

EVALUATION OF A METHOD SUPPORTING THE INTEGRATION OF PACKAGING DEVELOPMENT INTO PRODUCT DEVELOPMENT USING AN ASSESSMENT FRAMEWORK FOR METHODOLOGIES UNDER DEVELOPMENT

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ABSTRACT

This paper presents the evaluation of a method supporting the integration of packaging development into product development through the use of an assessment framework for methodologies under development. While the evaluation of the integration method itself is critical for its further development the main objective is to use this evaluation as a further testing of the assessment framework. The assessment framework has only been tested once in its current version and replications are needed. The results of the testing of the support method indicate that it has high consistency but should be further developed with regards to simplicity of use, and overall attractiveness. About the framework, only minor changes were needed to assess the support method. The testing also shows that the framework can also be used for the assessment of methods, not only methodologies.

KEYWORDS

Methodology development, methodology evaluation, methodology assessment, evaluation framework, assessment framework, product development, packaging development

1. INTRODUCTION

Many elements need to be taken into account for a successful methodology — defined a process model displaying a set of activities and a set of related methods and tools (see [25, pp. 373-374] for a

discussion on definitions). A methodology should not only fulfill its intended purpose but also be adopted by, and adapted to its target group, it should be implementable in a thought-through way, the learning curve needs to be traded-off by its effectiveness, etc. As such, the evaluation of a methodology needs to cover these diverse aspects.

To that end, an *assessment framework for methodologies under development* has been developed and presented in [25]. Its core stems from the evaluation framework of Ben Ahmed et al. [2], intended for the assessment of engineering models (used for example to assess templates for accidentology [1]). This assessment framework for methodologies under development is a systematic categorization of the characteristics of methodologies that help the researcher or methodologist to identify what to focus on, and what to evaluate.

This assessment framework has been used for a methodology developed for predictive design analysis, the PDA methodology [13]. This helped establishing the assessment framework into its current shape, see [25]. In order to contribute to the further establishment of the framework, the latter has been used for the assessment of a method under development, namely, a method supporting the integration of packaging development into product development (hereafter shorted to IPPDM).

The IPPDM presents several features that makes it advantageous for further testing the framework. First it is a method rather than a methodology. In [25, p.

383], the question was raised whether the framework would be suitable for assessing methods as well. A method can be used in one or some specific activities of a methodology, aiming at achieving a certain goal (see [14, p. 130; 20, p. 67; 28, p. 9; 32, p. 91]). But a method can also be used independently from a methodology, it consists also of several steps, and it uses tools (e.g. software). It has also a structure similar to that of a methodology, the main differences seem to be in term of magnitude rather (larger scope, larger number of steps, larger number of tools for methodologies) than in term of kind. So it is relevant to study whether the framework is suitable for method assessment, and the IPPDM is a good candidate.

The IPPDM presents also some other features that differentiates it from the PDA. The IPPDM is much less advanced in its development and it is interesting to study whether the framework is usable at a very early development stage. Unlike the PDA, the IPPDM has not been tested in industry, which could make the assessment more challenging. The IPPDM has also a different scope and has been developed by different persons (although connections exist with the two groups).

From a methodical perspective, this second assessment is similar to case study research with cases of polar types, as described in e.g. [11]. Significant, relevant differences between cases enrich the knowledge around the object of study. And if the assessment of the IPPDM is relatively problem-free, this will serve as a provisional confirmation that the framework delivers what it is supposed to. The framework, as any new theory/method/methodology, is at a too early stage to be stringently tested (i.e. in an experimental setup that would try to falsify it). In effect, novel theories/methods/methodologies have less ground and are easier to falsify before being fully developed; confirmation in this case has a higher value than falsification. An analogy can be made with the efforts to confirm systematic engineering design methodologies by industrial applications (e.g. [5; 31; 33]) before more severe testing were performed (e.g. [3; 12; 27; 29])—see [21] for a review. Like these industrial applications, the IPPDM assessment can serve as an illustration of the use of the framework.

Some changes in the assessment framework are also derived from further literature sources, mainly from quality models within software engineering. These changes are also reported.

The paper is organized as follows. In a first part, the framework is summarized. In a second part, the IPPDM and its evaluation are presented. Finally, the implications for the framework are discussed.

2. THE FRAMEWORK

The framework and its foundations are described in greater detail in [25], see also [2] and is only summarized here.

2.1. Motivation and structure

As introduced above, a methodology should not only be evaluated by its effectiveness (i.e. its ability of the methodology to target all aspects of the goals of a project). Many other requirements, or *characteristics*, need to be taken into account. For example, according to [10], the low penetration of design methodologies is explained by the methodologies' 'lack of readiness' for application (i.e. not being in a ready-to-use format) than lack of effectiveness.

The framework tries to capture in a systematic way the characteristics that can be of importance to assess the quality of a methodology. The approach is similar to that of software engineering where requirements are traditionally divided in functional requirements (determining what the software has to do), and quality requirements determining how well the software behaves [16; 17].

The framework is organized following five axes, based on systems theory [18]. Basically, the methodology to be developed has a goal to fulfill, and to that end has a structure (steps, methods, tools) that will function in an environment and in interaction with users. The methodology will also evolve with time. These five axes are the following:

- The ontological axis regroups the characteristics linked to the structure of the methodology. Such characteristics are for example *consistency* and *completeness* (the complete list of characteristics, in italics in the text, and their definition is given together with the evaluation of the method, Section 3.2).
- The functional axis regroups the characteristics concerned by 1) the use of the methodology under normal conditions, 2) the use of the methodology under stressful conditions (e.g. *robustness* and *reliability*), and 3) the interactions with the user (e.g. usability-related characteristics).
- The teleological axis regroups the characteristics regarding how well the goals of the methodology

are attained (*effectiveness, accuracy*).

