An Approach to Determining the Need for Integrating Quality Management into Industrial PLM Implementation

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Abstract
In practice, companies use different tools and systems to plan and manage product and process quality. Most of these tools and systems are disconnected from product data/information management systems. The downside of disconnected tools for quality management is that the repeating issues that appear in multiple systems can obscure root cause investigations by isolating related data elements, with no means to understand relationships among them. Redundant work identifying and resolving quality issues can happen in multiple tools without an automated way to communicate knowledge learnt to other teams. This leads to inconsistent and incomplete problem resolutions that impede, not improve, product and process quality. In the recent development of new technologies, many IT tools have become available on the market and among them are the PLM systems proving very popular among companies which enable the creation and maintenance of complex industrial products. A comprehensive solution in the PLM Platform is presented in this paper that aims to link quality to product design, manufacturing planning, and business-critical processes such as change management. The approach provides cross-disciplinary teams and the extended supply chain with powerful closed-loop capabilities to identify and manage risk, improve quality, meet customer requirements, and attain environmental, safety, and information management compliance.

Keywords: Quality Systems; Product Quality; Product Lifecycle Management; Product development

1. Introduction

Currently, due to the strong competition between companies, the level of customer satisfaction is becoming a key factor in ensuring the success of manufacturing companies. To this end, high-quality products and services are an exploitable solution for these companies seeking to stand out from their competitors by trying to attract as many customers as possible and retain existing ones. From this point on, the notion of quality becomes the major issue for any company that wishes to make itself sustainable. It is important to note that its management procedures are not negligible throughout the life cycle of a product because it leads to a sustainable reduction in costs and favours the development of quality products that increase customer satisfaction and consequently increase the number of satisfied customers. Companies must therefore improve their quality management systems (QMS) to guarantee meeting the requirements, whether they are expressed or not, of the company's internal and external stakeholders and the consideration of risks of all kinds. The effectiveness of such a system, therefore, depends on the rapidity with which companies can react to external and internal requirements and on

the possibility of implementing automated quality control and management systems in production processes [1].

The industry has already developed many methods to improve quality. Originating mainly in Japan and the United States, these methods are now gathered in a well-defined corpus and have a global reach. It is therefore important for each company to continuously improve its quality policy according to its objectives and keep up with the evolving demands. The question of modernising these quality methods comes up with the digitalisation of the 21st century. On the other hand, with the recent development of new technologies, many IT tools have become available on the market and among them, Product Lifecycle Management (PLM) systems are very popular among companies thanks to the many functionalities they offer. In particular, Product Lifecycle Management (PLM) software enables the creation and maintenance of complex industrial products throughout their lifecycle. This brings multiple benefits to the company, such as faster time-to-market, improved productivity and collaboration, better product quality, reduced prototyping costs and much more.

From this point of view, these Quality Management Systems (QMS) and Product Lifecycle Management (PLM) seem to be two systems that have proven their worth in supporting product quality improvement. However, although complementary, they are usually used by different departments discretely at times, such as quality and engineering teams [2]. Distinguishing between them as two distinct and separate processes creates a loss or poor flow of information between the stakeholders in product development, which is very detrimental to the quality of a product. Since the information is produced by different software tools, it is highly heterogeneous given that it is presumably managed using different data formats and structures. In this way, complexities of dispersed teams, disconnected systems, and a changing regulatory environment could create isolated data elements without counting that key stakeholders may no longer understand the relations between these elements. All of this creates barriers to the development of quality products. A one-way flow of information prevents engineers from obtaining the necessary quality information after the product has been manufactured. This closing of information loops throughout the life cycle of a product is very important since activities such as design, production, sales and maintenance must be able to produce products with a better ratio between the expected characteristics and the delivered characteristics, so quality information is crucial information that especially the engineering staff must receive.

The idea then arises to consider even wider use of the PLM system by adding quality management, that will enable quality professionals to manage product quality throughout the lifecycle of the product and thus allowing the actors involved in the development of the product throughout its life cycle to have easy access to as much information as possible, especially quality information, which they need on platforming better-connected platforms. This would result in better management of quality, reliability, and risk at every stage of the product life cycle, thus enabling the reduction of costs of poor quality. Moreover, the combination of these two systems seems to be an obvious continuity for their individual developments. The objective of this article is to determine the interest in integrating quality management into the PLM system.

