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## Sources and characteristics of information about product use

Stefan Wellsandt<sup>a\*</sup>, Karl Hribernik<sup>a</sup>, Klaus-Dieter Thoben<sup>a, b</sup>

<sup>a</sup>BIBA - Bremer Institut für Produktion und Logistik GmbH at the University of Bremen, Hochschulring 20, 28359 Bremen, Germany

<sup>b</sup>Faculty of Production Engineering, University of Bremen, Badgasteiner Straße 1, 28359 Bremen, Germany

\* Corresponding author. Tel.: +49-421-218-50166; fax: +49-421-218-50007. E-mail address: [wel@biba.uni-bremen.de](mailto:wel@biba.uni-bremen.de)

### Abstract

Knowledge about the activities happening beyond the point of sale is valuable for product and product-service design. In the product design community, the importance of this knowledge is accepted for several years, for instance through concepts like participatory design, as well as the living lab movement. An extensive involvement of users, in order to gain the desired knowledge, may prove time consuming and thus too expensive. Therefore, it appears expedient to utilize the existing information that is generated beyond the point of sale as effective as possible. In order to support research in this field, this paper provides an overview about different types of currently existing product information originating from the so-called middle of life phase. The overview is based on application cases that belong to different research and innovation projects, as well as practical examples from internet-based services. It briefly covers, for instance, data from embedded information devices, maintenance information, user-generated contents such as videos and product reviews. Within the subsequent discussion, some characteristics of middle of life information are highlighted. The characteristics are related to the different appearance of information and concern, e.g. differences among measured and articulated information, as well as the relation between instance- and class-based product information.

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### 1. Introduction

Traditionally, manufacturers of tangible products have very limited information about their products once they are sold to the end customer. In Product Lifecycle Management (PLM), the point of sale is the moment a product enters the middle of life (MOL) [1]. While the product is in its MOL, it is used in various contexts, maintained, repaired and different other value-adding services are applied as needed by the user. Due to these activities, the MOL is sometimes stated as the product's usage phase or use phase. According to [2], the MOL ends once "[...] a product no longer satisfies its user [...]". Strategies like product reuse by another user, as well as special use situations like multiple or anonymous users are intentionally omitted in this paper for reasons of complexity.

Information from the product usage phase is valuable for the product design. From this information, new knowledge can be concluded that can be beneficially applied in new product development [3] and product improvement [4]. The importance of this knowledge is recognized in the design community for several years, for instance in participatory design and the living

lab movement [5]. Participatory design approaches are based on the extensive involvement of users in design decisions.

The extensive involvement of users through techniques, such as structured interviews, moderated focus groups and experts' observations, may prove as an expensive approach for companies to gain information about the usage of a product. With respect to the cost of active user involvement, it can be suitable to work on information that is already available. This information may originate from maintenance activities and embedded sensor devices, as well as from the internet in the form of user-created contents.

Since there is no common definition for what the information from the MOL phase exactly is, a working-definition is suggested in this paper. The working definition is influenced by a similar definition of the term "field data" in [6]. With respect to the domain of PLM, a product's middle of life information is any product-related information that is created after the product is sold to the end customer and before the product is no longer useful for a user.

The paper aims to provide an overview about different types of MOL information, in order to substantiate future research and discussions concerning the MOL phase and the effective

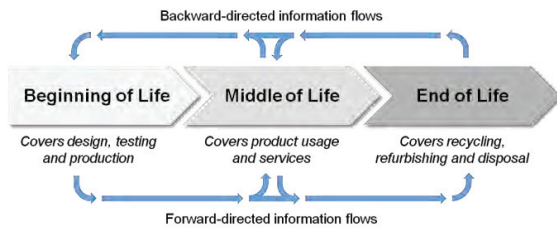


Figure 1: Phases and information flows of the product lifecycle

application of MOL information in beginning of life phase. Therefore, it doesn't cover PLM activities like product design (e.g. participatory design) and testing even though these activities might benefit from MOL information.

For this purpose, the remainder of the paper will be structured as follows: Section 2 will introduce the context of this paper, i.e. closed-loop PLM. It will further clarify the role of the MOL phase and provide examples of existing work concerning MOL information. Section 3 will briefly introduce the selected approach for this paper and is followed by the overview about the types of MOL information in Section 4. Based on this overview, there will be a discussion of the different types in Section 5. The paper closes with a conclusion and outlook listing future research tasks.

