ORIGINAL ARTICLE

Implementation framework for PLM: a case study in the fashion industry

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Abstract

The implementation of a PLM is a great process of change, representing a critical phase due to the inertia that characterizes some organizations. This evidence especially occurs in industry new to PLM, such as the fashion one, where a lack of clear guidelines for implementation significantly increases the risk of failure of that process. In addition, an adequate project management approach that actively includes final users during the whole process will avoid the mismatch between outcomes and requirements. To support an efficient and effective introduction of PLM, it is then important to define a structured implementation method that involves all interested users from the early stages. A literature review has been conducted as preliminary step to investigate if bottom-up approaches to PLM implementation in fashion industry have already been studied. Based on the evidences from literature review, a framework was therefore defined, detailing the step-by-step procedure to follow for effectively implement a PLM considering the peculiarities of the fashion industry. To give evidence of the applicability of the proposed framework, it has been successfully used during the implementation process of a PLM software in a real context. The Italian company involved in the case study, Graziella, belongs to the gold-working district of Arezzo, in Tuscany, and has been working for more than 60 years in the gold jewellery sector.

Acronym list

BI	Business intelligence
BOM	Bill of Material
BPMN	Business Process Model and Notation
ICAM	Integrated Computer-Aided Manufacturing
IDEF0	ICAM DEFinition for Function Modelling
ISM	Independent Scoring Method
PDM	Product data management
PLM	Product lifecycle management
QFD	Quality function deployment
RFQ	Request for quotation
SKU	Stock keeping unit

1 Introduction

The acronym PLM (product lifecycle management) has a wide meaning, being considered business model based on a strategic approach to managing processes, information and resources to support a dynamic configuration of the product lifecycle. PLM was born in the 80s in the aerospace and automotive sectors, but it has recently become important also in other industries, such as the fashion one.

The fashion industry is currently worth around $300 billion, which is expected to rise to over $360 billion by 2025.[1] In this context, Italy stands out with 24 of the 100 largest fashion and luxury companies operating worldwide.[2] The fashion sector is a dynamic reality that has witnessed radical transformations in recent years. First, the lifecycle of products is getting shorter and shorter because customers require new products faster than ever. Second, fashion companies have to manage a very large number of stock keeping units (SKUs), due to the combinatorial explosion of variants. Finally, supply chain networks show a higher complexity because companies

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[1] Kantar, "Fashion Innovation Week", Lugano, April 2019
[2] Deloitte, "Global Powers of Luxury Goods", 2019

have started to outsource non-core activities in a global scenario. The trade-off between the characteristics listed above and the mandatory outstanding quality level to be guaranteed on the market justifies the growing interest of this sector for PLM. This tool allows companies to create and update a unique archive that contains all the information related to the products, avoiding the proliferation of data. It facilitates collaboration and real-time sharing of updated information along the entire supply chain. Thanks to PLM, it is also possible to make internal processes more efficient, eliminating activities without added value. Although the benefits of PLM are clear, it is a process of change that is not always easy to implement, being often time-consuming and leading to inefficiencies if not well-managed.

To understand how these issues could be approached, a literature review on Scopus database has been conducted to frame the topic. The used keywords were "PLM" or "Product Lifecycle Management" associated with the term "Fashion" or others that refer to the main product categories that characterize the fashion sector (i.e. "Apparel", "Garment", "Goldworking", "Footwear", "Jewellery", "Leather", "Textile"). This research results in 143 papers, but 88 of them have been excluded according to the following criteria: (i) publication date of 2000 or later; and (ii) title and/or abstract focused on the reviewed topic.

Only 6 of the remaining 55 papers have dealt with PLM implementation in the fashion industry, but a single reference for a detailed and structured application framework, covering all the phases from the initial ones to the post go live ones, is still missing.

D'Avolio et al. [3] provide points for reflection for academics and entrepreneurs who are trying to reach a full PLM implementation in their business, aligned to the best practices. D'Avolio et al. [4] conduct a case study to describe PLM implementation and merge business processes with enabling information technologies. This article, differently from the one proposed, has the limit to investigate only the earlier phase of a PLM implementation. D'Avolio et al. [5] compare current practices in conducted PLM implementation projects with the PLM implementation guidelines from the literature review, also covering the post-implementation stages. Unlike the present work, this paper reports the guidelines present in the literature, but they do not focus on identifying a step-by-step process that covers the whole project of PLM implementation. D'Avolio et al. [6] propose a framework for effective implementation of PLM in the fashion industry based on four consecutive phases: identification of business issues and needs, model process and data, identification of PLM business objects and a scenario analysis to select a PLM solution, without describing the detailed implementation and tests needed before go-live. Li and Qi [11] present an Agile methodology but it focuses only on the implementation step. Vezzetti et al. [20] propose a PLM implementation framework in the textile

industry but it does not provide clear guidelines from a managerial point of view.

According to this overview, in the following paragraphs, an implementation framework is proposed and applied in a real context.

The paper is structured as follows: in the first section, the proposed PLM implementation framework is presented and described in detail in all its phases; the second section presents the main evidence from the case study; finally, the main conclusions and further developments are listed in the last section.

2 Methodology

The proposed framework aims to identify a PLM implementation roadmap in order to make the application steps of this software more effective within companies. The starting point has been the model proposed by Vezzetti et al. [20], improved to overcome its limitations.

To support an efficient introduction of a software, it is important to define a structured implementation method that involves all interested users from the early stages. According to this, a focus has been made on mapping the needs of key users involved in the lifecycle management of products, confirming the attention paid on using a bottom-up strategy [1, 15]. Beside this, the proposed framework has been developed to include clear, quantitative and objective guidelines for PLM implementations in real scenarios, due to the evidence that a rigorous procedure to follow increases the successfulness of these processes [2] Moreover, details to the most effective project management approach to be used during the implementation process are given to define how to gain the expected results with the less unneeded efforts.