- Finally, the genetic axis regroups the characteristics concerned by the conception and evolution of the methodology as well as its place within the family of similar methodologies.

The framework presents also some limitations to have in mind.

First, while using systems theory ensures a good categorization of the characteristics, it will not ensure its completeness, even if the literature search for its devising has been extensive [1; 2; 25]. The terms used for describing the characteristics have often different meanings in different fields and terminological choices had to be made.

Another important point is that the different characteristics are not independent from one another. First they can influence each other. Trade-offs are necessary between characteristics: striving for a very effective methodology can require a high learning curve, for example. Second some characteristics are overlapping. This is however of lesser importance. It is more important to have criteria that cover all the aspects to be evaluated. One could think that independent criteria are necessary for a stringent evaluation; in fact, some researchers in decision theory do not regard it as problematic at all [8].

In the choice of the characteristics, there is also a part of arbitrary. For example, the characteristic *simplicity of use* is very broad and cover the concepts of usability and more, while three separate characteristics deal with errors: *error tolerance* (ability of the methodology to operate normally despite the presence of erroneous inputs), *fault tolerance* (ability of the methodology to operate normally despite the presence of erroneous methodological elements), and *error proneness* (ability of the methodology to allow the user to intentionally or unintentionally misuse the methodology). The rationale behind this is that the sub-characteristics of simplicity of use are extensively discussed in the literature on usability and user experience while being aware with the errors characteristics above is less common. But one could have also chosen to group these characteristics into one, based on a different rationale.

Finally, the framework, like any other method, does not prevent errors to be made in the evaluation of method/methodologies (this is illustrated during the analysis of the IPPDM, see Table 4).

2.2. Use of the framework

Similar to the development of a product, the methodologist should go through what is of importance for the methodology to be developed. As a first step, the assessment framework might act as a checklist that the methodologist can go through and in which he or she can select a number of characteristics to focus on. At an early development level, the methodologist can use the characteristics as they are presented, and assess the methodology under development qualitatively. As the development progresses, the characteristics might be decomposed in more precise and quantitative characteristics, such as describing the different variables that can affect the *robustness* characteristic of the methodology.

2.3. Characteristics of the framework

Due to lack of space, the characteristics are listed and defined together with the assessment of the IPPDM, in Tables 2-7 (This will incidentally facilitate the reading of the assessment of the IPPDM).

3. APPLICATION OF THE ASSESSMENT FRAMEWORK

The framework is applied to the IPPDM. The first section describes this method. The second section applies the framework to the method. The third section reports the implications for a further development of the method. The reflection on the framework is in Section 4.

3.1. The IPPDM

The IPPDM has for objective to integrate the development of packaging in the development of products, mainly physical goods, but also for process-based (food and pharmaceutical) products. The IPPDM has been presented in [22-24].

In many companies, the packaging is still developed separately and/or posterior to the development of the product. Concurrent engineering in that area is still quite limited. The reasons are manifold: culturally, packaging is seen as a part of production and logistics rather than development; packaging is also considered as something that is to be adapted to the product and therefore should only take place after product development; and simply the packaging development is most of the time outsourced, therefore tends to be neglected by the designer. In a product lifecycle perspective, however, packaging should be seen as a part of a product, as it performs

functions that otherwise should be the product's: as a protection during transport, as support during installation, as a container during resale or recovery. An efficient integration would also prevent issues or optimize costs: for example, if transport is anticipated, minor changes to the product geometry could make it fit European pallets in greater number while ensuring sufficient protection by the packaging; the product could also take upon some of the protection and handling functions during delivery, etc.

One way to deal with this problem is to try to merge generic product development and packaging development process models, see e.g. [9]. The IPPDM on the other hand is based on a set of generic factors or *attributes* characterizing the interactions between the product and the packaging during the whole product lifecycle, and that companies should take into account in their own specific development process, organization and information system. Some examples of attributes are gathered Table 1. Based on the attributes of the product-packaging system (PPS), the IPPDM presents a set of so-called integration tasks using these PPS attributes:

- At the strategic level, the main task is to go through the set of attributes, determining those that are recurrent (or critical) for most of the company's products, establishing how and where they affect the company development process model, organization and information system, and define or refine appropriately the company's integrated development policy (that is, its development process model, organization and information system);
- At the tactical level, the main task is to adapt the company's existing integrated development policy to each development project, again using the set of attributes;
- At the operational level, the tasks have for goal to make relevant decisions regarding the PPS during an ongoing development project.

More specifically, for the integration tasks at the strategic level, the decision maker has two possibilities: use a set of predetermined product development activities, organization elements or information system elements (called integration elements) that can be selected and integrated in the company's existing development policy, or use five general types of integration strategy as *inspiration*: total integration (product and package are developed in-house), packaging as a specific business unit

(SBU), extended enterprise (long-term partnership with a packaging company), virtual enterprise (partnership at a project level), and the classic supplier-buyer relationship. Using the most recurrent PPS attributes, the manager should be able to devise a specific integrated development policy.

For the integration tasks at the tactical level, the project planner would use the company's integrated development policy and take into account the PPS attributes that are more specific to the particular project in order to adapt the policy accordingly.