## 2. Related work

The first part of this section summarizes the current understanding of PLM. It further clarifies the meaning of the MOL phase with respect to PLM. In the second part, existing work about product use information is briefly presented.

### 2.1. Product Lifecycle Management

The process of handling product data and information across a product's lifecycle is termed *PLM* [1]. The product lifecycle can be structured into three subsequent phases stated as beginning-, middle- and end of life. Within the EU-funded large-scale research project PROMISE, the concept of PLM was further extended to specifically demonstrate that information loops among different processes across the lifecycle can be reasonably closed [7]. This *closed-loop PLM* takes advantage of the improvements in ICT technology by sharing item-level data and information collected by product embedded information devices (PEID). With respect to the design of new products and the improvement of existing ones, information flowing into the beginning of life phase is most relevant. An illustration of the three lifecycle phases and related information loops is provided in Figure 1.

The *MOL phase* is typically described by the interplay of the actual usage activities and product-related services. Because the product's usage is a central aspect of the MOL, it is also referenced as the product's "usage" phase [8]. The actual use of the product results in consumption/wearing of the product over time. The degradation is compensated by maintenance, repair and overhaul (MRO) services. These services aim for the extension of the product's lifetime which is especially relevant

for expensive products like machinery. During the MOL, other value adding services can be conducted, such as insurance, financing, leasing, status monitoring and location tracking.

Due to the rapid developments in computer science and servitization in manufacturing industry, complex products such as vehicles, home appliance and mobile devices tend to be combinations of physical components, software and services that can be subsumed as product-service systems [9]. In order to respect this development, the provided content in this paper has to be seen in light of product-service systems. In case a specific (unique) tangible product is addressed, the term "product instance" will be used in this paper.

### 2.2. Existing work about MOL information in PLM

Within the field of PLM, several authors covered MOL information already. Common synonyms are field data and product use information.

Early work on MOL information and its feedback into product design is provided in Jun et al. [10]. The authors considered the following contents as relevant (non-comprehensive summary):

- Maintenance and failure information: e.g. ease of maintenance, reliability problems, maintenance date, critical component list and root causes.
- Technical customer support information: e.g. customer complaints, customer profiles and response.
- Usage environment information: usage condition (e.g. average humidity, internal/external temperature), user mission profile and usage time.

Another perspective is taken by Fathi and Holland that argue about subjective customer feedback and measurable information stated as "product use information" (PUI) [11]. The latter ones are considered as more objective. Examples for PUI of a manufacturing machine are:

- Sensor data of the product (i.e. machine)
- Environmental parameters
- Quality parameters of the produced item
- Failures and breakdowns
- Incidences of maintenance

Since the aforementioned work is focused on quantifiable information, user generated contents (e.g. user feedback) are not covered. User feedback, on the other hand, is covered in [12].

## 3. Approach

In order to identify types of MOL information, real applications are investigated in this paper. The applications are demonstrated in research and innovation (R&I) projects or exist as web-based services in the internet. Though MOL information is a term used in the context of PLM, other domains investigate very similar information from other perspectives. Examples for related domains are marketing (e.g. after-sales management), context-based system development (e.g. adaptive interfaces and personalized content), and service engineering. Since the paper argues from the perspective of PLM, the aforementioned domains are out of scope for this

paper and related practical examples will not be considered in this paper.

#### 4. Findings

In this section practical examples of MOL information are provided. The examples are divided into application cases from PLM-related research and innovation projects, as well as practical examples available in the internet. The web-based examples contain established and in some cases well-known websites.

##### 4.1. Application cases in R&I projects

MOL information is part of many demonstrators in R&I projects from the engineering domain. Table 1 provides an overview of the application cases selected for this paper. The covered MOL information was taken from the sources following the respective authors' wording.