The 4-steps implementation methodology proposed in the present work is shown in Fig. 1.

From a project management perspective, compared to the sequential model developed by Vezzetti et al. [20], Fig. 1 shows the proposed hybrid Waterfall-Agile implementation framework. The hybrid approach has been chosen to gain benefits from both of them, as widely confirmed by the literature [10, 16–18]. On the one hand, the 4 steps are sequential each other, following a Waterfall approach to guarantee a structured planning of the main phases of the project. On the other hand, the implementation step (i.e. "Detailed implementation" in Fig. 1) follows an Agile approach, providing micro-releases to be tested by key users after each time-boxed sprint. This approach, as confirmed in literature for deployment activities, ensures frequent feedback from the final users to avoid mismatches between users' requirements and functions released at the end of the project.

Going deeper in details, the first phase of the proposed model concerns the analysis of the processes (i.e. "Processes analysis" in Fig. 1). For implementation in fashion supply
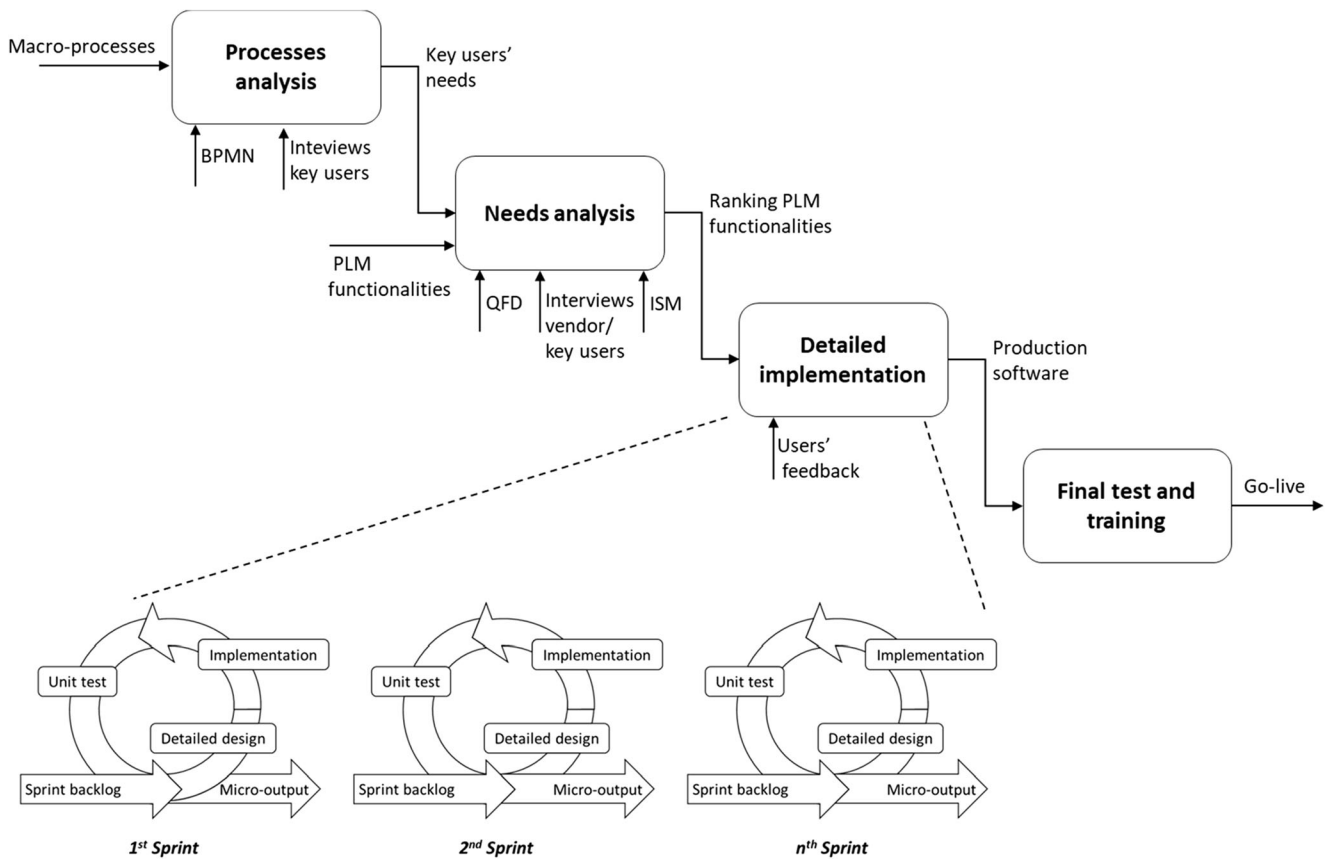
Fig. 1 Proposed implementation framework

chains, the macro-processes involved are the ones identified by Fani et al. [7] for that industry: (i) design, (ii) prototyping, sampling and engineering, (iii) sourcing, (iv) production and (v) ordering and retail. Each one of them has to be splitted in activities, mapped with the Business Process Model and Notation (BPMN) standard. It is a well-known graphic modelling inspired by flowcharts, often chosen for being easy to understand even by operating staff. To map the process, it is then necessary to consult the involved key users. Semi-structured interviews are used as efficient method to collect data to fully understand company realities through a bottom-up approach [12]. Each activity reported in the BPMN mapping has to be linked to the identified macro-processes, in order to focus the implementation of the only PLM functionalities connected to them. After a second round of interviews, the needs related to each activity described in the mapping are identified to highlight the main issues key users have to face with.

