Information Quality in PLM:
A Production Process Perspective

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Abstract. Recent approaches for Product Lifecycle Management (PLM) aim for the efficient utilization of the available product information. A reason for this is that the amount of information is growing, due to the increasing complexity of products, and concurrent, collaborative processes along the lifecycle. Additional information flows are continuously explored by industry and academia – a recent example is the backflow of information from the usage phase. The large amount of information, that has to be handled by companies nowadays and even more in the future, makes it important to separate the "fitting" from the "unfitting" information. A way to distinguish both is to explore the quality of the information, in order to find those information that are "fit for purpose" (information quality). Since the amount of information is so large and the processes along the lifecycle are diverse in terms of their expectations about the information, the problem is similar to finding a needle in a hay stack.

This paper is one of two papers aiming to address this problem by giving examples why information quality matters in PLM. It focuses on one particular lifecycle process, in this case production. An existing approach, describing information quality by 15 dimensions, is applied to the selected production process.

Keywords: Product lifecycle management · Quality management · Manufacturing · Production · Production planning and control · Data quality

1 Introduction and Problem Description

Closing the information loops along the product lifecycle is a recent effort under-taken by research projects [1, 2]. One of the reasons why closing information loops is so important is the expectation that activities like design, production, sales and maintenance will be able to realize products and services with a better ratio between expected and delivered characteristics (i.e. higher quality). As product quality is directly influenced by the quality of the production processes [3, 4], an increased availability of information will benefit production planning and control activities. Additional

information can help to understand complex problems and take the most suitable decisions to address them in a timely manner – common examples for these benefits are Concurrent Engineering [5] and agile software development [6].

Technical capabilities for the collection and analysis of information, as well as a sound business case are important prerequisites to increase the availability of information in decision-making. However, the growing amount and heterogeneity of information caused by, e.g. the industrial Internet and the Internet of Things, foster the need to identify information that is fit-for-purpose (i.e. focus on information quality). Recent literature about PLM puts little emphasis on this aspect.

This paper will discuss the importance of information quality in PLM from the perspective of production. The same issue but from a product design perspective is described in a sister paper (see [7]). Section two of this paper outlines information flows in PLM and an exemplary approach to describe information quality.

2 Related Work

2.1 Information Flows in PLM

Handling product data and information along the complete product lifecycle is stated as PLM [8]. A product's lifecycle can be structured into three subsequent phases stated as 'beginning of life' (BOL), 'middle of life' (MOL) and 'end of life' (EOL). The initial concept of PLM was extended during the EU-funded large-scale research project PROMISE – it demonstrated the possibilities of closing information loops among different processes of the lifecycle [9]. The recent concept of PLM is illustrated in Fig. 1. Internal information flows within the phases are not covered in the illustration.
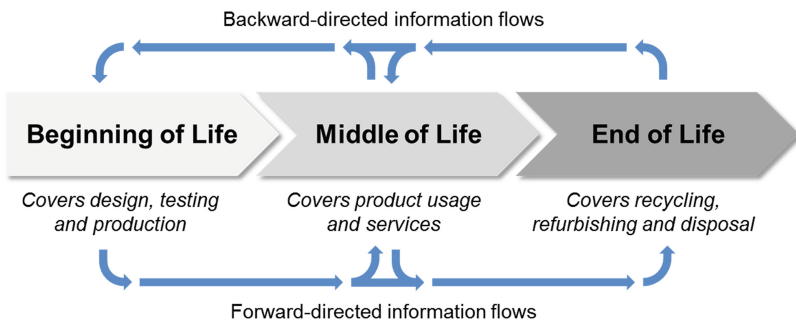
Fig. 1. A product lifecycle model and its major information flows [10]

Among the three lifecycle phases, at least two types of information flows can be established. The forward-directed flows are the ones that are typically mandatory to design, produce, service and dismiss the product. Backwards-directed flows are typically optional and allow optimization of processes/activities.

2.2   Information Quality (IQ)

Seamless decision-making processes are largely based on high-quality information. Decision-makers realize issues with information quality if their expectations about the information are not met. Examples for potential problems caused by low information quality are summarized in Table 1.

