MASTER

Data-centric business process modelling
a comparison of methods

van de Crommert, W.L.M.

Award date:
2013

Data-centric Business Process Modelling: A Comparison of Methods

By
W.L.M. van de Crommert

BSc Industrial Engineering
Student identity number: 0631920

In partitial fulfilment of the requirements for the degree of

Master of Science

In Operations Management and Logistics

Supervisors:
prof. dr. ir. H.A. Reijers, TU/e
dr. ir. I.T.P. Vanderfeesten, TU/e

Subject headings: data-centric, process, modelling, methods, evaluation

Management Summary

As the environment and competition of firms is dynamic and increasingly complex, businesses should be able to continuously adapt their way of working in order to remain competitive. In this attempt to remain competitive and act on changes in technology and environment, business processes play an important role.

Business process design and redesign, often used under the heading of Business Process Management, is well known and used in practice. In the last decade however, also new initiatives were proposed; so-called data-driven methods try to extend the activity-centric approaches, by focusing on the main data-objects in the process.

Although different attempts exist, much is currently unknown about these initiatives. Even though the ideas sound promising, many alternatives exist and few of these methods are currently actively used. In a previous study (Diaz Garcia, 2011) carefully selected three leading methods and conducted a first comparative study on these methods, identifying strengths that were claimed by the developers of the methods, and using an experiment to test whether these strengths were perceived by users as well.

This study continues were the previous ended. Again the Data-driven Process Structures of the University of Ulm, Product Based Workflow Design of the Eindhoven University of Technology, and Artifact-Centric Process Modelling of IBM Watson Research Laboratory, are considered. However, in contrast to the study performed by Diaz Garcia, this study tries to acquire more specified information on the user's perceptions towards the methods.

Four main phases can be distinguished in this study:

1. In the first phase, literature is studied in order to capture claims made by the developers of the methods, that address one or multiple quality attributes. The five quality attributes used in this Theoretical Evaluation are: Functionality, Usability, Efficiency, Maintainability, and Flexibility. The obtained claims are used to create an overview of the contents and focus of the methods, and at the same time enable the mapping of the methods to each other. An overview of this set of claims can be found in Table 7.
2. The second phase, called the Empirical Evaluation, includes three workshop sessions in which participant actively work with one of the methods. Not only do they *read* about the important entities of a method, they are also provided with examples and even exercises, in order to obtain some hands-on experience. A questionnaire and discussion are used to gather the users' perceptions of the methods.
3. The third phase is used to compare the claims acquired in the Theoretical Evaluation with the perceptions obtained in the Empirical Evaluation. Perceptions can support or contradict the claims, and sometimes are indecisive. In addition it can occur that claims are unaddressed in the workshops, or perceptions are identified that do not directly relate to a claim. These are captured as well.
4. Using both the claims of the developers and the statements made by the participants, the different methods are individually evaluated. After stating a methods strengths and weaknesses, the methods are compared to one another, capturing relative strengths and weaknesses, as well as opportunities for improvement.

One of the main findings of this study was that indeed users currently are not used to using methods that go beyond ordinary process modelling. Struggling with fairly simply examples, it can be said that an extensive training is required in order to use these kind of methods for complex, practical situations.

With respect to the Data-Driven Process Structures, proposed by the University of Ulm, it can be said that this method is very efficient and highly maintainable. This high efficiency and maintainability is achieved using very generic models, which can be difficult to formulate. Though the method is currently most often applied in the manufacturing domain, where structured products are modelled, it might be interesting to use this method in other environments, in order to test its applicability to other domains.

The Product-Based Workflow Design focused not on efficiency of modelling or on maintainability, but instead is used to optimise the process that is modelled. Users of the workshops struggled with the complexity of negative paths (knock-outs), used in the Product Data Model; participants preferred a tree-like structure without these alternative routings.

The final method discussed, Artifact-Centric Process Modelling, proved to be fairly difficult for the participants. The creation of these models proved to be fairly complex; and even though the artifacts described are self-explaining, the models that incorporate these artifacts are still difficult for business users. The claimed added value for analysing, managing, and controlling the business operations, in addition, remained somewhat unclear.

As can be seen, each of these methods has its own strengths and weaknesses; it might however be possible for these (and other) methods, to tackle some of their own weaknesses by incorporating functionality that is based on other methods.

Artifact-Centric Process Modelling, for example, could try to incorporate some of the aspects of efficiency and maintainability, used in Data-Driven Process Structures. For PBWD it might be interesting to increase its readability, improving understandability for business users.

As can be seen, data-centric process modelling methods can still be improved; refinements are required to all of the methods. However, data-centric modelling methods do propose some interesting ideas for improving the analysis, management, and control of business operations.

Acknowledgements

The Master Thesis in front of you is the result of the research I conducted during the past seven months. Many persons helped me and supported me during this process, and I would like to express my thanks to them here.

First of all, I would like to thank my supervisors: Hajo Reijers, for the interesting discussions we had that helped me push my research to a higher level, and Irene Vanderfeesten, for her continuous support and optimism. Both of you helped me to overcome periods in which progress came to a halt, finding new spirit to tackle the encountered problems.

Secondly, I would like to thank the people who contributed to this thesis in one way or another. Manfred Reichert from the Ulm University, and Emily Rong Liu from the IBM Watson Research Laboratory, who helped me adjusting and improving the tutorials. Furthermore, I would like to thank all business professionals and students that participated in the workshops, and thereby contributed to results of the Empirical Evaluation.

I also thank my colleagues from the Paviljoen, especially Han and SG, for the estimated total of 1000 cups of coffee we drank together, and the often welcome distraction during long days. Han, special thanks for the feedback and discussions on different parts of my study.

Patricks, thanks for the wonderful time I had in Eindhoven, you were great.

The last words are for my family, for their continuous support and confidence in me. You encouraged me, and helped me to put things in perspective. Thank you all.

Wim van de Crommert
Eindhoven, January 2013

Contents

List of Figures

List of Tables

1 Introduction

As the environment and competition of firms is dynamic and increasingly complex, businesses should continuously adapt their way of working in order to remain competitive. In this attempt to remain competitive and act on changes in technology and environment, business processes play an important role; both physical, like manufacturing processes and logistics, and non-physical processes (e.g. digital forms). The field that addresses the design, redesign and management of processes is called Business Process Management (BPM) (Hammer, 2010), (Van der Aalst, Ter Hofstede, & Weske, 2003).

The activity-centric approach of BPM is widely known and accepted. In the last decade however, also new initiatives were proposed that aim at improving activity-centric methods; so-called data-centric methods try to extend the activity-centric approaches, by focusing on the main data-objects in the process.

Although different attempts exist, much is unknown regarding these initiatives. Therefore, in this study, the data-centric methods of three institutes are evaluated: Data-driven Process Structures of the University of Ulm, Product Based Workflow Design of the Eindhoven University of Technology, and Artifact-Centric Process Modelling of IBM Watson Research Laboratory. These methods were selected as the main data-centric BPM approaches by Diaz Garcia in his master thesis on the Evaluation of Data-Centric Process Modelling Approaches (Diaz Garcia, 2011).

Although the selected methods are leading examples, the field of data-driven process modelling approaches is still in its infancy; none of the previously named methods is widely accepted nor used. In order to test the users' perceptions (perceived ease of use and perceived usefulness) of the methods, Diaz Garcia provided participants with a brief description of the approach, followed by a set of models that were created using the method (Diaz Garcia, 2011). This thesis in contrast uses a more active approach: using an empirical setting, participants are provided with self-explaining tutorials, including examples and exercises. Using this hands-on experience, participants are better able to point out strengths and weaknesses of the different methods. Furthermore, a structured approach is used to extract the claimed strengths and weaknesses of the three methods from literature, enabling a comparison of the strengths and weaknesses claimed by the developers, with the ones perceived by participants of the workshops.

1.1 Research Goal

As briefly mentioned at the beginning of this chapter, three methods will be evaluated on both a theoretical and practical level: not only will the study be used to determine the functionality and added value *claimed*, but also how these aspects are *perceived* by users, in order to better understand and compare these different methods. The research goal can be formulated as follows:

> *Create a better understanding of both the claimed and the perceived strengths and weaknesses of Data-Driven Process Structures, Product-Based Workflow Design, and Artifact-Centric Process Modelling.*

In order to acquire an answer to this goal, three questions can be described:

1. What are the theoretical differences between the selected methods?
2. What are the modellers' perceptions towards the different methods?
3. What are the main strengths and weaknesses of the selected methods?

The first research question is addressed by performing an in-depth analysis (literature review) of the three different methods. Different quality attributes are used to take all important characteristics into account; a schematic overview helps in comparing the different methods.
In order to gather information on modellers' attitudes towards the different methods, a survey is set up to collect information on users' perceptions towards the method and specific aspects of this method. Using the Method Evaluation Model (Moody, 2003), information on the users' perceived ease of use and perceived usefulness is collected. Furthermore, a discussion will be used to acquire information on specific aspects of the approaches.

The final research question helps to define possibilities to improve different aspects of the selected methods. Using the results from both theoretical and empirical evaluation, strengths and weaknesses (e.g. in representation, number of models, complexity, et cetera) are considered. Knowledge obtained here can be used to propose improvements for the existing methods.

1.2 Research Design

Four main stages in the research design can be defined, which will be further explained in their corresponding subsections.

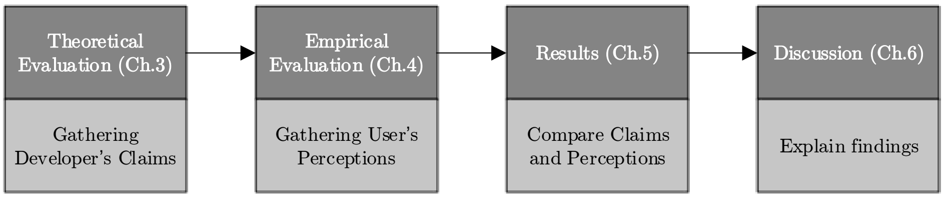


Figure 1 - Research Design

1.2.1 Theoretical Evaluation

In the first phase, which is described in Chapter 3, the available literature is studied in order to find claims made by the developers, regarding functionality or attributes of the method. Using a stepwise coding method, based on the Grounded Theory used in qualitative research, claims are gathered, coded, grouped in concepts, and finally allocated to one of five quality attributes: Functionality, Usability, Efficiency, Maintainability, and Flexibility. The result of the Theoretical Evaluation is a set of claims for each of the methods that indicates what is claimed in literature with respect to different quality attributes.

