Improving The Sustainability of Cosmetics Small and Medium Industries: A Case Study

***Abstract*— Inefficiency and environmental hostility are major concerns in cosmetics small and medium industries (SMIs). Sustainability has become a goal desired by cosmetic customers. This study aims to encourage the development of sustainable cosmetics SMIs by integrating lean and green principles into production practice. This research combines the lean and green methods and tools suitable for SMIs, namely, green value stream mapping and life cycle impact assessment to evaluate manufacturing waste and environmental impact. We conducted kaizen events to improve existing processes. A case study of a liquid face soap manufacturing company was analyzed. The proposed ideas improved their manufacturing cycle effectiveness (MCE) by 1.8%, shortened inventory lead time by 36%, and reduced environmental impact by 33%. The company also achieved monthly electricity cost reductions of 41%. Despite an insignificant rise in the MCE, this study highlights the scope for using lean and green principles for social-environmental improvement, particularly in reducing damage to human health. Various other industries can emulate these methods.**

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Index Terms— ***Sustainability, lean and green, green value stream mapping (GVSM), life cycle impact assessment (LCIA), kaizen events, cosmetics small and medium industries (SMIs)***

I. INTRODUCTION

Inefficiency and low regard for environmental issues pose a challenge to cosmetics small and medium industry (SMI) managers facing demands for making businesses more sustainable. Most SMIs tend to operate traditionally [1], generating severe amounts of hazardous waste [2], thereby causing environmental pollution [3]. These weaknesses would negatively affect cosmetics SMIs business, employment rate, and the environment. Then soon, the SMIs could no longer compete with big industries.

Cosmetics are chemical products that make direct contact with the human body. Their production generates chemical waste that is harmful to the environment. Therefore, the cosmetics industry must comply with global regulations to produce safe and environmentally friendly products. The first regulation regarding good manufacturing practices requires that manufacturing processes meet international quality standards in production requirements, quality control, personnel, facilities and equipment, sanitation, and hygiene [4]. The second policy, the green industrial policy, focuses on evaluating environmental performance, including the environmental impacts of products and processes [5].

Cosmetics SMIs face several obstacles in complying with these obligations. Firstly, the workforce's limited skillset leads to inefficient and environmentally hostile processes [3]. Secondly, capital constraints cause SMIs to operate with outdated technology [6]. In addition, limited facilities and equipment cannot support the SMIs' attempts at becoming sustainable [7]. Hence, SMI managers need a combination of simple yet scientifically sound tools to conduct the required performance analysis and guide their companies in following a sustainable manufacturing approach. These needs have prompted researchers to search for the right combination of sustainable methods to solve the challenges faced by cosmetics SMIs.

Several studies have examined lean and green principles implemented by the SMIs to achieve sustainable manufacturing [2, 8]. Studies in the literature have so far focused on the benefits of lean and green integration, exploration of lean and green techniques widely used in SMI, and the number of SMIs that have successfully implemented these practices. In comparison, specific studies on the practice of lean and green combination techniques and analysis of the positive impacts of their integration on business sustainability are limited. Moreover, previous studies rarely incorporated quantitative lean and green indicators to measure process efficiency and environmental impact. This study provides details about simple and suitable scientific steps to help SMI managers understand and assess their manufacturing process sustainability from the early stage. It encourages SMI managers' awareness of some shortcomings in their current manufacturing process and how to protect themselves from more significant problems in the future. Following this research methodology, the SMI managers' can prove their readiness to compete with large industries.

Our research evaluates the application of combined methods and tools to help cosmetics SMI managers identify and implement lean and green processes and achieve sustainable manufacturing. We chose the green value stream mapping (GVSM) method and life cycle impact assessment (LCIA) as tools for this study. The GVSM method specifically aims to reduce waste, and LCIA supports the calculation of environmental impact. These methods employ the quantitative indicators manufacturing cycle effectiveness (MCE) and environmental impact score, respectively. The MCE is a ratio that describes the waste-free effectiveness of a process. Besides, the environmental impact score indicates the problems and damages a process causes to human health, ecosystems, and resources. Both indicators focus on those aspects of the processes that generate waste and their impact on the environment.

We have conducted kaizen events in this study to reduce the waste generated; waste generation affects the financial strength of a company and poses environmental hazards. The kaizen method is suitable for SMIs because of its simplicity and effectiveness in triggering ideas for improvement across the workforce. Combining GVSM, LCIA, and kaizen is expected to help cosmetics SMI managers apply lean and green techniques to create manufacturing sustainability while meeting customer and government demands regarding product quality and process safety.

The remainder of this paper is structured as follows. The design and methodology used in this study are outlined in the 'Research methods' section. The detailed implementation of the case study is covered in the 'Lean and green implementation: A case study' section. Subsequently, concluding remarks are presented.

II. Literature Review

The lean and green principle integrates lean thinking and green practices that support efficient and environmentally friendly businesses [8]. The waste elimination technique used in the lean and green principle guides industries to become economically, ecologically, and socially valuable [9].

There is a fundamental difference between cosmetics SMIs that have implemented lean and green practices versus those that have not. **Error! Reference source not found.** summarizes these differences. Lean and green SMIs exhibit continuity of performance with a broader business perspective. Such SMIs maintain operational efficiency and show high environmental and social performance by applying well-defined methods and techniques.