Table 1: Examples of products collecting middle of life information

No.	Application case	Ref.	Considered MOL information
1	Leisure boats	[13]	Atmospheric pressure, external temperature, air humidity and engine RPM, geo position
2	Hydraulic systems	[4]	Temperature (inside system and environment), pressure, rotation speed, vibration, time of use, load during use, time of failure, kind of failure
3	Furniture	[14]	Human use and product wear, pollution, light, relative humidity
4	Offshore wind turbines	[15]	Weather data, sea level, stress on structural components, salinity, employee know-how, inventory and personnel planning
5	Ships	[16]	Temperature, turbidity, pressure, salinity, pH, humidity
6	Electrical discharging machine	[11]	Running time, rotation speed, latest maintenance, ambient temperature

The selected application cases are used in context of the novel MRO activities (e.g. case 4 and case 5) or the general improvement of the targeted product through design changes (e.g. case 2 and case 3). For this purpose, information of the current state of the focused products is collected in each application case. This information includes measures like temperature, humidity, force and pressure. The required information is typically collected by measurement techniques, for instance through embedded sensor nodes or manual measurement by technicians. In some cases, textual information is available through maintenance reports. An example of MOL information generated in application case 1 is illustrated in Figure 2. It visualizes the measured temperature and relative humidity for a boat within a time frame of 2 hours.

##### 4.2. Practical examples from the Internet

The internet and the extensive content growth caused by the web 2.0 (i.e. the participatory web) stimulated the creation of numerous sources for user-created content (e.g. social media) [17]. Some of these contents describe the users' experience

while using products. These contents are located in, for instance, shopping websites, social networking services, media platforms, review websites and user forums.

- **Shopping websites.** One of the most famous shopping sites is *Amazon.com*. The website maintains a product review system where customers (not necessarily the actual user) can rate their experience with the purchase. Reviews may contain information about the provided delivery service, and the in-use performance of the product.
- **Social networking services (SNS).** SNS like *Facebook*, allow their members to share messages, images and videos. Contents posted in dedicated groups and company profiles (e.g. Apple Inc. and Wal-Mart) may contain information about product usage and the user's satisfaction with the product. In addition, SNS members can discuss product characteristics and performance with other members from their contact network privately (restricted access).
- **Media platforms.** Certain websites are specialized in sharing of media, such as pictures, audio or video files. An example for MOL information from a media platform is the *YouTube* video provided in [18]. The video illustrates the performance of a vacuum cleaner robot. It is filmed by the user while it performs the cleaning task in a real home environment. The environment contains various obstacles the robot has to deal with. The video is verbally commented by the author and there are additional textual comments by other members of the YouTube platform. By leaving text comments other members can share their opinion and ask questions about the product.
- **Product review websites.** Product reviews on dedicated websites are typically based on a predefined review process where the product is evaluated. The evaluation of products may follow a specific procedure, such as predefined testing scenarios reflecting real use situations [19]. An example for a popular review website is *Phonedog* which is focused on reviews for Smartphones [20]. The website provides product use information through text, pictures and videos.
- **User forums.** Forums are web-based platforms for moderated discussions on specific topics. An example for a forum specifically dealing with MOL information is the "*Bob community*" of Bosch [21]. The forum aims for professional users of Bosch power tools and allows them to discuss recent products, services and specific product features. Among other topics, there is a section for user reviews containing information about product performance and cases of misuse (i.e. other than intended by the designer). The platform is moderated by a support team that is checking questions and asking users to provide more information in case the initial question was ambiguous or vague.

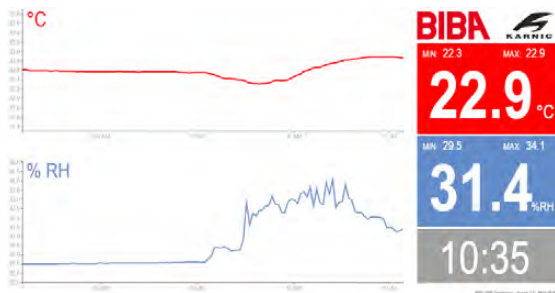


Figure 2: Example of MOL information based on measures

## 5. Discussion

In this section, some characteristics identified for different types of MOL information are briefly discussed. The characteristics covered in this paper are meant to provide a starting point for further organization of the information provided in Section 4.

### 5.1. Entities used in MOL information

The MOL information covered in Section 4 concern at least three common entities, i.e. product instance, stakeholders and product environment.

