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Value chain analysis of patchouli oil using value stream mapping and porter's model

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ABSTRACT

Patchouli oil has a strategic position in the world essential oil industry. Compared to other essential oils, patchouli oil has high aroma stability and fixation power, tends to have greater economic value, and has the potential to generate significant income for stakeholders. However, farmers have not cultivated patchouli sustainably. Moreover, there are indications of inefficiency in the cultivation implementation. This condition makes industrial activities vulnerable to mishandling or noncompliance with standards, which affects the productivity and quality of patchouli oil. Mapping and analyzing the value chain of industrial activities from upstream to downstream is a priority and urgency of this research in realizing a sustainable patchouli oil industry. Industrial activities are thoroughly and comprehensively mapped, ensuring that each production activity is carried out in a measured and targeted manner, utilizing efficient resources to produce high-quality products. By integrating the Value Stream Mapping Method and Porter's Value Chain Analysis, this research successfully identified bottlenecks and waste in pre-production, production, and post-production activities. Improvements to waste and bottlenecks identified from upstream to downstream include Unused Talent (37.3%), Defects (27.5%), and Waiting (23.5%). The future state map formulation with internal improvements yields a Type I duration of approximately 218 to 292 hours, and the Type II path becomes approximately 248 to 296 hours, resulting in an overall range of approximately 218 to 296 hours (approximately 9.08 to 12.33 days). Therefore, the efficiency gains calculated for outbound logistics, which encompasses all upstream and downstream processes, amounted to 35.46%. This study recommends prioritizing improvements in Inbound Logistics (standardization, competency-based training, SOP enforcement) and Operations (cultivation, distillation) to reduce unutilized potential, defects, and lead times along the patchouli oil value chain.

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INTRODUCTION

To date, Indonesia continues to play a major role as a supplier of patchouli oil in the global market (Vonna et al. 2020, Yusnidar et al. 2021, Sultan et al. 2023). Most of Indonesia's patchouli oil supply is sourced from patchouli oil processing units located throughout the province of Aceh, which is renowned for its high-quality patchouli oil, making it a leading commodity in the region (Ernawati et al. 2021, Kok et al. 2023). However, issues surrounding productivity and patchouli oil quality remain a concern in the patchouli oil industry, and researchers continue to develop effective and efficient solutions to achieve measurable production stability (Xu et al. 2011, Setiawan 2021, Prakhyath et al. 2024). This indicates that the patchouli oil value chain in Indonesia currently still faces serious challenges (Alighiri et al. 2017). The patchouli oil industry still faces various obstacles related to production process inefficiencies and inconsistencies in the quality of the final product (Paul et al. 2010, Uhlenbrock et al. 2018, Utomo et al. 2018). Further examination revealed errors in industrial activities, including pre-production activities that did not meet standards, suboptimal production processes, and post-production activities that were often neglected (Zikri et al. 2021, Peacock 2022). Dependence on conventional practices, low technology adoption, and a lack of understanding of cultivation and distillation standards have resulted in suboptimal product bargaining power (Reis-Vasco et al. 2000, Danh et al. 2010, Ahmed et al. 2012, Silvia et al. 2024).

Most of the patchouli oil processing industry in Indonesia consists of small to medium-sized industrial units operated by local communities, mainly those involved in patchouli farming (Pebrianto and Putri 2022). The majority of farmers do not own the land for patchouli cultivation; instead, they rent land under a profit-sharing system. Patchouli cultivation has not been carried out sustainably by farmers; some even only grow patchouli as a secondary crop (Swamy and Sinniah 2016, Marpaung and Safrin 2020, Ernawati et al. 2021). The farmers' behavior was also exacerbated by indications that their activities did not adhere to standard practices for effective and efficient patchouli cultivation (Maizi et al. 2020, Lubis et al. 2022, Kumar et al. 2024, Santoso et al. 2025). These conditions make the implementation of patchouli oil processing activities prone to errors in handling or non-compliance with standards, which have an impact on productivity and the quality of the patchouli oil produced (Lal et al. 2020, Patnala et al. 2021, Maizi et al. 2024, Singh et al. 2024, Verma et al. 2024).

In the context of sustainability and global competitiveness, systematic intervention is needed to optimize the patchouli oil industry value chain as a whole. The combination of Value Stream Mapping (VSM) and Porter's Value Chain Analysis model is highly relevant in addressing these issues. VSM is a powerful lean tool for visualising material and information flows and identifying waste within specific processes (Forno et al. 2014). However, VSM was originally developed for intra-organisational analysis and may not fully capture the broader upstream and downstream linkages that define a value chain (Indriati et al. 2023, Costa et al. 2024, Maizi et al. 2025). In contrast, Porter’s value chain framework provides a strategic perspective on how primary and support activities contribute to value creation and competitive advantage, but it lacks detailed insights into process-level wastes, waiting times, and bottlenecks (JöRgensen 2008, Ullah et al. 2024). When used independently, each method presents significant limitations for diagnosing inefficiencies across an extended value chain. No previous studies have been found that explicitly combine these two approaches in the context of patchouli oil. This study integrates Porter’s value chain framework with VSM to clarify the value chain structure and the roles of each actor, and to map and quantify the flow of materials and information within and between these activities (Holweg and Helo 2014). This combined approach enables the identification of points where value is added or lost and supports the prioritisation of improvement opportunities that are both strategically significant and operationally impactful.

Therefore, the objective of this study is to analyze the patchouli oil value chain, identify inefficiencies and waste points, and formulate applicable and sustainable value-added enhancement strategies. This research is of high urgency given that patchouli oil is one of Indonesia's strategic export commodities. Optimizing the patchouli oil value chain through an efficiency and sustainability-based approach can enhance the competitiveness of products in the global patchouli oil market. Furthermore, this

research can contribute to the development of a more comprehensive value chain analysis method, enabling its application in other industries. Thus, the results of this study are expected to serve as a reference for stakeholders, including farmers, industry players, and the government, in formulating effective policies and strategies to improve the sustainability and competitiveness of Indonesia's patchouli oil industry.

