# Integrating VSM and Waste Identification with Cost Deployment into Leathergoods Production

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**Abstract**: The luxury industry serves as a vital economic pillar for various countries. Companies within this sector encounter several challenges, including high variability, low predictability, short product life cycles, and high product customization. These factors contribute to a significant level of uncertainty, frequently resulting in challenges to meet customer needs promptly. As a response, there is a growing imperative to streamline operations and enhance effectiveness to successfully navigate the dynamic shifts in the market. While the adoption of lean principles could address these challenges, implementing lean practices in a luxury enterprise proves challenging due to the high variability of products. Consequently, the transition to a lean factory is not a straightforward process. This paper aims to present a feasible approach for integrating lean principles into a luxury company to minimize potential waste. In this context, the Value Stream Map (VSM) is combined with Waste Identification (WID) to comprehend the distribution of wastes within various processes. Additionally, Cost Deployment (CD) is adopted to connect activities for waste reduction with cost reduction objectives. This final phase contributes to a deeper understanding of the company's financial landscape. The proposed framework is applied to a case study of a luxury company operating in the leather field. The framework could be adopted to identify and quantify wastes, leading to the detection of the most impactful ones. Accordingly, it could guide the prioritization of appropriate countermeasures, enhancing operational excellence and continuous improvement in companies.

**Keywords**: Luxury, Lean philosophy, Operational efficiency, High-end market, Waste reduction

## 1.Introduction

The luxury industry is a pivotal sector in several countries, among which Italy (Brun et al., 2008). In this context, luxury fashion companies play a pivotal role. Luxury products are usually characterized by multiple critical success factors such as premium quality, craftsmanship, style and design, and country of origin (Caniato et al., 2009). Due to their intrinsic features, luxury fashion products are affected by numerous challenges, among which high variability, low predictability, short product life cycles, and high product customization (Carmignani, 2016). All the former aspects create uncertainty and difficulties when managing operations, possibly leading to inefficiency and difficulties in meeting customer needs when required.

To reduce wastes and improve the efficiency, lean approaches and principles have been successfully adopted for different purposes. Examples include reducing improving automotive operations (Rifqi et al., 2021) and optimizing the patient flows in a hospital (Matt et al., 2018). Lean has seen applications also in the luxury context. However, due to the specificity of the industry, implementing lean practices could be particularly challenging (Carmignani and Zammori, 2015) and there could be some confusion when applying lean practices (Lemieux et al., 2012). Furthermore, in luxury fashion industry, lean approaches are more popular at a strategic or tactical level rather than the operational one (Carmignani and Zammori, 2015). Moreover, adapting lean tools is not straightforward due to difficulties in their generalization (Bertolini et al., 2013).

Based on the former considerations, this paper aims to propose a potential framework to identify wastes and prioritize their removal in the luxury fashion industry. To this end, a combination of three popular tools is proposed: Value Stream Map (VSM), Waste Identification Diagram (WID), and Cost Deployment (CD). The first two are used to detect wastes, while the third one is adopted to economically evaluate and prioritize them. The developed methodology has been applied to a real case study of a luxury fashion company in Italy. The proposed approach could be used by managers operating in the luxury fashion industry to reduce wastes and improve efficiency. As a reminder, the structure of the paper is as follows: Section 2 presents the background and related work, while Section 3 describes the adopted tools. In Section 4, the proposed framework is illustrated, while Section 5 and Section 6 reports the discussion and conclusions respectively.

## 2.Background

During the past years, some studies have investigated the application of lean practices in the luxury fashion industry. An interesting example is the study of Carmignani and Zammori (2015), who proposed a framework for selecting and implementing lean tools in a luxury fashion company, pointing out how lean could be exploited to obtain higher operational performance. Another work by Carmignani (2016) obtained operational benefits (reduced lead time and defects) through the implementation of a lean framework, leading to a re-layout. Similarly, Cantini et al., (2020) and Cantini et al., (2021) optimize the layout of a luxury company through lean principles, leading to a reduction in operating costs. A more recent study by Braglia et al., (2020) proposed a framework based on 5-Whys Analysis to identify and erase inefficiencies in a luxury supply chain. Lean Thinking has also been recently applied by Braglia et al., (2024) to identify suitable sustainability measures and priorities them, considering luxury plywood production company as case study.