Starting from the list of user needs, the second implementation phase begins (i.e. "Needs analysis" in Fig. 1). During this phase, the analysis is focused on identifying which are the main PLM functionalities that meet the customers' needs, solving the related issues. In analogy to Vezzetti et al. [20], the tool used to identify that match is the relationship matrix of the Quality Function Deployment (QFD) approach. In

addition, for implementation in fashion supply chains, the proposed model includes the PLM functionalities focused on that industry identified through a detailed literature review by Fani et al. [7]. First, during the second round of semi-structured interviews, key users were asked to declare an importance score (d_i) to each need on a Likert scale from 1 to 5, where 1 indicates the lowest degree of importance and 5 the highest. The relative importance (d_i') is then calculated as follows:

$$d_i' = \frac{d_i}{\sum\limits_{i=1}^{m} d_i}$$

For the compilation of the relationship matrix, semi-structured interviews with vendors are planned, aimed at understanding which PLM functionalities are able to satisfy each specific users' need and to what extent. If there is correlation, it is quantified using a scale of three values: 1, 3 and 9. The value 1 is used if the correlation is weak, 3 if it is medium and 9 if the correlation is strong. The matrix of relations is then filled with numerical values, indicated with r_{ij} in Fig. 2.

In order to obtain a ranking of the PLM functionalities, in analogy to Vezzetti et al. [20], the independent scoring method (ISM) is used. The absolute importance of each PLM

PLM Functionalities

			Functionality 1	...	Functionality j	...	Functionality n
Users' needs	User's need 1	d_1'	r_{11}	...	r_{1j}	...	r_{1n}
	...	...	...	...	...	...	...
	User's need i	d_i'	r_{i1}	...	r_{ij}	...	r_{in}
	...	...	...	...	...	...	...
	User's need m	d_m'	r_{m1}	...	r_{mj}	...	r_{mn}

Fig. 2 QFD relation matrix

functionality, indicated with w_j, is calculated as the sum of the relative importance of each user need (d_i') multiplied by the value that identifies how much a j-th functionality satisfies each specific request (r_{ij}):

$$w_j = \sum_{i=1}^{m} d_i'.r_{ij}$$

The relative importance of each functionality is therefore calculated as follows:

$$w_j' = \frac{\sum_{i=1}^{m} d_i'.r_{ij}}{\sum_{j=1}^{n} w_j}$$

The ranking of the PLM functionalities is obtained sorting them in descending order of relative importance.

Compared to Vezzetti et al. [20], the "Guidelines formalization" phase was replaced by two phases (i.e. "Detailed implementation" and "Final test and training" in Fig. 1). This choice is linked to the fact that, compared to Vezzetti et al. [20], the present work aims to go beyond the definition of a list of PLM functionalities to be implemented. In particular, a more detailed description of the phases that follow the analysis of processes and needs is included in the present work, covering the approaches to be adopted from the implementation to the autonomous use of the solution by final users.

Looking at the "Detailed implementation" phase, as mentioned before, an Agile approach is followed to effectively guarantee the results of the project. The ranking of PLM functionalities coming from the previous phase represents the input of this step. Depending on the specific use-case, some of those functionalities could be developed immediately while others postponed to next project waves that follow the go-live of the first one. According to the Agile approach, the deployments related to the project first wave are splitted on time-fixed sprints, usually covering the range of 1 to 4 weeks [19]. Based on literature evidences [9, 18], each sprint consists of the three phases shown in Fig. 1:

- "Detailed design", which provides the definition, review and validation of the deployments to be included in the sprint final release.
- "Implementation", in which functions included in the sprint are released by developers first in the development environment and, after their approval, in the test environment.
- "Unit test", in which key users verify the functions released in the test environment, giving feedback for possible changes and improvements. This phase ends with the release of a micro-output in the production environment.