Finally, during the project execution, three operational integrations tasks are distinguished: 1) At the onset of a project, take into consideration the needs related to the use of packaging within the whole product life cycle; 2) During the project, take into account new and modified needs at the product level or at the packaging level; Finally, 3) take relevant decisions during an ongoing development project, for example when a deviation from the development plan occurs. Knowing which PPS attributes are affected and where they impact the development, it is possible to change the course of the development project.

A first set of generic PPS attributes have been developed in [24]. The five types of integrated development policy have been proposed, mainly in [22]. In practice, the generic set of PPS attributes should be instantiated for the specific products of the company, and the specific actions that the designers and project managers should take for a given PPS should also be mapped to the specific attributes. An example of mapping of some generic PPS attributes to development activities are presented Table 1. Moreover, guidelines about what actions to take given the PPS attributes should also be devised by the company (general guidelines could also be added to the IPPDM). All this information need to be structured and easily retrievable, and maybe a knowledge based system (KBS) would be necessary.

At that stage, a first assessment of the IPPDM was performed with a very early version of the assessment framework as a support to decide of the next development steps. Regarding the KBS, a modeling of the integration tasks have been performed [23] using CommonKADS [30], whose formalism is similar to the Unified Modeling Language (UML). An example of such a modeling for one of the operational integration tasks is given Figure 2. The modeling helped simplifying the integration tasks, and it could be concluded that a

simple database or spreadsheet could handle the information, instead of a KBS.

At that stage, and in light of recent research in that area [19], it was necessary to update the first generic set of PPS attributes,. An assessment of the IPPDM under development was therefore adequate.

3.2. Assessment of the IPPDM

As mentioned above, the IPPDM has been assessed twice: before and after the modeling of the tasks by CommonKADS presented in [23]. These assessments are reported in Tables 2-7, In these tables, for each characteristic of the assessment framework, it is reported whether the characteristic was considered at

the onset of the development of the IPPDM (point A). The first assessment of the IPPDM is then presented and actions are decided to further develop the method, if applicable (point B). Finally, the second assessment is reported as well related action plans (point C).

As mentioned in the introduction, the framework has evolved slightly due to the assessment itself and due to new elements from the literature. When these changes were made, the assessment of the IPPDM was altered when necessary. The reported assessments use the updated framework. The changes are presented Section 4.2.

Table 1 Excerpt of the list of PPS attributes and their mapping to development activities [24]

	<i>Physical elements attributes</i>	<i>Mapping to development activities</i>
O1	Nature of the product	Product planning phase, market preparation, conceptual design
O9	Product structure	Embodiment design, production layout
O14	Surface finish	Production preparation
...
	<i>Modes of operations attributes</i>	
F2	Product is packed/filled in uncontaminated atmosphere	Production possibility study, production layout
F10	Sensitivity to humidity	Embodiment design
...
	<i>Function attributes</i>	
Te1	Necessary information must be present on PPS	Market preparation
Te3	Protect the environment against the product	Conceptual and embodiment design, detailing, production layout
...
	<i>Genetic attributes</i>	
G1	Frequency of change of form among the different products	Product planning
G4	Mix/Multiple product ship	Conceptual design, production layout
...

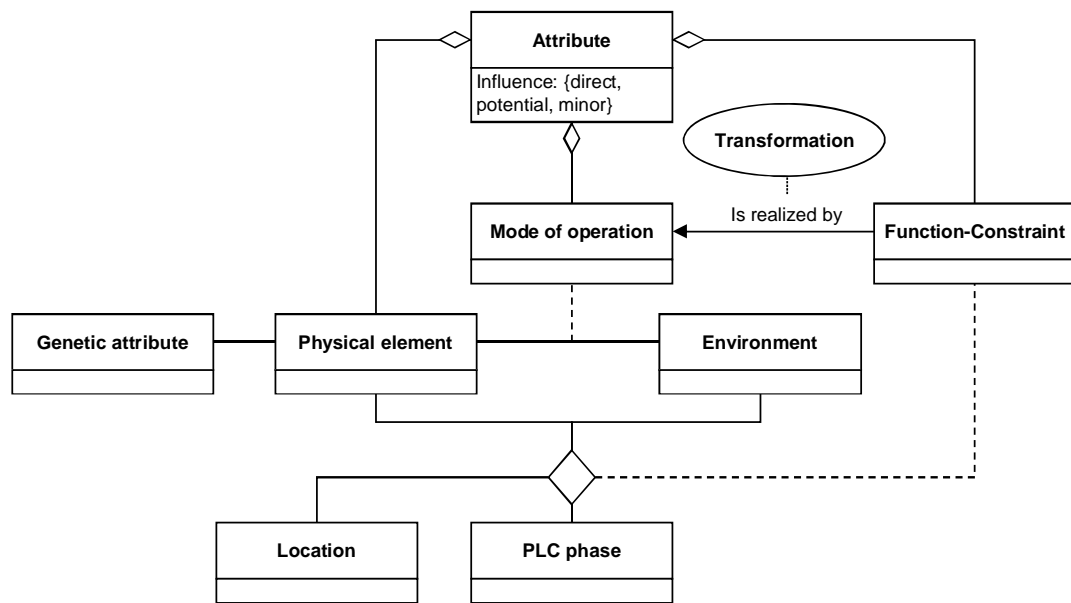


Figure 1 PPS attributes, further developed from [24]