1.2.2 Empirical Evaluation

Though it is interesting to determine theoretical differences between the methods, this study in addition tries to determine what the *perceived* similarities and differences of the studied methods are. Therefore, a tutorial is created and respondents are gathered, in order to test the methods in an empirical setting. A total of three workshops is conducted; one for each of the methods. The workshops provide different sources of information: a questionnaire, the models created in the exercises, and a group discussion. In order to extract the information from this final source, again Grounded Theory Coding is used. The result of the Empirical Evaluation is a set of users' perceptions for each of the methods, which again are categorised using the five quality attributes.

1.2.3 Results

In the third phase, the results from the Theoretical Evaluation and the Empirical Evaluation are combined: the claims of the developers are compared to the participants' perceptions, in order to check whether or not they are consistent with one another. Though most of the important claims are addressed in the workshops, some of the claims were not provided any attention during the workshops; these claims therefore cannot be tested in this section. As a final point, participants' perceptions that are not captured in claims, will be mentioned at the end of a method's section, as these results might be interesting for the discussion.

1.2.4 Discussion

Whereas the third phase does not provide an interpretation of the obtained results, in the fourth phase such an interpretation is provided. Often the results of the Empirical Evaluation support the claims of the developers, obviating the need for an extensive discussion. In other cases however, claims might only be supported partially, or even contradicted by the results of the workshops. Especially when the outcomes of the Empirical Evaluation are counterintuitive, the discussion is used to provide possible explanations of the obtained results. In addition to the interpretation of the results and their causes for an individual method, the second part of the discussion makes a comparison of the different methods, identifying relative strengths and weaknesses of the methods to each other. Opportunities for improvement for each of the methods will be addressed here as well.

1.3 Structure of the Report

This document is structured as follows:

- *Chapter 2 - Preliminaries* introduces the Business Process Management discipline, three data-centric methods, Grounded Theory Coding, and the Method Evaluation Model.
- *Chapter 3 - Theoretical Evaluation* documents the process of the Theoretical Evaluation, selecting relevant articles and extracting the claims.
- *Chapter 4 - Empirical Evaluation* describes the Empirical Evaluation, the creation of materials for the workshops, and the extraction of information from the obtained data.
- *Chapter 5 - Results* documents the combination of the results of both evaluations.
- *Chapter 6 - Discussion* describes the interpretation of the results obtained in Chapter 5, and in addition makes a comparison of the three methods.
- *Chapter 7 - Conclusion* summarises the study, addresses the limitations of the study, and provides directions for future research.

2 Preliminaries

Before the actual study is reported upon, first some prior knowledge is considered. The concepts and theories used in this thesis will first be briefly introduced in this chapter. The chapter is structured as follows: first, some general information on BPM and, more specifically, data-driven modelling will be provided. Though briefly, this section addresses basic knowledge required to understand this thesis. After this general introduction, a more in depth view on three data-centric modelling methods will be provided: Data-Driven Process Structures (2.3), Product-Based Workflow Design (2.4), and Artifact-Centric Process Modelling (2.5), which together form the subject of this study, will be granted a closer look. The final topic addressed in this chapter is an evaluation method used in the empirical evaluation of this study.

2.1 Business Process Management

Although different definitions of BPM exist, (Van der Aalst, Ter Hofstede, & Weske, 2003) provide a very clear yet complete definition of BPM:

> *"Supporting business processes using methods, techniques, and software to design, enact, control, and analyse operational processes involving humans, organisations, applications, documents and other sources of information."*

When decomposing this definition, one sees that it involves business processes (what), methods techniques and software (how), to design, enact, control, analyse (why), involving humans, organisation, applications, documents and other sources (with whom). Although not included in the definition by (Van der Aalst, Ter Hofstede, & Weske, 2003), BPM is seen as a continuous process; a good design is never final, since environment and techniques continuously change (Hammer, 2010).

BPM helps to achieve both operational benefits (consistency, cost, speed, quality, service) and strategic benefits (flexibility, globalisation, merger, ERP implementation) (Hammer, 2010). Business Process Management provides the benefit that seemingly incompatible goals can be achieved by creating a new design for the process.

2.2 Process Modelling Perspectives

In (Diaz Garcia, 2011) a clear overview of different BPM perspectives and their goals is provided. The author distinguishes four different perspectives of process modelling, from which the last three tackle problems encountered by the first and most common modelling technique: the activity-centric approach.

Activity-centric Process Modelling: In this traditional type of process modelling, the set of activities that need to be executed, their relations and order of execution, are key concepts; workflow patterns are a well-known example of such an approach. The limitation of activity-centric approaches is the need of a highly structured process; when the process is more dynamic, only idealised models can be created (as accurate models become unmanageable), which merely

serve as idea rather than as concrete model. The lack of flexibility is the major problem concerning activity-centric process modelling approaches.
Data-driven Process Modelling: Data-driven or information-driven approaches are based on informational entities handled in a process, which are used as central driver for the design. As many different types of information entities exist or can be created by combining information into new entities, multiple data-driven approaches exist.
Organisational-based Process Modelling: This approach focuses on the different roles in the process, the actions that correspond with these different roles, and the interactions between roles which are required to achieve a certain business goal.
Goal-oriented Process Modelling: As indicated by the name, goal-oriented process modelling focuses on the ultimate goals instead of a focus on the path to achieve these goals. Goals are "statements which declare what has to be achieved or avoided in a company" (Kueng & Kawalek, 1997). Goals are decomposed into sub-goals which in turn can be directly allocated to activities.

This study will focus on Data-centric Business Process Modelling methods. In a preceding study, Diaz Garcia selected three methods that were renown, covered distinct groups of data-centric methods, and showed prominence of the data perspective (instead of relying on traditional activity-centric modelling techniques). Furthermore, from a practical point of view, he only selected those methods for which it was possible to directly inquire the promoter researchers. The three selected methods are the Data-Driven Process Structures, Product-Based Workflow Design and Artifact-Centric Process Modelling (Diaz Garcia, 2011). Each of these methods will be discussed in the following sections: section 2.3 will address the Data-Driven Process Structures of the University of Ulm and Daimler Chrysler, section 2.4 addresses the Product-Based Workflow Design from the Eindhoven University of Technology, and section 2.5 addresses the Artifact-Centric Modelling from IBM Watson Research Laboratory.

2.3 Data-driven Process Structures

Developed in a collaboration between the University of Ulm and Daimler, Data-driven Process Structures proposes a separation of the data structure on the one hand from process logic on the other. Modelling efforts can be reduced by increasing reusability and maintainability, facilitated by the separation of data and process logic.

2.3.1 Main entities

The data-driven process structures approach consists of two different levels: the model level and the instance level. Each of these two levels in turn consists of two models, resulting in a total of four models (Müller, Reichert, & Herbst, 2006), (Müller, Reichert, & Herbst, 2007).

Step 1. Definition of the Data Model Step 2. Definition of the Life Cycle Coordination Model	Model level
Step 3. Definition of Data Structures Step 4. Automatic creation of Data-driven Process Structures	Instance level

Data Model. The first model created is the *Data Model*. This model shows all object types incorporated in the model, as well as the relation types between object types. Object types often represent levels of hierarchy, such as system, subsystem, and part.
Object Lifecycles. Second step in the creation of a data-driven process is the creation of object lifecycles. Object lifecycles in data-driven process structures are, in contrast to lifecycles in the artefact-centric approach, not based on a specific object, but merely on an object *type*. For each object type specified in the data model, a lifecycle is created. When the object types defined in the data model are replaced by object lifecycles, and relation types are replaced by relations between lifecycles, one obtains the Lifecycle Coordination Model (LCM).
Data Structure. In the third step, a Data Model (as created in the first step) is instantiated: object types are replaced by actual objects (including name, type, ..) and the corresponding relations are drawn, thereby creating a *Data Structure*. It is possible that a subsystem is used by, though not included in, a system; this can be represented by the relations.
Data-driven Process Structure. The fourth and final step is the automatic creation of a data-driven process structure. Based on the LCM and the Data Structure, the generally defined lifecycles of the LCM can be instantiated using the objects defined in the data structure.

2.3.2 Example: Car Navigation System

To illustrate the described method, the method will be used to explain the addition of a navigation system to a car (Müller, Reichert, & Herbst, 2008). The release management (RLM), which systematically tests and releases different systems, subsystems, and components, requires several processes to be executed for each electrical component. These processes should be synchronised with processes of other components (test an assembly only after its components are tested individually). Note that the first two steps are performed by domain experts and are not specific for the navigation system, but for the automotive domain as a whole.

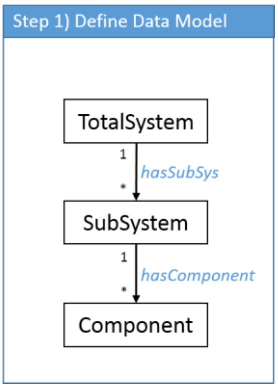


Figure 2 - Data Model

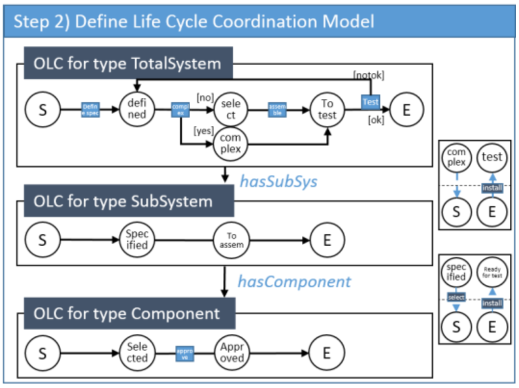


Figure 3 - Lifecycle Coordination Model

The first step is the definition of a Data Model by a domain expert, shown in Figure 2. As can be seen, three levels of hierarchy are defined: TotalSystem, SubSystem, and Component. There are only two different types of relations (*hasSubSys* and *hasComponent*) indicating that all SubSystems (Components) are related to the TotalSystem (SubSystem) in an identical way.