Table 1. Ordinary versus lean and green cosmetics SMIs

MANUFACTURING PHILOSOPHY	ORDINARY SMI	LEAN AND GREEN SMI
Basic principles	- Short term thinking (profit) - Maximum utilization of resources	- Sustainable thinking (profit, people, and planet) - Efficient utilization of resources, waste reduction, environmental friendliness, continuous improvement, and people commitment
Manufacturing Characteristics	Large inventory, inconsistent quality, long lead times, unquantified emissions.	Well-managed inventory, quality standardization, short lead times, controlled waste and emissions.
Focus	- Cost-cutting - Increase in selling price	- Production efficiency - Efficient resource management, minimum inventory, reduced defects, short cycle time, reduce solid and liquid waste, and reduced air emissions.
Standardized Methods/ Tools	Simple documentation, no standardized method	Well-defined lean and green tools, standardized processes

Some powerful lean and green techniques applied to SMIs are GVSM, life cycle assessment (LCA), and kaizen [10, 11]. Choudhary, *et al*. (2019) applied GVSM to improve the sustainability of packaging SMIs. Colley, *et al*. (2020) implemented the gate-to-gate LCA method to evaluate a food processing company's ecological and economic impact. Other studies adopted the VSM techniques coupled with a kaizen approach to tackle inefficiency in an automobile parts SMI [12]. However, few studies have analyzed the combination of all the aforementioned techniques. This research integrates the three techniques discussed above to address the sustainability problems in cosmetics SMI.

GVSM defines the goals, scope, and product family. It demonstrates the performance integration of lean metrics and green indicators to manage the environmental risks and the product value chain [13]. The lean metrics used to analyze SMIs include cycle time, workforce, inventory, and defect ratio [14], [15]. The green indicators include raw materials, energy, water consumption, and the amount of waste and emissions generated [16]. GVSM maps the current processes and collects all input and output data for each manufacturing process to determine the lean and green metrics. Then, the performance is measured and waste identification activities using process mapping activity (PMA) and LCIA are carried out.

PMA is a popular waste identification tool in GVSM that consists of three stages [17]. The first stage involves observing work elements, cycle time, displacement distance, and workers. The second stage groups the process elements into five categories, namely operation, inspection, moving, delay/waiting, and storage. In this stage, PMA uses the MCE indicator to measure the operational performance [18].

The third step of PMA involves analyzing value-added (VA), necessary but non-value added (NNVA), and non-value added (NVA) work elements. The NVA elements of the lean principles consist of overproduction, defective products, unnecessary inventory, inappropriate processing, excessive transportation, waiting, and unnecessary motion [19]. The NVA elements cause green waste through excessive use of electricity, water, and materials and increased garbage, transportation, and emissions and cause harm to biodiversity [12].

GVSM, in combination with LCIA, serves as a tool to measure green performance. LCIA is part of the LCA method that assesses environmental impact throughout the life cycle of a product [20], [21]. LCIA requires clarity in the study's objectives and scope [21], [22]. In addition, it measures the overall impact in multiple categories. The categories are listed in Fig. 1. This measurement avoids the allocation of impacts to different categories. The environmental impact value is assumed to be a baseline value that assists decision-makers to assess the impact of any changes in the production process on the environment, thereby determining the priority areas for improvement [23]. There are two approaches to assess the ecological effects by using LCIA: midpoint analysis and the endpoint review. Midpoint analysis is oriented towards the problem, whereas endpoint review is based on the damage caused [24]. One of the strengths of the LCIA method is in aligning environmental problems at midpoint levels and damage at endpoint levels [ReCiPe2016 [25]]. Fig. 1 shows the mapping of impact categories at midpoint and endpoints based on the ReCiPe2016 method [26].

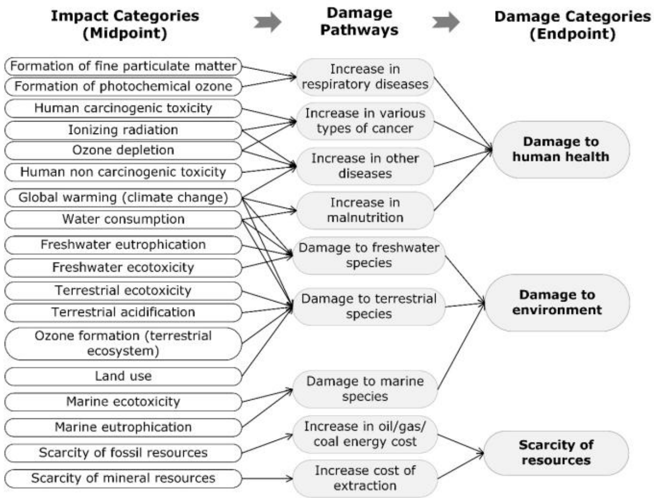

Fig. 1. Impact categories modelled according to ReCiPe2016

(Source: author's elaboration on the basis of *PRé* Sustainability, 2020)

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Performance measurement and waste identification help managers and decision-makers determine the area of improvement through the kaizen approach. Kaizen is a continuous improvement strategy that involves the entire workforce of an organization [28]. Kaizen events are implemented in SMIs because of their simplicity in their structural hierarchy [29]. SMI managers must conduct kaizen events to improve workforce contributions in delivering improvement strategies [30]. Kaizen events are useful if held periodically and attended by top management officials and the shop floor staff members alike.

III. RESEARCH METHODS

This study combined the GVSM method with LCIA tools to make it easier for managers to understand and assess how lean and green their manufacturing processes are. We then recommended improvements based on the outcome of the kaizen events. This section discusses how the combination of GVSM, LCIA, and kaizen events was designed.