In the final step (i.e. "Final test and training" in Fig. 1), key users conduct an integration and system test. This step is useful to verify that the PLM software works as expected [13], and no problems occur in the interaction between the individual micro-outputs that have been independently developed during each sprint. After the previous tests, a training phase is scheduled, during which all users are trained on the use of the software. The relevance of this step is related to the fact that one of the main causes of failure during software implementation is the lack of adequate user training [8, 14]. The output of this phase is the go-live, representing the moment when the software tested only by key users is made available to all the interested users. Finally, it will be necessary to
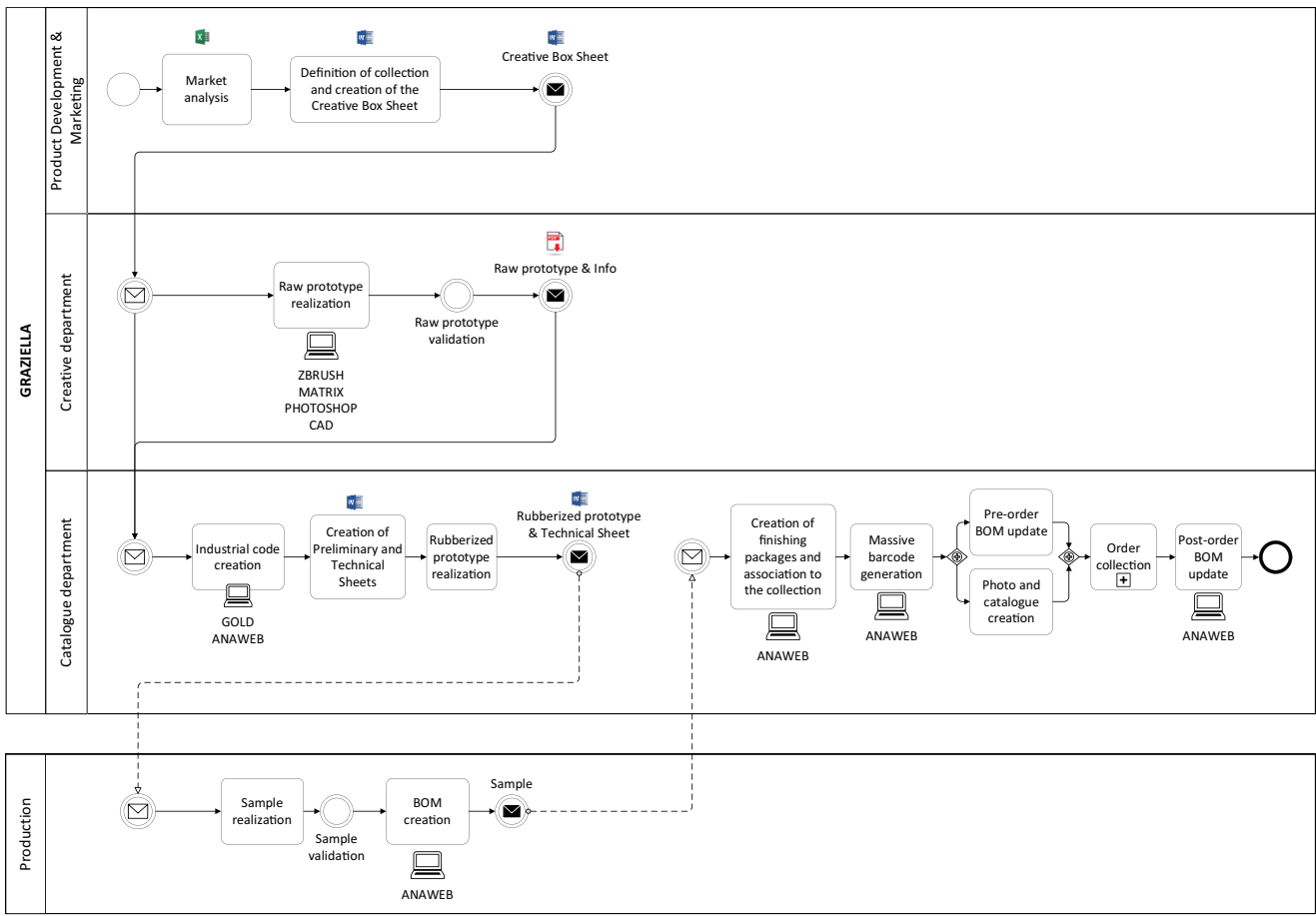
Fig. 3 BPMN mapping for Graziella company

Table 1 Relationship between BPMN activities and macro-processes in Graziella

Macro-processes / BPMN activities	Design	Sourcing	Prototyping, sampling and engineering	Ordering and retail
Market analysis	x			
Definition of collection and creation of the Creative Box Sheet	x			
Raw prototype realization	x		x	
Industrial code creation			x	
Creation of Preliminary and Technical Sheets		x	x	
Rubberized prototype realization			x	
Sample realization			x	
Bill of Material (BOM) creation			x	
Creation of finishing packages and association to the collection			x	
Massive barcode generation			x	
Pre-order BOM update			x	
Photo and catalogue creation				x
Order collection				x
Post-order BOM update			x	

Table 2 General key users' needs

General key users' needs
Have tools to support market analysis
Have unique interfaces
Define project timeline
Digitize data
Access to the updated version of the various documents
Define privilege sets for users or groups
Manage notifications to interested users
Be integrated with other tools
Support guided/automated procedures
Structure cost calculation

provide a post-go-live phase, during which the software house supports final users to solve problems that could arise immediately after the adoption of the new tool.

3 Results

To demonstrate the applicability of the proposed framework, it has been concretely used within Graziella company during the whole PLM implementation process. This single-case study does not have the purpose to validate the framework but to give evidence about its usability in a real scenario.

Graziella Group S.p.a. is an Italian fashion company founded in 1958 by Graziella Buoncompagni, the current Honorary President, who began to create handcrafted gold jewellery characterized by a personal and innovative style at a very young age. From the past small laboratory in the province of Arezzo (Tuscany) to the new headquarter inaugurated in 2000, Graziella has become an international leader in the world of fashion and luxury made in Italy.

As "step zero" for the application of the proposed framework, the macro-processes to be included in the PLM implementation project have been identified during the kick-off meeting, choosing among the ones identified by Fani et al. [7]. More in details, the macro-processes of design, prototyping, sampling and engineering, sourcing and ordering and retail have been taken into consideration.

According to the "Process analysis" step, the BPMN mapping standard has been used to highlight activities, resources and documentation involved during the selected macro-processes. The result is shown in Fig. 3.

Each activity identified in the BPMN mapping has been reconducted to one of the macro-processes identified in the previous step, as shown in Table 1.

At this point, semi-structured interviews to the key users identified during the kick-off meeting have been realized to understand the main needs connected to each mapped activity (i.e. Table 5 in Appendix).

The output of the first step is the list of the users' needs that will be the input for the second step. Key users' needs have been grouped into 10 macro-categories, as shown in Table 2.

Looking more in details at the listed general needs, one of the users' needs for the first mapped activity (i.e. "Market analysis") is having tools to support market analysis. In particular, users need support to the development and consultation of new market trends. Furthermore, it is important to analyze sales of previous seasons for the various reference markets in order to understand if the results were consistent with expectations and, consequently, if they are replicable for the current season.