- **Product instance.** Referring back to PLM, the product instance is the focal point of the MOL information. Information used, for instance in product maintenance, concern the current state of a product instance according to predefined characteristics. Examples for characteristics are the internal product temperature, product movement (e.g. rotation speed) and geo position.
- **Stakeholders.** Users and service personnel are important stakeholders during the middle of life phase. Users are interacting with the product, in order to achieve certain goals. In some cases, the explicit differentiation of customer and user is important, in order to understand and correctly interpret MOL information (see example in Figure 3). Technical service personnel maintain, repair and overhaul products, thus extending the lifetime of a product instance.
- **Product environment.** Processes, such as degradation and wear of the product, are influenced by the surrounding environment (e.g. rust and dissolving). The environment also influences the user's goals when using the product (e.g. a leisure boat is less attractive to use while it is cold, windy and raining).

### 5.2. Measures and articulated information

In line with arguments provided in [11], MOL information can be divided into those originating from measurement equipment and those created by persons through articulation (e.g. speech, text and pictures).

**Measures.** MOL information can be based on measures (see Figure 2). Measures are data created by measurement equipment such as embedded sensor nodes. Measures focus on particular physical phenomenon, such as a boat's engine

temperature. Measured data are typically stored in database tables together with a timestamp and a reference object (i.e. unique identifier).

Unless the measured data is analyzed further, it unlikely that knowledge can be gained from it. In case of predictive maintenance, for instance, data is analyzed by feeding it to degradation models, in order to estimate the remaining lifetime of a product (e.g. case 3). Due to the fact that the creation of measures follows a structured and reproducible process (measurement), they are considered as objective. Review sites like [19] use this characteristic, in order to create reviews that are comparable among each other.

**Articulated information.** Information can be articulated by users and other persons dealing with the product while it is in the MOL. An example for articulated information is illustrated in Figure 3. The example shows an entry on Amazon.com containing semi-structured information, such as the author's name, the product's name, a timestamp, as well as quantified and qualified information about the actual use of the product including a statement about the actual user – user and author (customer) are different persons in this particular example. Depending on the contents of the articulated information, different entities may be covered through environmental conditions, acting stakeholders (typically user) and the state of the product instance.

In general, articulated information can be communicated in different format such as text, audio, pictures (articulation in a wider sense) and videos. Since the internet is a social medium that is used to express and share experience, most of its contents are articulated in one or the other way (e.g. entries in forums, social networks and shopping sites).

### 5.3. Stakeholder statements and discussions

Articulated information that is created, for instance, in the internet or through service reports can range from a single statement of a person (e.g. product review) to extensive discussions containing several participants (e.g. in a forum).

**Statements.** A statement represents a single piece of content created by an individual author. It may contain facts and opinions of the author. Statements occur in product and user reviews, as well as single comments in social networks, media platforms and shopping sites. Depending on the context of the statement, it can be very short (e.g. single sentence response in a social network) or quite long (e.g. user report in a forum and a maintenance report). Additionally, the content can be clearly stated or not (e.g. user report in contrast to a comment for a video).



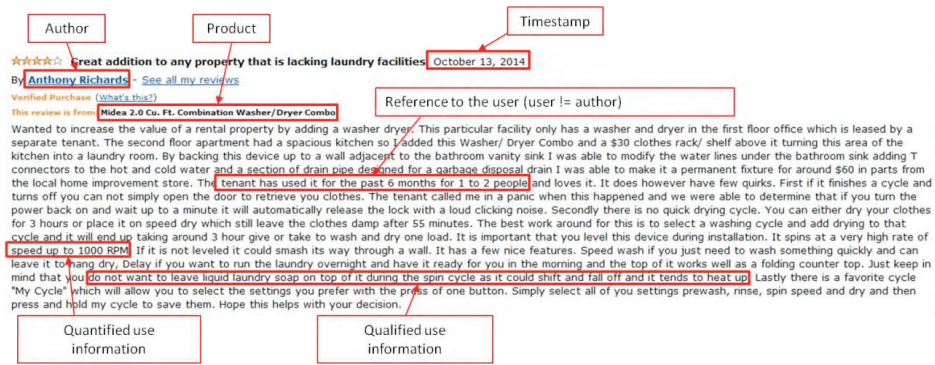


Figure 3: Example of articulated MOL information from Amazon’s shopping website

**Discussions.** A conversation, on the other hand, describes the exchange of several statements from different persons involving reasoning and arguing among participants. In forums and social networks, for instance, users can in principle share and discuss their experience with products. The discussion can reveal facets or viewpoints of the discussed topic that were unknown at the beginning. However, based on the survey done for this paper it appears that the majority of the discussions in social networks and media platforms hold very limited MOL information. Most of the samples did contain a long list of entries, however, many of these entries didn’t relate to each other (statement) nor did they provide contents about the actual use of a product. In many cases the comment function was used to ask questions about the product or indicate that the product is liked or not by the author.