Despite all these efforts, literature on lean application related to the operations of luxury industry is still rare, and there is no universal framework (Carmignani and Zammori, 2015). Therefore, there is the need to investigate possible solutions to integrate lean practices into luxury operations. This study aims to provide a potential framework based on VSM, WID, and CD. VSM has already been applied in previous studies for the luxury industry. However, VSM has some drawbacks such as inability to represent production flows, absence of graphical indicators for transport and queues, and absence of layout representation (Dinis-Carvalho et al., 2019). WID could be integrated with the VSM to overcome some of its typical limitations (Dinis et al., 2015), while maintaining the information flow that is not tracked by WID. Despite that, as far as the authors know, it has not been extended to the luxury field. WID could also be able to report some economic indicators. However, it does not provide a systematic way to evaluate potential countermeasures to remove wastes. Thus, CD is adopted for this purpose as a systematic approach to economically evaluate wastes, propose solutions, and give them priority.

## 3.Material and Methods

This work exploits three main approaches: i) VSM, ii) WID, and iii) CD. These approaches are described in the following sections.

### 3.1 Value Stream Map

The VSM is a very popular tool employed to visualize the flow of materials and information from the supplier to the customer. The VSM aims to identify non-value added activities that should be reduced or eliminate (Dinis-Carvalho et al., 2019), along with depicting both the current and potential future ideal state (Rother and Shook, 2003). The VSM consists of four main phases as follows (Dinis et al., 2015): i) product family selection, ii) drawing the VSM associated with the current state, iii) drawing the VSM of the desired future state, and iv) definition and development of the required actions. The VSM should be drawn with a pencil and a rubber to allow subsequent amendments. Furthermore, it is usually recommended to carry out the drawing process in the Gemba, following the real flow starting from the customer. Finally, useful information such as Takt Time, Cycle Time, and Lead Time of each process should be collected.

### 3.2 Waste Identification Diagram

The WID is a graphic representation tool introduced by Sá et al. (2011). The aim of WID is to identify wastes and display them through user-friendly visual diagram quick to comprehend. The WID representation is composed of three main symbols: three-dimensional blocks, bi-dimensional arrows, and a pie chart (see Figure 1). Blocks and arrows identify machines (equipment, workbenches, stations, or processes) and transports between machines respectively, while pie charts represent how much time the workers dedicate to different purposes (e.g., moving, overprocessing, etc…) (Dinis-Carvalho et al., 2019). The length and the width of each block represent the Work In Process (WIP) upstream the station and the Setup Time (ST) respectively. A block will be two-dimensional in case its associated ST is null. The height of each block represent the Takt Time related to the activity. Moreover, the height could be divided into different sections depending on the kind of representation. The basic representation divides the height of the blocks between Cycle Time (CT) and Idle Time. In the advanced version the height is divided into multiple sections, each of which could be related to a component of the Overall Equipment Efficiency (OEE) (Dinis et al., 2015). Considering the arrows, their length has no particular meaning, while their width is related to the Transportation Effort between the upstream and downstream block. Its value is obtained as the product between the transported quantity (or cost) and the travelled distance. The transported quantity could be measured through different units such as parts, kilograms, or costs (Sá et al., 2011).

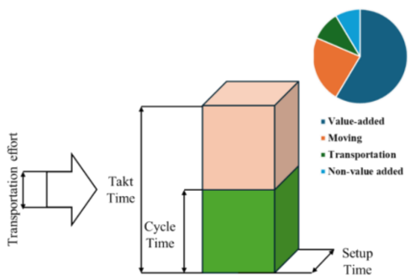


**Figure 1: schematic representation of WID.**

The bigger a given block, the bigger is the waste associated with the corresponding process. Furthermore, while blocks represent the inventory (WIP) and overprocessing, the arrows identify the transportation waste. Another interesting piece of information is that the frontal area of each block represents the Throughput Time (Dinis-Carvalho et al., 2015), obtained through the Little's Law.