2. Overview of Available Systems

Recently, the subject of PLM system is the subject of numerous research. Indeed, with the development of new technologies, companies need to adapt their tools to new trends. Among these, PLM System stands out by showing evidence of its advantages. However, there is still potential for improvement, especially regarding the issue of the importance of quality management in the system. As the subject is still quite new, very few papers directly address this problem. But a relationship between the PLM system and quality management has been noticed by many authors and some companies have seized the opportunity by developing PLM software that includes quality management.

2.1 Quality Management in PLM Systems

Aras [3], an American developer, and publisher of product development software has rethought the way PLM is designed and now is offering Aras Innovator®, a full-featured Product Lifecycle Management software that supports companies in their development from all aspects. Among these, quality management is not negligible. That's why Aras has developed the Aras Quality Management System application, which provides companies with advanced product quality planning (APQP) tools to manage risk, improve quality, and achieve environmental, regulatory, safety, medical, and other compliance. In that respect, by combining PLM and quality, this approach can support regulatory compliance by reducing the number of systems companies use to manage quality information, manage product and process risks more easily by having all visibility on a single platform, and finally close the loop on product quality by having all necessary information in the same software allowing better coordination of tasks and organisation. Indeed, this connection of data relating to quality activities, from the design phase of the product life cycle through to production, in a single source ensures visibility and accountability of related processes. In this way, quality is improved through this two-way communication of controls and results obtained by linking quality planning with feedback along the life cycle.
Siemens PLM [4] software is also equipped with tools to manage quality management directly to support the optimisation of products throughout their life cycle. Siemens' PLM software has been developed in response to the needs of the industry, as they have understood the many benefits that this represents, including system homogeneity resulting in data concentration, reduction of manual activities and paper documentation, standardisation of reports, reduction of process time and, above all, transparency of processes. Quality functionalities that are developed are

- Advanced product quality planning (APQP)/project management,
- Failure mode and effects analysis (FMEA),
- Control plan,
- Process flow chart,
- Inspection planning, and
- Product part approval process (PPAP).

All this, combined with other features of the PLM system, allows actors to intervene early and thus better manage the quality of the final product.

Windchill system offered by PTC [5], is an approach to quality is has many quality tools including change and configuration management, requirements and test management, CAPAs, non-conformances, customer experience management (CEM), audit, document control, failure mode and effects analysis (FMEA), fault tree analysis (FTA), critical to quality

(CTQ), and risk-based design (RDB), that are centrally stored and aligned with engineering, manufacturing, and service bills of materials and process plans. All of this allows a solution that can be shared across engineering, quality manufacturing, supply chain and regulatory teams and consequently improve their collaboration, thus accelerating the development process of high-quality products. The value of integrating quality management into the life cycle management system is then supported by the development of all these quality functions in the latest PLM software. Unifying the Engineering, quality, and regulatory teams by introducing best practice change, document, and design control processes. The challenge now is to know how to adapt and use these new features of the PLM system is to achieve the quality objectives set by the company. Furthermore, it is interesting to note that these software suppliers do not stop at this innovation and continue their research, by furthering the Digital Twin approach.

2.2 Quality Management Systems

Quality Management plays an important role, in helping companies to accomplish excellence in their business excellence. Many studies have explored the impact of Quality Management on firm performance. Figure 1 presented a conceptual research model that illustrates that quality management does have a positive impact on market share performance and innovation performance, which are essential to industrial success . To this end, quality management systems must meet the unique needs of a company, and therefore various methods are deployed. One of the most widely used is the Quality Function employment (QFD). Indeed, many researchers have discussed applications of the QFD method to translate the voice of the customer into engineering characteristics for a product [6] by making customer expectations a mathematical correlation.
Figure 2 highlighted the benefits of applying the QFD method [7]