We applied GVSM methods in four steps, as shown in Fig 2, Steps 1 and 2 include a few standard practices conventionally adopted in GVSM methods, starting with identifying the goal of the current process and mapping the current state. In step 3 of GVSM, we combined PMA with the MCE as a lean indicator and LCIA with an endpoint score as a green indicator. We used the SimaPro application as the LCIA calculation tool in this study. However, this paper does not discuss the environmental impact calculations performed by SimaPro. In addition, a cause analysis based on the '5 whys' was also performed. This technique is simple, practical, and widely used by researchers and industry practitioners to determine the root causes of various problems [31]. We proposed kaizen events in step 4 to encourage the workforce to formulate ideas for improvements and create the future state map of value stream mapping. These collaboration techniques will improve the operational efficiency of the SMI without compromising the health of the environment. The series of methods and techniques in Fig 1 applies to all manufacturing industries in general. The implementation steps of the lean and green evaluation framework in detail is explained in the following section.

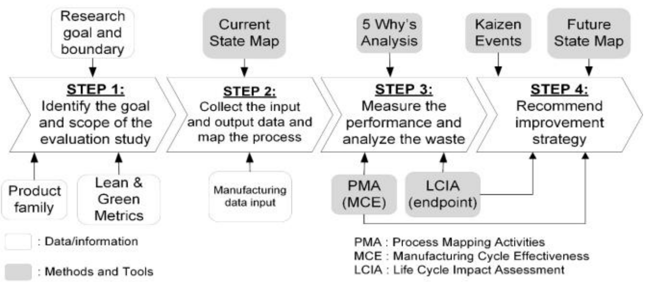

Fig 2. Lean and Green Evaluation Framework

IV. LEAN AND GREEN IMPLEMENTATION

We started by selecting a body care cosmetics company in Depok, West Java, as the subject for this case study. The process of liquid face soap manufacturing was analyzed in this study. This case study examined a complex process observed in real-time [32]. Although we considered only one company as the research subject, this case study can explore research variables in greater detail [33]. This case study required detailed observation and analysis of the environment of the cosmetics company. The study included an analysis to determine the problems and their areas of occurrence, the reason, and the methods to overcome them. We followed the framework shown in Fig 2. The following subsections describe all the four steps of the framework in detail.

A. Goal and Scope

As mentioned above, this study analyzed a body care cosmetics manufacturing company's sustainability performance and identified areas for improvement. The scope of this study is from gate to gate, i.e., it starts from the receipt of raw materials at the company's warehouse gate and ends at the product shipment's gate. The primary production process of all body care products of the company, such as shampoo and soap, is similar. The liquid face soap is the highest selling product of the company and has the most superior material composition among all the products of the company. This research chose to study the manufacturing process of liquid face soap.

We identified eight lean and green metrics by referring to previous studies. These were: cycle time, workforce, inventory, defect ratio, material consumption, energy consumption, water usage, and discharge of effluents in water.

B. Current State Mapping of The Manufacturing Process

We analyzed the manufacturing process from gate to gate by covering every aspect of manufacturing from the factory's material receiving gate to the product delivery gate through current state mapping. The cycle time data were recorded for each process, including time spent in processing, inspection, moving, waiting, and storage time, as shown in Table 2. The total cycle time was 21,870 s/batch. In addition, we also noted the workforce required, inventory (raw material, work in process, and finished products), defect ratio, material consumption, energy consumption, water consumption, and waste generated as the parameters for the lean and green metrics specified in the research methodology section.

Table 2. Liquid face soap manufacturing cycle time(s)

Process Name	Process Time	Inspection Time	Storage Time	Moving Time	Waitin g Time	Total Cycle Time
Saponifica-Tion	2,310	0	15	210	0	2,535
Quality control 1	100	20	15	0	0	135
Mixing	1,340	0	15	60	0	1,415

Quality control 2	0	1,180	0	0	0	1,180
Filling and packaging	14,830	300	120	875	480	16,605
Total	**18,580**	**1,500**	**165**	**1,145**	**480**	**21,870**

Fig. 3 demonstrates all the manufacturing processes and relevant data. It shows that the company used a simple push–pull system. The company ordered raw materials from suppliers by using a push system based on a forecasted demand of 900 kg/week. The chemical raw materials were ordered every two weeks, while the packaging materials were ordered once a week. The company had two warehouses, consist of a chemical material warehouse that was an enclosed space with air conditioning and a packaging material warehouse that used ventilated glass rooms without air conditioning and lights.

The saponification workstation first processed the raw material to produce 150 kg of the base liquid for every batch of the liquid face soap. The base liquid was then stored as work in process inventory, followed by inspection of its viscosity and colour. The mixing workstation processed the base liquid of the liquid face soap according to production orders (pull system, first in, first out). The production manager arranged the number of production orders according to the customer's purchase order and a safety stock to account for defective products and fluctuations in demand. The labelling, filling, and packaging workstations processed the mixed liquid face soap to ensure that it satisfied the quality of the production orders and then sent it to the delivery department. We ensured the completeness of the data and processes on the current state map and proceeded to the lean and green performance assessment stage.

C. Current State Mapping of The Manufacturing Process

This stage is demonstrated in Table 2 and Fig. 3. The VA and NVA work elements are identified using PMA tools, as shown in Appendix 1. Fifty-one work elements were utilized to produce liquid face soap, of which 28 were classified as VA, 9 as NNVA, and 14 as NVA. We calculated the MCE value of liquid face soap production as an indicator of lean performance using equation (1).