### 3.3 Cost Deployment

The CD is a tool that aims to identify production losses, guiding the decision-making process related to cost reduction improvements in a systematic way (Yamashina and Kubo, 2002). prioritizing appropriate improvements to reduce losses.

The CD is characterized by a sequence of seven steps (Braglia et al., 2019): i) identify loss and waste categories, ii) quantify losses and wastes, iii) clarify cause-effect relationships between losses, iv) convert losses into costs, v) define improvement projects, vi) determine the costs related to the improvements and the cost-benefit ratio, and vii) select most appropriate improvements and implement them. The seven steps are associated with the building of specific matrixes (Giovando et al., 2017).

During the first step, useful data and information are collected. In the second step, the "A-Matrix" is built. The "A-Matrix" links the losses or wastes (vertical axis) to the processes (horizontal axis). Furthermore, the "A-Matrix" reports different symbols based on the impact of each loss in terms of frequency or occurrence. In the third step, the "B-Matrix" is built. A given loss could generate additional losses. The "B-Matrix" places the causal losses and their locations on the vertical axis, while the resultant losses and their locations are placed on the horizontal axis. Through a specific symbol (e.g., a cross or a circle), the causal losses are linked to the resultant ones. During the fourth step, the "C-Matrix" is created to convert each loss into a cost. This phase is carried out considering different cost factors such as direct material cost and direct labour cost. The losses should be eliminated through a systematic approach. To this end, the "D-Matrix" is created in the fifth step. The "D-Matrix" lists the causal losses and their locations on the vertical axis, and it links each causal loss to potential improvements placed on the horizontal axis. To evaluate each improvement and compare them, the Impact-Cost-Easiness (ICE) index is defined. As the name suggests, the ICE considers the benefits arising from the investment, its cost, and the easiness of implementation. Each of the former factor is usually evaluated through a 1 to 5 scale, and it could be added to the "D-Matrix". Next, the "E-Matrix" is created to keep track of the implemented investments and give them priority. This matrix reports a measure of investment efficiency for each investment, such as the Net Present Value (NPV) (Braglia et al., 2021) or the ratio between expected benefits and expected cost (Yamashina and Kubo, 2002). Finally, the last step of the CD requires the implementation of the amendments, along with monitoring them. This could be carried out through an additional matrix named "F-Matrix".

## 4.Proposed Framework

The proposed framework is composed of three main phases as shown in Figure 2. The phases are: i) waste identification, ii) economic evaluation of improvements, and iii) implementation and monitoring.

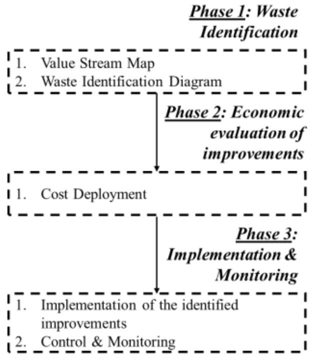


**Figure 2: steps of the proposed framework.**

During the first phase, the process is mapped through the VSM. This tool is widely recognized for its effectiveness in mapping processes within the realm of lean applications. To have a better understanding of the wastes through economic indicators and graphic representation, the WID is adopted in this phase as well. The VSM and WID are integrated to identify the most impactful wastes, following previous works (Dinis-Carvalho et al., 2017). This combination allows to have different perspectives on wastes, possibly providing a better understanding of them.

The former phase is not sufficient to guide improvements since it lacks an economic analysis. Therefore, the CD is employed during the second phase to perform an economic analysis of the wastes and identify possible improvement activities. The CD allows to prioritize the improvements and guide the subsequent decision-making process. The CD is carried out based on the wastes identified through the previous phase. Based on the former considerations, the first phase is related to the identification of wastes that should be removed or reduced. On the other hand, the second phase guides the decision-making process related to the amendments that should be implemented. The amendments could involve typical lean approaches (e.g., "5S").