Figure 3 shows the Lifecycle Coordination Model: the object lifecycles and relations between these lifecycles. From this representation the link between the object type TotalSystem and the object lifecycle for TotalSystem, as well as its position in the hierarchy, immediately becomes clear. The relation types defined in the Data Model are also specified; the states of the different object types are connected to each other.

With the first two models defined, the model level is completed. The third model created is the instantiation of the Data Model, and is called the *Data Structure* (Figure 4). This level is the first level in which the Navigation System has a role: the navigation system is a SubSystem used in the TotalSystem (Car B), and includes the Main Unit as only Component.

Figure 4 - Data Structure

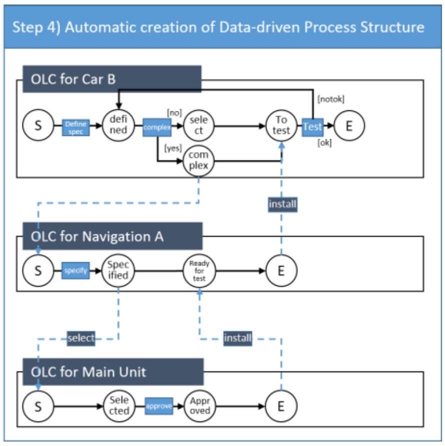


Figure 5 - Data-driven Process Structure

The final model created is the Data-driven Process Structure (Figure 5). This automatically generated model is constructed in a similar manner as the LCM in Figure 3; the objects of the Data Structure are replaced with object lifecycles, and the relations are added as well.

2.3.3 Remarks

The most beneficial aspect of Data-driven Process Structures is that changes can be made fairly easy: changing the product does not automatically imply a complete redesign of the process structure, but is driven by changes of the product's data structure; these changes are automatically mapped to adaptations of the corresponding process structure, thereby saving efforts when evolving the process instance structure. In addition, data-driven process structures can easily contain many elements as they are constructed automatically.

2.4 Product-based Workflow Design

The next method discussed origins from the Eindhoven University of Technology, and is named Product-based Workflow Design (PBWD) (Reijers, Limam, & Van der Aalst, 2003). Inspired by the manufacturing field and the Bill Of Materials (BOM), in which production, inventory management, and purchase management is driven by the structure of the product, PBWD proposes a similar approach for more data-intensive processes; using dependencies between data elements, workflow models can be created (Kamphuis, Vanderfeesten, Reijers, & Van Hattem, 2008), (Vanderfeesten, Reijers, & Van der Aalst, 2011).

2.4.1 Main entities

Product-based Workflow Design is inspired by the Bill Of Materials used in manufacturing; however, since some of the aspects of the BOM are unnecessary (for example, cardinalities), an adjusted model for data-centric processes, the Product Data Model, is created (Reijers, Limam, & Van der Aalst, 2003). The main entities of the PDM are discussed below.

Data Element. Represented as circles that contain the name of the object (or a letter representing this name), data elements are objects that contain specific information. Some elements are determined by the external environment ('leaf elements'), while other elements are determined by combining information of other objects. Once determined, data elements have fixed values (i.e. they cannot be updated). A special instance of a data element is the *Top Data Element*, for which the outcome has to be determined, it is the end product/final decision.
Production Rule. A production rule (represented by a black dot) is used to combine information of data elements to create a value for another element. In the provided example, information of data elements B and C is combined to create a value for data element A. Rules can be either concrete or abstract; for both types an example is provided.

- Concrete   A = 3 * B + C
- Abstract   Human judgment on suitability of A based on elements B and C

Attributes of Production Rule. Attributes provide information about other characteristics of activating the production rule. For example an identifier, cost and time can be provided.
Product Data Model (PDM). This is the main entity of PBWD. It provides a complete overview of the different data elements and their relations, as well as the according production rules.

2.4.2 Example: the Helicopter Pilot

This example shows the product data model that describes the process to determine someone's suitability to become a helicopter pilot (Reijers, Limam, & Van der Aalst, 2003). The top element is **A**, which corresponds to the suitability to become a helicopter pilot. Decisions are based upon psychological fitness, physical fitness (**B** and **C**), latest results of a suitability test from the last two years (**D**), and the quality of reflexes and eyesight (**E** and **F**).

As can be seen from the arrows leading directly to **a**, a decision can be made based upon a combination of psychological and physical fitness **{B,C}**, results of a previous test **{D}**, or **{F}** quality of eyesight. In a similar way, a value for **c** can be obtained using the results from **{E,F}**.

A decision (either positive or negative) can be made using one of the above described sets of data elements. However, to be able to choose the optimal path, additional information is required about time and cost. This kind of information is added to production rules; executing a production rule has a specified cost and time; the optimal path is determined by the selected optimisation criterion.

Using the model and its constraints, the best solution with respect to a performance indicator (cost, time) can be selected. For the leaf elements in this example (elements that are acquired from external environment) no attributes of the production rules are specified; one can consider the cost and time for creating these elements to be zero.

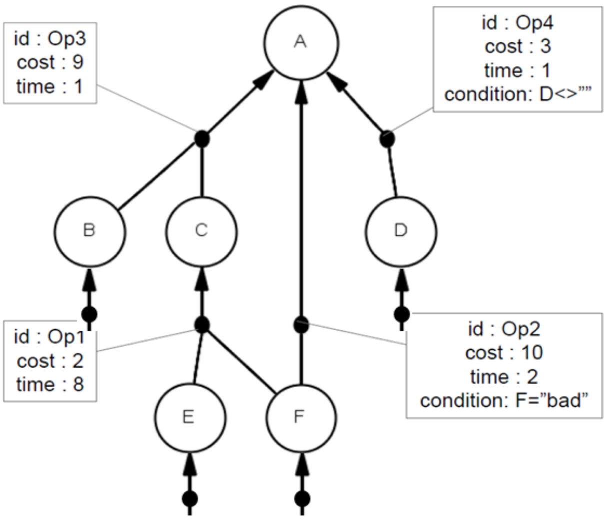


Figure 6 - Product Data Model

Using heuristics (Kamphuis, Vanderfeesten, Reijers, & Van Hattem, 2008) or by using the PDM directly (Vanderfeesten, Reijers, & Van der Aalst, 2011), a workflow can be created which is executable. However, both of these methods are not very sophisticated such that most often the PDM is used to obtain new insights in the process and is used as an aid in creating new workflow designs.

2.4.3 Remarks

Product-based Workflow Design proposes a true clean sheet method, only considering the actual data elements used in the process and their relations to each other. In addition, from the methods discussed, PBWD is the only one that is able to generate *optimised* processes. Limitation of the method is the required creation of a PDM, based on for example product specification, handbooks, production procedures, et cetera. Furthermore, the automatic generation of workflow designs is not yet refined, forcing manual creation of workflow designs. As a final comment, it can be seen as a limitation that data elements cannot be updated, making PBWD a more static method in this sense.

2.5 Artifact-centric Process Modelling

IBM's Artifact-centric Process Modelling approach for the design of data-centric business process models is based on the concepts of business artifacts and their lifecycles. By combining data and behavioural properties, an approach is developed that can be used to analyse, manage, and control business operations (Nigam & Caswell, 2003), (Bhattacharya, Gerede, Hull, Liu, & Su, 2007).

2.5.1 Main entities

In the Artifact-centric Process Modelling approach, five different types of entities can be distinguished: artifacts, a business artefact information model, lifecycles, services, and associations. Together these five are the Business Operations Model, the logical specification of business process execution.

Business Artifact. Concrete, self-describing, and unique entity that corresponds to a key data object. Artifacts have *attributes* that contain all information required for executing business processes. One of these attributes is an artifact's unique identity (ID) that cannot be changed; the other attributes of artifacts can be changed at will. An example of an artifact could be a customer, an invoice, or a task.
Business Artifact Information Model. Overview of all artifacts in a system, including their relations to each other and the corresponding cardinalities. In addition, attributes of artifacts are included as well. Business artifact information models can be described perfectly using Entity-Relationship (ER)-models.
Business Artifact (macro-level) Lifecycle. The lifecycle of an artifact provides its end-to-end process; it describes the states of an artifact from creation to disposal. Artifact may have different life expectancies: some live short, others long, and some are essentially permanent.
Service. Unit of work that is meaningful to the business process. Services make changes to one or more artifacts; these changes are transactional; the service has exclusive control over the involved artifacts when making changes. Each service can be decomposed in four properties, which define the actual service in a structured manner. The four key aspects are Inputs, Outputs, Pre-conditions, and Effects (IOPE). For all required changes, the artifact and attribute that are changed are specified. When an artifact changes state as a result of the service, this is defined here as well.
Association Rules. Changes made by services to artifacts are subject to a number of constraints. These constraints can be procedural (order of execution) or declarative (based on rules and properties) and are captured in rules. For each *association rule* an Event, Condition, and Action (ECA) are defined. When required, the person performing the action can be added as well ('By').

2.5.2 Example: the Restaurant Case

A brief example, based on Nigam and Caswell (Nigam & Caswell, 2003), is shown here to illustrate the described method. The example considers a restaurant case, in which the restaurant offers a menu consisting of different meal options (e.g. pasta, pizza), thereby offering the opportunity to specify some additional features of the meal option (e.g. sauce). Since the specified meals can be very diverse, the required ingredients are not always directly available; unavailable ingredients should be prepared first (e.g. cutting vegetables). For each customer the restaurant keeps a Guest Check, on which the different ordered goods and their prices are listed.

The first step in creating an artefact-centric process model is selecting all important artifacts and linking them to one another.