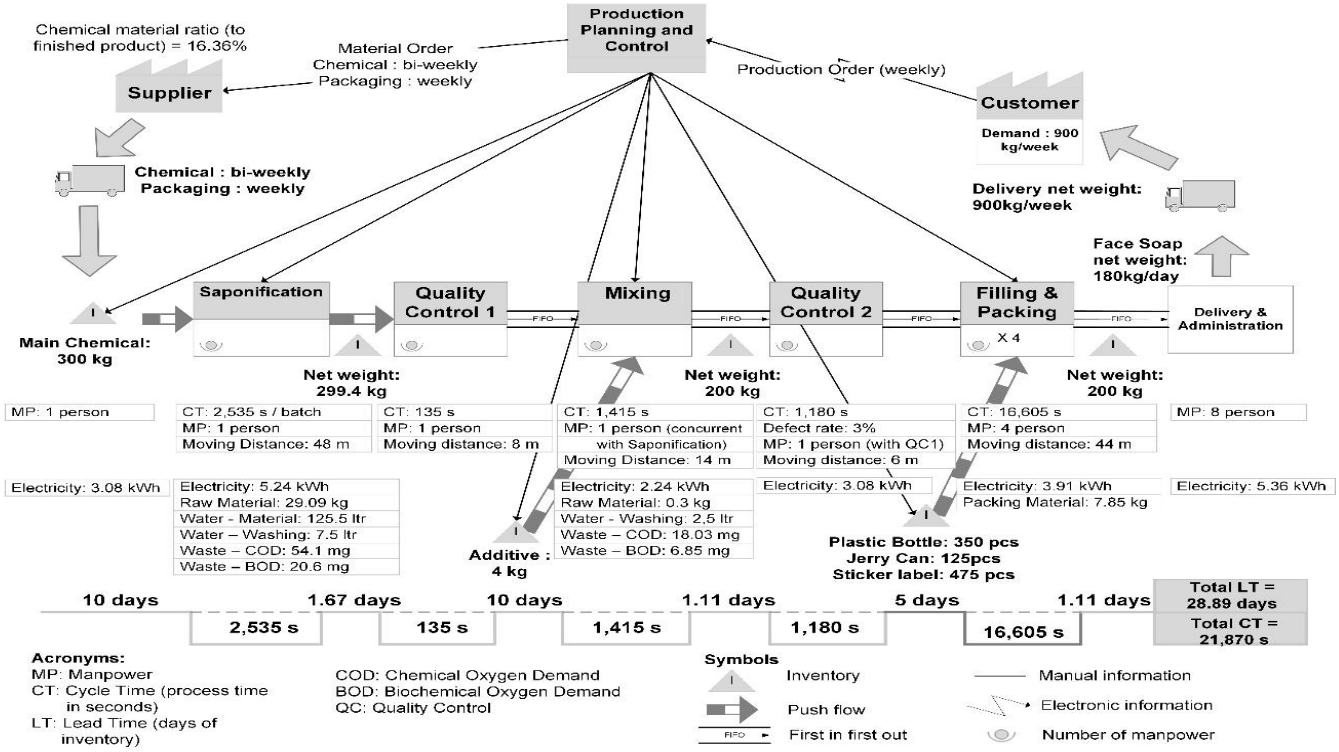

Fig. 3. Current State Mapping

$$MCE = \frac{\text{Processing Time (VA)}}{\text{VA+NNVA+NVA}} \times 100\% \quad (1)$$

$$= \frac{18{,}580}{18{,}580+1{,}500+165+1{,}145+480} \times 100\%$$

$$= 84.96\%$$

The LCIA of the SMI manufacturing process was calculated using the SimaPro application through the ReCiPe Endpoint method. The LCIA calculation assumes the net weight of liquid face soap to be equal to 900 kg, as visualized in the current state map. The data related to electricity consumption, water usage, and emissions resulting from each process in Fig. 3 are inputs to SimaPro.

Appendix 2 lists in detail the SimaPro output, which consisted of impact characterization values of 22 quantities according to damage to human health, ecosystem quality, and resources. The human health damage category showed some of the most significant problems, including the formation of fine particulate matter, global warming, and non-carcinogenic and carcinogenic toxicity. These problems can cause various diseases that could severely impact human health. The Disability-Adjusted Life Years (DALY) score of 0,00237 indicates that a human being could experience a disability within 0.00237 years (0.87 days) upon the production of 900 kg of liquid soap by the company.

The SimaPro software normalized and weighed 22 impact characterization values in Appendix 2 to obtain a single score. Tab. 3 provides the results of endpoint impact assessment of 900 kg of liquid face soap in a single score in Points or Pt. The 1Pt score represents the average burden every 1000 Europeans place on the environment in a year [34]. In this study, the impact score of the total damages caused due to the production of 900 kg liquid face soap was 40.42 Pt. Human health damage contributed to 98.7% of the score. Table 3 presents the scores of each workstation, which brought an interesting observation to light. The administration workstation had approximately the same damage score as those of the saponification and mixing workstations. These observations are revealed in the following subsection.