Finally, the third phase is related to implementing the improvements, along with controlling and monitoring their effectiveness.

## 5.Results

To demonstrate the application of the framework, an Italian leather factory has been chosen as case study.

### 5.1 Case study

The company under investigation serves various customers, each managed through distinct strategies. Regardless of the customer, to fulfil the request of any new item, a prototype is produced. In case it is accepted by the customer, the production starts, and it is maintained till the ordered quantity is reached.

Even if the realized products could be different, the production phases are generally the same. First, there is the cutting phase, which involves cutting the raw materials according to the specifications outlined in the bill of materials. Subsequently, the cut materials undergo various processing steps, which vary depending on the specific product. This phase is known as material preparation, and a common step involves branding the leather with the customer's logo. For the purposes of the present study, only one client has been considered. The client has been chosen based on the relevance it has for the considered company. Furthermore, the framework has been applied to the cutting phase.

### 5.2 Identification of wastes through VSM and WID

First, Phase 1 (Wase Identification) is carried out. The VSM of the desired process is built. The cutting phase is characterized by different machine. There are twelve machines of five kinds, each of which is dedicated to five different materials. A different VSM is built for each machine and material. Indeed, the CT and lead time of each machine are different. As an example, Figure 3 depicts part of the VSM related to the automatic blade machine used for cutting the leather. The data listed in Figure 3 do not correspond to the real one due to privacy policy.

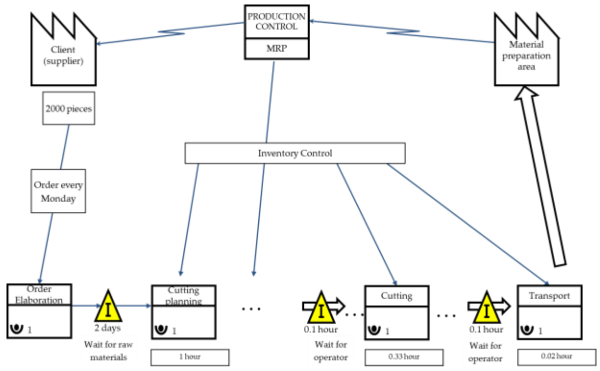


**Figure 3: Portion of the VSM developed for a cutting station.**

To extract the information related to the VSM, the CT and lead time are estimated as the mean time among all the operators that can perform a given activity. For each operator, multiple time are measured. The VSM are directly drawn in the Gemba, following the production orders. During the VSM creation, some critical aspects emerged. First, the stocking process is poorly organized due to lack of space. Many shelves are filled with old materials that have not been properly disposed. New materials are located where there is enough space, and their location is not tracked. Materials could be located on the production floor, limiting the movements of operators and hindering the picking phase. This, in turn, leads to high waste related to the search of required materials and useless material movements.

Following the flowchart of Fig. 2, the WID is drawn. Figure 4 reports a portion the WID realized for the cutting phase. Specifically, the WID is related to the aforementioned twelve machines dedicated to the cutting phase. The values are normalized due to company policy. The normalized Takt Time is equal to 89.3 seconds. The ST is estimated as the ratio between the required ST of each machine and the batch size. The height of the arrows represents the transportation efforts. The distances are estimated as Euclidean distances. Relevant data are listed in Table 1.

**Table 1: Normalized data for the WID associated with each machine.**

| Station ID | CT [s] | ST [s] | WIP [pieces] | Transportation Efforts [pieces*meter] |
|---|---|---|---|---|
| 1 | 16 | 1.140 | 14 | 22 |
| 2 | 16 | 1.140 | 16 | 26 |
| 3 | 16 | 1.140 | 20 | 25 |
| 4 | 10 | 1.047 | 49 | 82 |
| 5 | 20 | 0.837 | 40 | 14 |
| 6 | 20 | 0 | 35 | 25 |
| 7 | 20 | 0 | 47 | 47 |
| 8 | 20 | 0 | 18 | 24 |
| 9 | 15 | 0 | 104 | 171 |
| 10 | 13 | 0 | 12 | 16 |
| 11 | 13 | 0 | 10 | 10 |
| 12 | 13 | 0 | 18 | 32 |