Fig. 4 Example of filled QFD relationship matrix

Raw prototype realization	d'ᵢ	BI	BOM Management	Calendar Management	Collaborative Tool	Collection Book	Colour Management	Composition and Care Label	Costing	Integration software	Line Planning	Material Management	Order Collection	PDM	Portfolio Management	Project Management	Quality Management	Range Planning	Report	RFQ	Size Range Management	Storyboarding	Supplier Auditing	Sustainability and Compliance	Technical Sheet Management	Trend Analysis	Visual Merchandising	Workflow
User needs																												
Need to exchange files / data with graphics software (e.g. CAD, ZBrush, Matrix and Adobe Photoshop)	0.02		3							9				3														
Communication to interested users of the realization of raw prototypes	0.02		3		9									3														3
Communication to interested users of the validation of raw prototypes	0.02		3		9									3														3
Block the process flow before validation of raw prototypes	0.02		3	3										3														9
Define the deadline for validating raw prototypes	0.02		3	9																								
Need for a single interface to insert/consult an archive of files/data related to raw prototypes	0.01		9		9									9														

Table 3   Sprint definition

Sprint	Definition
Sprint 1	Hierarchy Structure Definition and Master Data
Sprint 2	Colour Management and Master Data
Sprint 3	Material Management and Master Data
Sprint 4	Article Management and Master Data
Sprint 5	BOM Management
Sprint 6	Line & Range Planning
Sprint 7	Cost sheet
Sprint 8	Documentation
Sprint 9	Definition of user profiles and allowed actions
Sprint 10	PLM-AS400 Integration

The "Market analysis" activity in the current AS IS configuration is based on the compilation of an Excel sheet containing information related to the target market (e.g. competitors, main products, price range). Photos and inspirations are collected during business travels to understand the potential buyers' preferences. However, these data are not currently stored in a structured way, making having a single interface a primary need: in this way, these data could be easily consulted by final users. The same need has been also highlighted for storing files related to the raw prototypes obtained from 3D scans and reworked by suitable graphics software. Similarly, it is also requested for photos and data related to samples and final products used for the catalogue.

During the interview, another need highlighted by the key users has been that a timed flow of activities with clear deadlines has never been established. This is one of the main reasons of inefficiency during the order collection phase, which represents the first contact between company and customers during fairs. For example, catalogues with photos associated with specific barcodes are often not ready, making sales agents unable to collect orders in a structured way. It often happens that samples to be shown to customers do not match the initial requirements, because to meet the fair date, there

Table 4   Ranking of PLM functionalities

PLM functionalities	Absolute importance w_j	Relative importance $w_j^{'}$ (%)
PDM	3.74	22.15
Collaborative tool	3.27	19.38
BOM management	2.93	17.37
Workflow	1.29	7.63
Calendar management	1.13	6.71
Integration software	0.59	3.52
Colour management	0.57	3.36
Material management	0.57	3.36
Line planning	0.49	2.94
Range planning	0.49	2.94
Technical sheet management	0.48	2.85
Costing	0.44	2.60
Collection book	0.30	1.76
Storyboarding	0.21	1.26
Trend analysis	0.17	1.01
Report	0.13	0.75
Order collection	0.07	0.42
Business intelligence (BI)	0	0
Composition and care label	0	0
Portfolio management	0	0
Project management module	0	0
Quality management	0	0
Request for quotation (RFQ)	0	0
Size range management	0	0
Supplier auditing	0	0
Sustainability and compliance	0	0
Visual merchandising	0	0

was no time to effectively carry out the activities needed and non-compliance with the specifications emerged. According to this, defining project timelines allows a greater awareness of all the actors on meeting deadlines. For instance, due dates must be defined for both the validation of raw prototypes and sharing the Preliminary and Technical Sheets. In addition to a punctual definition of deadlines, a need to insert blocks to the process flow has emerged. In particular, the activity related to the "Industrial code creation" can only take place once raw prototypes have been validated by the Creative department, to avoid the creation of unnecessary industrial codes for not-approved products. Another block must be inserted before the validation of samples, so that the subsequent "BOM Creation" activity will be done only once the sample has been approved.

At various points along the product development process, the need to digitize product data emerges. The Creative Box Sheet is a simple Word file where information relating to the products are entered (e.g. line, creative theme, basic technology), as well as the Preliminary Sheet, an evolution of the previous one that includes the industrial code of the finished product. The Technical Sheet for each product is also a Word file where the Catalogue department manually enters information such as the required semi-finished products, main suppliers and price range. The digitization of these parameters makes the process more efficient and less error prone. In general, all the information contained in the current information systems must therefore be digitized, such as those relating to the BOMs and the finishing packages.

Several actors throughout the development process make changes and updates to the various documents. All interested users must have access to the updated versions of them to avoid errors that arise from the use of incorrect information relating to the products. Examples of documents to be consulted are the following:

- The Creative Box Sheet
- The Preliminary Sheet
- The Technical Sheet
- Documents related to raw prototypes
- BOM updates emerged during the product development and realization or following changes requested during the order collection phase (e.g. information related to the product weights, updates of the price range, changes of product finishes due to customer requests).

Everyone has a specific responsibility within the product development flow, so a need that has emerged is to give specific privileges to specific user groups. For instance, only the staff of the product development office can fill in and edit the Creative Box Sheet, while the staff of the Catalogue department is the only one who can fill in and modify the Preliminary and Technical Sheets. Finally, the BOM can be created and edited only by the Production staff and the Catalogue department.

Product development is a process that involves cross-functional teams and the timely communication about the realization of raw versions of products and their evolutions among the various actors is a necessity that emerges along the process. The most important information to be shared for the Graziella company is related to the following:

- The creation of the Creative Box Sheet
- The validation of raw prototypes and samples
- The creation of industrial codes for finished product and semi-finished product
- The massive generation of barcodes
- The BOM updates in the pre- and post-order collection phase.

Parallelly with the implementation of the PLM, the company is carrying out a software selection to evaluate the introduction of cataloguing and order collection tools. The integration with these tools is therefore required, as well as with the graphics software already used in the prototyping phase (e.g. CAD, ZBrush, Matrix and Adobe Photoshop).

Some procedures currently managed on the company's information systems must be automated to both reduce time-consuming activities and data entry errors. The guided creation of industrial codes and barcodes according to the product master characteristics (e.g. product line, mood) and the relative finishes are particularly important. The guided association of finishes to collections and finished products must also be reproduced.

