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Motte, Damien; Bjärnemo, Robert; Jönson, Gunilla

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PO Box 117
221 00 Lund
+46 46-222 00 00

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# MODELLING OF THE INTEGRATION TASKS OF PRODUCT AND PACKAGING DEVELOPMENT

**Damien Motte***

**Robert Bjärnemo****

**Gunilla Jönson*****

*) Lund University, Department of Design Sciences LTH, SE-221 00 Lund, Sweden
E-mail: damien.motte@mkon.lth.se, Tel: +46 46 222 85 13

**) Lund University, Department of Design Sciences LTH, SE-221 00 Lund, Sweden
E-mail: robert.bjarnemo@mkon.lth.se, Tel: +46 46 222 85 18

***) Lund University, Department of Design Sciences LTH, SE-221 00 Lund, Sweden
E-mail: gunilla.jonson@plog.lth.se, Tel: + 46 46 222 94 44

## ABSTRACT

**Purpose**

There is a growing demand for a concurrent development of product and packaging in order to better take into account the supply chain needs. Different tasks are required to integrate packaging and product development: 1) At the strategic level, it is necessary to define or refine an integrated development policy; 2) For each new development project, an adaptation of this policy must be undertaken; 3) Under the execution of each project, relevant decisions need to be made when a deviation from the development plan occurs. These integration tasks are knowledge-intensive and a rigorous modelling of these tasks would help the manager filtering and structuring the necessary knowledge and make more informed decisions.

**Design/methodology/approach**

The integration tasks have been modelled with CommonKADS, a knowledge engineering methodology. It has contributed to clearly define which activities and which knowledge elements are necessary.

**Findings**

The tasks have been modelled and the necessary knowledge elements identified. Some elements are generic, while for some others the knowledge base need to be company-specific.

**Research implications and limitations**

The formal modelling makes it possible to develop support for these integration tasks (computer-based or not). The task models need however to be refined with empirical data. It is also necessary to assess empirically the acceptance of this approach by managers before it can be diffused in industry.

**Original/value**

Integration aspects in development are generally dealt with general process models. The proposed approach gives more guidance to the manager. The used formalism ensures the coherency of the modelled tasks.

*Keywords: integration, packaging development, product development, CommonKADS, supply chain needs*

# 1. INTRODUCTION

One of the aims of logistics is to efficiently transport goods, that is, transport products enclosed in a packaging. The embodiment of the product and packaging system (PPS) has therefore a large impact on logistics. Over the years there has been a growing demand for a concurrent design and development of product and packaging that would enable to better take into account the needs originating from the supply chain (Bjärnemo *et al.*, 2000; Klevås, 2005; van Hoek and Chapman, 2007; Sohrabpour *et al.*, 2016) and other stakeholders of the logistics system. Indeed, during the whole product life cycle, especially of course during production, handling, transport, marketing/sale, and even during recovery (recycling or re-use), many of the needs in the logistic flow can be fulfilled by either the product or the packaging. For example, in a case study by Bramklev and Hansen (2007), the redesign of an automated car-washer equipment of a large size (originally not fit for distribution) resulted in a reduction of its transportation costs by 25%. Another example is that of a consumer product company that redesigned its product, process, and supply chain in parallel (so-called three-dimensional concurrent engineering, 3DCE), which resulted among other improvements in "changing the product design in terms of packaging" (Ellram *et al.*, 2007, pp. 307-308). On the other hand, packaging might provide some of the functions that are traditionally allocated to the product, such as ease of manufacturing and ease of installation (Bjärnemo *et al.*, 2000).

An integration of the design and development of packaging and product is therefore of high importance. This has been highlighted in several publications, see e.g. (Bjärnemo *et al.*, 2000; Klevås, 2005; Bramklev, 2007; Sohrabpour, 2014). In (Bramklev, 2007, Paper VI), a general integration model is proposed based on the potential interactions between a generic product development process model and a generic packaging development process model. In (Sohrabpour *et al.*, 2016), a set of methods are proposed to better integrate supply chain needs in a given product and packaging development process model. Sohrabpour (2014) looked also into the information systems necessary to handle such integrations aspects.

As noticed in (Lindh *et al.*, 2016, p. 227), a difficulty is that many attributes characterizing the packaging, and therefore the product-packaging system (PPS), are very dependent on the type of product, which itself defines much of the supply chain. To that it can be added that many of the existing product development process models are very specific to companies (Eriksson *et al.*, 2017), even if they are derived from generic product development process models. For example, Tetra Pak has adapted Olsson's integrated product development process model (Olsson *et al.*, 1985) to fit its unique development needs (Sohrabpour *et al.*, 2016). It is therefore quite difficult to present generic guidelines or development models to help companies integrating product and packaging development when so many factors affect the structure of this integration.

As an alternative to generic guidelines and development models alone, it was proposed in (Motte *et al.*, 2007b) to map guidelines and models to a set of factors (or attributes) based on the PPS characteristics and its environment during the whole product life cycle. Knowing which factors would be relevant to a particular product type, development project, and/or company and context, the decision maker can then select and adapt those guidelines and models that are relevant to him or her. For example, knowing that elements of the products are sensible to corrosion, the decision maker can choose to investigate different product materials or to provide a protection in form of a packaging. Knowing in which activity of the product development process model this aspect is dealt with, he or she can choose to involve the packaging department or supplier in this activity.

This approach gives a concrete and operative guidance to the decision maker but is also knowledge intensive. Much information is needed, and this information can be hard to find.

This knowledge might also be used differently depending on integration goals and tasks undertaken. This information needs also to be structured and there is a need to know what is relevant and what is not.