METHODS

Study Design

The solution to the problem addressed in this study is to utilize a combination of the Value Stream Mapping Method and Porter's Value Chain Analysis approaches to optimize the sustainable value chain for patchouli oil. The combination of the two methods is shown in Figure 1.

The integration of the Value Stream Mapping Method and Porter's Value Chain Analysis provides a comprehensive approach to mapping the value chain of the patchouli oil industry. This approach focuses on the flow of materials and information from upstream to downstream, starting from the procurement of patchouli leaves, the drying process, distillation, and the distribution of essential oils to consumers. Even in agro-industrial products, mapping is carried out long before the production stage, which is generally referred to as the pre-production stage. Thus, wasteful points and obstacles that cause inefficiency and inconsistency in processes, from pre-production to post-production, can be identified and corrected (Antiochia et al. 2007, Prasetyawan et al. 2021). On the other hand, Porter's Value Chain Analysis highlights key activities (inbound logistics, operations, outbound logistics, marketing & sales, service & support) and supporting activities (infrastructure, human resource management, technology, and resource procurement) that strategically shape the value chain structure.

By integrating these two approaches, stakeholders in the patchouli oil industry can enhance operational efficiency and strengthen their competitiveness. VSM helps streamline processes to save time and money, while Porter's analysis emphasizes how each activity contributes to the creation of added value. As a result, the patchouli oil industry is not only able to produce high-quality products more cost-effectively but also optimize its marketing strategy, strengthen relationships with farmers, and ensure the sustainability of its supply chain in the face of global competition.

Value Stream Mapping Method

Value Stream Mapping is a tool within the lean manufacturing framework used to identify waste, assess process efficiency, and design more optimal workflows (Forno et al. 2014, Habib et al. 2023). In the context of the agroindustry, Value Stream Mapping has proven effective in analyzing complex production and distribution processes to support continuous improvement (Andrade et al. 2016, Singh 2023). The application of Value Stream Mapping in the patchouli oil industry is highly relevant given that the production process involves lengthy and labor-intensive stages, ranging from patchouli cultivation, harvesting, withering, and distillation to produce high-quality essential oil. Through value stream mapping, the patchouli oil industry can identify potential waste, such as inefficient drying times, delays in transporting raw materials to the distillation unit, or inefficient energy use in the distillation process (Andrade et al. 2016). With Value Stream Mapping, the patchouli oil value chain can be organized more effectively, thereby increasing productivity and production quality (Azizi 2015, De Naddya et al. 2023). Furthermore, this mapping also supports integration between farmers, processors, and distributors in the patchouli oil supply chain, which ultimately enhances the competitiveness of Indonesia's essential oil industry in the global market.

Porter's Analysis

Porter's value chain model divides business activities into two broad categories: primary activities and support activities. This analysis aims to understand the contribution of each activity to value creation and competitive advantage (JöRgensen 2008, Liao et al. 2017). In the agroindustry sector, this approach is relevant because the supply chain for agricultural products is often long, involving many actors, and characterized by significant variations in the quality of raw materials (Kulsum et al. 2024). Porter's value chain approach can identify critical points in the production, distribution, and marketing processes that require efficiency or innovation (Koc and Bozdag 2017). Its application in the patchouli oil industry can help map the value stream from upstream to downstream. During the main activity stage, quality improvements in

patchouli processing through modern distillation technology can increase the yield and quality of patchouli oil. Meanwhile, supporting activities, research, and technology development to enhance the quality of patchouli seedlings, as well as training farmers in sustainable cultivation practices, will strengthen the industry's competitiveness. Thus, Porter's approach to the patchouli oil agroindustry not only helps improve efficiency but also strengthens the industry's position through a sustainable value chain.

Research Flow

The research method was conducted by integrating VSM and Porter, allowing for the combination of these two methods to effectively identify inefficiencies in the patchouli oil value chain and formulate competitive advantage strategies. The research methodology is shown in Figure 2.

The process begins with identifying the Current State Map to document the existing patchouli oil value chain using data and field information. Initially, primary data are collected through field observations at several patchouli oil processing industry units and cultivation sites in Aceh Besar and Aceh Jaya. In Aceh, the provincial investment and agricultural authorities have designated Aceh Besar and Aceh Jaya as priority areas and principal centers for patchouli cultivation and processing. These regions serve as geographic hubs for smallholder-based patchouli value chains (Keumalasari et al. 2021). Consequently, these districts provide a representative, information-rich context for analyzing value chain performance, waste generation, and bottlenecks from upstream cultivation to downstream distillation in the patchouli oil industry. The data collection resulted in a Current State Map based on Porter's value chain components, focusing on the main activities as presented in Figure 3.