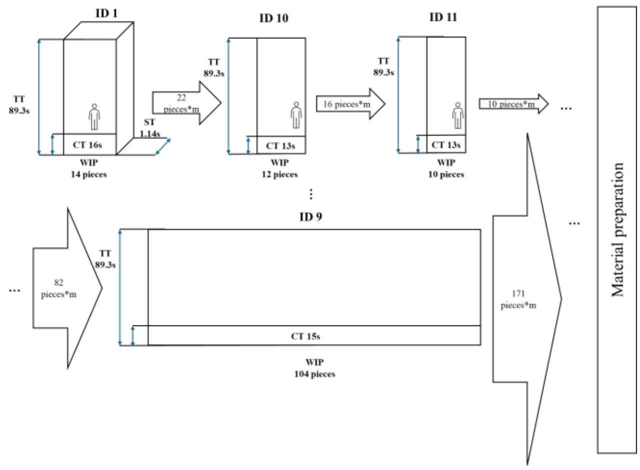


**Figure 4: WID of a portion of the cutting phase.**

Analysing the WID, the station characterized by the highest waste is the ninth (see Figure 4). Indeed, the frontal area of the associated block is the largest. As a reminder, this area is obtained as the product of the WIP and TT. Moreover, the fourth station is characterized by the highest idle time given by the difference between its TT and CT.

Besides the former diagram, the WID requires also to report a pie-chart denoting how the operators employ their time. This step is important to identify the greatest sources of waste. In this study, the following activity types are considered: i) waiting (e.g., waiting for materials), ii) moving (e.g., picking the leather pattern from the shelves), iii) transporting (e.g., re-placing the boxes on the shelves), iv) adding value (i.e., cutting and defect detection), and v) non-adding value (e.g., counting of cut items or leather preparation). Measuring the time employed for each of the former activity type, the pie-chart of Figure 5 is obtained.

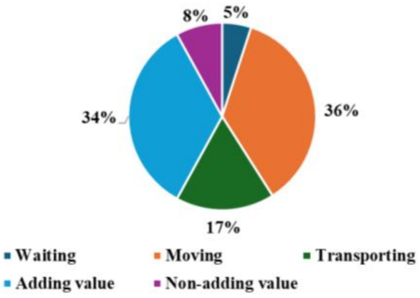


**Figure 5: Pie-chart of the activity types related to the cutting phase.**

It emerged that most of the wastes are associated with the moving activities (36%), followed by the transporting ones (17%). Furthermore, 5% and 8% of the time is employed for waiting and non-value adding activities respectively. Finally, 34% of the time is dedicated to value adding activities.

### 5.3 Economic evaluation of losses through CD

Moving onto the second phase of the framework (see Figure 2), the CD is carried out to economically quantify the identified wastes. The first step of the CD is identifying losses and wastes. This step has already been conducted thanks to the VSM and WID. In this work, four kinds of loss are considered: i) Machines, ii) Workforce, iii) Procedures, Management, and Logistics, and iv) Training. Within the "Machines" (MAC) category, breakdowns, maintenance, and machine underusage (MUU) are included. The "Workforce" (WF) class is related to the losses related to human resources (e.g., distraction, inexperience etc…). The following losses fall within this category: incorrect/omitted declaration of consumption (IDC), direct labour loss, missing information, omitted material registration of incoming materials, partial control on the quality of incoming materials, and failure to prompt supplier delay. The "Procedure, Management, and Logistic" (PMS) set comprehends all the losses, but the ones related to human and physical resources. This class includes for instance excessive movements of operators, excessive (high) CT, warehouse management costs (WMC), re-planning costs (RPC). Finally, the "Training" category is related to extra-consumption and failure to use informatic systems due to unprepared workforce or lack of training. For brevity, only a portion of the former losses will be discussed. Considering the aforementioned losses, the "A-Matrix" is built to link the losses to their location and assess their impact. For brevity, Table 2 lists a portion of the developed "A-Matrix". The impacts of the losses are evaluated as a scale from 1 to 3, where 3 is the highest impact.