In order to identify and structure the knowledge needed to perform integration tasks, a useful approach is to model these tasks by using knowledge-based engineering (KBE). Besides defining clearly for each task which knowledge is necessary, a KBE approach makes visible potential knowledge re-use (the same type of knowledge can be re-used for different tasks). Using a formal representation ensures the coherency of the developed task models. Finally, it can bring out knowledge gaps, for which further research might be needed.

This paper presents the modelling of the knowledge required to perform tasks to integrate the development of product and packaging. The next section specifies the signification of integration of product and packaging development and the integration tasks that are covered in the remaining of this publication. The third section discusses related works on formal process modelling. The fourth section presents the chosen KBE methodology to describe the integration tasks, CommonKADS (Schreiber *et al.*, 2000). The models of the tasks and their related knowledge elements are then presented, followed by an application of the knowledge modelling.

## 2. INTEGRATION OF PRODUCT AND PACKAGING DEVELOPMENT

This section takes up the concept of integration used in this paper. An integrated product and packaging development (IPPD) means basically that there are some interactions between the two activities. These interactions can vary in depth and breadth (see Section 5), depending on the company structure, development strategy, supply chain networks, etc. This integration implies changes in the development process, the company's development, manufacturing and supply chain organisation, and in the information system (IS) that support both. Integration also occurs at the strategic, tactical and operational levels (Bramklev, 2007, p. 37), for each of which specific types of tasks are necessary. These integration tasks can be defined as follows:

- At the strategic level, it is necessary to define or refine the company's integrated development policy (that is, its development process, organisation and IS);
- At the tactical level, it is necessary to adapt the company's existing integrated development policy to each development project;
- At the operational level, it is necessary to take relevant decisions during an ongoing development project, for example when a deviation from the development plan occurs.

These three types of integration tasks form the basis of the modelling presented Sections 5, 6 and 7. Note that the term integrated development policy includes all the functions involved in the IPPD. This includes manufacturing, purchasing and supply chain, see (Motte *et al.*, 2007a; Ulrich and Eppinger, 2012, p. 15; Olsson *et al.*, 1985). This is elaborated upon in the beginning of Section 5.

## 3. PROCESS MODELLING AND MANAGEMENT

In the business literature, the dynamic design of processes, organisations and ISs at the level applicable to this work have been dealt within the approaches of business process management (BPM), business process re-engineering (BPR) or with process capability maturity models (CMM). There is an extensive literature on this topics, see e.g. (De Bruin and Rosemann, 2005) for an overview. However, it is claimed by authors such as (Kreimeyer and Lindemann, 2011; Torcato, 2013; Vajna, 2005; Wynn, 2007) that the development of products (including packaging as seen as a product) is a complex activity that distinguishes itself from several other business processes. Manufacturing and distribution processes are of course also subject to changes, but in case of development the knowledge created during the process significantly influences and alters it (Vajna, 2005, p. 371). The large uncertainties around the development of products limit the use of similar process modelling and management methods (Torcato, 2013; Wynn, 2007).

More concretely, at the start of a development project, the product needs and specifications are imperfectly known. According to Thomke and Reinertsen, in average only 58% of the requirements are specified (Thomke and Reinertsen, 1998). They are also often modified during the project due to changes in the market, new specifications from the customers, or due to the product concretizations that often induce new needs and specifications. The information-flow is concretised in the progress of the design process (Paetzold, 2015, p. 2). For many development activities, the output is not known with certainty, which migh result in iterations and feedback loops.

For these reasons,

- At the strategic level it is difficult to develop a detailed integrated development policy that can be used directly for each project;
- At the tactical level, the overall integrated development policy needs large adjustments to each specific development project while maintaining some flexibility for its execution;
- At the operational level, decisions are made to alter the development plan depending on the context.

At the strategic level, an answer to these difficulties has been to offer generic process models as a guidance to the companies and developers, see (Wheelwright and Clarke, 1992; Cooper, 2011; Hubka and Eder, 1996; Pahl and Beitz, 2007; Ulrich and Eppinger, 2012). These models need then to be adapted to the developing company and its environment. The literature has been scarce on proposing guidelines for the adaptation of these models (Costa *et al.*, 2015), apart for some exceptions, e.g. (Cooper, 2011, Chapter 10). But more and more methodologies are emerging, such as (Hollauer *et al.*, 2016) in engineering design, and in software engineering (Pedreira *et al.*, 2007).

Another approach is to define the company's development model using process "modules" (process elements) instead of complete generic process models. Embedded in a knowledge-based system (KBS), these process elements can be put together to form a complete model. Such an implementation has been done in the software *ProNavigator* (Vajna, 2005), where the selection and arrangement of process elements (that are customized for each company) is partly automated.

At the tactical level, tailoring of the company's development policy is often done on an ad-hoc basis. Some tools are available such as the design structure matrix (DSM, Smith and Eppinger, 1997) that identifies the links between development activities and help devising relevant activity cluster. The same is also true for the operational level, where "decisions are made situation-specifically" (Paetzold, 2015, p. 3).

Common to those guidelines and tools for definition, tailoring and adaptation of a development model is the necessity to have specific, context-dependent “factors” that help performing those activities, as underlined by Paetzold (2015). One of the first works on the influence of context-dependent factors and implications for the management of the development process is found in Hayes (1991), further developed in (Hales and Gooch, 2004). Knowing the factors influencing an activity, or a process and knowing what can be done given the factors, actions can be taken.