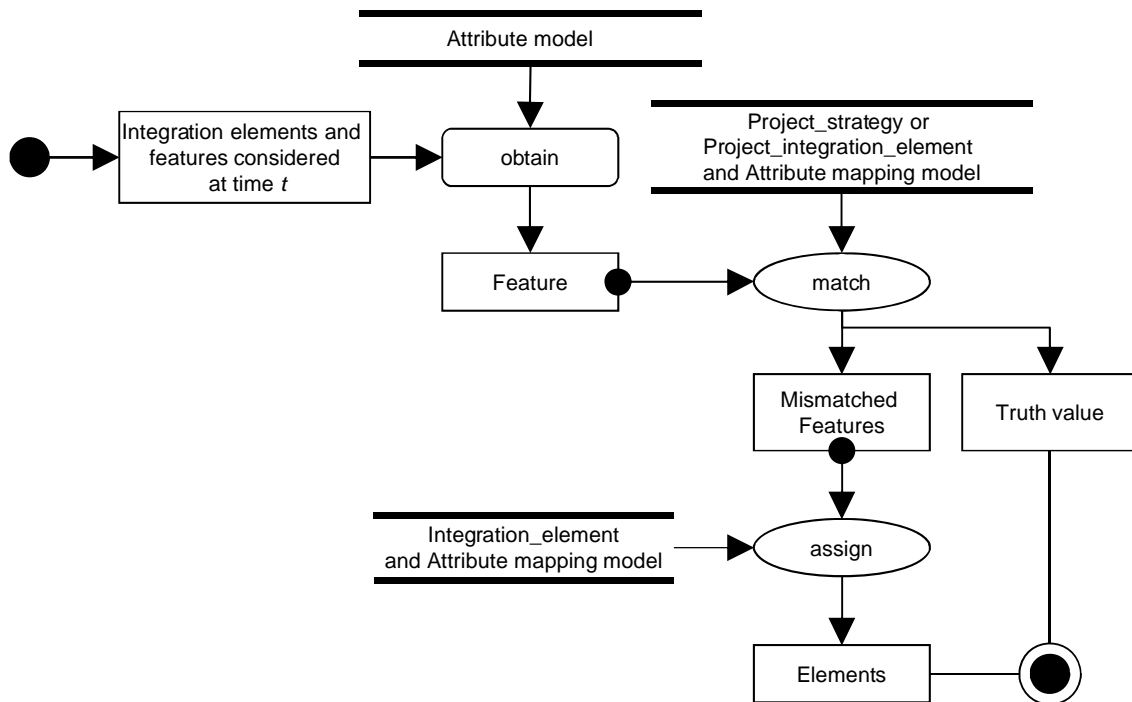


Figure 2 Structure of the third operational integration task, see Section 3.1

Table 2 Assessment the IPPDM along the ontological axis

Characteristic and definition	Assessment
Architecture (structure): extent to which the elements of the body of knowledge are organized, integrated or separated (modularity aspects).	<p>A) A starting point for the development of the IPPDM was to make its elements of knowledge as modules so that they could be used by companies regardless of their product and packaging development policy. This was also one of the top priorities of the IPPDM, in contrast with the then dominating general development process and organization models, e.g. [9].</p> <p>B) The first development round [22; 24] showed that it was clearly feasible, but it became clear that the handling of the elements of knowledge required integration tasks with</p>

Characteristic and definition	Assessment
<p><i>Self-descriptiveness</i>: degree to which the descriptions in the methodology are self-explanatory versus how much is left to the user. Regards also meta-knowledge elements.</p>	<p>complexity level that in turn would prevent the <i>simplicity of use</i> of the IPPDM. It would also probably require a KBS to support the IPPDM.</p> <p><i>Action plan</i>: model the tasks themselves through a KBS modeling formalism (CommonKADS) and find common activities in order to ease the use of the IPPDM. The same modeling would help devising a KBS if necessary.</p> <p>C) By modeling the different tasks and further modeling the knowledge elements (PPS attributes, see Figure 1, and integration elements) with CommonKADS, it could be showed that all tasks could be decomposed in a small set of activities that were recurrent in similar form in all tasks. These activities are, using the CommonKADS terminology: obtain (knowledge), match (it with the domain knowledge elements) and assign (knowledge elements to the overall development policy or the development project). An example is given Figure 2. Very importantly, it also showed that a KBS might not be required. Paradoxically, the simplification and modularization of the tasks have made it more difficult to handle by human users. If a KBS is not used, such abstraction and modularization is counter-productive.</p> <p>It was also noted that the tasks at the strategic levels were unlikely to be performed by the same persons than at the tactical and operational level, unless the company be quite small. Therefore, the strategic level tasks can be handled separately.</p> <p><i>Action plan</i>: there is no action plan associated with this characteristic, the presented reflections are oriented towards <i>simplicity of use</i> and other characteristics instead, see below.</p>
<p><i>Representation formalism</i>: extent to which the knowledge described is formalized.</p>	<p>A) Not prioritized.</p> <p>B) The IPPDM as described in [22; 24] was quite self-explanatory (although complex), but was not complete: the task at the strategic level was almost fully described, but the tasks at the tactical and operational level were just sketched. The guidelines were virtually not developed.</p> <p><i>Action plan</i>: further develop the descriptions through accumulation of empirical data.</p> <p>C) The action plan was not fulfilled. The priority was on the CommonKADS modeling of the tasks and knowledge elements as this could help accumulate and organize the empirical data. But that resulted in a procrastination of the data gathering. The modeling makes actually all the tasks explicit (tactical and operational), but it requires that the user be familiar with CommonKADS or UML.</p> <p><i>Action plan</i>: same as B.</p>
<p><i>Consistency</i>: indication of the level and number of contradictions (low consistency indicates high number of contradictions).</p>	<p>A) As the IPPDM would make extensive use of knowledge elements, having a good representation formalism was important.</p> <p>B) The attributes of the PPS were modeled with CommonKADS (cf. Figure 1). The rest was mainly textual information.</p> <p><i>Action plan</i>: As described in the <i>architecture</i> characteristic, it became necessary to model not only the domain knowledge elements (e.g. the PPS attributes and the development activities) but also the integration tasks.</p> <p>C) The tasks have now also been formalized (cf. Figure 2). The IPPDM is almost completely formalized. See also discussion regarding the <i>architecture</i> and <i>simplicity of use</i> characteristics).</p> <p><i>Action plan</i>: none.</p>
<p><i>Completeness</i>: indication of the level to which the necessary elements are</p>	<p>A) This was prioritized. The elements of knowledge and their structure should present high consistency, especially the sets of attributes of the PPS.</p> <p>B) There was no sign of inconsistency after the first development [22; 24].</p> <p><i>Action plan</i>: none.</p> <p>C) After formalizing the complete IPPDM, the level of consistency was very high. It was at that point that it was realized that such high consistency prevented <i>simplicity of use</i>. This IPPDM whose goal was to facilitate the integration of packaging into product development is complicated to use because of its formalism (at a meta-level this is indeed a inconsistency). At the same time, as mentioned Section 3.1, new research works entail a revision of the sets of attributes of the PPS.</p> <p><i>Action plan</i>: relax the consistency condition. Revise the set of attributes of the PPS.</p>
<p><i>Completeness</i>: indication of the level to which the necessary elements are</p>	<p>A) As for <i>consistency</i>, <i>completeness</i> was prioritized. As the IPPDM is knowledge driven, it was important to work on its <i>completeness</i>. The <i>completeness</i> of the sets of attributes of the</p>