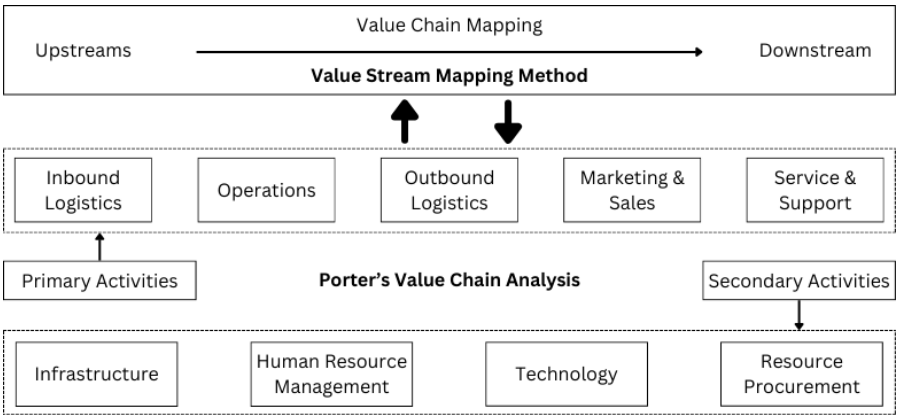


Figure 1 Combination scheme method

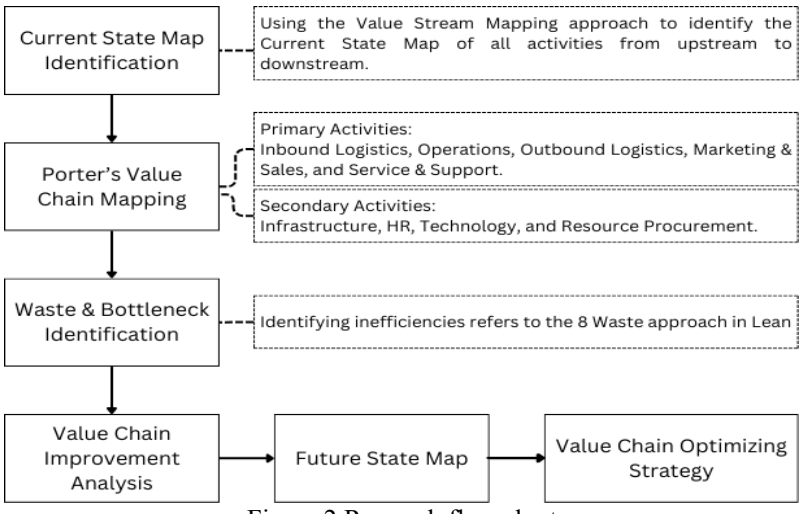


Figure 2 Research flow chart

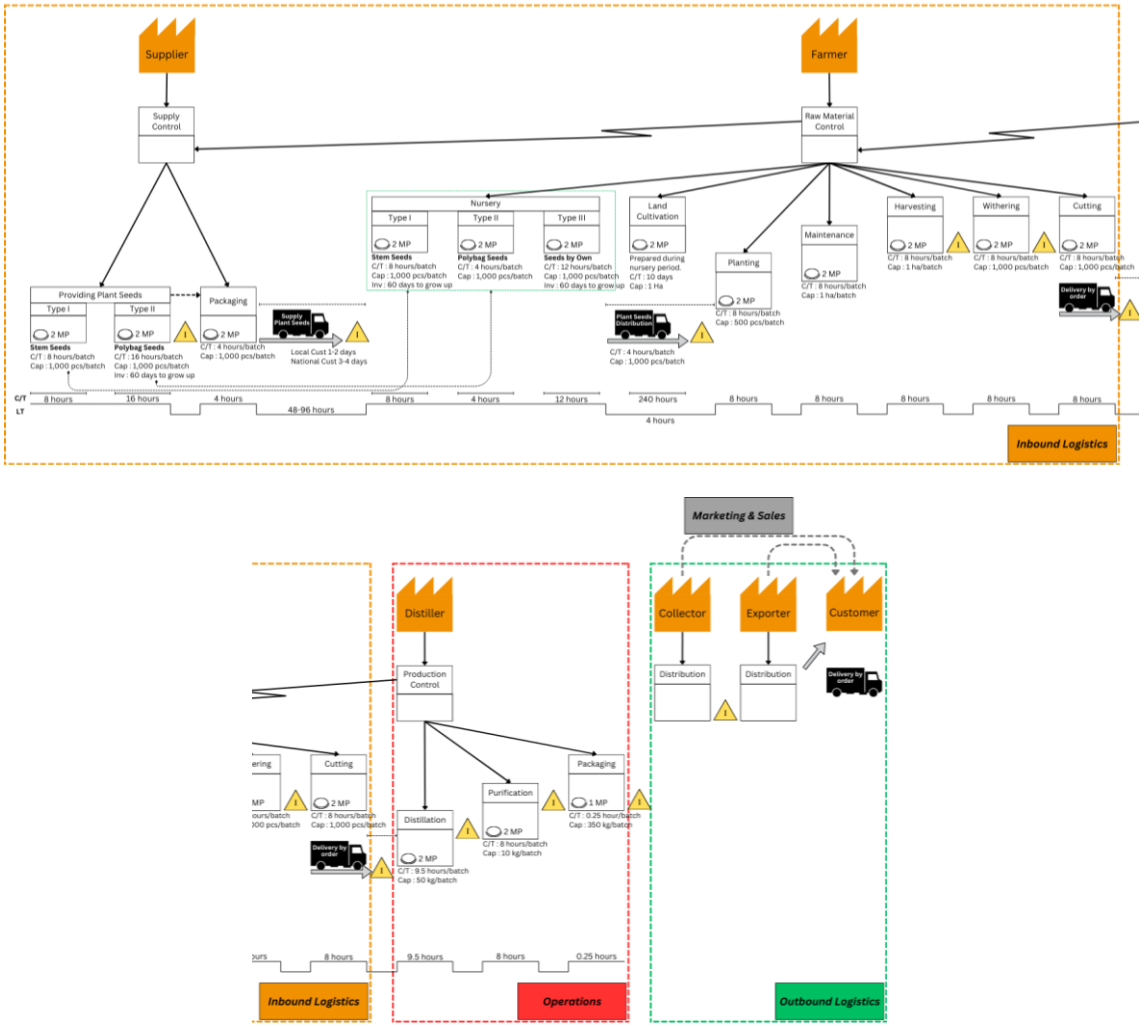


Figure 3 Current State Map

After mapping the Current State, the next stage is to identify waste and bottlenecks. All activities mapped based on Porter's value chain are reanalyzed using a specific instrument to examine causes of inefficiency, guided by Value Stream Mapping (VSM) and the 8 Wastes in Lean.