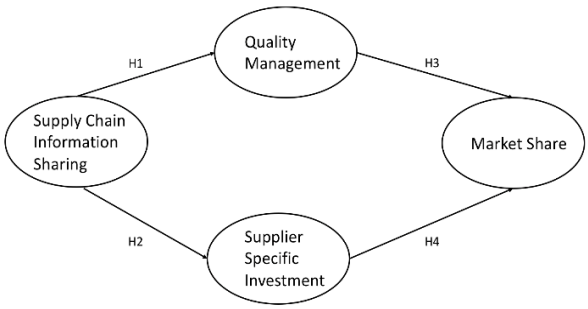


Fig. 1. Concept model of quality management impact

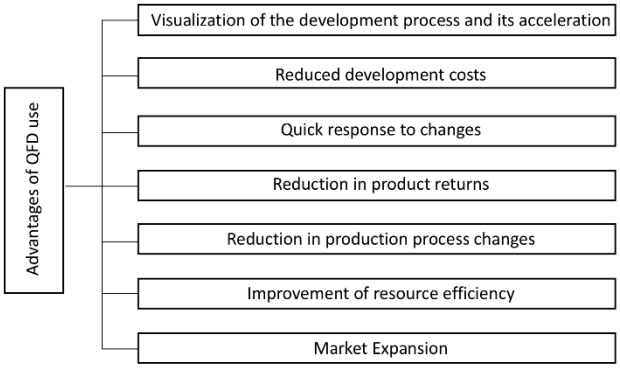


Fig. 2. Benefits of using QFD

They also support the idea of combining the use of the QFD method with information technologies such as the PLM system and consider this as an effective solution for product development. A study that seeks to identify the customer requirements and engineering attribute expectations of an innovative product using QFD and Kano's model is proposed. In addition, an approach combining the Kano model (Fig. 3) and the QFD to satisfy customer requirements through optimal product design based on the objective-based programming approach is deployed [8]. That allows engineering designers and manufacturers to clearly understand what customers want. This is particularly useful for those seeking to establish strategies for product development and thus improve product quality.

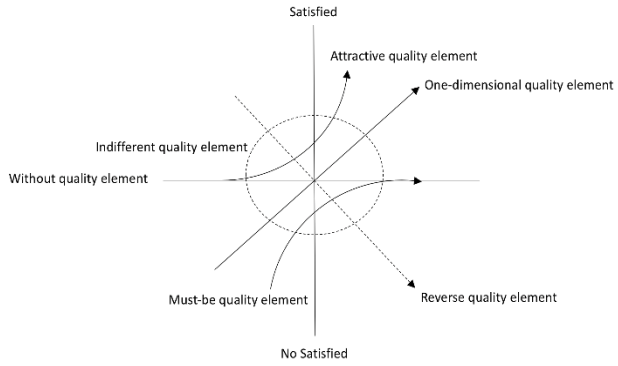


Fig. 3: Kano's Two-Dimensional Quality Model and Five Types of Quality Elements

A survey is carried out based on the use of Modern Management tools and techniques that can improve the accuracy of product design like QFD [9]. This paper summarises the research undertaken by the authors in the field of QFD, from which the advantages of this method are strongly demonstrated. It helps the product development management team make decisions about the product quality by studying and improving its characteristics. However, this customer research approach had some limitations as it depends on many limited and uncertain parameters, thus this does not guarantee the success of a product. Other methods particularly known for their benefits in quality management are also discussed such as Total Quality Management (TQM) and Six Sigma (SS).

An integrated hospital quality management model had developed from the practice of TQM and SS to provide synergy in improving performance as an example. Both have enabled hospitals to improve their performance, where TQM is more focused on addressing improvements at the system (macro) level, while Six Sigma produces improvements at the operational (micro) level [10]. The most precise work on quality systems are based on QMS and methods as Kaizen, Six Sigma or Lean production are widely used. But now with the development of the modern digital economy, new quality management systems and methods should be proposed and developed. The main idea here is to integrate elements of digital technologies such as PLM, ERP, SCM and others into quality management [11] as shown in Fig. 4.

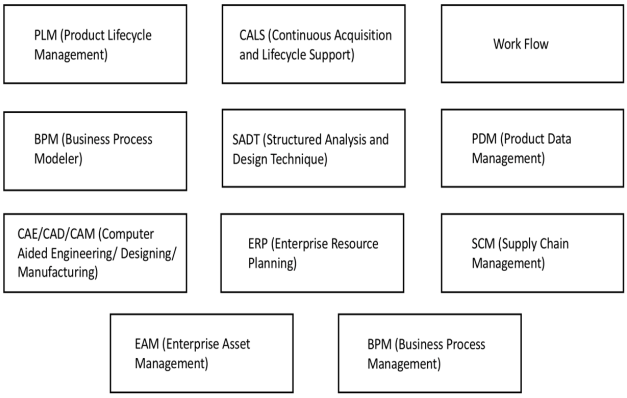


Fig. 4. Elements of Digital Technologies for Integration into the Quality Management System [11].