5.4. Instance-based and class-based information

Information from the MOL phase has different levels of abstraction. It can be valid for a single product instance or a class of products sharing the same or similar characteristics.

**Instance-based information.** Most of the information from the provided examples in Section 4 refers to a specific product instance. An example is the information needed for maintenance. This MOL information describes the current or past state of the targeted product instance. Information about the product state is needed, in order to decide on suitable MRO actions extending the remaining product lifetime [22]. Another slightly different example is articulated information found in the internet. The information is typically authored by an individual person. In order to understand whether the author is the user of a product, the content of the information has to be analyzed. An example where author and user are different persons is provided in Figure 3 as per the example of an Amazon product review. As seen from the two examples, product maintenance and Amazon.com, the “instance”-characteristic is supported, as long as additional (meta-) information is available containing the specific reference object (i.e. author, customer, user or product).

**Class-based information.** While a product instance concerns a single product item, a class contains several products with the same or similar characteristics. Instance-based information can be transformed into class-based information through abstraction. In application case 1, for

example, instance information of several leisure boats can be combined, in order to conclude that a number of boats operate in the same environment. This information, on the other hand, can be relevant for service providers that want to promote their service to the respective boat owners. The abstraction of instance-based information typically requires the analysis of the information. This can be done, for instance, by applying inferential statistics [23].

5.5. Time-dependent information

Information from the MOL can describe past, current and future states, activities and behavior of entities. An event log, for instance, is a source for information about past behavior of the product, the environment and stakeholders (e.g. case 3). Current information can be drawn, for instance, by embedded sensors as by the example of leisure boats and ships (cases 1 and 5). Future information is related to cases where planning or scheduling occurs, e.g. a maintenance plan for offshore wind turbines (case 4). Each of the different time references allows the deduction of different knowledge, e.g. tracked product failures can be used to identify weak spots and otherwise flawed behavior of a product class.

5.6. Summary

Figure 4 illustrates the presented characteristics of MOL information. The summary provides an overview of the characteristics and indicates the structure of the characteristics. While most characteristics appear as separated branches of the root node (i.e. MOL information), some characteristics split up into additional sub-characteristics. This is the case for articulated information that may appear as statements or discussions.

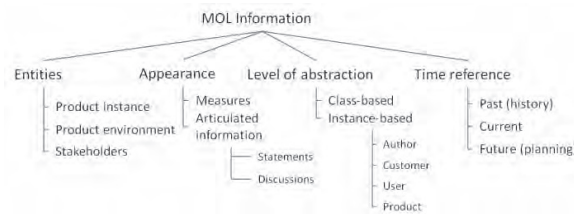


Figure 4: Examples of characteristics for middle of life information

## 6. Conclusion and Outlook

In light of the closed-loop PLM concept, the paper presents an overview about existing kinds of information from the MOL of products. The overview is based on application cases from R&I projects, as well as web-based services operating in the internet (e.g. Amazon and Facebook). The findings are discussed and summarized according to characteristics of the introduced MOL information providing ground for further studies.

Since the presented results are far from a thorough investigation, further tasks have to be performed before recommendations for the use of MOL information in closed-loop PLM can be substantiated. These tasks include:

- Extension of the collection of practical examples, in order to find additional characteristics of MOL information.
- Extension of the investigation towards the content perspective. Some aspects on the topic are already discussed in [24].
- Structuring of the different kinds of MOL information according to the identified characteristics.
- Investigating of the validity, reliability and interpretability of MOL information. A relevant problem related to articulated information is discussed, for instance, in [25].
- Identification of methods and techniques needed to make MOL information usable (e.g. processing approaches).
- Identification of different application areas of MOL information in the beginning of life.
- Identification of problems in the beginning of life phase that can be addressed using MOL information.

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