The factors influencing development is naturally huge, and several categorizations have been made. Gerricke *et al.* (2013), drawing on (Hales, 1991; Hales and Gooch, 2004), group them into the categories design, project, management, corporate (including extended enterprise network, thus including supply chain), market, environment. Under these categories, 239 factors were identified. To these factors, the product characteristics should also be added.

Packaging factors that have an influence on the supply chain can be found in (Azzi *et al.*, 2012; Lindh *et al.*, 2016). They could be used to improve supply chain processes and some of them to improve the product and packaging development process.

The use of factors based on the PPS (characterized mainly by the interactions between product and packaging and their environment along the whole product life cycle, including the logistic flow) to model their development process at the strategic, tactical and operational levels is also relevant and motivated. This formalization and structuration of knowledge should also contribute to the research within development process modelling and management.

# 4. MODELLING KNOWLEDGE FOR KNOWLEDGE-BASED SYSTEMS

As mentioned in the introduction, modelling the integration tasks with a KBE methodology helps defining clearly the necessary knowledge and identifying knowledge gaps. A formal representation also ensures consistency. Modelling is also the art of “constructing a good description (that is, good enough for your purpose) of only a few aspects of knowledge and leaving out the rest” (Schreiber *et al.*, 2000, p. 15). In other words, it helps reducing the search and acquisition for relevant knowledge, a bottleneck in the development of support to many knowledge-intensive activities. It permits to identify same knowledge elements that can be used for different tasks. And very importantly, it permits to exploit the task templates developed in research in KBE. CommonKADS presents such a task typologies (Schreiber *et al.*, 2000, Chapter 6). Re-using these task templates whenever possible ensures quality models and facilitates the identification and structuring of the necessary knowledge.

The CommonKADS knowledge model elements and its templates are introduced below.

## 4.1. The CommonKADS knowledge models and templates

The CommonKADS knowledge model consists of three categories:

- *Domain knowledge*: facts, data, information, type of knowledge about the specific domain under modelling (e.g. assignment of a paperboard type to a packaging given its usage specifications). It consists in:
    - *Domain schema*: model, description or structure of the domain-specific knowledge (e.g. listing of characteristics of paperboard, such as burst test, edge crush test, ring crush test, shock absorption, tear resistance, grammage; listing of specifications of a packaging, such as humidity rate, weight of the product…).

    - *Knowledge base*: instances of domain schema (e.g. the actual values of the characteristics of known paperboards using the structure from the domain schema).
- *Inference knowledge*: description of basic reasoning steps (mainly of the form of inferences) that are made using the domain knowledge (e.g. “obtain” the relevant specifications and “assign” the material with the best correspondence to the specifications).
- *Task knowledge*: Task knowledge describes the goal(s) of the use of knowledge and how these goals can be realized through a decomposition into inferences using the domain knowledge (e.g. selection of the most suitable paperboard material using the sequence of 1) acquisition of the specifications and 2) assignment of material).

The task types covered in CommonKADS, representing the majority of knowledge-intensive tasks, are: classification, assessment, diagnosis, monitoring and prediction for the analytic tasks; design (configuration design), modelling, planning, scheduling and assignment for the synthetic tasks. Each task type is described by the necessary inference knowledge elements with their input and output and the typical domain schema. Many inferences are standardized (they have also a general definition and description) and can be found in several types of task. The inferences are considered as black boxes, but typical (computational) problem solving methods are suggested for further development. The tasks whose template has been used will be described when appropriate.

CommonKADS uses a graphical formalism similar to and drawn from the United Modelling Language (UML) class and activity diagrams, and is compatible with it.

### 4.2. Use of the CommonKADS templates for the modelling of the integration tasks

The approach adopted here is to match each of the integration tasks to one or several of the task templates proposed by CommonKADS (Schreiber *et al.*, 2000; Breuker and Van de Velde, 1994). This provides 1) a well-established structure for the task, 2) the inferences necessary to fulfill the task, 3) the necessary domain knowledge. Moreover, it helps identifying and establishing the knowledge components that can be used across tasks.

Sections 5, 6 and 7 present the task structure, the domain knowledge and the inference knowledge for the strategic, tactical and operational integration tasks respectively (for sake of clarity, the knowledge elements are written in Arial font in the body text). As the CommonKADS terminology is used, an interpretation of the knowledge elements, especially regarding the generic inferences, are given when appropriate.

## 5. MODELLING OF THE MAIN STRATEGIC INTEGRATION TASKS

The strategic integration task goal is the following: Define an integrated development policy for the company. This includes: the definition of a general IPPD process model, the definition of an organization model, the definition of an IS model.

There are two ways of structuring this task to help the decision maker:

- Help the decision maker to choose within a predefined set of integrated development policy models, that he or she is free to develop and integrate in the company’s existing organization, for example:

- o Total integration of packaging development in the product development, e.g. (Motte *et al.*, 2007a).
- o Dedication of strategic business unit (SBU) to packaging, like IKEA (Klevås, 2005).
- o Extended enterprise (Browne and Zhang, 1999)—long-term partnership between the packaging and product development companies.
- o Virtual enterprise (Browne and Zhang, 1999)—intense but project-limited partnership between the packaging and product development companies.
- o Supplier-Buyer (the most traditional variant), see examples in (Bramklev, 2009).

- Help the decision maker define his or her IPPD process, organization and IS by giving him process, organization and IS elements (modules) that he/she can assemble and integrate in the company's existing organization, similar to Vajna (2005)'s approach.