The results from the waste and bottleneck identification then inform an improvement analysis using the VSM approach, aiming to reduce inefficiencies in primary activities of the Porter value chain. Based on this analysis, a Future State Map is formulated to design a more streamlined production flow. The final step is to develop a value chain optimization strategy, referring to Porter's strategy, which guides improvements in competitiveness through increased process efficiency using VSM.

RESULTS AND DISCUSSIONS

Observations indicate that the patchouli oil industry value chain system at the research site comprises five main actors: farmers, distillers, local collectors, exporters, and consumers. Farmers carry out various activities, including land cultivation, nursery management, planting, maintenance, harvesting, drying, and chopping. Distillers play a role in the distillation, purification, and packaging processes. Meanwhile, local collectors, exporters, and consumers play a greater role in the logistics and distribution of products.

The analysis of the patchouli oil industrial process using Value Stream Mapping (VSM) and Porter's Value Chain approaches provides a more comprehensive picture of activity flows, potential inefficiencies, and opportunities for strategic improvement. The initial stage begins with the role of suppliers who focus on providing patchouli seeds through supply control, packaging, and distribution to farmers. Suppliers play a role in providing patchouli seeds in various forms, including stem cuttings and polybag seeds. On the

other hand, there are also seeds that have been developed independently by farmers. The supply control process at this stage aims to ensure consistent availability of planting materials, but often faces obstacles in the form of long waiting times (60 days for seedling growth). Additionally, the process of packaging and distributing seeds generates potential waste in the form of transportation and waiting time, particularly when there is a mismatch between farmers' needs and the distribution schedule.

At the farmer level, the production process includes several critical sub-processes, namely seedling cultivation, land preparation, planting, maintenance, harvesting, drying, and cutting of raw materials under raw material control. At the nursery stage, seedling production capacity reaches 1,000 units per batch, while planting capacity is only 500 units per batch, resulting in potential overproduction that leads to wasteful use of resources. Additionally, the seed failure rate (defect) is also high when environmental conditions are not optimal, resulting in inconsistent raw material output. The land cultivation process, which occurs simultaneously with the nursery, is highly dependent on labor availability and weather, making it prone to variability in cycle time.

Plant maintenance activities aim to maintain the quality of raw materials, but are often not supported by uniform operational standards, which increases the risk of further defects. The harvesting, drying, and cutting stages, although relatively simple, have the potential to cause delays if labor capacity and production facilities are not adequately balanced with the volume of raw materials.

Table 1 Waste and bottleneck identification

No	Detail	Category	Freq
1	The condenser water is not circulating.	Waiting	1
2	The pressure indicator is not working properly.	Overprocessing	1
3	Unhealthy patchouli parents will produce disease-prone seedlings.	Defect	2
4	Firewood is not dry.	Waiting	1
5	The condition of the kettle cover rubber seal is not good so that there is no pressure in the kettle.	Waiting	1
6	Direct contact without gloves can increase the probability of seedlings developing diseases.	Defect	4
7	The land has not been cleared.	Waiting	1
8	Inappropriate planting holes.	Waiting	1
9	The composition of the growing medium is not ideal, hindering the growth of the seedlings.	Waiting	2
10	Workers lack understanding of the ideal composition of planting media.	Unused Talent	2
11	Workers neglect to wear gloves, resulting in direct contact with plants.	Unused Talent	4
12	Workers neglect the equipment sterilization stage.	Unused Talent	4
13	Workers are unable to detect plant diseases early.	Unused Talent	1
14	Workers do not understand proper harvesting techniques.	Unused Talent	1
15	The packaging of the polybag seedlings was not good so that the planting medium was spilled.	Defect	1
16	The packaging of stem cuttings seedlings is too dense and there is a risk of them breaking.	Defect	1
17	Delivering polybag seedlings before they have grown optimally will risk the seedlings dying.	Defect	1
18	Replanting is done with new seedlings.	Waiting	1
19	Unsterilized equipment increases the probability of seedlings developing diseases.	Defect	4
20	The surface of the filter paper is quite small so the filtering capacity is minimal.	Waiting	1
21	Seedling growth is optimal in 60 days.	Inventory	2

No	Detail	Category	Freq
22	Terna is placed above ground level.	Unused Talent	1
23	Terna exposed to direct sunlight.	Overprocessing	1
24	Terna in the kettle is not compacted.	Unused Talent	1
25	No pruning is carried out.	Unused Talent	1
26	No pest/virus prevention spraying.	Defect	1
27	No weeding is carried out.	Unused Talent	1
28	No watering is carried out.	Waiting	1
29	The moisture level of the seedlings is low.	Waiting	1
30	The cutting size of the cuttings is not ideal.	Overprocessing	2
31	The enumeration size is not uniformed.	Unused Talent	1
32	No selection of parents (variety/ stem diameter/ number of stem books/ etc).	Unused Talent	2
33	Unstable heating.	Waiting	1

The distillation stage is the core of the patchouli oil industrial operation. The distillation process takes 9.5 hours per batch with a relatively small capacity (50 kg per batch), making it the main bottleneck in the production chain. As a result, raw materials accumulate in the pre-distillation area, increasing the risk of inventory waste and extended waiting times. The risk of defects is also significant because the quality of the distillation results is greatly influenced by process variables, including temperature, pressure, and distillation time. This indicates the need for modernizing distillation equipment and implementing stricter process controls.

Furthermore, the purification and packaging processes are relatively shorter (0.25–8 hours per batch), but still cannot compensate for the delays caused during the distillation stage. Another potential waste arises in the form of distillation results that do not meet quality standards, indicating a risk of defects.