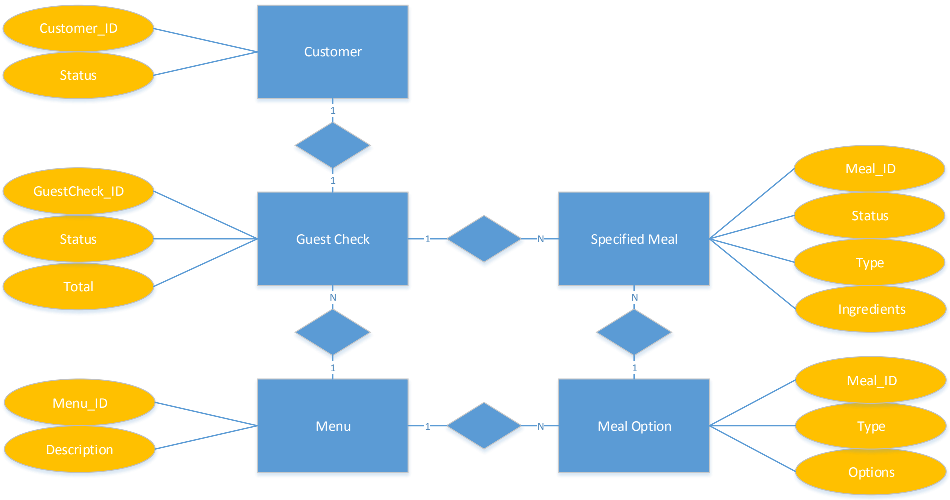


Figure 7 - Step 1 : Create Business Artifact Information Model

Figure 7 shows the five main artifacts that can be distinguished from the case description (blue rectangles). Where most artifacts are relatively straightforward, meal option and specified meal might require some explanation: on the menu, different meal options are specified. When a customer selects one of these meal options, he or she should directly make some choices regarding for example sauce and side dish; these choices are captured in the artifact specified meal, which in turn can be sent to the kitchen. Further note that all artifacts have different attributes (yellow ellipse), though *all* of them have an own, unique, identity (ID).

In the second step lifecycles of artifacts are created. The case description did not provide much information regarding the lifecycle of artifacts; therefore there is relatively much freedom in creating these lifecycles. The lifecycle of the artifact *Customer* will be explained in Figure 8; other lifecycles are created in a similar way. When a new customer enters the restaurant, he/she will be allocated to a table. The customer is offered a menu, from which a meal can be selected (or specified, referring to the names used in the artifact information model). A customer then waits for the meal to arrive and starts eating when it does. During or after eating, new meals and/or drinks can be ordered from the menu. If the customer is done eating, he or she asks for the check, pays, and leaves the restaurant.

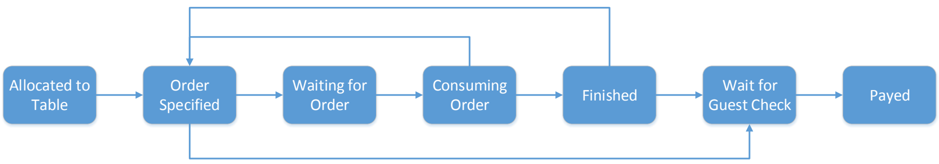


Figure 8 - Step 2: Create Artifact Lifecycles

When artifacts are defined and linked, and lifecycles are created, the third step is to define the *Services* that can change states and attributes of artifacts. In Table 1 the service *CreateCustomerProfile* is specified. As can be seen, no input artifacts are required; a *Customer* artifact is created when a new customer arrives that is not yet created in the system. This customer directly gets an ID and is put in state *Allocated to Table*.

Service	*CreateCustomerProfile*
Input	(none)
Output	Customer
Pre-condition	Customer is not yet created
Effects	- Define Customer ID - Define state of Customer (**Allocated to Table**)

Table 1 - Step 3: Create Services

Rule 1	*Register New Customer*
Events	Order is received
Conditions	Customer is not yet registered
Actions	Invoke CreateCustomerProfile

Table 2 - Step 4: Create Associations

The final step considered of artifact-centric process modelling is the creation of *Rules*. Rules determine when a Service is invoked: at a certain event, that meets specified conditions, the according action is performed. The rule stated in Table 2 specifies when service *CreateCustomerProfile* is invoked.

Four steps are currently defined in the creation of an artifact-centric process model. However, the final step performed did not directly lead to a process model; two additional steps can be performed that result in the actual creation of a process model, being i) Design of Conceptual Flow Diagram, and ii) Workflow realisation. These steps are considered too complex for inclusion in this thesis; in addition, as the other approaches also stop modelling at this point, this decision should not influence the evaluation.

2.5.3 Remarks

Artifact-centric process modelling provides overviews of all important artifacts and their relations. In addition, the use of lifecycles allows greater flexibility to artifacts, including revisioning, checks, et cetera. Services and associations clearly specify which artifacts and attributes are changed, in what situation, and what conditions should be met. Although very specific, this set of models and tables might result in a relatively complex method, especially when models become bigger (Bhattacharya, Gerede, Hull, Liu, & Su, 2007); in addition, the relations between all models and tables in this method even further increase its complexity.

2.6 Qualitative Research

With the methods under study discussed in the previous three sections, this section will focus on the qualitative research aspect of this study. As social changes in the world occur rapidly and frequently, traditional deductive methodologies are often difficult to apply. Instead of using deductive methodologies, which test hypotheses from theoretical models using empirical evidence, inductive strategies can often be applied; these inductive strategies do not start from theories and testing to quantify the problem, but try to explore or define the problem at hand; empirical data is used to develop theories for the topic of study.

An approach that is often used in qualitative research is the Grounded Theory. Using this methodology, one is able to extract information from different types of data (e.g. text, observations, illustrations, spoken word), using a stepwise approach. The next section will elaborate on Grounded Theory Coding, and the aspects relevant for this study.

2.6.1 Grounded Theory Coding

One research method which enables one to extract valuable information from text, observations, spoken word, et cetera, is the Grounded Theory (Glaser & Strauss, 1967), (Strauss & Corbin, 1998). Using a stepwise coding approach, this method is used to analyse data in order to develop one or multiple theories that are "*grounded in data*", i.e. are based on the data from the used sources. The method should not be seen as an attempt to create a single truth; it tries to conceptualise what is going on in the data (Flick, 2009).

It can be said that Grounded Theory operates in a reverse fashion from traditional social science research. Instead of formulating hypotheses and test them using the available data, data is obtained, coded, grouped, and finally categorised; the obtained categories can be used to formulate theories, or hypotheses.

Stage	Purpose
Codes	Identifying anchors that allow the key points of the data to be gathered
Concepts	Collections of codes of similar content that allows the data to be grouped
Categories	Broad groups of similar concepts that are used to generate a *theory*
Theory	A collection of explanations that explain the subject of the research

Table 3 - Different Levels of Coding

Four main phases can be determined (Flick, 2009):

1. Initial phase
2. Conceptual phase
3. Selective Phase
4. Reflexive phase

2.6.1.1 Initial phase

After the field and target population are selected and the required data is gathered, the first coding can be done. This open coding is not restricted in any ways, and is most often used to familiarise oneself with the data, creating a deeper understanding of the text (Flick, 2009). *Codes* are attached to the data, which are still closely related to the text; codes that are similar or even identical can be grouped into *concepts*, which are the basic building blocks of theories.

2.6.1.2 Conceptual phase

Using the codes and concepts determined in the initial phase, this second phase is used to define and refine *categories*, which are used to relate different concepts to a single category. While concepts are often self-describing, categories are more abstract descriptions.

2.6.1.3 Selective phase

In the selective phase, the categories defined in the second phase are evaluated, comparing the core concepts of a category to those of another. In this selective phase, *theories* can be formulated and checked against the data. As the different levels of coding (codes, concepts, and categories) are documented in a structured manner, the coding can be used for formulating different theories as well.

2.6.1.4 Reflexive phase

In the reflexive phase, the quality of the used methodology is evaluated. Two quality attributes are important in this evaluation: Reliability and Validity of the method. Both these quality attributes will be briefly discussed here, thereby addressing how to tackle possible problems.

Reliability. Two aspects regarding reliability are of importance. The first considers a clear separation of statements made by the subjects under study, and statements and interpretations made by the researcher. This distinction should be clear in order to create objective theories, theories that are really grounded in theory. Secondly, the methodology used to extract the information should be clearly and unambiguously defined, enabling others to trace the steps of the researcher.
Validity. The validity concept discussed here is procedural validity. Elaborating on the second aspect of reliability, which states that the used procedure should be clearly defined, procedural validity describes some concrete aspects. Wolcott defines nine important aspects of validity:

> *(1) The researcher should refrain from talking in the field but rather should listen as much as possible. He or she should (2) produce notes that are as exact as possible, (3) begin to write early, and in a way (4) which allows readers of his or her notes and reports to see for themselves. This means providing enough data for readers to make their own inferences and follow those of the researcher. The report should be as complete (5) and candid (6) as possible. The researcher should seek feedback on his or her findings and presentations in the field or from his or her colleagues (7). Presentations should be characterised by a balance (8) between the various aspects and (9) by accuracy in writing. (Wolcott, 1990).*

The main idea that becomes clear from these nine aspects, are that the researcher should try to limit his own input in the discussion, capture the statements of subjects as exactly as possible, and document the used approach completely and transparently. Validity is further increased if feedback is provided and used for improving the used approach.

2.7 Method Evaluation Model

Where research often focuses on validating statements, which are either supported or not, evaluating methods is far less straightforward, since they only have pragmatic value: instead of right or wrong, methods are merely effective or ineffective. In order to try and evaluate the design methods of information systems, (Moody, 2003) uses the Technology Acceptance Model

(TAM) as a starting point. TAM measures whether or not users accept the proposed technology; Moody adapts this model in such a way that is can be used to evaluate technology design methods.

The three main aspects of TAM are perceived ease of use, perceived usefulness, and intention to use. Perceived ease of use corresponds to the extent to which a person believes that using the particular system will be free of effort. Perceived usefulness corresponds to the extent to which a person believes that using the particular system will help achieve the intended objectives. Intention to use corresponds to the extent to which a user intends to use the particular system (Moody, 2003).

To measure the success of a method, two dimensions are proposed:

1. Actual efficacy: whether the method improves performance of the task
   a. Actual efficiency: how well are the achievements compared to the required efforts?
   b. Actual effectiveness: how well are the objectives achieved?
2. Adoption in practice: whether the method is used in practice.

Moody stresses the fact that although a model can be superior to another model, the model is 'unsuccessful' if it is not used in practice. A model which is used in practice but does not improve the performance of the task (or at least not significantly) can be considered unsuccessful as well.