In the different integrated development policy models above, supply chain is supposed to be included. As an illustration, in the total integration model, specific activities are carried out by different functions of the companies for each phase of the development process. Specifically for the product planning phase, the marketing function carries out prospective customer and trend studies, the engineering design function performs economical intelligence and generate product and packaging alternatives, the manufacturing function considers different production possibilities, the business function consider different financing options, the logistics function sets out supply chain strategy, etc. On the contrary, in the supplier-buyer model, the traditional sequential model is preserved and supply chain intervenes last.

Considering the two possible ways of structuring an integrated development policy for the company, two task alternatives have been devised.

## 5.1. Tasks

In the first alternative, the decision maker wants to match his or her integration requirements with one of the most suitable general types of integrated development policy models. In CommonKADS this can correspond to the "classification" task type. A classification task consists in finding a class or an instance of a class which would have the most similar attributes to what the decision maker searches (cf. classifications in biology).

A simplified version of the classification task adapted for the strategic integration task is represented Figure 5.1. The task reads this way: Given the requirements that the decision maker has in mind (regrouped under the term Strategy), and a set of predefined attributes (Attribute model) that characterize the interactions between product and packaging (the "factors" mentioned Section 3), the decision maker selects the relevant attributes (Feature). These valued attributes are then matched (match) to the set of pre-defined strategies (Strategy_class). The decision maker is given the best match (Truth value). The corresponding domain knowledge and inference knowledge are discussed in Sections 5.2 and 5.3.

The classification task is simplified in comparison to the CommonKADS template as the domain knowledge might be modelled as one strategy class with several instances. The graphical notations are the following (simplified): Rectangles are input/output to inferences. Ovals represent inferences. Rounded boxes are transfer functions, i.e. inferences whose input and reasoning come from the decision maker. The collection of domain knowledge elements used in the inferences are written between two thick lines. They can consist in the whole domain or just a part of it. In Figure 5.1, Attribute model uses only the attribute knowledge while the Strategy_class and Attribute mapping model uses most of the domain knowledge (see

Section 5.2). To the structure of the task the start and end symbols used in UML activity diagrams have been added.

In the second alternative, the decision maker would extract process, organization and IS integration elements from the knowledge system that he or she could implement in the company's development model. This approach is of a more modular nature, thus probably more suitable when an integrated development policy model already exists. In CommonKADS this can correspond to the "assignment" task type. An assignment task consists in creating a relation between two or more groups of objects, in that case, matching (via the attributes) requirements to integration elements. A simplified version of the assignment task adapted for the strategic integration task is represented Figure 5.2. The task reads this way: Given the requirements that the decision maker has in mind (Strategy), and a set of predefined attributes (Attribute) that characterize the interactions between product and packaging and their environment along the product life cycle, the decision maker selects the group of attributes (Attributes subset) relevant to his or her requirements. The integration elements (Integration_Element s) that are relevant are to the chosen attributes (thereby to his or her requirements) are then assigned (assign). The assigned elements (Elements) can be embedded in an overall integrated development policy model. This embedment needs probably some guidance, therefore guidelines must be associated to the integration elements and provided to the decision maker (that is, the domain knowledge must contain guidelines).

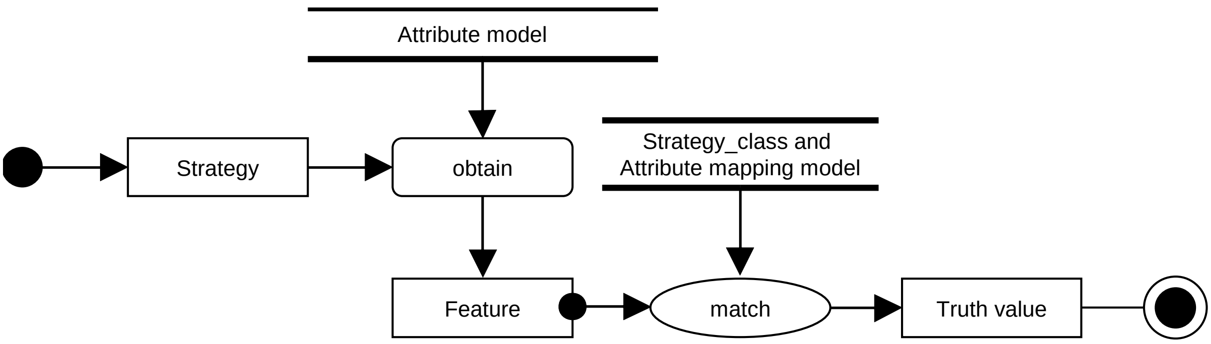


*Figure 5.1 Structure of the strategy integration task with a predefined set of strategies*

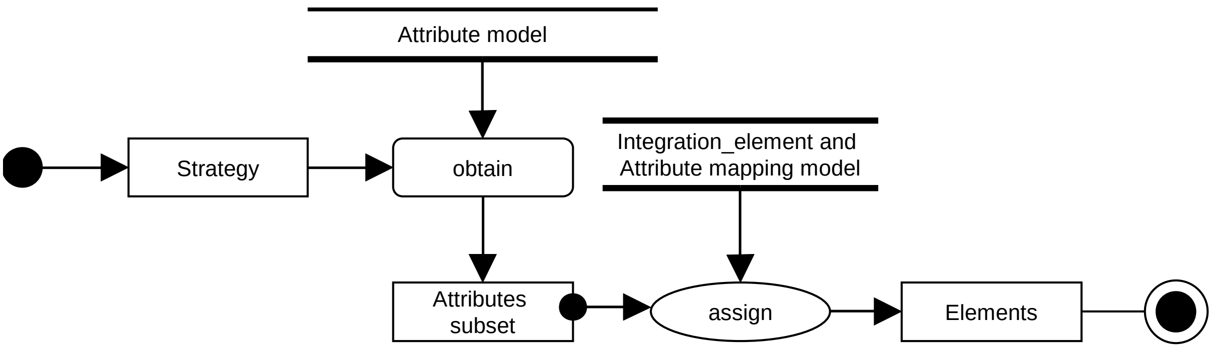


*Figure 5.2 Structure of the strategy integration task with a predefined set of elements*

