on FSN classification.

From Fig. 3, it is known that the Slow-Moving category is the most available material in inventory, accounting for 72% of the total available pipe materials. Meanwhile, the Fast-Moving category accounts for 18% and the Non-Moving category for 10%.

3.5. Inventory classification using MUSIC-3D

Inventory classification using the MUSIC-3D approach is carried out by grouping all previously obtained classification results into a large group to facilitate policy determination. At this stage, each classification result is assigned a value according to its priority level, so classification A, Scarce (S), and Fast Moving (F) are given a score of 3. Then, classification B, Difficult (D), and Slow Moving (S) are given a score of 2. Meanwhile, classification C, Easy (E), and Non-Moving (N) are given a score of 1. Each of these scores will then be summed to obtain a total score, which will later be used to group the inventory based on its priority level according to the established criteria. The classification results based on the MUSIC-3D approach are shown in Table 6. Based on Table 6, the quantity of materials with their priority levels can be determined as shown in Table 7.

3.6. Inventory policy analysis

Based on the classification results of the MUSIC-3D method, an analysis of material inventory control policies can be conducted. The recommended inventory policy analysis is shown in Table A1 (see Appendices). Inventory control policies can be determined based on the results of the MUSIC-3D classification, which considers the importance/criticality level of the material, lead time in the procurement process, and the rate of material usage. In this case, the determination of EOQ, SS, ROP, and ordering schedules can be adjusted to optimize availability and cost efficiency.

Economic Order Quantity (EOQ) is used to determine the most economical order quantity to minimize ordering and holding costs. Safety Stock (SS) is established to provide buffer stock to address uncertainties in demand and lead time, thereby preventing stock shortages that could disrupt

operations. Reorder Point (ROP) is the reorder point calculated based on the rate of material usage and lead time, ensuring that reordering is done on time before the inventory runs out. An accurate ordering schedule helps coordinate the timing of orders with lead time, so that materials are available as needed without causing overstock or stockout.

By implementing this policy, the company can ensure the availability of critical materials, reduce inventory costs, and improve operational efficiency. The MUSIC-3D analysis provides a comprehensive basis for understanding the characteristics of each material, allowing inventory control policies to be specifically tailored to each material category. This is very important to maintain operational smoothness and achieve overall business goals.

3.7. Managerial implications

The implications of this study for inventory management in oil and gas companies have significant benefits, considering the complexity and high operational costs in this sector. The use of the MUSIC-3D method in making inventory policies in oil and gas companies is more accurate because it can combine three classification methods. This method can also be used in other companies that have many types of materials, as well as diverse procurement process lead times and usage patterns.

4. Conclusions

Based on the research conducted, the classification results of the MUSIC-3D method, which is a combination of ABC, SDE, and FSN classifications, show that there are 45 materials that fall into the very high priority criteria and consist of 8 classifications. Then, there are 91 materials that fall into the moderately high priority criteria and consist of 9 classifications. Meanwhile, the criteria that can be ignored consist of 1 material in 1 classification. Materials with the highest score, which is a score of 9 with the ASF classification, need to be closely monitored by the company because they fall into the category of materials with a long lead time but high usage and consumption rates. Therefore, strict control needs to be implemented using various methods such as determining safety stock, reorder point, and EOQ value.

Overall, materials with very high and moderate priority criteria need to be closely monitored by the company with safety stock control, reorder point, and EOQ adjusted to lead time and fluctuations in demand or material usage. Meanwhile, materials with criteria that can be ignored can be given leniency in their control processes and further evaluation. In this case, scheduling the ordering of each material needs to be done, especially for materials that are the company's top priority.

Declaration statement

Erwin Shafira Winoto: Conceptualization, Methodology, Data Collection, Formal Analysis, Writing-Original Draft. Nabila Noor Qisthani: Supervision, Validation, Review & Editing.

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