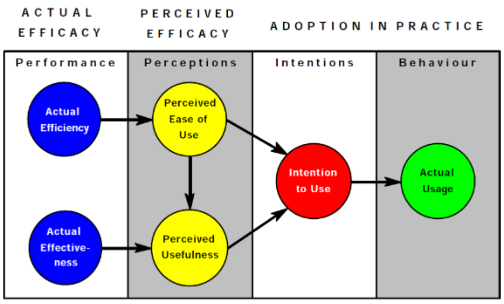


Figure 9 - Method Evaluation Model

3 Theoretical Evaluation

In this chapter, the Theoretical Evaluation will be described. The first section of this chapter addresses the definition of quality, and the selection of quality attributes. These definitions and selected attributes will be used in both the Theoretical Evaluation (described in this chapter) and in the Empirical Evaluation (described in Chapter 4). For all three modelling methods, literature is studied for statements made by the developers of the methods, which address aspects and attributes of the different methods. Using Grounded Theory Coding, as described in section 2.6.1, these statements are coded and grouped, resulting in a set of claims made by the developers; which is the end product of this Theoretical Evaluation.

3.1 Quality and quality attributes

Before any evaluation (Theoretical or Empirical) can be conducted, one should first define *quality,* and define and select *quality attributes*. The following two subsections address these definitions, which will be used in the Theoretical Evaluation as well as in the Empirical Evaluation.

3.1.1 Quality

Before defining different *attributes* of quality, a definition for quality is provided first. The IEEE Standard Glossary of Software Engineering Terminology (IEEE, 1990) proposes two alternative definitions:

1. The degree to which a system, component, or process meets specified requirements;
2. The degree to which a system, component, or process meets customer or user needs or expectations.

The first definition addresses the *specified requirements* of an entity, while the second focuses the customer's *needs and expectations*. In the Theoretical Evaluation the focus is on the specified requirements: capturing claims made by the developers, which address aspects and attributes of the methods. In this first evaluation, the quality attributes are only used to group the different aspects and attributes of the selected methods. The second evaluation, the Empirical Evaluation, focuses on the users' perspective (capturing the needs and expectations of the users), thereby addressing the second definition of quality.

3.1.2 Quality attributes

The ISO/IEC 9126 *(Software Engineering - Product Quality)* is an international standard for the evaluation of software quality. Though the evaluation considered in this report is not directly a software quality evaluation, the ISO standard provides a great starting point for evaluating conceptual modelling methods. The six different quality attributes distinguished by ISO/IEC 9126, being functionality, reliability, usability, efficiency, maintainability, and portability, will be briefly addressed, providing short definitions of these attributes as used in the IEEE Standards. As already mentioned, not all concepts described in ISO/IEC 9126 are directly useful for this evaluation. Since the selected concepts are normally considered in a software environment, some of the selected attributes relate specifically to software, and are not suitable for evaluating a conceptual modelling method. The attributes that not suit conceptual modelling will be discussed first.

Reliability, specifically in its provided definition of "a system performing under stated conditions for a specific period of time", is not considered, since the actual creation of a system or model is outside the (selected) scope of the method. Using the same reasoning, portability ("the ease with which a system or component can be transferred from one hardware or software environment to another.") can be left out as well.

An important attribute that is not incorporated in the ISO/IEC 9126, but that might be interesting for this study, is *flexibility*. Although flexibility is to some extent related to portability, it better fits the quality of process modelling methods. Flexibility is defined by the IEEE as "The ease with which a system or component can be modified for use in applications or environments other than those for which it was specifically designed." (IEEE, 1990). The flexibility attribute thus takes into account whether the approach is usable in a variety environments, or that it is constrained to specific environments or domains.

The complete list of quality attributes selected for this study can be found in Table 4.

Quality attribute	Definition
Functionality	A defined objective or characteristic action of a system or component.
Usability	The ease with which a user can learn to operate, prepare inputs for, and interpret outputs of a system or component.
Efficiency	The degree to which a system or component performs its designated functions with minimum consumption of resources.
Maintainability	The ease with which a software system or component can be modified to correct faults, improve performance or other attributes, or adapt to a changed environment.
Flexibility	The ease with which a system or component can be modified for use in applications or environments other than those for which it was specifically designed.

Table 4 - Selected Quality Attributes

3.2 Claims by Developers

Literature of the selected methods is explored for quotes made by developers regarding aspects and attributes of their method. These quotes are coded and grouped using Grounded Theory Coding, after which claims can be defined. These claims are used to create a mapping of the selected methods to each other; such a mapping is essential for a fair comparison, as the methods differ in origin, use, and goal.

The selection of articles will be discussed in section 3.2.1, the coding process will be discussed in section 3.2.2, and the acquired claims are provided in section 3.2.3. Finally, section 3.2.4 explains how the table of claims can be used in the comparison of methods.

3.2.1 Selecting Articles

An important aspect of this Theoretical Evaluation is the selection of articles, as it determines the quality of claims as well as the maximum number of claims extracted. Note that a large number of claims not necessarily implies a 'better' method; additional claims merely indicate that more is studied (or at least claimed) by developers.

Method	Year	Article	# Cited
DDPS	(2007)	Müller, D., Reichert, M., & Herbst, J. (2007). Data-Driven Modeling and Coordination of Large Process Structures. *Lecture Notes in Computer Science, 4803*, 131-149.	68
	(2008)	Müller, D., Reichert, M., & Herbst, J. (2008). A New Paradigm for the Enactment and Dynamic Adaptation of Data-Driven Process Structures. *Lecture Notes in Computer Science, 5074*, 48-63.	59
PBWD	(2003)	Reijers, H., Limam, S., & Van der Aalst, W. (2003). Product-Based Workflow Design. *Journal of Management Information Systems, 20*(1), 229-262.	120
	(2011)	Vanderfeesten, I., Reijers, H., & Van der Aalst, W. (2011). Product-Based Workflow Support. *Information Systems, 36*(2), 517-535.	48
ACPM	(2003)	Nigam, A., & Caswell, N. (2003). Business Artifacts: An Approach to Operational Specification. *IBM Systems Journal, 42*(3), 428-445.	218
	(2007)	Bhattacharya, K., Gerede, C., Hull, R., Liu, R., & Su, J. (2007). Towards Formal Analysis of Artifact-Centric Business Process Models. *LNCS*, 288-304.	146

Table 5 - Articles Used for Claims

The following approach is used to determine the set of articles. First, the names of the different methods were inserted in the Google Scholar search engine. The articles that indeed related to the methods targeted in this study (using knowledge from previous search attempts, authors, and abstracts) were selected and sorted in a decreasing order of times cited. For each method, the two articles that were cited most were used as input for the Theoretical Evaluation. An exception is made for (Vanderfeesten, Reijers, & Van der Aalst, 2011): while (Vanderfeesten, Reijers, & Van der Aalst, 2008) was cited more often, it considered a conference proceeding, while another article from the same authors and with a (nearly) identical title was published in a journal. Table 5 provides an overview of the selected articles.

3.2.2 Coding the Articles

The articles selected in section 3.2.1 are studied and directly *coded*; codes capture the essence of quotes from the articles. This first 'open coding' helps understanding the article, while at the same time it initiates the coding process. Similar or identical codes can be grouped into *concepts*; these collections of codes describe the underlying idea of multiple codes. The final level in this coding hierarchy is obtained when similar concepts are grouped in order to obtain *categories*. Categories are special in this study, as they correspond to the quality attributes selected in section 3.1.2. For each of these categories (or 'quality attributes'), *theories* ('claims') can be defined, using the different levels of coding as a guide. An overview of the used hierarchy of coding is provided in Table 6.

Level	Purpose
Quote	Direct statements made (often text or recording)
Codes	Capturing essence of quote, noise removed
Concepts	Collections of codes of similar content, capturing its underlying idea
Categories	Groups of related concepts; in this study, categories correspond to *Quality Attributes*
Theory	Idea of what is actually going on in the data; in this study, theories correspond to *Claims*

Table 6 - Hierarchy of Coding

Using this transparent approach, claims can be derived from text, while remaining all original information intact. The coding process is not only used for identifying internal similarities in a method; formed concepts can also be used externally, identifying topics addressed in multiple methods. The resulting set of claims for each method is grounded in literature, and can be used in the evaluation and comparison of the three data-centric methods. Please note that this theoretical evaluation itself is not intended to judge or rate the methods; its most important goal is to create a mapping of the methods to each other, thereby providing a basis for a fair empirical evaluation.

3.2.3 Acquired Claims

Table 7 contains all claims that were extracted from the literature, clustered to their corresponding quality attributes; note that this clustering neither adds nor removes information, as it merely proposes an order of representation of the selected claims. The original coding tables can be found in Appendix D (DDPS), Appendix E (PBWD), and Appendix F (ACPM). In order to enhance understanding of the set of claims provide in Table 7, some examples and interesting parts of the table will be highlighted.

From Table 7 one can for example deduce that with respect to Efficiency, all methods allow multiple instantiations of their models (see **D6**, **P8**, and **A7**). While Product-Based Workflow Design mentions the creation of different process models based on different optimisation criteria, Artifact-Centric Process Modelling and Data-Driven Process Structures stresses the specification and instantiation of generic schemas with multiple customisations.

The claims that are allocated to Flexibility even show greater similarities; all developers claim that their method is applicable in other domains, though the developers of PBWD temper this by stating that a clear concept of the product should exist (claim **P11**).

Not all claims made by the developers are purely positive claims. For example claim **D5** (attribute: Usability) addresses that experts should require profound business knowledge in order to be able to create the models used in the approach; this could be explained as negative, as creating the models becomes a task that can only be performed by some experts. It should therefore be noted that once these claims will be tested, one should carefully take into account whether the support/contradiction considers positive or negative statements.

The set of claims that is provided in Table 7 is most importantly intended to be in accordance with the selected literature; it might be that additions to this table could be made when additional articles were selected, or when the developers themselves were asked to provide input based on the given quality attributes. However, as the used articles were selected with great care and the claims were extracted in a comprehensive and structured manner, the set of claims should be at least representative.