## 5.2. Domain knowledge

The domain knowledge for the first alternative is represented Figure 5.3. A strategy class (N.B.: a class is called a *concept* in CommonKADS) possesses a general IPPD process model, an organization model and an IS model. Five instances of the strategy_class are also represented. They correspond to the five integrated development policy models presented above. The links between the attributes and the strategies are represented by the class constraint rules. If each type of strategy would require a different set of rules, they should be modelled as classes instead of instances.

The domain knowledge for the second alternative is represented Figure 5.4. As understood from the figure, the Integration_Element consists IPPD process elements (instead of an overall model as in the first alternative, IS elements and organization elements.

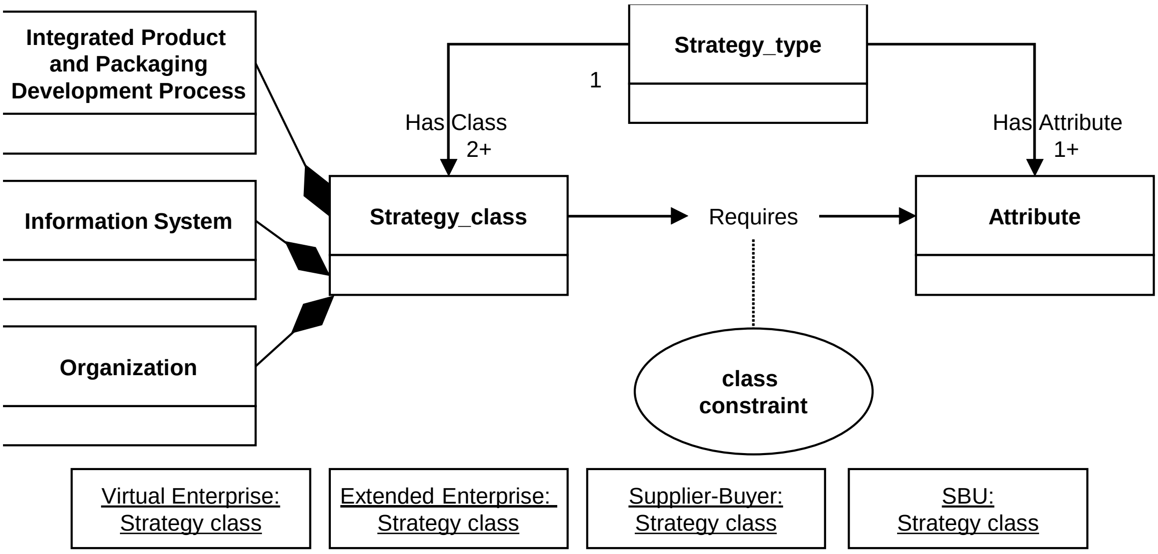


*Figure 5.3 Domain knowledge for the first task alternative*

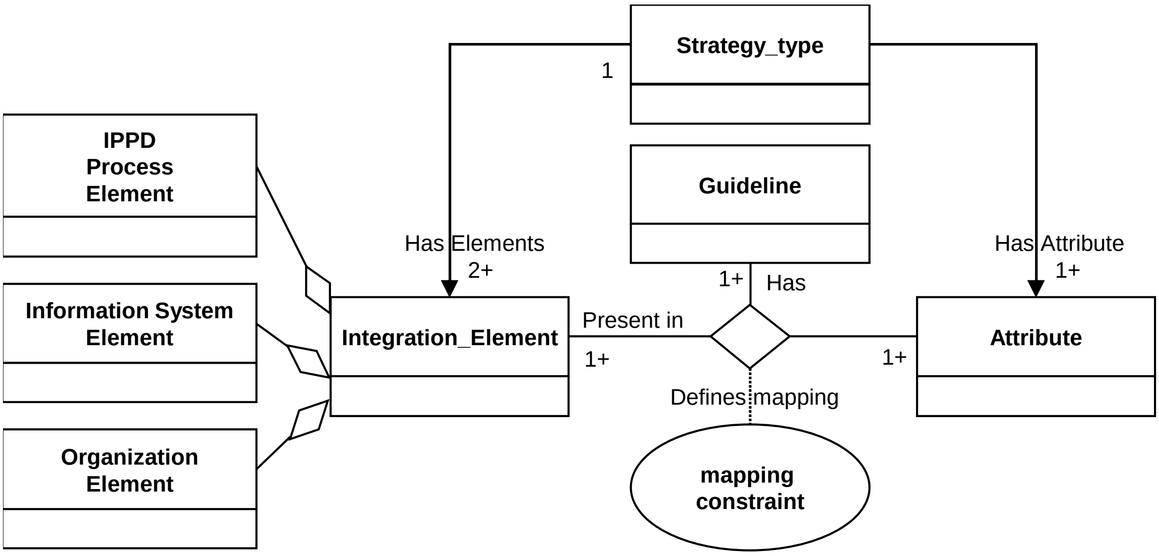


*Figure 5.4 Domain knowledge for the second task alternative*

## 5.3. Inference knowledge

Only two inferences need to be developed: match and assign. The match inference is not trivial as the requirements from the decision maker will never match perfectly any of the pre-defined sets of integrated development policy models. In a computational point-of-view, many methods exist, based on, for example, 'distance' minimization to find the closest match. This might require an advanced modelling of the information though. More discursive methods are more likely to be useful as a first step.