<i>Characteristic and definition</i>	<i>Assessment</i>
<p>present.</p> <p><i>Independency</i>: refers to the independency of the methodology from its developer.</p>	<p>PPSs was especially important, cf. Section 3.1.</p> <p><i>B</i>) Using systems theory ensured that the higher level categories were present (Figure 1). However, there is no easy way to ensure <i>completeness</i> of all PPS attributes. It is however possible to increase the likelihood of covering the major aspects by a gathering of empirical data on many PPSs.</p> <p><i>Action plan</i>: gather empirical data on PPSs.</p> <p><i>C</i>) As discussed above, the gathering of empirical data has not been performed.</p> <p><i>Action plan</i>: same as <i>B</i> with completing literature research, cf. [19].</p> <p><i>A</i>) Not prioritized but the IPPDM was supposed to be used independently of its developers, e.g. not tied up to specific knowledge and not to be used within consulting.</p> <p><i>B</i>) Not prioritized either. The formalism would ensure <i>independency</i>.</p> <p><i>C</i>) In its current form, difficult to use by those who are not familiar with the formalism. The formalism is however not tied to a specific person and <i>independency</i> is still supposed to be achieved.</p>

Table 3 Assessment the IPPDM along the functional axis – normal conditions of use

<i>Characteristic and definition</i>	<i>Assessment</i>
<p><i>Efficiency</i>: how well the methodology provides an appropriate performance, relative to the amount of resources used (time, human resources, etc.), in the given environment.</p>	<p>A) This is one of the implicit goals of the IPPDM. The integration of packaging development in product development should increase product development performance.</p> <p>B) Too early to assess.</p> <p><i>Action plan</i>: the actions taken for the other characteristics serve indirectly this one.</p> <p>C) The lower number of activities required for performing the tasks after the modeling should lead to increase in performance (once the IPPDM is learnt and understood).</p> <p><i>Action plan</i>: In the future, need to assess the IPPDM thoroughly for efficiency. The characteristic <i>simplicity of use</i> is however prioritized before <i>efficiency</i>.</p>
<p><i>Repeatability</i>: how the methodology generates the same results under the same functioning conditions given the same input.</p>	<p>A) Not prioritized. This characteristic is usually important but for this particular IPPDM, deviations are not unwelcome unless they result in much poorer results. Moreover, there will virtually never be the same functioning conditions and the same input: each company, project, product, are unique.</p> <p>B) No specific action plan.</p> <p>C) No specific action plan.</p>
<p><i>Reproducibility</i>: how the methodology generates the same results under the same functioning conditions given the same input but different users, tools and environment.</p>	<p>A) Not prioritized, with the same reasons as for <i>repeatability</i>.</p> <p>B) No specific action plan.</p> <p>C) No specific action plan.</p>
<p><i>Generality</i>: Breadth of the range of functions the methodology enables to perform.</p>	<p>A) A goal has been that the IPPDM can be used for all physical products (goods), as well as for pharmaceutical and food industry, cf. [24].</p> <p>B) The sets of PPS attributes have been devised with the types of product above [24]. Different types of companies and their development policy have been taken into account [22].</p> <p><i>Action plan</i>: No specific action plan.</p> <p>C) No specific action plan for now. In the future, empirical testing should encompass several types of products and industries.</p>
<p><i>Interoperability</i>: ability of the methodology to be used with complementary methodologies, or with similar methodologies, or with related processes such as QA and internal processes of the company.</p>	<p>A) One built-in goal has been that the IPPDM should allow the integration of packaging development in a company's existing development policy. Hence the method is to be built for <i>interoperability</i>.</p> <p>B) At the strategic level, a large array of development policies have been taken into account. For the "total integration" strategy, a generic product development process model was used as an illustration [26], which means that <i>interoperability</i> also is present with classical integration models from the literature (which does not prevent the IPPDM not to use them). At the tactical and operational levels, the integration tasks are not intrusive and should not interact much with the company's other processes.</p> <p>C) No specific action plan.</p>
<p><i>Replaceability</i>: how the methodology can be used instead of another specified methodology for the same purpose in the same environment.</p>	<p>A) Not prioritized. There is no obvious necessity for <i>replaceability</i> in this context.</p> <p>B) No specific action plan.</p> <p>C) No specific action plan.</p>
<p><i>Compliance</i>: how the methodology complies with standards, conventions, or regulations related to the areas of application of the methodology.</p>	<p>A) Not prioritized. There is no obvious necessity for <i>compliance</i> in this context. (Standards or regulations regarding the PPSs are taken into account in the set of PPS attributes.)</p> <p>B) No specific action plan.</p> <p>C) No specific action plan.</p>