		METHODS				
		Data-driven Process Structures		**Product-Based Workflow Design**		**Artifact-Centric Process Modelling**
FUNCTIONALITY -Goal of method	**D1**	Data-driven modelling of large process structures; ensuring correct coordination, reducing modelling efforts, and providing mechanisms for maintenance.	**P1**	Method that (re)designs a process reasoning from the desired outcome, without directly discussing how to achieve it.	**A1** **A2**	Representation usable by business people to analyse, manage, and control business operations Substantial new insights can be acquired by managers
-How to achieve goal	**D2**	Separation of data and process logic, leading to an enact able process structure	**P2**	Analytical, clean sheet approach: rational and quantitative way of deriving an optimised process design.	**A3**	Declarative approach, that incorporates formality required for rigorous design and analysis
-IT Support	**D3**	IT Support for automated creation and soundness checks	**P3**	PDM (in)directly used to steer workflow: basis for process model.		
USABILITY -Understandability			**P4** **P5**	Created models are accepted by end users as valid and workable. Based on existing concept (BOM)	**A4** **A5**	Intuitive appeal to business managers, somewhat foreign to business process professionals Based on existing methods and techniques
-User: ease of use	**D4**	Intuitive integration of data and (sub-)processes enables users to instantiate and adapt model without process knowledge (by adapting data structure at a high level of abstraction).				
-Expert: ease of use	**D5**	Process experts require profound domain knowledge to create data model and LCM.	**P6** **P7**	Efforts required to collect data for PDM differs for every company. Constructing PDM is manual task	**A6**	Identifying artifacts is an iterative process that requires understanding of entire business process.
EFFICIENCY -Multiple instantiations of models	**D6**	Instantiating different data structures and generating the respective data-driven process structures	**P8**	Using different optimisation criteria, different process models can be created.	**A7**	Enabling specification of generic schema with multiple customisations.
-Automated creation	**D7**	Automated creation of Process Structure	**P9**	Algorithms and PBWS can be used to automatically generate process models or recommendations for carrying out operations.		
-Reusability	**D8**	Standardising processing of objects in order to increase the reuse of process models and reducing modelling efforts.				
-Reduce modelling efforts	**D9**	Separation of data and process logic results in a reduction of modelling efforts.			**A8**	Separation of data management concerns from process flow concerns
-Optimising process			**P10**	Optimisation of the process by including optimisation criteria.		
MAINTAINABILITY -Changing models	**D10**	Changes can be made at data-level (during either build time or runtime) and are automatically translated into corresponding adaptations of the process			**A9**	Changes can be made to conceptual flow and business workflow, while preserving the same Business Operations Model.
FLEXIBILITY -Other environments	**D11**	Usable in other environments, not specifically the engineering domain.	**P11**	Restricted to fields where clear concept of the products to be delivered exists.	**A10**	Usable in other environments, particularly in the use of consumed and non-consumed goods.

Note: for the derivation of the quotes and the corresponding articles, see Appendix D (DDPS), Appendix E (PBWD), Appendix F (ACPM).

Table 7 - Theoretical Evaluation: Claims by Developers

3.2.4 Comparison

Table 7 can be used to compare the methods. Using the categories and concepts in the left column, one can pick a concept that is addressed by multiple methods, and compare the methods on that concept. The high level description of the concept enables the comparison between methods. It should however be noted that the identified claims merely address the same *concept;* the exact *contents* of the claims might be different.

An example is provided in order to illustrate the described approach. Suppose one wants to know whether models should be created by hand or can be generated automatically. At the header Efficiency, one will find 'Automated Creation', and will see that at least to some extent the Data-Driven Process Structures and the Product-Based Workflow Design claim to provide some automated creation possibilities (and hence can be compared).

Two important notes should be made regarding the use of Table 7. Firstly, one should note that the concepts are defined using the selected articles. Therefore, the list of concepts might not be complete: the concepts should only be seen as a classification of the identified claims, an aid in reading the table and identifying similarities and differences. The second aspect to consider is that an empty cell in Table 7 does not necessarily imply that the method does not have any initiatives regarding this concept; the concept is merely not discussed in the selected articles. Though the selected articles should provide an objective and representative set of claims, it is possible that specific concepts are not addressed in the selected articles, and thereby not captured in Table 7.

4 Empirical Evaluation

For the Empirical Evaluation of the three methods, workshops are used to acquire peoples' perceptions and opinions about the selected methods. A total of three workshop sessions is conducted; in each of these sessions one of the methods is studied and discussed, thereby obtaining the participants impressions of the method.

This chapter addresses the approach used for this Empirical Evaluation, and is structured as follows: first, in section 4.1, the used methodology is discussed. Next, in section 4.2, the actual results of the Empirical Evaluation are provided. In Chapter 5 these results will be combined with the results from the Theoretical Evaluation.

4.1 Methodology

The three methods are evaluated in a workshop setting. The idea of these workshops is to provide participants with a tutorial of one of the methods, which the respondents have to study. Hereafter, a brief questionnaire is filled in, capturing participants' first impressions, followed by a group discussion in which different strengths, weaknesses, ambiguities and improvement opportunities are discussed among the participants. The workshop sessions conclude with discussing the solutions of the exercises. In addition to the three workshops, people unable to attend at one of the sessions were given the possibility to participate digitally, thereby only participating in the first two steps (the tutorial and questionnaire). See Figure 10 for an overview of the layout of the workshops.

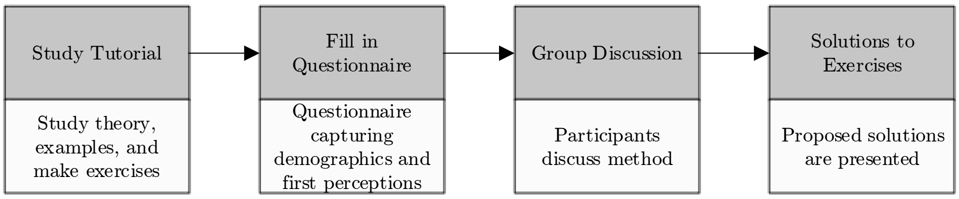


Figure 10 - Overview of Workshop Structure

In each of this chapter's following subsections, the different elements of the workshops are studied in greater detail: the tutorials (section 4.1.1), questionnaire (section 4.1.2), discussion questions (section 4.1.3), respondents (section 4.1.4), the workshop setup (section 4.1.5), and finally the approach to extract results from the discussion (section 4.1.6).

4.1.1 Tutorials

In order to provide the participants with sufficient knowledge to evaluate the different methods, tutorials are created that should be clear and correct. The goal of the tutorials is not to provide a complete manual for the methods; instead it should be seen as a first introduction to the method, showing its ideas and opportunities. The tutorials are created to be self-explaining; no input of the researcher during the workshops is required.

A first draft of the tutorials is created based on the existing literature. The tutorials are then revised by developers of the method, thereby ensuring that the contents of the tutorial are correct. After adjustments are made and additional information received from the developers is included, two master students are asked to study the tutorials in order to identify any existing unclear sections or figures, which are then adapted or removed as well. The resulting tutorials are in this way approved on both content and understandability.

The tutorials are created using the following structure. First, a general description of the method is provided, defining the goal and approach used in the method. Next, the main concepts of the method, including all entities, models, and tables created, are described. An example is then used to illustrate the method, followed by a number of exercises to get some hands-on experience. This last part of the tutorial, that contains the exercises, is also used as information source for the empirical evaluation. The complete tutorials can be found in Appendix A (DDPS), Appendix B (PBWD), and Appendix C (ACPM).

4.1.2 Questionnaire

A brief questionnaire is created that should be filled in directly after the tutorial is completed. The questionnaire consists of two parts: the first part addresses demographic traits of the participants and their experience with process modelling. These questions are based on the demographic questionnaire as used in the Cheetah Experimental Platform (Pinggera, Zugal, & Weber, 2010). Cheetah Experimental Platform is developed in order to foster experimental research on business process modelling; it enables the quick assembly of workflows, and in addition can include questionnaires, used for capturing additional data (e.g. demographic data). The questionnaire used for obtaining this demographic data, was provided by one of Cheetah's experts. This part of the questionnaire provides insights into the composition of the group of participants, as well as into their previous experience with modelling and with different modelling methods.

The second part of the questionnaire focuses on the first impressions regarding perceived ease of use, perceived usefulness, and intention to use, as proposed in (Moody, 2003). This section of the questionnaire thus captures the respondents' first impressions of the method, before discussing any of the methods' aspects with the other participants. It thereby provides a good impression of the respondents' perceptions of the method, based on the tutorial alone. The complete questionnaire can be found in Appendix G.

4.1.3 Discussion questions

After the tutorial and questionnaire, discussion questions are proposed to share and discuss ideas among the participants. As the participants in a single workshop session all received an identical tutorial, they can discuss their own interpretation of any ambiguities present. The discussion will thereby capture the interpretations of the participants; the way they think the method is intended or should function best. In order to facilitate a structured analysis, all discussions are recorded such that they can be literally analysed in a later stadium.

The questions addressed in the discussion are the following:

1. Were there unclear sections regarding method or application of method?
2. What do you think are strong points of this approach?
3. What is in your opinion a limitation or weakness of this approach?
4. Was the method complete? What was lacking?
5. How versatile do you think the method is?
6. Do you have any suggestions for improving the method?

Though the questions are stated here as a list of things to be discussed, the discussion was semi-structured; the statements were shown on a slide as a guideline for the discussion, a set of interesting topics to address. A semi-structured discussion enables participants to elaborate on their responses, disclosing important and often hidden perceptions (Qu & Dumay, 2011); it is in this sense very useful for obtaining users' perceptions.

4.1.4 Participants

The participants for the workshops were volunteers gathered from the mailing list of the BPM Round Table Eindhoven[1]; this is a group of business professionals and academics with an interest in business process management and modelling. It should be noted that members of this mailing list are merely interested in the subject, not necessarily experts in process modelling. However, as the participants volunteered, most of them are likely to have at least some experience in the modelling of processes and an interest in data-centric modelling approaches.

All members of the mailing list received an email with an invitation for the workshop. After a reminder was sent, a total of 26 positive responses was received: fourteen respondents that were able to participate in the workshop sessions and twelve participants willing to attend the digital sessions. The fourteen respondents that were able to attend at the workshops were allocated to one of the sessions. Due to planning restrictions, these initial groups differed in size; six graduate students were therefore asked to complement the groups such that each workshop session contained six or seven participants. The professionals that registered for digital participation were distributed evenly over the three sessions (four digital participants for each of the methods).