Table 3. Single score damage impact of 900kg liquid face soap manufacturing

Workstation	Unit	Damage Category			
		Human Health	Eco system	Resour ces	Total
Material Warehousing	Pt	5.16	0.06	0.01	5.23
Saponification	Pt	9.57	0.11	0.01	9.69
Mixing with Perfume	Pt	9.70	0.12	0.01	9.83
Labelling, Filling, Packaging	Pt	6.53	0.08	0.01	6.62
Administration	Pt	8.39	0.11	0.01	9.05
Total	Pt	39.89	0.48	0.01	40.42

Two stages of waste analysis are discussed in this section. The first stage involves the identification of NVA waste and waste generated during the manufacturing process. The unnecessary back-and-forth movement of the operator while weighing material during the saponification and mixing processes (240 s) and waiting during the packaging process (480 s) is considered as NVA. The inventory lead time in the chemical warehouse (10 days) was greater than that in the saponification workstation (1.67 days). The total resource usage, including electricity consumption in administrative and warehouse locations, was examined. The electricity consumption in administrative and warehouse locations was 8.44 kW h/batch, which is equal to 58% of the electricity consumed in production (14.47 kW h/batch). This percentage is unacceptable for non-production workstations. This study also analyzed the efficiency of electricity consumption at the production site. The production machines and equipment were fully operational during working hours, irrespective of whether production was taking place or not.

The second step involved exploring the root causes for the identified problem areas. The 5-whys technique to identify the root cause is chosen. Furthermore, the researchers arrange kaizen events involving all workers from the production, maintenance, warehouse, and administration areas.

We conducted kaizen events by using the brainstorming method and involving eight essential employees: one operation manager, three administration staff, and four members from the manufacturing division. They proposed five waste elimination strategies, as shown in Table 4.

In this study, three categories of kaizen recommendations were developed. The first category recommends that the SMI managers optimize the operating procedures by reducing walking and waiting time. The second category suggests reducing inventory by collaborating with other cosmetics manufacturers to share the truckload, reduce drum size, and implement the kanban system. The third category recommends installing green facilities by replacing desktop computers with laptops and facilitating shared air conditioning for rooms. Table 4 discusses the potential tangible benefits of the application of kaizen ideas. The first benefit includes a 1.81% rise in the MCE by reducing the walking and waiting time by 460 s. The second benefit involves reducing the inventory lead time by 36% or 10.56 days. Another benefit is an improvement in the LCIA score by 13.16 Pt (33%) by reducing electricity consumption in both production and non-production areas. The company can reduce expenses by Rp. 0.51 million/month (41% from the monthly electricity cost) by combining air conditioners in warehouses, filling workstations, and replacing desktop computers with laptops.

Fig. 4 shows these improvement ideas as a recommended future state map. Blitz symbols represent these ideas [35]. Fig. 4 also emphasizes the changes to the production order information flow by utilizing the kanban system. The production planning and control staff issue the production kanban orders to the dispatch workstation. The workstations before the delivery workstation use the kanban system to order production and request goods under the pull system. Table 5 demonstrates the implementation of the GVSM method for the production of 900 kg of liquid face soap.

Table 4. Improvement strategies proposed during the kaizen events

ROOT CAUSE	KAIZEN IDEAS	MERIT	THINGS TO DO
The operator does not seem aware that the back-and-forth movement in weighing each item is wasteful.	Eliminate unnecessary motion in weighing materials: - Saponification process: replace the repeated movement six times with the movement that shall be repeated twice. - Mixing process: replace the movement that was repeated twice with the movement that shall be performed once.	Reduce the moving time by 180 s and distance by 36 m. This reduction includes 150 s (30 m) in saponification and 30 s (6 m) in the mixing process [improve MCE by 0.7%].	Rewrite the standard operating procedure and facilitate training for the operator.
The operator simply follows the instructions.	The operator need not wait for the water to boil. After switching on the electric kettle, the operator can simultaneously prepare the container.	Reduce waiting time by 280s [improve MCE by 1.1%]	Rewrite the standard operating procedure and facilitate training for the operator.
The supplier has offered a minimum price if the company were to buy the material in bulk quantities.	Collaboration with other cosmetics manufacturers in the same area to share truck loading and reach the minimum order lot size.	Reducing inventory lead time to ten days	Develop a kanban system to avoid shipment errors.
The operator chose the 150 kg drum because of the long expiration time of the base liquid.	Reduce the production of the base liquid of the face soap inventory to 200 kg by changing the drum size to 100 kg.	Reduce inventory lead time by 0.56 days	Prepare some supermarkets and kanban systems to avoid errors in production numbers.
- The material warehouse air conditioner had the power of 1 HP. It was excessive for a 7 m^2 warehouse. - The administration computers were of the desktop type and consumed 100 W in a span of 8 h.	- Reduce 1 AC unit (3 kW h/batch) by combining the use of the AC in the warehouse (7 m^2) and in the filling workstation (15 m^2) - Replace the desktop with a laptop (100 W □ 65 W). The potential energy reduction is 1.35 kW h/batch.	Decrease the damage impact by 7.32 Pt. Electricity savings/month = (3 + 1.35) kW h/batch x 2 x 22 day = 191.5 kW h/Month = Rp. 0.29 million/month	- Make a hole in the wall between the warehouse and the filling room. Estimated expense is Rp. 1 million - Purchase 5 laptops at the cost of Rp. 20 million Estimated revenue from the sale of the used AC and PCs is Rp. 6 million
Lack of awareness of efficient use of the machines and equipment	Updating work standards by turning off machines and equipment right after use	Reduction in the damage impact by 5.84 Pt. Electricity savings/month = 3.43 kW h/batch x 2 x 22 day = 150.9 kW h/Month = Rp. 0,22 million/month	Designing job monitoring and energy-saving campaigns