Table 4 Assessment the IPPDM along the functional axis – stressful conditions of use

<i>Characteristic and definition</i>	<i>Assessment</i>
<p><i>Robustness:</i> ability of the methodology to operate normally despite large variations in the environments or in the projects.</p>	<p>A) The IPPDM intends to be usable for a wide range of industries and products and robustness was (naively) seen as implicitly solved.</p> <p>B) The integration tasks at the strategic and tactical levels are planning activities and are highly unlikely to be performed under stressful conditions of use. Some of the integration tasks at the operational level (check if new needs should be tackled at the product level or at the packaging level, check if the current product and packaging development state correspond to the planned development state and act accordingly) are there to handle deviations from the development plan. How well they will fulfil these aims in practice is not obvious.</p> <p><i>Action plan:</i> ensure that the integration tasks at the operational level can perform as intended under various conditions.</p> <p>C) The CommonKADS modeling of the integration tasks have clarified how they should be performed. However, they are not described at a level of detail that would ensure a robust use. These tasks are also data-driven and their performance will depend on the quality and quantity of the data.</p> <p><i>Action plan:</i> devise guidelines for adequate use. Only the implementation and use of the IPPDM in a company would help verifying <i>robustness</i> of the integration tasks at the operational level.</p>
<p><i>Error tolerance:</i> ability of the methodology to operate normally despite the presence of erroneous inputs.</p>	<p>A) Not considered at the onset of the IPPDM development.</p> <p>B) At the evaluation, it was assumed that the PPS attributes model (Figure 2 and [24]) would help reducing the number of errors.</p> <p><i>Action plan:</i> none.</p> <p>C) It turned out that the first evaluation was misleading: A company using the IPPDM can still populate the database incorrectly, by not identify the relevant interactions between product and packaging and/or by not mapping them correctly to its development process, organization and information system. Then the IPPDM will not operate normally.</p> <p><i>Action plan:</i> Empirical study needed to know whether this is likely to happen or not.</p>
<p><i>Fault tolerance:</i> ability of the methodology to operate normally despite the methodology elements faults.</p>	<p>A) Not considered at the onset of the IPPDM development.</p> <p>B) The focus on <i>consistency</i> should prevent faults.</p> <p><i>Action plan:</i> see <i>consistency</i>.</p>
<p><i>Error proneness:</i> ability of the methodology to allow the user to intentionally or unintentionally introduce errors into the methodology or misuse the methodology.</p>	<p>C) At the current level of development, it is believed that they are no elements of faults.</p> <p>A) Not considered at the onset of the IPPDM development.</p> <p>B) This characteristic was not considered important for this particular method.</p> <p>C) see B.</p>
<p><i>Uncertainty handling:</i> ability of the methodology to take into account the knowledge uncertainties of the user (epistemic uncertainties), that is, whether the user does not know all the elements necessary to perform the recommended actions in the methodology.</p>	<p>A) Not considered at the onset of the IPPDM development.</p> <p>B) The <i>uncertainty handling</i> characteristic was not present in the framework when the first evaluation was made.</p> <p>C) For this method, <i>uncertainty handling</i> can be considered in different contexts. Regarding knowledge uncertainties about the company's PPSs, the attributes model (Figure 1 and Table 1) helps the user uncovering the knowledge elements he or she needs to know. The same regards domain knowledge elements on the development process and organization. Other domains of epistemic uncertainties have not been covered.</p> <p><i>Action plan:</i> Empirical study needed to know whether relevant epistemic uncertainties are covered.</p>