**Table 2: "A-Matrix" built for the considered case study.**

| Loss class | Loss | Process | | |
|---|---|---|---|---|
| | | Stocking | Picking | Cutting |
| MAC | Breakdown | | | 3 |
| | Maintenance | | | 3 |
| | MUU | | | 3 |
| WF | IDC | | 2 | |
| | DLS | | | 3 |
| | Missing information | | | 2 |

From the "A-Matrix" emerged that the most critical process is the cutting, which is most impacted by losses falling within the PMS. Next, the "B-Matrix" is created to define the cause-effect relationships between losses. A portion of the "B-Matrix" is shown in Table 3. Breakdown is a causal loss, which could result in MUU, excessive CT, production re-planning, and direct labour loss. Maintenance is also a causal loss that generates MUU. MUU is the only resultant loss identified for within the MAC class. A similar process is applied to detect the remaining causal and resultant losses.

**Table 3: "B-Matrix" built for the considered case study.**

| Loss class | Causal Loss | Resultant Loss | | | | |
|---|---|---|---|---|---|---|
| | | MAC | WF | PMS | | |
| | | MUU | DLS | High CT | WMC | RPC |
| MAC | Breakdown | X | X | X | | X |
| | Maintenance | X | | | | |
| WF | IDC | | | | X | |
| | Missing Information | X | X | X | | |

The fourth step of the CD approach involves constructing the "C-Matrix" (see Table 4) to transform causal losses into costs, a crucial step for prioritizing improvement activities. The data collected during the VSM and WID are used to perform the economic evaluation of losses. The workforce cost is standardized at 28 €/hour. The cost linked to each machine is calculated as the combined total of its energy and depreciation costs. The energy cost is determined by multiplying the total energy cost of the department by the percentage of machine hours compared to the entire department hours worked. All the causal losses are economically evaluated as the product of the hours associated with a given loss and the hourly cost related to the cost factor that is impacted by that loss. Table 4 lists the normalized costs associated with each loss, considering three cost factors: Machine Cost Factor (MCS), Indirect Workforce Cost Factor (IWCF), and Direct Workforce Cost Factor (DWCF). By analysing the costs, the PMS loss category emerged as the predominant one, accounting for 57% of the total costs. Within the former losses, the excessive movement of operators is depicted as the most impactful one.

**Table 4: "C-Matrix" built for the considered case study**

| Loss class | Causal Loss | Cost factor | | |
|---|---|---|---|---|
| | | MCF | IWCF | DWCF |
| MAC | Breakdown | 36 | | |
| | Maintenance | 36 | | |

| | | | |
|---|---|---|---|
| WF | IDC | | |
| | Missing information | 1 | 3 |

The former steps are fundamental to identify the losses and quantify them. Next, it is required to determine potential approaches to reduce or remove them. Furthermore, for each loss and improvement an index able to guide which loss should be addressed first should be estimated. In this work, the ICE index is considered (Braglia et al., 2019) as the product of three Factors: I, C, and E. I, C, and E represent the impact factor of each loss, the cost factor related to the potential improvement activities, and the easiness of reducing or removing the loss respectively. All of them are evaluated through a scale between 1 and 5. The impact factor was evaluated by defining five clusters of the ratio between the impact of each loss and the total loss of the department. The cost factor was estimated based on the estimated costs related to the improvement. Finally, the easiness factor was defined based on the predicted required resources and time to reduce or remove the loss. Considering the former factors, a value equal to 1 is associated with low impact and low easiness. However, to make the scale comparable, a value equal to 1 is assigned to high cost of implementation. A portion of the developed “D-Matrix” is shown in Table 5 (ICE index) and Table 6 (potential improvement). Based on the ICE index definition, the higher its value, the higher the priority of the given loss. Accordingly, the excessive movement of operators has the priority since it has the highest ICE.