Table 1. Examples of problems related to flawed information [11]

not based on fact	consists of inconsistent meanings	is irrelevant to the work
of doubtful credibility	is incomplete	is hard to manipulate
presents an impartial view	is hard to understand	–

From a general perspective, the quality of information can be defined as the degree that the characteristics of specific information meet the requirements of the information user (derived from ISO 9000:2005 [12]). Since the topic is intensely discussed for at least two decades, several sophisticated definitions for 'information quality' exist. Since the purpose of this paper is not to discuss these fundamental concepts, a thoroughly discussed definition is selected for this paper. Rohweder et al. propose a framework for information quality that is an extension of the work conducted by Wang and Strong [13] – the framework contains 15 information quality dimensions that are assigned to four categories as summarized in Table 2.

Table 2. Dimensions of information quality [13]

Quality category	Scope	Quality dimensions
Inherent	Content	Reputation; free of error; objectivity; believability
Representation	Appearance	Understandability; interpretability; concise representation; consistent representation
Purpose-dependent	Use	Timeliness; value-added; completeness; appropriate amount of data; relevancy
System support	System	Accessibility; Ease of Manipulation

The selected definition of information quality contains four categories of dimensions that are related to a specific scope. Each category has dimensions that characterize information by two to five dimensions (15 in total). A brief description of some dimensions is provided in Table 3.

In order to receive a specific statement about the actual quality of an information item, the as-is characteristics of the item must be compared with the required characteristics (preferably using all of the quality dimensions). The better the matching is, the higher the information quality is considered.

Table 3. Excerpt of quality dimensions and their description (based on [14])

| Quality dimension	Description
Reputation	Credibility of information from the information user's perspective
Free of error	Not erroneous; consistent with reality
Objectivity	Based on fact; without judgment
Believability	Follows quality standards; significant effort for collection and processing
Understandability	Meaning can be derived easily by information user
Interpretability	No ambiguity concerning the actual meaning; wording and terminology
Concise representation	Clear representation; only relevant information; suitable format
Consistent representation	Same way of representing different information items
Accessibility	Simple tools and methods to reach information
Ease of Manipulation	Easy to modify; reusable in other contexts

3   Approach

Production is the process of realizing products according to the specifications originating from product development. In this paper, production includes production planning, manufacturing and assembly processes. During production, several characteristics of the later product and its behavior during usage are defined, e.g. by the chosen materials, machines and machine parameters. The decision of which materials, machines and parameters are going to be used is taken during the production planning phase and the previous product development phase. In this paper, the product development phase is not in the focus.

During production, information between different manufacturing processes is exchanged. The exchanged information is highly important to ensure the final product quality [13]. In manufacturing, especially in the area of process monitoring and control, information quality can play a decisive role in whether an analysis and the subsequent action is successful or not. In order to apply the selected quality dimensions to production, relevant information flows are divided into three categories as illustrated in Fig. 2.
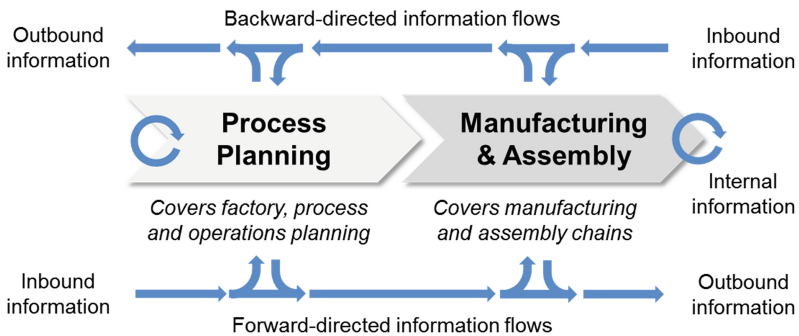
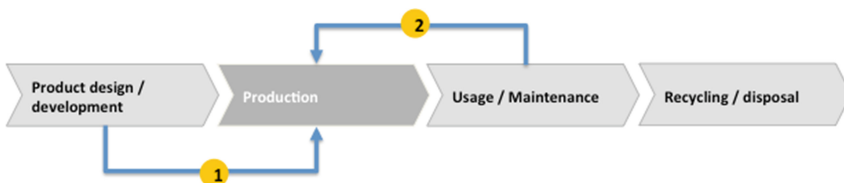**Fig. 2.** Types of information flows in production