Table 5 Assessment the IPPDM along the functional axis – interaction with users

<i>Characteristic and definition</i>	<i>Assessment</i>
<i>Simplicity of use:</i> ease of use of the methodology.	<p>A) At the onset of the IPPDM development, it was considered that the method would be easier to use than generic process models.</p> <p>B) Tasks were relatively simple at an abstract level but complex to apply in an industrial setup. No “user interface”, i.e. description of the IPPDM in form of vulgarization or seminars or workshop was developed. A KBS was considered, implying that some of the task activities would not be performed by a human user.</p> <p><i>Action plan:</i> none until KBS devised.</p> <p>C) The CommonKADS modeling of the tasks helped developing and verifying <i>architecture, representation formalism, consistency and completeness</i>. It is understood now that the tasks might be performed without a KBS [23]. However, the way the tasks are described is not at all user-friendly. Moreover, it would be necessary to have more guidelines on how to deal with the PPS attributes (e.g. give recommendations on actions to take once an attribute has been deemed important).</p> <p><i>Action plan:</i> making the IPPDM easy to understand and use should be a top priority. The complex theory(-ies) behind the IPPDM need not to be visible to the user.</p>
<i>Suitability:</i> how well the methodology is suitable for a particular project.	<p>A) Should be particularly suitable for its aim of supporting the integration of packaging development into product development.</p> <p>B) Seems to be suitable but no empirical data to confirm it.</p> <p><i>Action plan:</i> gathering of empirical data by looking at several PPSs.</p> <p>C) Action plan not performed.</p> <p><i>Action plan:</i> see B.</p>
<i>Adaptability:</i> how well the methodology meets contradictory and variable users’ constraints and users’ needs.	<p>A) Packaging companies and product development companies might have contradictory needs. The IPPDM should help them identifying them.</p> <p>B) Same as A; the modularity should make it adaptable to new needs.</p> <p>C) In the future, it might be necessary not only to help identifying contradictory needs but also to have guidelines to deal with specific issues. This is however at the boundary of the IPPDM scope, and other managerial and strategic methods are available to deal with this aspect.</p> <p><i>Action plan:</i> No specific action planned.</p>
<i>Guidance:</i> degree to which the methodology allows to perform only the necessary functions relevant for a particular project.	<p>A) Unlike general process models where the choice of what to use and what to adapt is left up to the user, the knowledge-driven principle of the IPPDM should guide the user into choosing what he or she needs.</p> <p>B) Evaluation not performed.</p> <p>C) <i>Guidance</i> seems high. Empirical testing is needed to confirm it; it is possible that the large sets of PPS attributes that are presented lead the user to take actions for attributes that are actually not important or irrelevant.</p>
<i>Learnability:</i> degree to which the user learns from the methodology.	<p>A) The IPPDM should make companies aware of the need of integration of packaging development into product development. Moreover the large sets of PPS attributes should enhance the user’s knowledge on PPS interactions.</p> <p>B) Same as A.</p> <p>C) Informally confirmed through discussions with companies.</p>
<i>Attractiveness:</i> degree of appeal of the methodology for the intended group (independently of the goals of the methodology), e.g. through simplicity or use of established terminology.	<p>A) Neglected.</p> <p>B) <i>Attractiveness</i> was difficult to assess at the current level of development.</p> <p><i>Action plan:</i> Need to test the IPPDM after further development.</p> <p>C) <i>Attractiveness</i> now top priority. The IPPDM will not be accepted if it is not presented in a more pedagogical way and substantiated by empirical evidence.</p>
<i>Satisfaction:</i> positive attitudes resulting from use of the methodology.	<p>The level of development of the IPPDM prevents the testing at a company level, and therefore prevents the assessment of the user satisfaction level.</p>

Table 6 Assessment the IPPDM along the genetic axis

<i>Characteristic and definition</i>	<i>Assessment</i>
<p><i>Extendibility (or expandability)</i>: how easily modifications can be performed to increase the methodology functional capacity.</p>	<p>A) This aspect was not considered, because there was no reason for increasing the IPPDM's functional capacity.</p> <p>B) See A.</p> <p>C) After a presentation at a logistics and supply chain conference [23], it became obvious that the integration of the PPS in the supply chain was also neglected in the sense that it is considered as a static black box that needs to be transported, not as a system that could be re-designed to better fit the supply chain. There might be a need to extend the IPPDM to the supply and distribution chain.</p> <p><i>Action plan</i>: not determined yet.</p>
<p><i>Maintainability</i>: how easily modifications can be carried out to correct methodology errors.</p>	<p>A) Not prioritized.</p> <p>B) So far, difficult to assess.</p> <p>C) While the form and content of integration tasks is considered stable, the attributes of the PPS (Figure 1 and Table 1) might need to change, cf. <i>consistency</i>. The IPPDM must be further developed and enter a stable state prior to further release.</p>
<p><i>Testability</i>: how easy it is to test parts of the methodology or the whole methodology.</p>	<p>A) Not prioritized.</p> <p>B) Not easy to test at this point.</p> <p>C) Each integration task can be tested separately which simplifies testing. There does not seem to be a need to alter the IPPDM to facilitate testing.</p> <p><i>Action plan</i>: no action plan.</p>
<p><i>Positioning</i>: how well it is positioned in relation to other methodologies of the same family.</p>	<p>A, B and C) The IPPDM position in relation to other methods and methodologies is quite clear, see Section 3.1.</p>
<p><i>Implementability</i>: ease with which the methodology can be implemented (decision makers need to accept the methodology, plan for implementation, training).</p>	<p>A and B) Not a specific goal.</p> <p>C) What is needed is a simplification of the presentation of the IPPDM for acceptance. It might be necessary to accompany the company in the implementation phase for populating the database of PPS attributes, although this was not intended at first. Maybe concrete support such as spreadsheet templates are necessary. Should definitely be a future action.</p>
<p><i>Flexibility</i>: how easily modifications can be carried out to use the methodology in different projects or environments.</p>	<p>A, B and C) The IPPDM should easily be used in different projects, as it is one its core aspects.</p> <p><i>Action plan</i>: Only empirical testing can show potential limitations in <i>flexibility</i>.</p>
<p><i>Evolutivity</i>: how well the methodology adapts over time to changes in the environment and the user's practices.</p>	<p>A, B and C) Once the database is populated, changes should be easy to perform. The CommonKADS modeling indicates that large changes should not occur.</p> <p><i>Action plan</i>: empirical testing should potential limitations in <i>flexibility</i>.</p>