After production, patchouli oil enters the outbound logistics stage, where it is collected and exported before reaching consumers. Distribution is carried out based on a delivery-by-order system, which makes the continuity of the distribution chain highly dependent on market demand. This system has the potential to cause waste in the form of prolonged waiting times, excess inventory, and increased distribution costs when demand is volatile. Dependence on exporters also reveals strategic weaknesses in terms of market diversification, as the industry tends to be reactive to orders rather than developing proactive strategies for expanding into new markets.

When analyzed using Porter's Value Chain framework, inbound logistics activities focus on controlling seed supply and distribution, which needs to be improved through the integration of modern logistics systems and collaboration between suppliers and farmers to reduce waste. Operations activities encompass the entire process, from seedling to distillation and packaging, with a primary focus on optimizing distillation capacity, standardizing cultivation processes, and enhancing output quality.

Outbound logistics needs to be strengthened with a distribution system that is more adaptable to international market demand, including the digitization of the supply chain to minimize dependence on manual order delivery (Zhao et al. 2023, Atieh et al. 2025). In terms of marketing and sales, the existing strategy remains passive, so it is necessary to strengthen branding, penetrate new markets, and diversify patchouli oil derivative products to enhance global competitiveness. Meanwhile, supporting activities such as supply control, raw material control, production control, and technological support are important pillars in ensuring consistency in quality and process efficiency.

Overall, the integration of VSM and Porter provides a clear mapping of inefficiencies and a strategic framework for improvement. VSM highlights operational aspects such as cycle time, lead time, inventory, and bottlenecks, whereas Porter situates these aspects within the broader context of value creation. Efforts to improve the competitiveness of the patchouli oil industry require not only technical efficiency but also proactive business strategies in building added value through innovation, quality, and market orientation.

Waste & Bottleneck Identification

This research identified various wastes and bottlenecks along the value chain, from upstream to downstream. In the upstream sector, low crop productivity commonly occurs. Poor seed quality, non-standard cultivation practices, and suboptimal land utilization lead to this issue. Farmers' limited access to quality seeds, fertilizers, and efficient cultivation technology forms the main bottleneck at this stage. This situation causes variability in the quality of patchouli leaves.

In the post-harvest stage, handlers often fail to meet standards for handling terna, which refers to the plant material being processed. Uneven drying raises the moisture content in the terna, lowering the quality of raw materials for distillation. Post-harvest bottlenecks include insufficient drying rooms and storage warehouses. Farmers also lack knowledge of pre-processing, which refers to the steps taken to prepare the terna before distillation.

At the distillation stage, inefficient firewood and energy use, excessive process time, and inconsistent oil output result in wasted resources. Traditional technology creates these issues. Limited equipment capacity and low oil extraction efficiency cause unstable oil volume and quality.

At the downstream stage, including distribution and marketing, long distribution chains, high logistics costs, and limited access to international markets for farmers and small entrepreneurs create waste. Large traders and exporters concentrate the market, thereby weakening the bargaining position of farmers and refiners. Furthermore, insufficient quality certification and product standardization hinder entry into the global market.

Table 1 presents the results of identifying 33 forms of waste and bottlenecks that occur in the patchouli oil production chain, starting from the upstream stage (nursery, planting, and harvesting) to the downstream stage (processing and refining). Based on this data, the identified waste is categorized into several types: Waiting, Overprocessing, Defect, Inventory, and Unused Talent.

Based on a total of 51 occurrences of patchouli oil production activities, the Unused Talent category contributes significantly to waste, with 19 occurrences. Furthermore, the Defect category has a total of 14 events, the Waiting category has a total of 12 events, the Overprocessing category has a total of 4 events, and the Inventory category has a total of 2 events.

Waste Priority Analysis

Waste and bottlenecks identified in all upstream and downstream activities are prioritized using Pareto analysis, allowing each entity involved to focus on improvement and development. This enables the effective and efficient mitigation of problems that occur. The improvement and development are certainly a step toward minimizing and even eliminating the adverse impacts caused.

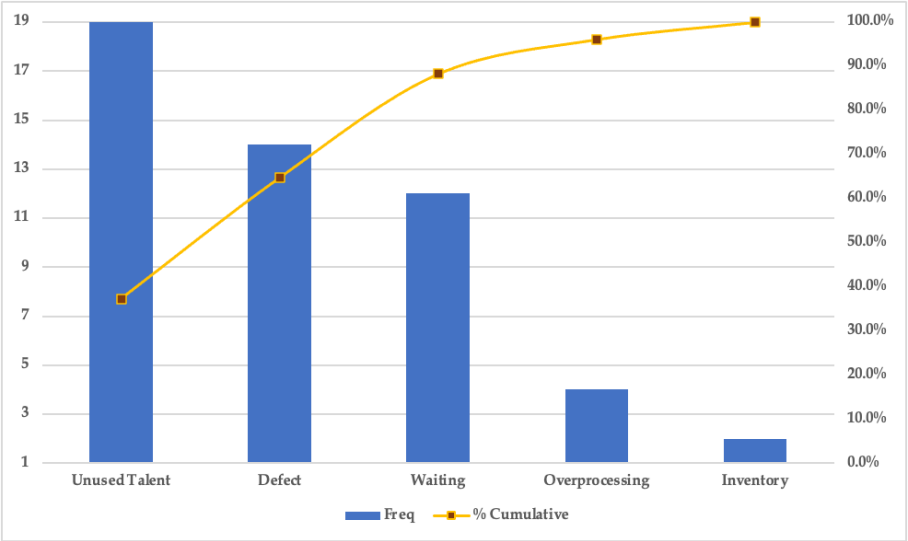


Figure 4 Pareto diagram

Figure 4 shows the accumulated problem contributions by waste category. The cumulative line breaks the 80% threshold at category 3, indicating that the vital few segment comprises Unused Talent (37.3%), Defects (27.5%), and Waiting (23.5%). The distribution of events shows that Unused Talent is spread across four supplier activities, 14 farmer activities, and one refiner activity. Defects appear in six supplier activities and eight farmer activities. Meanwhile, Waiting occurs in one supplier activity, six farmer activities, and five distiller activities. This composition suggests that the primary source of inefficiency lies in the upstream stage, which subsequently causes defects or delays downstream.