Information Flows Within Production (Internal). In production, information quality is generally of very high relevance as it often has a direct impact on key figures of a company or a production network. Information used in manufacturing is often used as input for machines with a low level of robustness against, e.g., missing values. Today, production involves multiple processes exchanging not only physical goods but also information. Those process chains can become rather complex and can be considered dynamic. Looking at manufacturing at a more granular level, each process and product has to be considered individually due to, e.g., deviations in its materials (Fig 3).
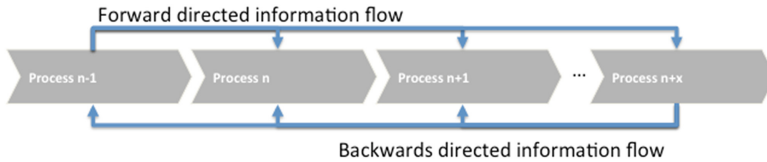
Fig. 3. Internal information flows of a production process chain

Through the backflow of information about the individual product earlier in the same process or from previous processes individual adjustment of process parameters becomes possible. These adaptions of the process may lead to significantly improved performance and/or avoidance of significant problems. Today, many decisions regarding value adding production processes are taken based on available information. Control loops, scheduling decisions and program planning are just some examples which strongly depend on information quality. Information in this context can include real-time sensor information, e.g., for monitoring and control purposes, as well as quality measures for subsequent process adjustments. A practical example can be information about the individual chemical composition of the steel, used during heat treatment. This information is vital for reaching the quality goal.

Information Flows Towards Production (Inbound). Extending this towards the potential use of information from lifecycle phases other than production to support production processes in a similar way, certain differences come to mind and present specific requirements towards the information quality. The two main inbound information sources are depicted in Fig. 4.: 1) information from the product design phase and 2) information from the usage and maintenance phase.

Fig. 4. Inbound information flows towards production

The product design phase is essential for production. In design the main properties of the later product are set and the processes and process parameters are chosen according to the information received from design. For information from usage, there are two possibilities. First, the information is directly transferred and utilized or the usage information is indirectly utilized via the design phase. An example for relevant information from usage/maintenance is the surface quality of a product that depends on environmental factors during usage. A product's surface characteristics can be influenced to some extend during the production process (e.g., heat treatment).

Information Flows From Production (Outbound). In production, information is not only utilized but also produced in large quantities – machinery and tools are equipped with sensors continuously producing information. Also process monitoring and advanced systems, like Manufacturing Execution Systems, contribute to the increased information generation. This information may be a valuable source for stakeholders outside of production. In Fig. 5., outbound information flows to three other lifecycle phases are depicted: 1) recycling and disposal, 2) usage and maintenance and 3) product design and development. Examples cases for these three information flows are:
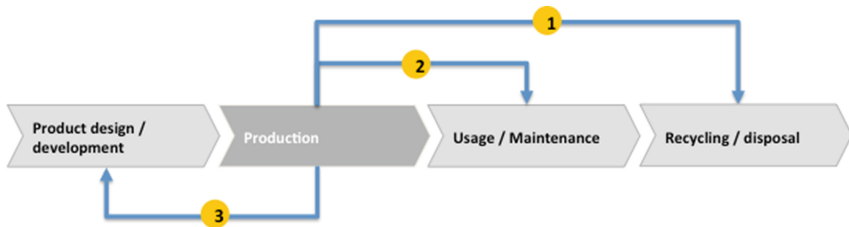

Fig. 5. Outbound information flows from production

1. Information about potentially hazardous materials of the product introduced during production (e.g. heavy metals).
2. Information about lubricants used during production which could influence the areas of application of the product (e.g. regulation in food processing industry).
3. Information can be directly utilized for future design improvements that lead to a variety of improvements, e.g. quality, efficiency or safety.

From the perspective of production, the example number three can be considered as the most important outbound information flow. Popular approaches like 'Design for Manufacturing' actually rely on such outbound information from production.

Within all these different possible information flows, an important aspect to consider is the information quality. Whereas the right information in the right quality may lead to significant improvements, flawed information may even have a worse impact than no information at all. In the next section, this is discussed according to the previously introduced IQ dimensions.