The assign inference is much easier, as it can consist in simply looking up the existing relations or rules between attributes and integration elements in the domain knowledge. In a general case, it suffices that an integration element is related to an attribute to elicit this element. Much more complex methods can be devised of course.

# 6. MODELLING OF THE MAIN TACTICAL INTEGRATION TASKS

The tactical integration task goal is the following: the planning of a specific product development project, which is interpreted as, adapting the company's IPPD process model, organization and IS to the planned product development project. This presupposes that the company has an integrated development policy model. This task consists in checking whether there is a mismatch between the company's development model and the current project and, based on these deviations, in making the necessary modifications.

## 6.1. Task

In CommonKADS, the tactical task would correspond to the "assessment" task template (assessing whether the company's integrated policy development model complies with the requirements of the project under planning). But one can see some similarities between the tactical task and parts of the strategic tasks. This can be exploited by re-using the developed knowledge elements. The specific company's integrated policy development model can be described as a new instance of the Strategy_class, cf. Figure 5.1. The activity "check whether there is a mismatch between the company's development model and the current project" can be transformed into "find if there is a match..." which corresponds to the first strategic task. The difference is that the potential mismatches must be specified. Similarly, "Make the necessary modifications" corresponds closely to the second strategic task, in the sense that one wants to assign specific integration elements to the parts of the company's integrated policy development model that are not adapted to the current project.

The resulting tactical integration task is represented Figure 6.1.

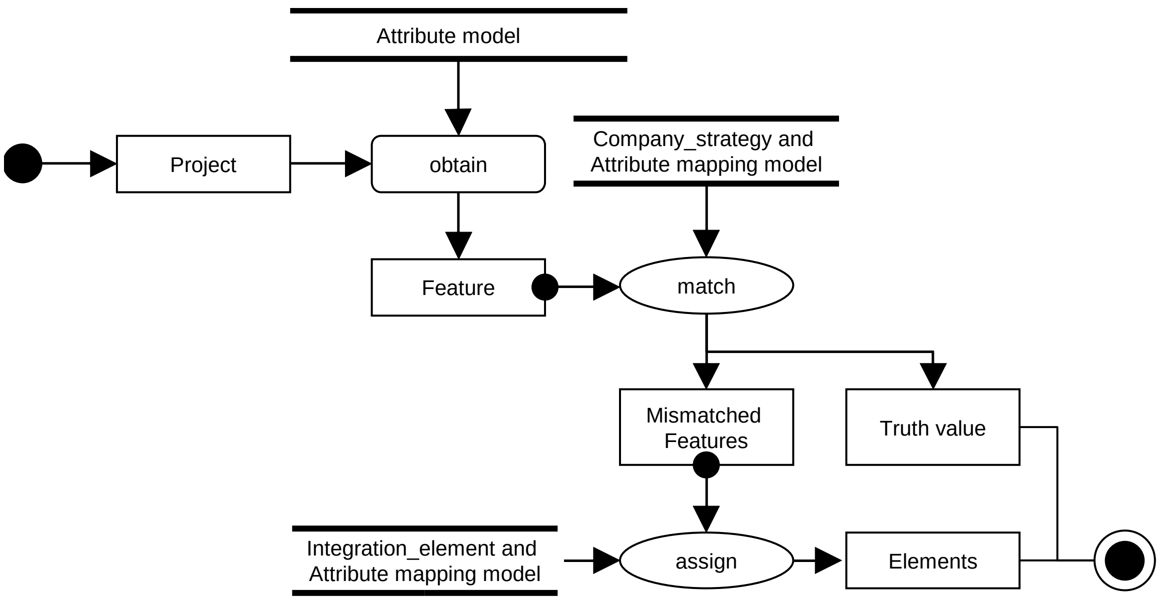


*Figure 6.1 Structure of the tactical integration task*

### 6.2. Domain knowledge

All the elements introduced in Section 5.2 can be re-used.

### 6.3. Inference knowledge

The inferences introduced in Section 5.3 can be re-used but the match inference must be enhanced to not only provide a truth value but also the mismatches.

## 7. MODELLING OF THE MAIN OPERATIONAL INTEGRATION TASKS

The operational integration tasks concern the activities during the current product development project. From an integration perspective, the main goal is to be able to make decisions depending on context changes. In a larger perspective, the elements of KBS can also be used for “integrated tasks”, that is tasks that already take into account conjointly packaging and product development. Three goals have been identified:

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 remaining of the product (and packaging) development project, if new needs or constraints arise, decide whether to tackle them at the product level or at the packaging level.
3. Check if the current product (and packaging) development state correspond to the planned development state and act accordingly.

### 7.1. Tasks

Regarding the first task, the Attribute knowledge domain can be exploited: the attributes can simply be systematically checked in order to complete a regular voice of the customer or an engineering specification activity. This indicates that there is an advantage in organizing the attributes so that this task be simple to execute. The search for customer needs can make use of attributes grouped in a functional axis (cf. Section 8) and the search for engineering specifications can make use of attributes about the structure of the product-packaging system (ontological axis).