Concentrating efforts on Unused Talent, Defects, and Waiting will have the biggest and fastest impact on waste reduction, lead time (LT) shortening, and patchouli oil quality stability because these three categories account for over 80% of the identified inefficiencies. Addressing these core issues should generate immediate improvements, while Overprocessing and Inventory can be managed subsequently to sustain ongoing progress (Gebeyehu et al. 2022, Sadikin 2023).

Value Chain Improvement Analysis

The vital few waste category targets two primary activities including Inbound Logistics (quality of seedlings and growing media) and Operations (cultivation and distillation), as well as three supporting activities namely Human Resource Management (competency gaps and SOP discipline), Technology Development (simple sensors/monitoring for pressure, temperature, flow, validated sanitation methods), and Procurement (PPE, food-grade equipment, dry firewood). This means that improvement is not just about reducing non-value-added activities, but also changing the structure of cost drivers and value drivers. The intention is to shift the cost structure from non-valuable activities to preventive and valuable activities, so that yield increases, quality stabilizes, the cost per unit decreases, and the bargaining power of patchouli oil in the market strengthens (Grodzicki and Skrzypek 2020, Gray et al. 2020, Ahmad et al. 2022).

In the primary Inbound Logistics activity, the source of value starts with the seeds, planting media, tools, PPE, and firewood that enter the system. At this point, Defects in suppliers (six activities) and Unused Talent (four activities) increase the variation in seedling quality due to non-uniform selection of parents, random cutting sizes, neglected sterilization of tools, and packaging that damages viability, which aligns with nursery and restoration studies indicating that systematic control of seed and seedling quality at the source enhances establishment and long-term performance (Haase et al. 2021, Grossnickle and Ivetić 2022). Waiting also occurs when the firewood has a high moisture content and is therefore not ready for use, a condition that has been shown to decrease combustion efficiency and reduce both yield and product quality in biomass and charcoal production systems (García Quezada et al. 2023). The consequences are increased costs of poor quality, planting delays, and unnecessary nursery WIP. Improvements are focused on quality at the source through the specification of cutting varieties and sizes, quality agreements with suppliers, check-sheet-based incoming inspection, and adherence to FIFO and wood drying standards. This issue is further illustrated by past cases where supplier quality management, digitized incoming inspection, and a structured FIFO inventory policy successfully reduced out-of-specification raw materials, shortened lead times, and improved economic and environmental performance (García Quezada et al. 2023, Flores et al. 2025).

In Operations activities on the farm, the absence of agronomic standard work, ranging from understanding the composition of planting media, planting hole size, maintenance, and treatment against pests/diseases, creates process variations that trigger defects from the source. Poor discipline in the use of PPE and inadequate hygiene exacerbate the situation, leading to seedling contamination and damage. On the VSM map, this pattern appears as a relatively short processing time but is interspersed with waste in the form of waiting and rework, so Process Cycle Efficiency does not occur. Normalizing work through step standardization, visual control, daily audits, and competency matrix-based training locks in defect reduction, lowers variation, and increases seedling survival rates (Mor et al. 2019, Hut-Mossel et al. 2021, Dillinger et al. 2022).

In the Operations segment of the refinery, waiting is a significant contributor, mainly due to unstable heating, unreliable boiler indicators and seals, disrupted condenser circulation, and flow-

limiting filtration capacity. The direct impact is that the energy per liter of oil increases, the process schedule is uncertain, and the risk of quality rework increases. To mitigate these problems, it is necessary to stabilize equipment availability and performance, establish dry firewood standards, and implement visual management of temperature and pressure parameters to reduce process variability (Okpala et al. 2020, García Quezada et al. 2023). Additionally, hygiene discipline needs to be tightened so that quality output becomes more consistent and key chemical components, such as patchouli alcohol, are better preserved (Tsuyuki and Hardin 2021).

Outbound Logistics plays a crucial role in ensuring that the value created is not degraded after the process. Without adequate storage governance and batch traceback, oxidation, contamination, or mixing between production batches can impact quality. The implementation of labeled harvest containers, FIFO, and batch tracking from farm block to distillery batch enhances traceability, reduces quality complaints, and lays the groundwork for a specification-based marketing strategy (Lan et al. 2025, Rossi et al. 2025).

Supporting activities are the primary lever for reducing Unused Talent and Defects. Human Resource Management should eliminate competency gaps with hygiene and work standards, bound by a quality KPI-based system. Technology Development prioritizes simple sensors and data loggers for pressure, temperature, and flow, as well as crop cutting tools to reduce the coefficient of variation. The procurement function ensures technical specifications of PPE, food-grade equipment, filter paper, and firewood are met (Dillinger et al. 2022, Alshammari et al. 2025).