An automatic price updating procedure will have to be introduced according to the weight variation. When the final price is defined, the estimated cost for the finished product is calculated. In the current configuration, this evaluation is based on the raw materials and not on the industrial costs. For gold jewellery, in fact, the cost has been always calculated according to the specific weight and title, also because the cost of the manufacturing process is almost irrelevant, but on silver items, it has a significant impact. According to this, the need that emerges is therefore to evaluate the final cost not only based on raw materials but also on the type of processing.

In the second step of the proposed methodology, structured interviews to users allow to establish an absolute importance score for each need identified in the previous step. This score is established using the Likert scale (d_i) and then the relative importance score (d_i') is calculated. The results are shown in Table 6 in Appendix.

In addition to users' needs, the 27 PLM functionalities identified by Fani et al. [7] are also considered as input. The

purpose of the "Needs analysis" step, in fact, is to identify a priority ranking of functionalities to be implemented in the company. As anticipated, two tools are used during this phase: the QFD relationship matrix and the ISM. The relationship matrix is filled according to structured interviews addressed to the software house that has been chosen for the implementation.

For instance, Fig. 4 shows the answers for the activity of the BPMN mapping related to the realization and validation of raw prototypes. On rows, the user needs declared for the analysed activity are listed, while columns show the PLM functionalities identified by Fani et al. [7]. Looking at the first row in Fig. 4, it refers to the emerging need in the prototyping phase related to the integration of PLM with graphics software, getting 2% as relative importance score ($d_i^{/}$) in the previous step. Moving to the results coming from this step, the involved software house declares that this need is completely satisfied by the integration software functionality, assigning a score of 9. On the other hand, also the product data management (PDM) and BOM management functionalities are involved, with an assigned score of 3. The evidence is that files and data extracted from the graphics software must be imported on the PLM, but also archived and linked to the BOMs, respectively. Finally, as shown in the following table, not all crossings are populated because not all the PLM functionalities on columns meet the needs on rows.

Using the ISM, a ranking of the most appropriate PLM functionalities to meet the needs of the interviewed users was obtained, as shown in Table 3.

The most relevant functionalities resulting from the ranking (i.e. see Table 4) have been included in the first deployments, while others have been postponed to future project waves.

More in details, the five features having an importance scores lower than 2% in Table 4 and the workflow and calendar management functionalities have been excluded from the first project wave.. This choice has been done to reduce the overall deployment time, as these features can be postponed to a second project wave without impacting what was foreseen in the first wave. In addition, the cataloguing and order collection software are currently under selection. Finally, the features with an importance score of 0 will not be implemented at all.

For the Graziella case study, the features identified in the first wave have been divided into 10 sprints (i.e. see Table 3), according to the Agile approach used in the "Detailed implementation" phase. The work to be done in each sprint has been planned in meetings called "Pre-sprint planning meetings" that take place at the beginning of each iteration. The input of each sprint is, in fact, a direct consequence of the micro-output of the previous one and the feedback collected by the key users.

Each sprint has been a duration of 4 weeks, including 2 weeks for the "Detail design", a week for the "Implementation" and a week for the "Unit test". Each "Unit test" ended with the release in production of what has passed the test, while the rest have been rescheduled in the next sprint.

The first sprint concerns the definition of the hierarchical structure and the relative master data. More in details, this sprint aimed at defining attributes, variations by season, markets, collections, themes and product categories, representing the basis for all the other sprints, and for this reason, it has been done first.

The second sprint (i.e. "Colour Management and relative Master Data") is directly linked to the Colour Management PLM function: in this phase, adherence to standards for the definition of colour and coding rules is established.

The third sprint (i.e. "Material Management and relative Master Data") is linked to the Material Management PLM functionality. The previous Colour Management functionality is preparatory to this module as the rules for associating colours with materials are defined at this stage.

The fourth sprint (i.e. "Article Management and relative Master Data") is linked to the functions of Colour and Material Management: in this phase, the rules for associating colours and materials to the articles are established. It is also connected to BOM Management because in this phase, the article code is established, representing the starting point for the development and the detailed description of the BOM.

The fifth sprint (i.e. "BOM Management") establishes the information that must be contained in the BOMs along the different phases of the product lifecycle, from prototyping, to sampling, to production. The functions of Colour Management and Material Management are preparatory to this phase since relevant information to be included in a BOM refers to the colours and materials associated with the article.

The sixth sprint (i.e. "Line & Range Planning") allows to implement procedures for a structured planning and a correct definition of the mix of products per market.

In the seventh sprint (i.e. "Cost sheet"), rules that allow users to define a preventive cost from the first stages of product development are established. That cost will then be updated by proceeding in development, up to the definitive one. The definition of the cost is directly linked to aspects such as materials, colours and BOMs: for this reason, the functions of Colour Management, Material Management and BOM Management are preparatory.

The eighth sprint (i.e. "Documentation") is used to manage all documents within the PLM. It is directly linked to the realization of the line and range planning, which include documents such as the collection form (i.e. the "Creative Box Sheet" for the Graziella company), as well as the Technical Sheet Management functionality. It is also linked to the Collaborative Tool and PDM functions, as it is at this stage

that documents containing updated product data can be organized in a single shared space available to all interested users. Furthermore, the possibility of associating with each document different states that identify its level of maturity (i.e. creation, validation or obsolescence) allowed by the PDM functionality is guaranteed.

The ninth sprint (i.e. "Definition of user profiles and allowed actions") is directly linked to the PDM functionality. In this phase, specific privileges are established for groups of users, determining the allowed actions which can be read only, write, modify and delete information within the sections of the PLM and related documents.

The tenth sprint (i.e. "PLM-AS400 Integration") plans to structure the data import/export procedures between AS400 and the PLM (e.g. import from AS400 to the PLM of customer and supplier master data; export from the PLM to AS400 of articles, materials, colours master data).