In the same spirit, the importance and the impact of digitalisation on the quality management system are now referred to as Quality 4.0 where traditional quality methods are associated with new technologies to achieve new optimums in performance, operational excellence, and innovation and finding how it works together will be the challenge [12].

3. Industrial Case Study

Using the Stage-Gate Approach, a conceptual and an operational model for the development, marketing, and removal of a product during its life cycle, allows gathering information needed to progress the project to the next gate or decision point. It consists of seven stages and requires the work and input of many teams from different functional areas. Among them, we can list Program Management, Marketing, Technical, Manufacturing, Supply, Customer Care and Finance team. To optimize their collaboration in the product development process, many tools and systems are available to them. However, most product information is stored separately according to its creator function. For example, the Engineering team stored CAD data in the CAD Data Management tool while manufacturing information is stored in ERP systems. To address this problem of heterogeneity of systems, PLM software as Windchill is used within the company. Indeed, as it is responsible for such issues as data access, storage and recall, information security and integrity, concurrent use of data, and archival and recovery, it connects engineering to the manufacturing and supply chain by integrating both systems. The benefits of these proposed changes in the application have convinced the company, which

now uses it as an essential tool for managing product data and using the change management functionality for releasing the product information thru the life cycle approval process which gets interfaced to the ERP system. For demonstration purposes, a CAD assembly model, see Appendix, was created to allow better tracking of the information flow managed by the PLM system of the partner company. The following can be constated: the Product Development Change Management in the company, as described in Figure 5, is a one-way system divided into several stages.

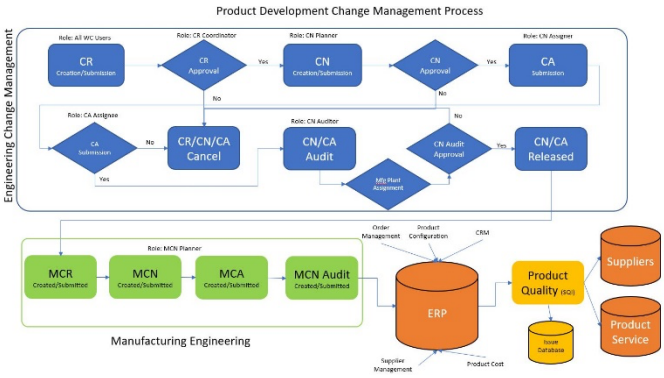


Fig. 5. Change Management Flow process in Product Development

Starting with the creation and submission of the Change Request (CR) used to describe a suggested improvement or correction to the design of a product within the engineering team, this, once approved, is followed by the creation and submission of the Change Notice (CN) and at the same time of the creation of Change Activity (CA) both by CN Planner. The first one is used to alert and communicate the details of the change to those involved while the second one represents all the tasks that the team needs to carry out to make the change and this includes designing and drafting the change. However, an order must be respecting this respect and it is only after the validation of the CN that the actions defined by the CA can be executed by the CA Assignee defined in the CN. At this stage a tri-approval is necessary before submission, the designer completes the task assigned to him/her, and then it must be validated by the Reviewer and finally a last time by the Technical Reviewer. All this, after the audit is carried out and validated, allows the release of the CN and CA, making them accessible to the whole team and especially to the manufacturing. As a supporting document, a Manufacturing Change Request (MCR) will be created at the end of its examination, followed by the Manufacturing Change Notice (MCN) and then the (Manufacturing Change Activity) MCA if everything is validated.

These latter documents and information, once checked and validated by reviewers are stored in the ERP system, which is not only used by the manufacturing group but also by other functions such as Order Management, Product Configuration, CRM, Supplier Management and Product Cost. This information will then be submitted to the quality function for checking based on the Service Quality Index (SQI), thus creating a reusable database of identified problems. This ensures the overall quality of the product is improved. Finally, this information is passed on to suppliers and product service providers to establish relationships for business exchange. The application of this process in the PLM system is summarised in Figure 6 where we can identify the different people involved in the process as well as the tasks they are assigned. We can observe that the steps are well

followed, and the system is quite complete to communicate, plan the assignment of manufacturing plants in advance and thus control the progress of the project.