**Table 5: “D-Matrix” reporting the ICE estimated for each loss.**

| ID | Causal Loss | Loss Class | Value | % | I | C | E | ICE |
|---|---|---|---|---|---|---|---|---|
| 1 | Breakdown | MAC | 36 | 8 | 3 | 3 | 2 | 18 |
| 2 | Maintenance | MAC | 36 | 8 | 3 | 3 | 2 | 18 |
| 3 | Missing information | WF | 4 | 1 | 2 | 2 | 1 | 4 |
| 4 | Excessive movement of operators | PMS | 41 | 9 | 3 | 2 | 4 | 24 |

**Table 6: “D-Matrix” reporting the potential improvement activities.**

| ID | Causal Loss | Loss Class | Improvement |
|---|---|---|---|
| 1 | Breakdown | MAC | Preventive Maintenance |
| 2 | Maintenance | MAC | |
| 3 | Missing information | WF | |
| 4 | Excessive movement of operators | PMS | Improve layout and 5S |

### 5.4 Implementing the amendments and monitoring

The last phase of the methodology is implemented for the loss with highest ICE. This phase involves the implementation of the amendments and monitoring (phase 3 of Figure 2). The new layout proposal followed the drawing of the spaghetti chart related to the operators' movements. Following the lean approach, subsequently, the first two “S” of the 5s approach have been applied as a lean tool to remove waste. First, the “Seiri” was applied to distinguish between necessary and un-necessary items. This has led to the replacement of fixed workbenches with easy to move carts. “Seiton” was used to optimize the space and place the required tools closed to where they are needed. The overall space was divided into two areas: one for stocking raw materials and the other for housing cutting machines, grouped by type. The placement of the machines allows the movement of operators and managers to track the advancements of production. Additionally, a new procedure has been introduced to reduce the movements of operators. Specifically, a milk runner has been introduced to supply the distinct working stations, while the machine operators should place their movable cart in a specific area at the end of the shift. This allows the warehouse operators to collect unused materials at the end of the shift. To further streamline processes, raw materials are organized on shelves according to type, with fixed locations identified by a new coding system. The placement of materials is based on an "ABC" analysis, with frequently used items placed in easily accessible locations.

## 6.Discussion

The developed framework allows the identification of wastes by combining the advantages of VSM and WID. This combination provides deeper insights into the wastes characterizing the process. Specifically, the VSM revealed issues in the picking process due to lack of space and organization. On the other hand, the WID provides information on the station characterized by the highest waste and that “moving” is the most common waste within the considered department. Adding the CD to the previous waste identification phase allowed to guide potential improvements, associating priority to each one. In this context, it is worth noting that the “E-Matrix” and “F-Matrix” typical of the CD have not been shown since the projects are currently under development. However, the CD has been successful to identify towards which loss direct the efforts, and which are potential solutions.

## 7.Conclusions

This paper presents the integration of three approaches, named VSM, WID, and CD. The first two are used to identify and map wastes and losses. The third is employed to economically quantify the identified wastes and guide potential improvements. To proposed framework has been applied to a luxury company. The application to the case study demonstrated how the framework could be effectively employed to identify waste and propose potential countermeasures. From a theoretical perspective, this paper defines a potential framework to reduce waste in the luxury fashion industry, potentially leading to a leaner process. Regarding the practical implications of this study, operations managers could adopt the developed framework to identify and prioritize wastes to enhance the efficiency of plants. The main advantages of the framework arise from the combination of WID and VSM to highlight wastes from different perspectives, while CD assists in identifying potential countermeasures and prioritize them. Therefore, it could be used as a decision-support tool. As any other works, this study conceals limitations. Indeed, the benefits arising from the improvements should be monitored for a longer period. Thus, it could be useful to monitor future updates. Furthermore, only a single case study is considered. Therefore, it is necessary to test the approach on distinct luxury companies to prove its effectiveness. In other words, up to now the framework has limited generalizability and lacks results related to long-term monitoring.

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