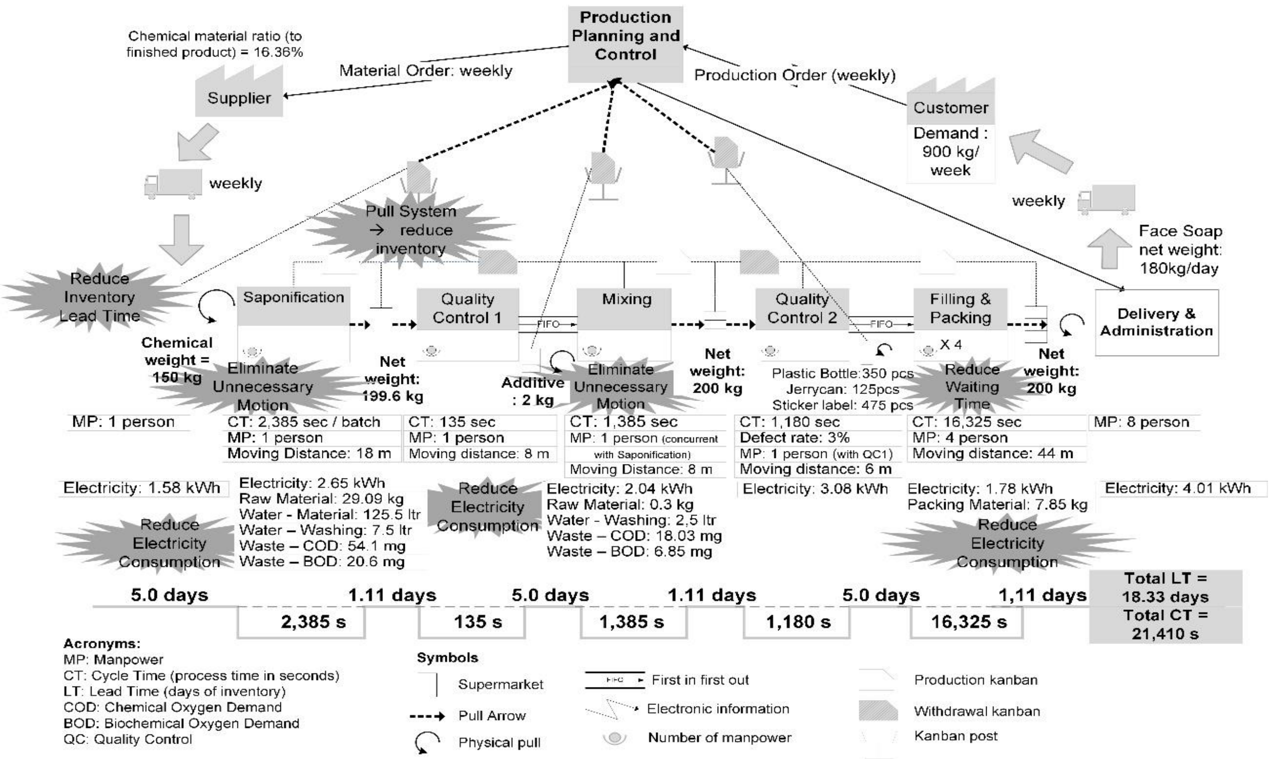

Fig. 5. Future State Map

Table 5. Result of GVSM implementation

SUSTAINABILITY INDICATORS	BEFORE LEAN AND GREEN	AFTER LEAN AND GREEN	IMPROVEMENT RESULT
Cycle Time	21,870 s	21,140 s	460 s
Inventory Lead Time	28.89 days	18.33 days	10,56 days (-36%)
Electricity Consumption	22.91 kW h	15.13 kW h	7.78 kW h
MCE	84.96%	86.87%	1.81%
LCIA Score	40.42 Pt	27.26 P7	13.16 Pt (-33%)
Cost Saving			Rp. 0.5 million/month

CONCLUSION

Inefficiency and environmental hostility in cosmetics SMIs and limited research on the practical implementation of lean and green principles motivated the researchers to conduct this study. This research aims to help SMI managers understand and assess the implementation of lean and green principles to achieve a sustainable production process. A combination of GVSM and LCIA techniques was used in this study to perform an in-depth analysis of the lean and green techniques used to make the manufacturing process sustainable. The MCE value and environmental impact score are used as the GVSM and LCIA indicators. These performance indicators lead to a critical process that needs to be examined by management. This process makes it easier for SMI managers to develop a business improvement strategy in the future. The GVSM analysis of the liquid face soap production investigated in this study included parameters such as time taken for movement, waiting time, and inventory waiting time. The MCE score was equal to 84.96%. A combination of the GVSM data and the LCIA method reported an environmental damage value of 40.42 Pt, 98.7% of which corresponded to human health. A breakdown of each workstation's indicator values demonstrated that waste was produced in the saponification, mixing, material warehousing, filling and packaging, and office sites.

A root cause analysis was performed in conjunction with the kaizen events. Based on this analysis, five kaizen ideas were proposed to help managers improve the lean and green performance indicators. These kaizen ideas shorten the cycle time by 460 s, thereby increasing the MCE value by 1.81%. In addition, the inventory lead time was reduced by 36% or 10.56 days, and the environmental impact score reported an improvement of 33% or 13.16 Pt. The company also reported savings due to the efficient consumption of electricity of Rp. 0.51 million/month (41% of the monthly electricity cost).