4.1.5 Workshop setup

Three different workshop sessions are conducted; one for each of the selected methods. All these workshops have an identical outline. First, the tutorials are handed out and studied by the participants. The tutorial and the corresponding exercises are self-explaining, individual assignments; no questions regarding contents can be asked. After completing the tutorial, the questionnaire (see section 4.1.2) is handed out in which a first evaluation of the method is made. Next, the participants discuss any present ambiguities, strengths, weaknesses, and possible improvement opportunities. This discussion is recorded, to be able to analyse it in detail in a later stadium. The session ends by showing the participants the solutions as proposed by

[1] For more information on the BPM Round Table: http://bpmroundtable.nl/

the developers of the method. Digital participants only participate in the first two steps; they cannot join the discussion and are not provided with proposed solutions.

4.1.6 Extracting Results from Discussion

Whereas the questionnaire includes clear variables and constructs, these variables and constructs are less prominently present in the discussion. In order to extract the information from the recording of the discussion, several steps were made to quantify the information included in the discussion.

The first step in extracting users' perceptions from the data, is the creation of an excerpt of the discussion, which is based on the recordings of the discussions. Though not identical to a transcript, which is a written record of spoken language, the excerpt serves an identical purpose. It can be seen as a set of quotes made by the participants, capturing their statements and responses to each other. Each quote is identified by a number, which can be used to relocate the specific quote.

After the quotes are captured, Grounded Theory Coding is used to code these statements in a structured manner. Using an approach similar to the one used for the extraction of claims from literature (discussed in section 3.2.2), codes are used to capture the essence of the quotes. As multiple codes might address the same quality attribute, codes are categorised to the different quality attributes defined in 3.1.2. This grouping of coding is a subjective task; some of the quotes could have been allocated to another attribute as well. However, no information is lost due to the mere fact that the division does not add or remove any information from the table; it only provides an overview of the quotes extracted from the discussion and their location in the table. An overview of the extracted results of the discussion can be found in Appendix I (DDPS), Appendix J (PBWD), and Appendix K (ACPM).

4.2 Results

Results obtained in this empirical study are obtained from three different sources. The first information obtained is received from the questionnaire, filled in by all respondents individually. In addition to the information obtained from the questionnaire, the results extracted from the discussion provide another source of data. The final source of information can be found in the exercises that were included in the tutorials.

The next subsections are divided in an identical way. First all information obtained from the questionnaire is provided, for each of the three methods. In section 4.2.2 the results extracted from the discussion will be addressed, again for all methods separately.

4.2.1 Results of Questionnaire

In this subsection the results of the questionnaire are considered. The first part of the questionnaire includes demographic questions for the participants, as well as some questions regarding their modelling experience. The second part of the questionnaire addresses the participants' first impression towards the method. Using the Method Evaluation Model (Moody, 2003), as described in section 2.7, the participants' perceptions towards ease of use, usefulness, and intention to use, are considered.

User demographics. The participants of the workshop sessions were business professionals as well as students, invited via the mailing list of the BPM Round Table. A total of 29 people were willing to participate (93% male); 20 professionals and 9 students. Of these participants, 9 were novices in modelling, 15 intermediates and 5 experts. Other demographic details can be found in Appendix O.

User perceptions. Although the used questionnaire and its constructs are already tested by Moody for their validity and reliability (Moody, 2003), an additional check is performed in this study to verify the results obtained by Moody. This ensures that the results from this study are in accordance with the study performed by Moody, before conclusions are drawn from the acquired data.

4.2.1.1 Validity

The questionnaire used to acquire information on the perceived usefulness, perceived ease of use, and intention to use, is constructed and validated by Moody (Moody, 2003). Unfortunately, the number of participants in this study is far below the minimum requirements for conducting a factor analysis (rule-of-thumb is 200 participants, (Field, 2005)), which therefore cannot be performed. For this reason, the validity of the questionnaire is not checked.

4.2.1.2 Reliability

As already mentioned, the relatively small sample size hinders the use of a factor analysis for checking the validity. Calculating the reliability of the components is however possible using a relatively small sample size. For each of the constructs, a reliability analysis is conducted, using Cronbach's alpha. Cronbach's alpha measures how much of the variation in a scale is due to systematic rather than due to measurement error. For the three constructs tested in the questionnaire the following values were obtained for Cronbach's alpha.

Construct	# items	Cronbach's alpha
Perceived Ease of Use	6	0,771
Perceived Usefulness	7	0,742
Intention to Use	2	0,522

Table 8 - Cronbach's alpha

In literature a score for Cronbach's alpha above 0,7 is often considered acceptable (Field, 2005); the score for Intention to Use is below this rule-of-thumb cut-off point. This low score for Cronbach's alpha indicates a systematic error; furthermore, as the scale only consists of two items, it is impossible to delete an item that causes this low score for Cronbach's alpha. The scales "Perceived Ease of Use" and "Perceived Usefulness", which have a value for Cronbach's alpha greater than the cut-off point, will be evaluated in the following section. The value obtained for "Intention to Use" is below this cut-off point; "Intention to Use" is therefore omitted from further analysis.

4.2.1.3 Scores

Since the number of participants was relatively low, it is difficult to detect significant differences between perceived ease of use and perceived usefulness for the different methods. An impression of the participants' responses to the questionnaire (or better, the tutorial), can be provided using a boxplot (Figure 11 and Figure 12).

From the boxplot it can be seen that PBWD is perceived as most easily usable; nearly 75% of the participants rated the ease of use with a score above three (which is the score for 'neutral'). DDPS scores worst on perceived ease of use, with over 75% of the respondents giving a score below three. Interestingly, DDPS scores relatively high on perceived usefulness. PBWD, which is perceived as relatively easy to use, in turn scores worst on the perceived usefulness. The Artifact-Centric approach has a median score above three for perceived usefulness, though the scores are ranging from less than two to four.

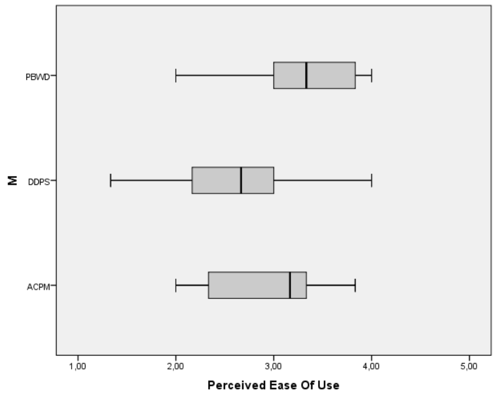


Figure 11 - Perceived Ease of Use

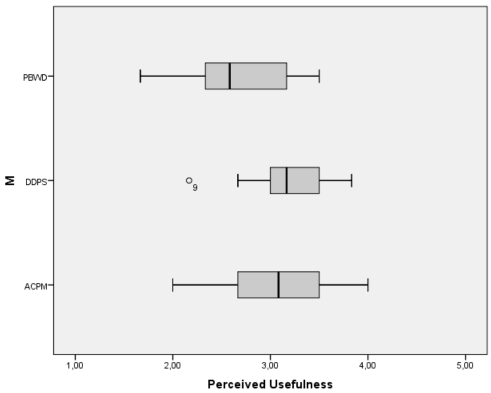


Figure 12 - Perceived Usefulness

In order to check whether or not students structurally provided different answers in the questionnaire, separate boxplots are generated for students and experts (Appendix H). The most interesting differences were perceived at DDPS, which contained a relatively large number of students. After checking whether or not these differences were significant (see Appendix H) it can be concluded that these differences were not. Therefore, all participants were included in the further evaluation.

4.2.2 Results of Discussion

The second data source considered is the group discussion. As explained in section 4.1.6, the recorded discussion is coded using the Grounded Theory, thereby extracting the users' perceptions towards the method in a structured and objective manner.

After coding the quotes from the discussion, stating whether they were positive (+), negative (-), or neutral/undecided (±) in nature, and grouping them to their corresponding quality attribute (see section 4.1.6), a table is created for each of the three methods that contains this information. For each of these tables a brief description per quality attribute is added, identifying main issues discussed. The overview of perceptions from the participants of the workshops can be found in Table 9 (DDPS), Table 10 (PBWD), and Table 11 (ACPM).

4.2.2.1 Data-Driven Process Structures

		Label	Quotes
Functionality	+	Controlling workflow using data	12, 27, 28, 36, 38
	–	Missing details: roles, triggers, process view, origin of data	45, 56, 64, 65, 66, 67
Usability	+	Hierarchy improves readability	31, 51, 53
	+	Increased understanding by using existing concepts/methods	46, 60
	+	User only has to instantiate data model	14, 16, 20
	±	System boundaries should be clearly defined	25, 39, 47, 49
	±	Abstract model should fit concrete situations	6, 9, 10, 13, 17, 21
	±	Fit of completeness and readability[1]	32, 33, 41
	–	Unclear overview: large models	34, 35, 37, 40, 52
	–	Business analyst requires profound business knowledge	22, 23
	–	Abstract models for analysts: too complex for users	1, 3, 4, 7, 8, 19, 63
Efficiency	+	Automated generation of workflow	15, 54, 62
	+	Reusability of models	29, 42, 43, 59
	+	Separation of data and process logic	44
Maintainability	+	Adaptation of model in one place	11, 30, 57
	+	Automatically translate adaptations into a new process	55, 58
Flexibility	+	Generic model	26, 61
	+	Usable in other environments	5, 26, 50, 61

1. Though represented at usability, this label also refers to functionality: balancing completeness (functionality) and readability (usability)

Table 9 - Overview Discussion: Data-Driven Process Structures

Functionality. Controlling the workflow, and invoking sub processes according to specific states, is a positively evaluated aspect of functionality. A negative aspect addressed the limited details incorporated in the models, which are perceived as vital for the creation of workflows.
Usability. Hierarchy is perceived as one of the major benefits of the method: it improves readability and enables reasoning using abstract models. Furthermore, known concepts are incorporated in the method, which are easily recognised by users. Creating the Data Model and LCM is done by an expert, while a user should be able to instantiate the Data Model. However, the abstract model Data Model is perceived too complex for users, making instantiation difficult. In addition, the definition of a generic Data Model suitable for all different situations, is perceived as difficult as well. The final remark addresses the automatically derived Process Structures: these models quickly become unreadable and chaotic.
Efficiency. The most often mentioned perceived aspect of efficiency is the automated generation of a workflow. Modellers only need to define the Data Models and an LCM, and based on the Data Structure (defined by the user) and the LCM, a model is generated. In addition, Data Models and OLCs can be easily reused, which is efficient as well.
Maintainability. Adaptations to the model, both in processes and data elements, can be made in their corresponding place. This reduces the risk of errors compared to systems in which a single change has to be made in several places. Furthermore, as the model is generated automatically, these adaptations can be automatically translated into a new process design.
Flexibility. The method is applicable in many different environments. The generic structure can be seen as one of the major advantages for use in different environments.