Table 7 Assessment the IPPDM along the teleological axis

<i>Characteristic and definition</i>	<i>Assessment</i>
<p><i>Effectiveness</i>: the ability of the methodology to target all aspects of the goals of a project.</p>	<p>A) Implicit goal.</p> <p>B) So far, the integration tasks seem to cover all aspects.</p> <p>C) It is believed that the IPPDM is able to target all the aspects of integration (lest the IPPDM is extended to the supply chain, see <i>extendibility</i>). The integration aspects regarding information systems have not been developed thoroughly though.</p> <p><i>Action plan</i>: empirical data is needed to assess whether some goals have been omitted or neglected.</p>
<p><i>Accuracy</i>: how well the methodology provides the right or agreed results or effects.</p>	<p>A) One of the goal of the IPPDM.</p> <p>B) Not accurate at that point.</p> <p>C) The <i>accuracy</i> is mainly dependent on the set of PPS attributes presented in the IPPDM. They will determine if the attributes are effectively identified. How accurate their handling will be by the user will depend partially on the IPPDM, partially on extraneous factors.</p>

3.3. Further developments of the IPPDM

From the second assessment, several development axes have emerged.

First it is necessary to revise the set of PPS attributes. This is not only because of new research results but also because of the realization that a stable set of PPS attributes is essential: if the method diffuses in the industry, it will be nearly impossible to reach the companies implementing the IPPDM for “important updates”. Related to this, it is necessary to study extensively different PPSs in order to ensure that the method fits most of them.

A condition *sine qua non* for the adoption of the method will be its vulgarization. Its current formalism hampers its *simplicity of use*, its *attractiveness* and *satisfaction*.

It might be necessary to investigate whether the method need be extended for the supply chain (see *extendibility*, Table 6). This is however not a priority.

Finally, implementation in a company is obviously needed to get feedback on several characteristics (e.g. *efficiency*, *robustness*, *error tolerance*, also *extendibility*, etc.) and to improve subsequently the method.

4. DISCUSSION AND CONCLUSION

4.1. Impact of the framework on the IPPDM

As can be noticed from Section 3.1, some of the further developments could be identified without the framework, namely the further development of the PPS attributes and empirical testing of the method. For the framework to be valuable, it has to be able to bring elements that could not be easily foreseen without it.

In the case of the IPPDM, the framework has highlighted the following elements. In assessing the *robustness* characteristic (Table 4) it became clear that the operational integration task were not necessarily resilient and that could affect their use. The assessment highlighted also that the method might be sensitive to faults and that the users might handle knowledge uncertainties about their PPSs the wrong way (see *fault tolerance*, Table 4). The empirical testing of the method (i.e. implementation in a company) should include these elements. Finally, *maintainability* of the method, i.e. applying changes to the implemented method will not be easy

(Table 4), putting a much larger weight on having a consistent and stable set of PPS attributes.

4.2. Changes in the framework

In [25] there was still some concern about the overall structure of the framework. Mainly, *attractiveness* (Table 5) was at odd with the other characteristics, not being necessarily at its place on the functional axis, being broad and maybe a hint that other characteristics of that kind were missing. A literature search led back to the software requirement engineering disciplines. The quality models developed in this area, that is, the structures grouping the characteristics of quality of software development, are decomposed into the quality in use model, the product quality model and the data quality model (of less interest here), see ISO/IEC 25010:2011 [17]. The quality in use model includes characteristics that *result* from any interactions of the software with the users. For example, the satisfaction and freedom from risks characteristics are quality characteristics that can change even when no interaction occurs. On those grounds, *attractiveness* could be still considered a part of the functional axis, as interaction with the user (albeit, before use).

The software quality models were further scrutinized in terms of structure (developed Section 4.4) and characteristics. The scrutiny of the characteristics led to the addition of *satisfaction* to the framework, whose definition is adapted from the coming usability standard ISO/FDIS 9241-11 [15], cited in [4, p. 270]. While *attractiveness* reflects the user’s attitude towards the methodology before adoption or use, *satisfaction* reflects his or her attitude during and after use. Satisfaction was not present as it was considered to be the result of a correct fulfillment of the other characteristics, but as this definition points out, there is a part of the satisfaction judgment that is not related to the other qualities of the objects in mind.

The IPPDM mostly confirmed the current structure of the framework and did not lead to any change but that of the definition of *representation formalism* (Table 2), as it as an important characteristic. The definition now focuses more on the degree of formalism than only on formalism itself.

The definitions of the following characteristics have also been altered, with no real impact on their original meaning: *efficiency* (Table 3), *error proneness* (Table 4), *suitability*, *adaptability*,

abstractness has been changed to *guidance* (Table 5), *positioning* and *flexibility* (Table 6).

4.3. Use of the framework for method assessment

There was no difficulty in using the framework to assess the method. Some characteristics were not topical to the IPPDM, but so were other characteristics for the PDA [25]. The distinction method/methodology does not seem to be relevant for the framework.

4.4. Further development

The software requirement engineering standards are gaining momentum and there are potential benefits for a harmonization of the assessment framework to the standards. While this is true for the definitions of the characteristics, the structure of the quality models are rather specific to software engineering (e.g. focus on external quality characteristics for data input and output), while the structure of the framework has been adapted to methodology assessment. Modifying it does not seem pertinent yet.

At the characteristics level, research on software requirement engineering has highlighted the fact that while changes regarding characteristics will be irremediable (the quality models have continuously evolved in 30 years), most changes should be considered as secondary [7, p. 59]. In other words, further enhancements of that kind are likely to have less and less impact on the framework's effectiveness and accuracy.

If this framework has to evolve further, it should rather be regarding its interoperability with other methodologies. For example, its use together with the design research methodology (DRM), which is used in the development of methods and methodology in engineering design [6], should be investigated. There is also interest in making the framework more attractive and easy to use.

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