The results of this study can provide a blueprint for the assessment of the sustainability of cosmetics SMIs. The generality of using a combination of lean and green methods and tools in this research has made it applicable in various industries other than cosmetics. Although a substantial MCE rise has not been reported in this study, the recommended improvement ideas can significantly reduce the cosmetic manufacturing process' impact on human health. Future studies can explore additional improvements to increase the MCE value above 90% through chemical material substitution and advanced engineering methods. Besides, the kaizen events in this study only involve internal company employees. This research included brainstorming at the multi-actor level, involving all stakeholders to obtain an optimal sustainable manufacturing process improvement scenario. The scope of this research is still limited to the gate-to-gate manufacturing process. It requires a further and more in-depth study of sustainable performance at the whole supply chain level, from upstream to downstream.

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Appendices

APPENDIX 1. PROCESS MAPPING ACTIVITY

PROCESS	JOB ELEMENT	MOVING DISTANCE (m)	PROCESS TIME (s)	INSPECTION TIME (s)	STORAGE TIME (s)	MOVING TIME (s)	WAITING TIME (s)	CYCLE TIME (s)
			VA	NNVA	NNVA	NVA	NVA	TOTAL
Saponification	A.1. Prepare the empty drum		30					30
	A.2. Move the drum to the saponification area	6				30		30
	A.3. Walk into the material warehouse	18				90		60
	A.4. Weigh the chemical materials		150					150
	A.5. Walk into the saponification area	18				90		60
	A.6. Mix the ingredients in water until the mixture is homogeneous		1.230					1.230
	A.7. Bring the base soap drum to the quarantine area	2			15			15
	A.8. Wash the equipment and put it in its original place		900					900
	Sub Total	**44**	**2.310**	**-**	**15**	**210**	**-**	**2.475**
QC1	A.9. Add water until it reaches standard mass	2	100					100
	A.10. Viscosity and colour inspection	2		20				20
	A.11. Move the base into the stock area	4			15			15
	Sub Total	**8**	**100**	**20**	**15**	**-**	**-**	**135**
Mixing	A.12. Take the liquid base and place it in a separate container		90					90
	A.13. Walk into the warehouse area	6				30		30
	A.14. Weigh chemical materials		50					50
	A.15. Walk into the mixing area	6				30		30
	A.16. Mix ingredients until homogeneous		300					300
	A17. Slide the drum into the quarantine area	2			15			15
	A.18. Wash the equipment and place it in its original location		900					900
	Sub Total	**14**	**1.340**	**-**	**15**	**60**	**-**	**1.415**
QC2	A.19. Slide the liquid face soap drum from mixing into the QC area	6		580				580
	A.20. Check the viscosity and colour in the laboratory			580				560
	A.21. Label it as QC passed or store it in the "defect area" if it failed to be reprocessed			20				20
	Sub Total	6	**-**	**1.180**		**-**	**-**	**1.180**
Labelling	A.22. Prepare the bottle and jerry can		300					300
	A.23. Move the bottle and jerry can into the sticker room	10				300		300

PROCESS	JOB ELEMENT	MOVING DISTANCE (m)	PROCESS TIME (s)	INSPECTION TIME (s)	STORAGE TIME (s)	MOVING TIME (s)	WAITING TIME (s)	CYCLE TIME (s)
			VA	NNVA	NNVA	NVA	NVA	TOTAL
	A.24. Prepare the suitable label/sticker		180					180
	A.25. Move the label from the warehouse into the labelling area	4				60		60
	A.26. Tag the bottle and jerry can		3.300					3.300
	A.27. Move the bottle and jerry can with the sticker into the barcode area	10				300		300
	A.28. Set the barcode machine		60					60
	A.29. Barcode the bottle and jerry can		300					300
	A.30. Collect the bottle and jerry can in a large plastic bag		300					300
	A.31. Move the bottle and jerry can into the filling area	2				30		30
	A.32. Clean the labelling area		60					60
	Sub Total	**26**	**4.500**	**-**		**690**	**-**	**5.190**
Filling	A.33. Prepare the bottle/jerry can cap and the filling equipment		300					300
	A.34. Slide the liquid face soap until it approaches the filling table	1				20		20
	A.35. Fill manually		4.500					4.500
	A.36. Clean and wipe the bottle and jerry can			300				300
	A.37. Close the bottle and jerry can		750					750
	A.38. Coat the bottle with plastics		750					750
	A.39. Arrange the bottle and jerry can in a basket and store it		300					300
	A.40. Clean the area and equipment		60					60
	Sub Total	**1**	**6.660**	**300**		**20**	**-**	**6.980**
Packaging	A.41. Move the bottles and jerry cans into the packaging room	1				15		15
	A.42. Boil the water in an electric kettle		30					30
	A.43. Wait for the water to boil						480	480
	A.44. Shrink the plastic coat at the top of the bottle		1.350					1.350
	A.45. Shrink the plastic coat at the bottom of the bottle		1.800					1.800
	A.46. Walk to the packaging warehouse	5				**75**		
	A.47. Prepare the returnable container		130					130
	A.48. Walk back to the packaging area	5				**75**		
	A.49. Arrange the product in the container		300					300