4 Conclusion and future developments

From an academic point of view, this work led to the definition of a structured methodology for implementing a PLM software in the fashion industry that bridged the gap existing in the literature.

To do this, the method proposed by Vezzetti et al. in [20] has been expanded and improved in some of its points. The macro-processes and functionalities focused on the fashion industry identified by Fani et al. [7] are respectively introduced as input in the "Process analysis" and "Needs analysis" phases, to ensure the definition of guidelines dedicated to that sector. The main advantage gainable with this industry-oriented approach is to drastically reduce the probability of failure of software implementations that include standard functionalities despite dedicated ones. Standardization, in fact, could result in a misalignment with the peculiarities of the sector, increasing the risk of failure to meet the specific requirements of the final users.

Instead IDEF0 (ICAM DEFinition for Function Modelling), BPMN is used as mapping standard because it is more suitable for the representation of business processes that must be computerized.

The "Detailed implementation" and the "Final test and training" steps, only marginally described in the single item "Guideline formalization" proposed by Vezzetti et al. [20], are extensively detailed to be effectively used in concrete scenarios. Unclear guidelines, in fact, introduce subjectivity in key activities such as the selection of the PLM functionalities to implement and their priority that could lengthen project time. For instance, errors in the identification of the PLM functionalities, ranked by priority, that really meet the users' requirements result in unnecessary developments and extra-efforts needed to manage ongoing change requests.

To reinforce those results, the most appropriate project management method for the different phases was detailed, according to the well-known evidence that it is useful to adopt a hybrid Waterfall-Agile implementation model to get the benefits of both. As shown in Fig. 1, in fact, the first two steps and the last one will follow a Waterfall approach, while the central part of the project is carried out with an Agile approach, which provides micro-releases in production environment of functionalities tested and shared with customers. This overcomes the main limit of a pure Waterfall approach, allowing the collection of feedback from final users after each time-boxed sprint instead of when the whole implementation is completed.

The methodology was conceived as a guideline in a concrete context, assuming value also from a managerial point of view. The applicability of this model was confirmed by the case study of the Graziella company, which successfully implemented a PLM system using this methodology. Figures and tables in the sections "Results" and "Appendices", in fact, resume the step-by-step results obtained from the application of the proposed framework. This single-case study does not have the purpose to validate the framework but to give evidence about its usability in a real scenario. To reinforce the added value, future developments plan to widen the analyzed sample by involving other companies in the fashion sector.

Further researches could also include the application of the proposed framework to other industries in which PLM is emerging, such as the food one. The implementation on other sectors requires the identification of the macro-processes and PLM functionalities specific for those industries through a detailed literature review. Once they have been defined, the procedure to follow for an effective PLM implementation is the one described in the present paper. New companies involved as case studies, belonging to the fashion industry or not, will then require interviews to new key users. They could result in different BPMN-mapped activities and both detailed and general key users' needs, as well as different scores in the QFD relationship matrix and project sprints for the ranked PLM functionalities.

Finally, new studies could envisage the extension of the implementation methodology to other software, such as the ones related to the quality control and the warehouse management, as well as management software.

Authors' contributions V.F. designed and performed the framework, derived the models and analyzed the data, with the support of R.B. C.F. and

Appendix

Table 5 Identification of users' needs for each activity of the BPMN mapping

BPMN activities	Key users' needs
1. Market analysis	1.1 Have tools that allow the development/consultation of new market trends 1.2 Have tools that allow the development/consultation of sales analyses relating to the previous season with market segmentation 1.3 Need for a single interface to insert/consult an archive of photo/data collected during travel
2. Definition of collection and creation of the Creative Box Sheet	2.1 Define the deadline for sharing the Creative Box Sheet 2.2 Digitization of all information contained in the Creative Box Sheet (e.g. weight ranges and product categories for each collection, mood and line) 2.3 Need to access to the updated version of the Creative Box Sheet 2.4 Communication to interested users of the creation/updating of the Creative Box Sheet 2.5 Allow only product development managers to complete and modify the Creative Box Sheet
3. Raw prototype realization	3.1 Need to exchange files/data with graphics software (e.g. CAD, ZBrush, Matrix and Adobe Photoshop) 3.2 Communication to interested users of the realization of raw prototypes 3.3 Communication to interested users of the validation of raw prototypes 3.4 Block the process flow before validation of raw prototypes 3.5 Define the deadline for validating raw prototypes 3.6 Need for a single interface to insert/consult an archive of files/data related to raw prototypes
4. Industrial code creation	4.1 Guided creation of coding according to the product master characteristics (e.g. line, mood) 4.2 Communication to interested users of the creation of encodings
5. Creation of Preliminary and Technical Sheets	5.1 Digitization of all the information contained in the Preliminary and Technical Sheets (e.g. price range, semi-finished products) 5.2 Need to access to the updated version of the Preliminary and Technical Sheets 5.3 Communication to interested users of the creation/updating of the Preliminary and Technical Sheets 5.4 Define the deadline for sharing the Preliminary and Technical Sheets 5.5 Allow only those responsible for the cataloguing office to complete and modify the Preliminary and Technical Sheets
6. Rubberized prototype realization	6.1 Reporting the progress of rubberized prototypes
7. Sample realization	7.1 Need for a single interface to insert/consult an archive of photo/data related to samples 7.2 Reporting the progress of samples 7.3 Communication to interested users of the validation of samples 7.4 Block the process flow before the validation of samples 7.5 Define the deadline for validating the samples
8. Bill of Material (BOM) creation	8.1 Need to access to the updated version of the BOM 8.2 Communication to interested users of the creation/updating of BOMs 8.3 Calculation of the cost based on raw materials, weight range and type of processing 8.4 Allow only production personnel to create and modify the BOM