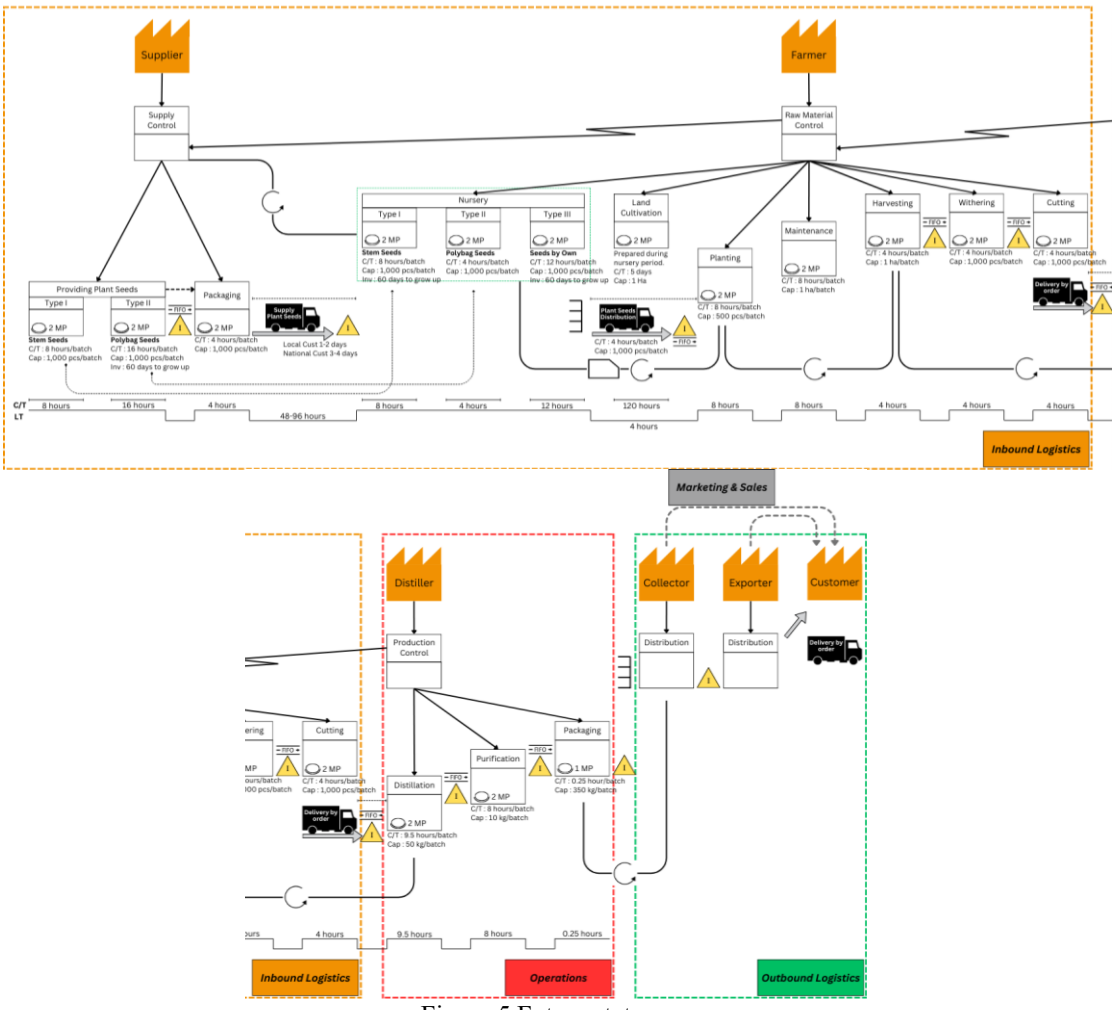


Figure 5 Future state map

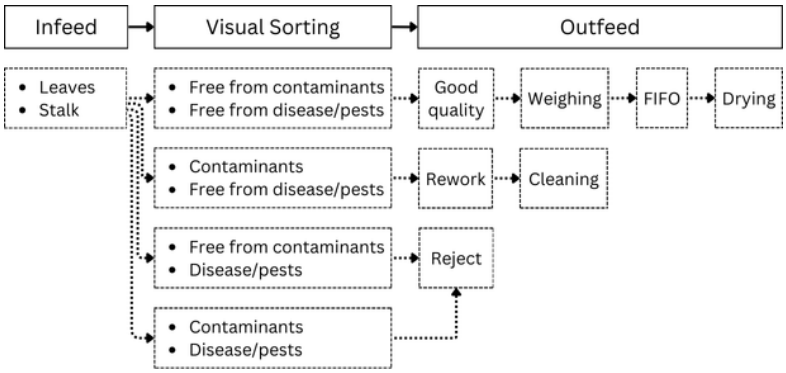


Figure 6 One-way sorting table

Future State Map Analysis

The draft Future State Map (FSM) for the patchouli oil industry was formulated as an optimization and development of the previously analyzed current state map. The main focus of optimization is to eliminate various wastes and bottlenecks that were previously identified as priorities, namely, unused talent, defects, and waiting.

The FSM design, shown in Figure 5, makes the refinery the pacemaker process, so the entire production schedule and signals flow from this point. The kanban-based pull mechanism is built in three main loops, namely (1) supplier - nursery; (2) nursery/planting - harvesting/pre-distillery - distillery; and (3) finished goods - distribution with supermarkets in the nursery section and in the final section. Implementation of the FIFO lane that restricts WIP between stations to maintain order, material life, and prevent accumulation that causes waiting.

At the supplier stage, seed quality standards are implemented through SOPs for seed sorting and packaging as well as batch labeling for direct traceability to farmers. The processing time at the supplier still refers to the CSM (Type I: 8 hours, Type II: 16 hours, packaging: 4 hours), but the FSM sets a clear distribution SLA to prevent delays from spreading downstream. The conservative scenario follows the current map (local 24-48 hours, national 72-96 hours), while the improvement program at suppliers targets stabilization to 24-36 hours (local) and 48-72 hours (national). The “60 days to grow” inventory is treated as pipeline inventory managed with seedling supermarkets, so that it does not extend the order lead time only when it is completely made-to-order (MTO). This growing phase is calculated to LT (+1,440 hours), which is operationally avoided through continuous seedling planning. A pure MTO policy addresses overproduction, obsolete inventory, and demand mismatch by aligning capacity, input utilization, and product variety with confirmed orders. Key benefits include improved responsiveness, more reliable delivery, and more sustainable resource utilization (Alnahhal et al. 2021, Gholami et al. 2023, Zhai et al. 2023, Upadhyay et al. 2025). Including the full 1,440-hour growing period in lead time (LT) would make patchouli cultivation commercially inefficient. To avoid this, continuous seedling planning is used. This keeps the nursery phase outside customer-visible LT while ensuring seedling quantities and types match projected demand.