Therefore, this one-way process used by the company is mainly focused on engineering and manufacturing in the early stages, whereas quality should not be neglected. The lack of a direct relationship, between the engineering and quality group, means that engineers don't have detailed access to customer feedback and so the reuse of data during product development is proving difficult. In that respect, this complicates the process of product development in terms of both cost and time. Figure 6 shows the current As-IS change management process in PLM without the involvement of the Quality team.

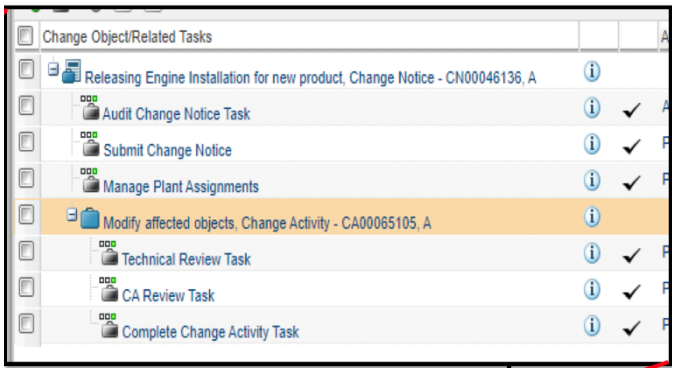


Fig. 6. Change Management Flow representation in PLM System

4. Proposed Solution

The importance of integrating Quality Management into Engineering Change Management is therefore highly beneficial. The proposed solution illustrated in Figure 7 consists of integrating an exchange flow between the engineering department and the quality department, when creating the Change Notice (CN), considering the new step as a Change Activity (CA) task. So, to do this, firstly a new change task must be created by the CN Planner as a first sequence and as usual, the document should be filled in with the name, description, need date, CA assignee and CA Reviewer. This first sequence is used to define people who will work on the design part of the product, and then a second sequence can be created in the same way for asking approval from the Quality department and suppliers. The idea is to email or sends a notification to Quality Function through the PLM system, in this way they can see all documents related to the task including the drawings (see Appendix for instance), and this allows them to identify if there is any problem with the parts and assembly. Based on their database of problems already encountered, they can then easily give feedback at this stage of the process and this simultaneously enables them to update their issue database. Their response will then be considered by the CN Auditor before releasing and if the quality aspect of the part or product is not validated, the CN planner is directly contacted back to make the necessary changes instead of losing time and energy compared to the previous scheme. Indeed, everything else works in the same way as described above, facilitating tasks and collaboration between the different actors.

In conclusion, the idea is to obtain validation at the quality level, before moving on to the following stages, especially before releasing the part and product. This allows engineers not only to have the right information at the right time but also to have real-time feedback on

the various quality issues that may affect their products. On the one hand, this is supposed to reduce the time wasted by engineers searching for quality information during the production of new products, and on the other hand to increase the collaboration between the two departments and thus their efficiency. From a general point of view, a reduction of the waste of staff and production time is also foreseen and thus an overall improvement of the product development system is expected.

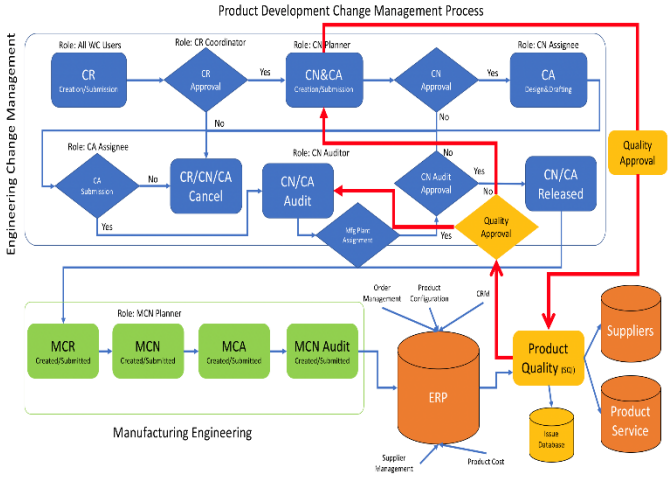


Fig. 7. Quality Function in Change Management Flow process in Product Development

Figure 8 shows the New Engineering Change Management process in PLM and as expected, we can identify the presence of a task requiring the approval of the Quality Service as a CA task before that of the change of the product. The process is no more complicated than the current one and provides a much better final effect.