Table 5 (continued)

BPMN activities	Key users' needs
	8.5 Digitization of all information contained in the BOM
9. Creation of finishing packages and association to the collection	9.1 Guided association of finishes to collections 9.2 Guided association of finishes to the industrial code 9.3 Communication to interested users of the creation of finishing packages 9.4 Communication to interested users of the finishing package association to the collection 9.5 Digitization of all information contained in the finishes package
10. Massive barcode generation	10.1 Guided creation of barcodes 10.2 Communication to interested users of the massive barcode generation 10.3 Define the deadline for massive generation of barcode
11. Pre-order BOM update	11.1 Communication to interested users of the updates related to the BOM status during the pre-order collection phase 11.2 Automated updating of the price according to the changes in weight
12. Photo and catalogue creation	12.1 Need for a single interface to insert/consult an archive of photo/data related to products per catalogue 12.2 Need to exchange product information/photos/data to cataloguing tool 12.3 Communication of the realization of photo to barcode association 12.4 Communication to interested users of the realization of the catalogue
13. Order collection	13.1 Need to exchange product information/photos/data to order collection tool
14. Post-order BOM update	14.1 Need to access the updated version of the BOM following changes that emerged during the order collection phase 14.2 Communication to interested users of the updates related to the BOM status following changes that emerged during the order collection phase

Table 6 Importance scores for user needs

General key users' needs	Detailed key users' needs	d_i	d_i'
Have tools to support market analysis	1.1 Have tools that allow the development/consultation of new market trends	3	0.01
	1.2 Have tools that allow the development/consultation of sales analyses relating to the previous season with market segmentation	3	0.01
Have unique interfaces	1.3 Need for a single interface to insert/consult an archive of photo/data collected during travel	5	0.02
	3.6 Need for a single interface to insert/consult an archive of files/data related to raw prototypes	3	0.01
	7.1 Need for a single interface to insert/consult an archive of photo/data related to samples	3	0.01
	12.1 Need for a single interface to insert/consult an archive of photo/data related to products per catalogue	5	0.02
Define project timeline	2.1 Define the deadline for sharing the Creative Box Sheet	5	0.02
	3.4 Block the process flow before validation of raw prototypes	5	0.02
	3.5 Define the deadline for validating raw prototypes	5	0.02
	5.4 Define the deadline for sharing the Preliminary and Technical Sheets	5	0.02
	7.4 Block the process flow before the validation of samples	5	0.02
	7.5 Define the deadline for validating samples	5	0.02
	10.3 Define the deadline for massive generation of barcode	5	0.02
Digitize data	2.2 Digitization of all information contained in the Creative Box Sheet (e.g. weight ranges and product categories for each collection, mood and line)	5	0.02
	5.1 Digitization of all information contained in the Preliminary and Technical Sheets (e.g. price range, semi-finished products)	5	0.02
	8.5 Digitization of all information contained in the BOM	5	0.02
	9.5 Digitization of all information contained in the finishes package	5	0.02
Access to the updated version of the various documents	2.3 Need to access to the updated version of the Creative Box Sheet	5	0.02
	5.2 Need to access to the updated version of the Preliminary and Technical Sheets	5	0.02
	8.1 Need to access to the updated version of the BOM	5	0.02

Table 6 (continued)

General key users' needs	Detailed key users' needs	d_i	d_i'
	14.1 Need to access to the updated version of the BOM following changes that emerged during the order collection phase	5	0.02
Define privilege sets for users or groups	2.5 Allow only product development managers to complete and modify the Creative Box Sheet	5	0.02
	5.5 Allow only those responsible for the cataloguing office to complete and modify the Preliminary and Technical Sheets	5	0.02
	8.4 Allow only production personnel to create and modify the BOM	5	0.02
Manage notifications to interested users	2.4 Communication to interested users of the creation/updating of the Creative Box Sheet	5	0.02
	3.2 Communication to interested users of the realization of raw prototypes	4	0.02
	3.3 Communication to interested users of the validation of raw prototypes	5	0.02
	4.2 Communication to interested users of the creation of encodings	5	0.02
	5.3 Communication to interested users of the creation/updating of the Preliminary and Technical Sheets	4	0.02
	6.1 Reporting the progress of rubberized prototypes	3	0.01
	7.2 Reporting the progress of samples	3	0.01
	7.3 Communication to interested users of the validation of samples	5	0.02
	8.2 Communication to interested users of the creation/updating of BOMs	3	0.01
	9.3 Communication to interested users of the creation of finishing packages	2	0.01
	9.4 Communication to interested users of the finishing package association to the collection	2	0.01
	10.2 Communication to interested users of the massive barcode generation	5	0.02
	11.1 Communication to interested users of the updates related to the BOM status during the pre-order collection phase	5	0.02
	12.3 Communication of the realization of photo to barcode association	5	0.02
	12.4 Communication to interested users of the realization of the catalogue	1	0.00
	14.2 Communication to interested users of the updates related to the BOM status following changes that emerged during the order collection phase	4	0.02
Be integrated with other tools	3.1 Need to exchange files/data with graphics software (e.g. CAD, ZBrush, Matrix and Adobe Photoshop)	4	0.02
	12.2 Need to exchange product information/photos/data to cataloguing tool	5	0.02
	13.1 Need to exchange product information/photos/data to order collection tool	5	0.02
Support guided/automated procedures	4.1 Guided creation of coding according to the product master characteristics (e.g. line, mood)	5	0.02
	9.1 Guided association of finishes to collections	4	0.02
	9.2 Guided association of finishes to the industrial code	4	0.02
	10.1 Guided creation of barcodes	5	0.02
	11.2 Automated updating of the price according to the changes in weight	3	0.01
Structure cost calculation	8.3 Calculation of the cost based on raw materials, weight range and type of processing	4	0.02

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