In the nursery stage, all waste from Defects and Unused Talent is addressed by tackling technical and human root causes. Standardizing the growing media and keeping daily pH and humidity control creates a stable environment for seedlings. This reduces variability in vigor and survival rates, lowering defect rates in downstream planting and distillation (Gallegos-Cedillo et al. 2024). Sterilizing equipment eliminates microbial contamination and curtails the spread of disease. This averts seedling mortality and quality failures at the source (Anikina et al. 2025). Implementing batch labelling of seedling lots enhances traceability, so that any nonconforming output can be traced back to specific batches and corrective actions can be taken on the corresponding inputs and practices, helping prevent repeat defects (Schuitemaker and Xu 2020). Finally, competency-based operator training aligned with nursery SOPs ensures that workers consistently apply these controls, use monitoring data effectively, and participate in problem solving, thereby reducing human-error defects and transforming Unused Talent into active capability for quality improvement (Masinde et al. 2023). As a result, First Pass Yield

(FPY) of seedlings increases, seedlings are of uniform age at planting, and there is no more waiting for proper planting media. Seedlings are planted in the field using kanban, which ensures planting numbers and timing align with distillery plans. Land cultivation is shortened from 10 to 5 days (120 hours) using capacity leveling, mechanization, and parallel scheduling—preparing fields before seedlings are ready for planting. This improvement eliminates the largest source of waiting in the current state.

The planting, harvesting, and pre-production transition are integrated into a small seamless flow. Harvest standards (planting age, cutting height, harvesting time), harvesting containers prevent terna defects, one-way sorting tables, and standardized drying with timers/data loggers stabilize moisture content. The harvesting, withering, and cutting sequence, which originally required 8+8+8 hours, was condensed to a maximum of 12 hours in total, with FIFO linking directly to the pacemaker. This eliminated overprocessing in the form of re-sorting and reduced waiting due to queue backlogs before distillation.

In the distillation process (pacemaker), delays and defects can be reduced by performing routine quality inspections on production facilities and infrastructure, and by implementing a clearly defined distillation SOP. Regular inspections and preventive maintenance detect equipment wear, leaks, and control issues before damage occurs, thereby reducing unplanned downtime and increasing equipment availability (Biswas 2024). In patchouli steam distillation, precise control and visual management of process parameters minimize deviations, reduce cycle times, and enhance both yield and product quality. These measures directly decrease delays and the frequency of off-specification batches at the pacemaker stage (Machado et al. 2024).

In outbound logistics, supermarkets can utilize demand-based FIFO and reorder point methods to ensure delivery reliability without excess inventory (Ching et al. 2019, van Donselaar et al. 2021). Collectively, these changes result in a systemic value chain optimization. The refinery functions as the pacemaker, while upstream and downstream inventories are managed through supermarkets and first-in, first-out (FIFO) lanes. Information flows are synchronized using Kanban, reducing waiting times, defects, and underutilized talent. With these internal improvements, the end-to-end lead time of suppliers decreased significantly. In the current state, the Type I results in 337.75-361.75 hours (local) or 385.75-409.75 hours (national), while the Type II path results in 341.75-365.75 hours (local) or 389.75-413.75 hours (national), resulting in an overall range of 337.75-413.75 hours (14.07-17.24 days). In the future state with internal improvements and fixed supplier assumptions, the Type I 218-244 hours (local) or 266-292 hours (national), and the Type II path becomes 222-248 hours (local) or 270-296 hours (national), so the overall range is 218-296 hours (9.08-12.33 days). If the supplier program is also improved (delivery lead time stabilization), this range can decrease even further. The difference between Type I and Type II on LT is relatively small (±4 hours) compared to the effect of supplier distribution and trimming the land cultivation process. Overall, implementing the FSM reduces the end-to-end lead time by approximately 35%, representing a significant optimisation for the patchouli oil value chain.

CONCLUSIONS

The integration of VSM and Porter's Value Chain offers a clear map of inefficiency points and a strategic framework for improvement. VSM focuses on cycle time, lead time, inventory, and bottlenecks. Porter's Value Chain places these in the broader context of value creation. Together, these approaches demonstrate that enhancing the competitiveness of the patchouli oil industry requires both technical efficiency and a proactive business strategy. Such a strategy must foster added value through innovation, quality, and a market-oriented approach.

Waste and bottlenecks in the patchouli oil industry occur due to inadequate production infrastructure, lack of consistently applied operational standards, and weak human resource management. The majority of the problems stem from the upstream stage (nursery, cultivation, harvesting). Improvements upstream will reduce defects downstream.

Pareto analysis allocates resources to nodes with the greatest impact on value. By focusing on Unused Talent, Defects, and Waiting in primary activities and activating levers on supporting activities, organizations achieve rapid, long-term improvements. These include shorter lead times and more consistent patchouli oil quality and market value.

Inbound logistics is strengthened by seed standardization. Operations become a source of cost and quality advantage through refining SOPs using the Total Productive Maintenance (TPM) approach. Outbound logistics is more reliable with FIFO and traceability. The supporting functions of HR, technology, and infrastructure become levers of sustainability. As a result, the process flow is lean, stable, and agile from upstream to downstream, meeting market needs with consistent quality and timeliness.

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