For the second task, the decision maker, by relating the incoming needs or specifications to the domain knowledge (attribute), can then assign them to relevant development activities (Integration_Element) that are present in the given project. He or she can take help from the guidelines (Guideline) associated with the integration elements. This is the same type of task (“assignement”) as the second alternative strategic integration task, cf. Figure 5.2. The main differences are that the input to the obtain inference is now the new needs or specifications and that the Integration_Element of the knowledge mapping model for the assign inference are instances specific to the project (i.e. Project_integration_element), and not the original domain schema.

In CommonKADS, the third task would correspond to the “monitoring” task template. Monitoring means that regularly or when necessary, the current project state is compared to the planned project. In our case, the planned project state at a time *t* is defined by the value of an attribute at a given phase or activity of the IPPD (cf. Figure 5.4). So, given a certain phase or activity, one can retrieve the concerned attributes and compare the forecast valued attributes to the present ones (features). If there is a discrepancy, the decision maker can act accordingly. Once again, one can notice a similarity with a previous task: the tactical integration task, where the company's development model is assessed relatively to the project at hand (Figure 6.1). In this case, that the input to the obtain inference is now the integration element and valued attributes (features) at time *t* and that the knowledge elements of the mapping model for the assign inference are the Project_strategy (or Project_integration_element) instance derived from the company's Company_strategy (or Company_integration_element).

### 7.2. Domain knowledge

The structure of the domain knowledge is the same as the one needed for the other integration tasks. However the operational tasks require a high level of detail in the description of the Attribute, Integration_Element and Guideline concepts.

### 7.3. Inference knowledge

The demands regarding the inferences should be the same as described in Section 6.3.

## 8. APPLICATION

This section exemplifies the strategy integration task model with a predefined set of elements (second alternative, Figure 5.2 and Figure 5.4) based on (Motte *et al.*, 2007a). The integration task proposed in (Motte *et al.*, 2007a) [1] can be formalized as presented Figure 5.2 and Figure 5.4 with: a set of integration elements (Integration_Element model), a set of attributes (Attribute model, related to interactions between packaging, its products and environment), a mapping of the integration elements with attributes (Attribute mapping model) and a guideline to select the integration elements of importance (given the attributes) that the company should consider to develop its integrated development policy (that is, the task itself and its inferences obtain and assign).

The Integration_Element of (Motte *et al.*, 2007a) consists of five phases (product planning, conceptual design, embodiment design, production preparation and product launch) divided into activities to be performed concurrently by four functions of the company (marketing, M, design, D, production, P, business/financing, B), that is, 20 activities in total for the IPPD Process Element, and 4 Organization Element. This set of elements is far from complete (no IS Element, the organisation elements do not include the supply chain network, etc.).

The Attribute used in (Motte *et al.*, 2007a) have been taken from (Motte *et al.*, 2007b). They are grouped in five categories: ontological (structure/properties of the PPS such as weight, surface finish…), functional (modes of operation/behaviours/reactions to the environment, e.g. sensitivity to light, to corrosion, ability of manual handling, etc.), teleological (the finalities of the PPS, generally similar to needs, e.g. resistance to shock, ease of manipulation, etc.) and "genetic" (e.g. belonging to a product or packaging family).

The Attribute mapping model (mapping of the attributes and the integration elements) are presented in tables in (Motte *et al.*, 2007b). An excerpt is given Table 8.1. As guidelines have not been developed, the Guideline concept, cf. Figure 5.4, is not represented.

Finally, the task structure is represented Figure 8.1. The steps involved in the obtain and assign inferences are detailed. The decision maker has to perform some steps (obtain) while the assign steps are automated thanks to the rules between the attributes and the integration elements.

[1] In fact, (Motte *et al.*, 2007a) combines the two strategy integration tasks presented Section 5. For sake of simplicity, only the second integration task is presented.

*Table 8.1 Excerpt of the list of attributes, their influence of integration and their interrelationship. The M/P/F column indicates the type of product primarily concerned by the attribute (mechanical, M, pharmaceutical, P, or food, F, industry), see Figure 8.1*

| | Physical elements attributes | Mapping to IPPD and organisation elements | | M/P/F |
|---|---|---|---|---|
| O1 | Nature of the product | product planning phase (B, M, D, P), market preparation (M), conceptual design (D) | | M/P/F |
| O1c | Solid | production layout (P), production preparation (P), manufacturing design (M) | | M |
| O9 | Product structure | embodiment design (D), production layout (P) | | M |
| O10 | Product elements | embodiment design (D) | | M/P/F |
| O14 | Surface finish | production preparation (D,P) | | M |
| | … | | | |
| | Modes of operations attributes | Mapping to IPPD and organisation elements | Mapping to physical elements attributes | |
| F1 | PPS made sterile | business conditions study (B), production possibility study (P), | O4 | M/P/F |
| F2 | Product is packed/filled in uncontaminated atmosphere | production possibility study (P), production layout (P) | O4 | M/P/F |
| F10 | Sensitivity to humidity | embodiment design (D) | O10 | M/P/F |
| F11 | Sensitivity to light | embodiment design (D) | O10 | M/P/F |
| | … | | | |
| | Functions attributes | Mapping to modes of operations attributes | Mapping to physical elements attributes | |
| Te1 | Necessary information must be present on PPS | F18, F19 | O3, O15 | M/P/F |
| Te2 | PPS must be sterile | F1, F2 | O3, O4 | M/P/F |
| | … | | | |
| | Product family factors attributes | | Mapping to IPPD and organisation | |
| G1 | Frequency of change of form among the different products | | Product planning: discuss with packaging department (D, P) | M/P/F |
| G4 | Mix/Multiple product ship | | Conceptual design (M), production layout (P) | M/P/F |
| | … | | | |

# 9. CONCLUSION

As mentioned in the introduction, packaging is an important element of the logistics system and a better integration of the packaging and product development can ensure a better fulfilment of the logistic needs. The modelling of the integration tasks using KBE techniques has permitted to clarify the structure and knowledge elements needed for these tasks. It has also allowed for a bringing together of the different knowledge elements. The six modelled tasks share most of the domain inference knowledge. It also helps ensuring consistency: the formalization of the task integration of (Motte *et al.*, 2007a) in the preceding chapter helped uncovering that the IS elements and the supply chain network organization elements were missing.