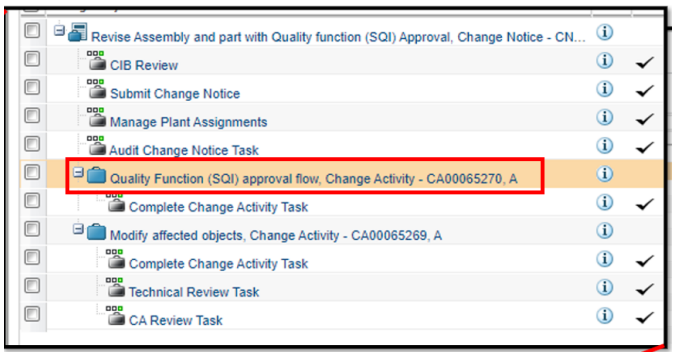


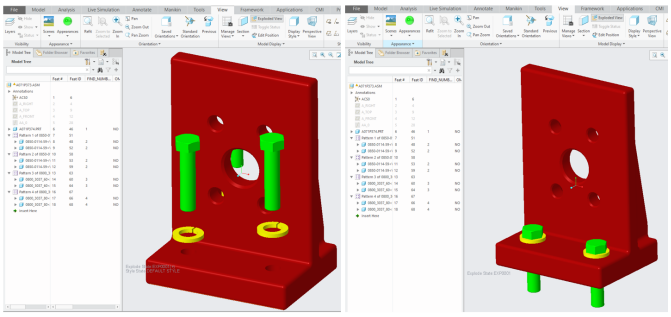
Fig. 8. Quality Function in Change Management Flow in PLM System

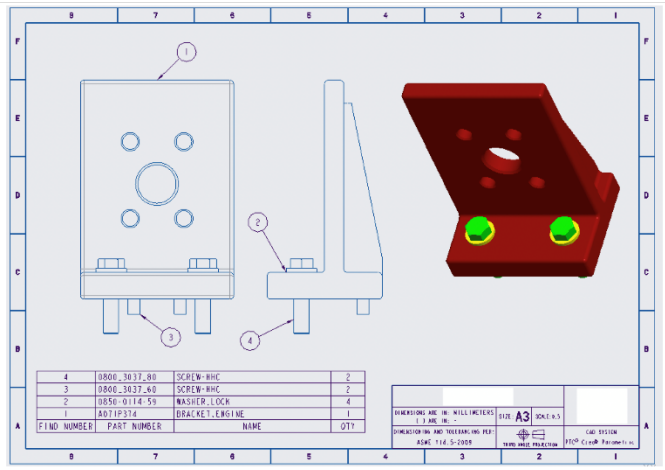
5. Conclusions

This paper discusses the need of integrating Quality Management functions in PLM based on an industrial case study. The result can serve as a reference for companies that are still reluctant to integrate their Quality Management System into PLM. These two systems, which aim to improve quality and product profitability, should not be separated from each other to minimise design and quality problems. Indeed, integrating QMS into PLM has many advantages, not to mention that its integration is not more complicated allowing an easy adaptation of the personnel. Among the benefits, those most valued by industry include:

saving time and money; an increase in product quality and therefore customer satisfaction; better collaboration and exchange within the company's teams, particularly between the engineering, manufacturing and quality departments and thus better performance; and improved project monitoring, which promotes the reuse of information and the development of new products.
These advantages are crucial for an industrial company seeking to stand out from the others in today's competitive market. As the direction of future work, the idea of going beyond the simple task of requesting approval of the quality service could be considered. Indeed, as the benefits of this association of these two complementary systems have been proven, it may now be interesting to study the other functions of the QMS that could be integrated into the PLM system to get maximum benefit.

Appendix: CAD Models for demonstrating the case study used in the Change Management process in PLM.





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