4   Discussion

In this section, the feasibility of the different IQ dimensions during application in manufacturing and production planning is discussed. The overall structure follows the one depicted in Table 2, with sub-sections resembling the four 'scope' categories. As mentioned, production is very diverse in the applied processes and also individual for each product type. Therefore, the given examples used to emphasize certain quality aspects are not meant to be comprehensive – there are, most likely, multiple other influences and aspects that are not covered in this paper. For each scope of the selected IQ framework, the three different information flows introduced in the previous section (i.e. internal, inbound and outbound) are briefly discussed.

4.1   Content Scope

The *content scope*, resembling the IQ dimensions 'reputation', 'free of error', 'objectivity' and 'believability', is very relevant in production. For information flows *within production (internal)*, 'free of error' is very important as the information is often directly utilized by technical systems. Given that process chains are often distributed between different locations and companies, 'reputation' and 'believability' may also be relevant. However, 'objectivity' may be considered less relevant in this area as measuring and sensor data can be considered rather objective by nature. For *outbound and inbound information* however, all four IQ dimensions are highly relevant. From a production perspective, these IQ dimensions matter most for inbound information. However, for other stakeholders within the product lifecycle, the importance of information quality of outbound information can be considered equally high. Here 'objectivity' is also relevant as these information items may contain human-authored feedback information including its characteristic of subjectivity – also stated as response-bias [13].

4.2   Appearance Scope

The relevant IQ dimensions of this scope are 'understandability', 'interpretability', 'concise representation' and 'consistent representation'. For information flows *within production (internal)*, all four IQ dimensions discussed here are important. In highly automated production environments, the appearance of information is mostly defined, due to standardization or design of the production system itself. If standards are not met nor the communication rules of the automated system are not followed, the system will fail in most cases. Thus, these IQ dimensions are hard requirements, which have to be fulfilled. In production processes with more manual work and thus more human-based decision-making, the appearance of information is less regulated and, therefore, must be controlled more. For *inbound and outbound information* flows, these IQ dimensions cannot be assumed fulfilled due to standardization. There, the information is more diverse and the possibility of different systems and/or requirements is rather high. Thus, these IQ dimensions have to be carefully considered prior to establishing collaboration along the product lifecycle.

4.3   Use Scope

Regarding the use scope, the IQ dimensions 'timeliness', 'value-added', 'completeness', 'appropriate amount of data' and 'relevancy' are in the focus. ***Within production (internal)*** it can be observed, that timeliness, completeness, appropriate amount of data, and relevancy are highly important. The often-automated use of information by machinery and monitoring tools relies on information fulfilling these requirements. For instance, even though today's computing power and algorithms can handle large amounts of data rather well, it is still important to evaluate what data is really relevant with the goal in mind. For ***inbound and outbound information*** flows in production these factors are also of relevance, however, there the potential use is broader and thus the variety of quality requirements acceptable may be higher. For all information flows in production the IQ dimensions 'value-added' is very important, as it is after-all a business operation.

4.4   System Scope

From a system perspective, 'accessibility' and 'ease of manipulation' are the desired IQ dimensions. ***Within production (internal)***, accessibility is critical, especially in distributed production environments. Assuming that in production information is mostly based on sensor or other non-human-authored data, the access is mostly depending on a) available communication means (technical) and b) the access rights. Ease of manipulation is on the other hand not considered critical within production. Regarding ***inbound and outbound information*** flows, accessibility is again highly critical, with access rights being rather complicated to manage. Ease of manipulation is more important here, as it might be necessary to reformat or pre-process information for different purposes.

5   Conclusion and Outlook

This paper discusses the importance of information quality in PLM from a production process perspective. From literature, a framework with 15 IQ dimensions is selected. Then three different categories of information flows are defined to structure the discussion. These flows concern the usage of information within production (internal), coming from production used elsewhere (outbound) and coming towards production form different phases (inbound). In the following discussion, the importance of information quality in production is discussed by mapping the IQ dimensions with the three types of information flows identified before.

While the depth of the investigation conducted in this paper remains rather low (e.g. few examples and no consistent use case), it aims to substantiate a debate about the importance of information quality in PLM. This topic is of major importance, as the amount, heterogeneity and velocity of available information is growing and the selection of relevant information becomes more difficult. The definition of three types of information flows (i.e. internal, inbound and outbound) can be applied to other processes along the product lifecycle, in order to receive examples for all major lifecycle phases. In future work, a combined paper is envisaged for that purpose.

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