The presented knowledge models need further research to be populated and completed, for example the types of strategies (which do not take into account the new circular economy models), attributes elements, the guidelines helping implementing the integration elements (see Figure 5.4). These models need to be populated with literature and empirical studies.

The proposed formalization has been clearly developed for the research purposes. Regarding its possible future applications to industry, it is the opinion of the authors that the highest potential lies in its use at the strategic level. At this level the company has a defined integrated development policy that needs to be adapted to new development projects. If a company adapts the presented knowledge elements and develop and maintain its related domain knowledge database (cf. Section 4.1) then the KBS can be re-used for each new project. This would be similar to *ProNavigator* (Vajna, 2005) which has proved successful. At the strategic level, the presented elements are more interesting as scenarios and sources of inspiration for a company and the KBS implementation would in many cases be too time-consuming. Finally at the operational level, the KBS for the tactical level can be consulted for some tasks but a complete implementation of a KBS at this level would be once again in many cases too time-consuming.

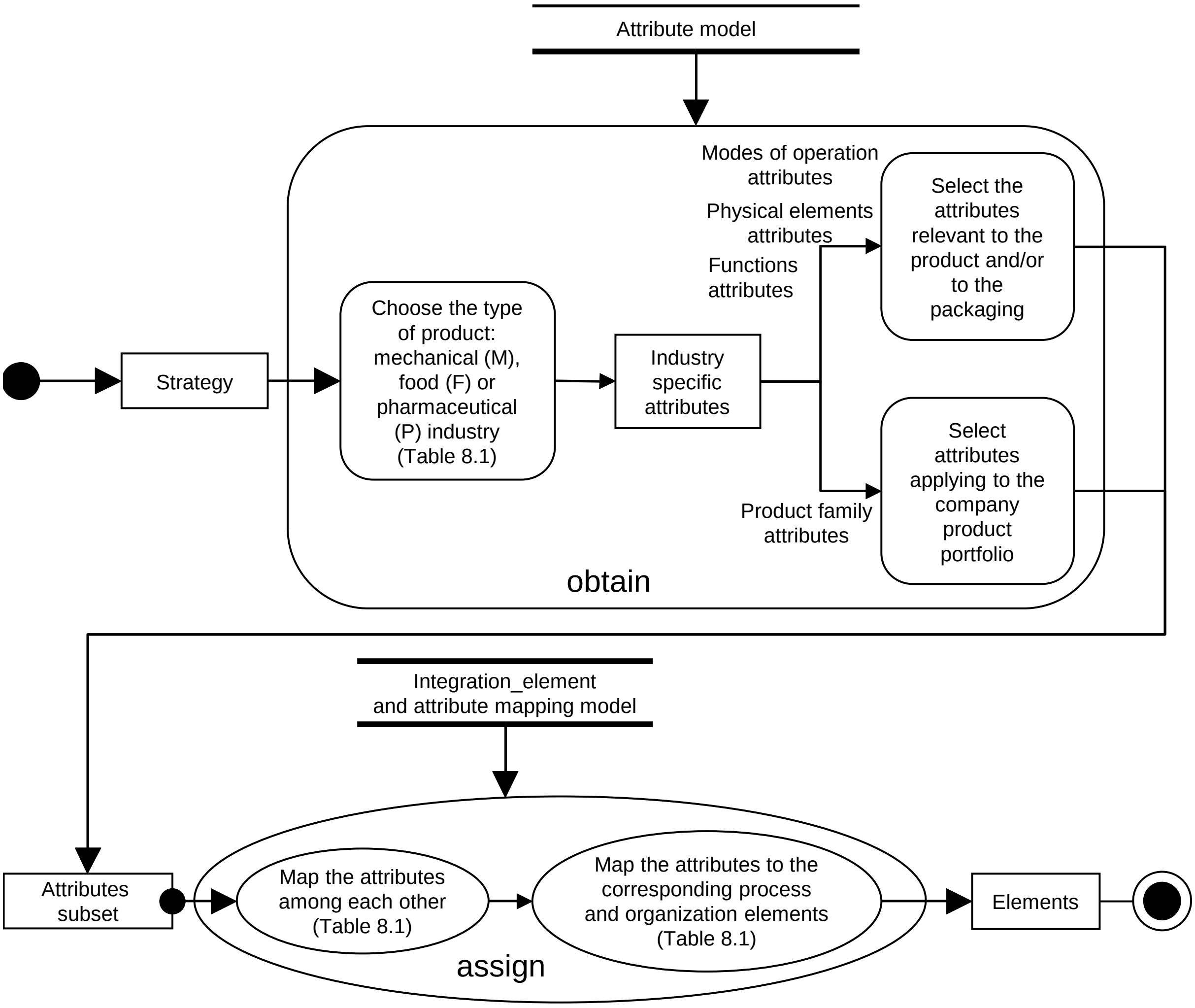


*Figure 8.1 Task structure with detailed inference steps, following (Motte* et al., *2007a)*

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