PROCESS	JOB ELEMENT	MOVING DISTANCE (m)	PROCESS TIME (s)	INSPECTION TIME (s)	STORAGE TIME (s)	MOVING TIME (s)	WAITING TIME (s)	CYCLE TIME (s)
			VA	NNVA	NNVA	NVA	NVA	TOTAL
	A.50. Move it to the final product storage	6			120			120
	A.51. Clean the area and equipment		60					60
	Sub Total	**17**	**3.670**	**-**	**120**	**165**	**480**	**4.435**

Appendix 2. Environmental impact per unit category

IMPACT CATEGORY	UNIT	TOTAL IMPACT	MATERIAL WAREHOUSING	SAPONIFICATION	MIXING WITH PARFUME	LABELLING, FILLING, PACKAGING	ADMINISTRATION
Fine particulate matter formation	DALY	0.00210	0.00027	0.00051	0.00051	0.00034	0.00047
Global warming	DALY	0.00016	0.00002	0.00004	0.00004	0.00003	0.00003
Human non-carcinogenic toxicity	DALY	0.00006	0.00001	0.00002	0.00002	0.00001	0.00001
Human carcinogenic toxicity	DALY	0.00004	0.00001	0.00001	0.00001	0.00001	0.00001
Water consumption. Human health	DALY	9.15E-07	1.18E-07	2.24E-07	2.21E-07	1.49E-07	2.04E-07
Ozone formation. Human health	DALY	3.93E-07	5.07E-08	9.39E-08	9.52E-08	6.53E-08	8.77E-08
Stratospheric ozone depletion	DALY	2.70E-08	3.47E-09	6.43E-09	6.52E-09	4.58E-09	6.01E-09
Ionising radiation	DALY	4.16E-09	5.39E-10	9.97E-10	1.01E-09	6.79E-10	9.31E-10
Human Health	**DALY**	**0.00237**	**0.00031**	**0.00057**	**0.00058**	**0.00039**	**0.00053**
Fine particulate matter formation	DALY	0.00210	0.00027	0.00051	0.00051	0.00034	0.00047
Global warming	DALY	0.00016	0.00002	0.00004	0.00004	0.00003	0.00003
Human non-carcinogenic toxicity	DALY	0.00006	0.00001	0.00002	0.00002	0.00001	0.00001
Human carcinogenic toxicity	DALY	0.00004	0.00001	0.00001	0.00001	0.00001	0.00001
Water consumption. Human health	DALY	9.15E-07	1.18E-07	2.24E-07	2.21E-07	1.49E-07	2.04E-07
Ozone formation. Human health	DALY	3.93E-07	5.07E-08	9.39E-08	9.52E-08	6.53E-08	8.77E-08
Stratospheric ozone depletion	DALY	2.70E-08	3.47E-09	6.43E-09	6.52E-09	4.58E-09	6.01E-09
Ionising radiation	DALY	4.16E-09	5.39E-10	9.97E-10	1.01E-09	6.79E-10	9.31E-10
Human Health	**DALY**	**0.00237**	**0.00031**	**0.00057**	**0.00058**	**0.00039**	**0.00053**

IMPACT CATEGORY	UNIT	TOTAL IMPACT	MATERIAL WAREHOUSING	SAPONIFICATION	MIXING WITH PARFUME	LABELLING, FILLING, PACKAGING	ADMINISTRATION
Global warming. Terrestrial ecosystems	species.yr	4.69E-07	6.06E-08	1.12E-07	1.14E-07	7.70E-08	1.05E-07
Freshwater eutrophication	species.yr	1.76E-07	2.27E-08	4.21E-08	4.27E-08	2.87E-08	3.93E-08
Terrestrial acidification	species.yr	1.24E-07	1.60E-08	2.96E-08	3.01E-08	2.03E-08	2.77E-08
Ozone formation. Terrestrial ecosystems	species.yr	5.60E-08	7.23E-09	1.34E-08	1.36E-08	9.32E-09	1.25E-08
Freshwater ecotoxicity	species.yr	7.96E-09	1.03E-09	1.91E-09	1.94E-09	1.30E-09	1.78E-09
Water consumption. Terrestrial ecosystem	species.yr	6.61E-09	7.53E-10	2.17E-09	1.44E-09	9.50E-10	1.30E-09
Land use	species.yr	2.42E-09	3.03E-10	5.90E-10	5.88E-10	3.95E-10	5.42E-10
Terrestrial ecotoxicity	species.yr	2.36E-09	3.04E-10	5.63E-10	5.71E-10	3.94E-10	5.25E-10
Marine ecotoxicity	species.yr	1.58E-09	2.05E-10	3.80E-10	3.85E-10	2.59E-10	3.55E-10
Marine eutrophication	species.yr	2.71E-11	3.51E-12	6.50E-12	6.59E-12	4.43E-12	6.07E-12
Global warming. Freshwater ecosystems	species.yr	1.28E-11	1.66E-12	3.06E-12	3.11E-12	2.10E-12	2.86E-12
Water consumption. Aquatic ecosystems	species.yr	9.32E-13	5.73E-14	5.77E-13	1.26E-13	7.23E-14	9.91E-14
Ecosystem	**species.yr**	**8.45E-07**	**1.09E-07**	**2.03E-07**	**2.05E-07**	**1.39E-07**	**1.89E-07**
Fossil resource scarcity	USD2013	6.85683	0.88800	1.64400	1.67000	1.11978	1.53505
Mineral resource scarcity	USD2013	0.02097	0.00272	0.00503	0.00510	0.00343	0.00470
Resources	**USD2013**	**6.87780**	**0.89072**	**1.64903**	**1.67510**	**1.12321**	**1.53974**