4.2.2.2 Product-Based Workflow Design

		Label	Quotes
Functionality	+	PDM basis for redesign: orderless, insights in indirect processes, and benefits in large processes	14, 22, 26, 27, 28, 29, 33, 58, 64, 66, 72
	+	Explicitly defined rules	41, 73
	±	PDM is no end product	21, 34, 39
	–	Missing details: input, roles, triggers, different views	7, 40, 62, 65, 69, 74
Usability	+	Business analyst creates PDM	13
	+	PDM understood by customer	35, 36
	+	Increased understanding by using existing concepts/methods	60, 71
	±	Fit between completeness/understandability	4, 31, 53
	±	Alternative approaches could reduce complexity of PDM	3, 5, 46, 48, 49, 55
	–	Abstract models for analysts: too complex for users	32, 37, 44, 61
	–	PDM does not help reasoning	19, 25
	–	Difficulties in use: alternative paths, orderless, rules, tables	1, 9, 43, 47, 59, 63
	–	Unclear overview: direct/alternative paths, large models	2, 30, 52, 54, 56, 57
Efficiency	+	Optimising: order, cost, and time	15, 16, 17, 18, 20, 23, 24, 42, 67
Maintainability			
Flexibility	+	Usable in other environments	38, 70
	–	Practical problems less straightforward	11, 12

Table 10 - Overview Discussion - Product-Based Workflow Design

Functionality. A PDM can be seen as a basis for redesign; the mapping of required and explicitly defined operations and data elements provides valuable insights for businesses. Note that the creation of a PDM is not a goal on its own; it should be used as a basis for redesign (e.g. optimising a workflow). As a PDM is sequence independent, an objective optimisation can be performed. Some comments were made regarding the limited details used in a PDM.
Usability. Alternative paths which are required for the completeness of a PDM, add additional links between operations and elements; the overview of a PDM becomes blurred by these alternative routings, and the readability of the PDM decreases as well. Alternatives were proposed to reduce the effect of alternative routings. Regarding usability for the client, no consensus was reached; it is unclear whether or not business professionals are able to understand a PDM and use it for reasoning, without intensive training.
Efficiency. PBWD offers opportunities to optimise the process. The PDM is based on the structure of the product and not the existing process; this objectivity ensures that only required operations are included, thereby optimising cost, time, etc.
Maintainability. In the discussion, maintainability was not addressed.
Flexibility. According to the participants, the method is applicable in almost every domain. However, to some participants it is unclear how problems in practice can be modelled using this method.

4.2.2.3 Artifact-Centric Process Modelling

		Label	Quotes
Functionality	+	Structured method: capturing knowledge, roles, and rules	12, 15, 16, 33
	+	Interaction of artifacts and lifecycles: communication, workflow	18, 19, 20, 24, 29, 39
	+	Hierarchy of artifacts possible	26
	+	New insights in process	8, 11, 28, 46
	–	Missing details: input, output	36, 40
Usability	+	Increased understanding by using existing concepts/methods	45
	±	System boundaries should be clearly defined	1, 2, 3, 6, 27
	–	Abstract models for analysts: too complex for users	7, 13, 14
	–	Difficulties in use: determination of artifacts, attributes, flow, and rules	4, 5, 23, 31, 34, 47
	–	Limited understandability: artefact not intuitive, unclear added value, confusing reasoning, and non-self-explanatory method.	17, 22, 25, 35, 38, 43
Efficiency	+	Reusability of Artifacts and Lifecycles	21
Maintainability	–	Adaptation of models in several places	9, 10, 30
Flexibility	+	Usable in other environments	32, 37, 44

Table 11 - Overview Discussion - Artifact-Centric Process Modelling

Functionality. Using rules and formal descriptions, this method is very structured. By defining and coupling artifacts and lifecycles or artifacts, interactions between these artifacts become clear, and new insights can be acquired. However, for this method to work, systems boundaries should be clearly set, and additional information for Services and Rules should be included in the model.

Usability. The participants had difficulties with artifact and lifecycles models; it is for example difficult for modellers to select all important artifacts and include the required attributes of these artifacts, or to define the Rules that state when Services are invoked. Overall, the added value of the method was somewhat unclear to the participants. Many of the modelling techniques used are however familiar to the users, which increasing the understandability of the method.

Efficiency. Though every artifact needs to be created separately, different workflows can use the same artifacts; they do not need to be created for every different workflow one would like to model. The reusability of artifacts contributes to the method's efficiency.

Maintainability. Adaptations to the model have to be made in multiple places. Especially in larger systems, the number and complexity of required changes increases.

Flexibility. The respondents agree that the method is defined very broadly and thereby applicable in different situations.

4.2.3 Results of Exercises

A final interesting source of data can be found in the answers provided to the exercises. All respondents present at the sessions, as well as most digital respondents, were able to provide answers to exercises in the form of drawings. In this section these drawings will be evaluated. Though the participants already have shared their views and opinions regarding the method, a closer look at their solutions to the exercises is provided. This not only provides additional insights to their *real* understanding of the method and its models, it also provides an indication from which part of the method possible difficulties arise.

It is neither likely nor required that the provided answers are identical to the proposed solutions; if the participant grasped the idea and created answers similar to the proposed solutions, these will be evaluated as 'good'. If the participant merely copied the examples of the tutorial, the rating will be 'fair'. If the participant created an incorrect answer or produced a wrong model, this will be evaluated as 'poor', and if no answer was provided at all, 'nil' is assigned. Note that nil can be assigned both to models participant did not know how to create, as well as to models that were not created due to time constraints; the final exercises are hence likely to have a relative high number of missing input, i.e. nils.

4.2.3.1 Data-Driven Process Structures

Table 12 provides a summary of the evaluation of the created models. The creation of lifecycles was often well done. Some of the participants made a fairly easy lifecycle, though this is probably not caused by a lack of understanding. Creating an LCM based on these OLCs did not lead to problems for most participants either, though some participants forgot (or possibly omitted) the initiators for SubSystems/Components.

		Good	Fair	Poor	Nil
2a	**Create Object Lifecycles**	78%	11%	11%	
2b	**Create LCM**	78%		22%	
3	**Create Data Structure**	67%		22%	11%

Table 12 - Results exercises: Data-Driven Process Structures

4.2.3.2 Product-Based Workflow Design

A summary is provided for the evaluation of the exercises created for the Product-Based Workflow Design in Table 13. As can be seen, relatively high scores were obtained for the first exercises; however, when the complexity of the assignments increased, these scores dropped.

	Good	Fair	Poor	Nil
1.1 Select Data Elements	100%			
1.2 Create Product Data Model	78%	12%		
2.2 Create Product Data Model	63%	25%	12%	
2.3 Create Production Rules	50%	38%	12%	

Table 13 - Results exercises: Product-Based Workflow Design

The respondents had quite some problems with alternative paths; both the idea of alternative paths as well as the identification of these paths. One participant for example showed multiple paths to the top element, while each of these paths included one of the *requirements* for 'qualification for the Dutch citizenship': this completely changed the functionality of the PDM (instead of knockouts, all these paths were now obligatory when applying for a Dutch citizenship).

4.2.3.3 Artifact-Centric Process Modelling

A summary of the results of the exercises is provided in Table 14. As can be seen, a relatively large percentage of the respondents had difficulties with the exercises: especially lifecycles, services, and rules were difficult assignments for the respondents.

Lifecycles differed considerably in level of detail. While some described complete processes of entering and ordering, others described only major changes, like registering, editing, and archiving. Both are possibilities, though the information in the lifecycles should be relevant for other artifacts and/or lifecycles.

	Good	Fair	Poor	Nil
1a Identify Artifacts	60%	30%	10%	
1b Provide lifecycles	40%	30%	30%	
2a Logical Design Artifacts	70%	10%	10%	10%
2b Specify Services	40%	30%	20%	10%
2c Specify Rules	30%	30%	10%	30%

Table 14 - Results exercises: Artifact-Centric Process Modelling

5 Results

After gathering all results and representing them in a systematic way, the results can be combined into aggregated views on the quality attributes of the method. The claims of the developers gathered in the Theoretical Evaluation (literature) will be reviewed using the Empirical Evaluation (questionnaire, discussion and exercises); an aggregated view for each of the methods, organised per claim, will be provided.

The next sections will be structured as follows. Each section starts with a brief overview of the scores for Perceived Ease of Use and Perceived Usefulness, as obtained from the questionnaire; this serves as a first impression. Next, the claims made by the developers (also see Table 7 on page 26) are listed, grouped by their corresponding quality attribute. Using the empirical results from the three available sources, these claims will be tested. There are four options for a claim, each of them with a corresponding colour code that directly indicates which of these four options is the case for the discussed claim.

The four options are:

1. The claim is supported by the participants (●);
2. There is no consensus amongst participants (●);
3. Participants contradict the claim (●);
4. The claim is not addressed in any of the sources (●).

A claim is contradicted if less than 35% of the participants support the claim; if support is between 35% and 65%, it is said that no consensus is reached; finally, a claim is said to be supported if at least 65% of the participants support the claim. In addition, it might occur that one statement supports, and another one contradicts a claim; in such a situation, it is said that no consensus is reached (option 2).

One of the quality attributes, Functionality, is difficult to evaluate using the structured methodology proposed, as functionality sometimes is captured in other quality attributes; statements that can be grouped in other quality attributes (for example *maintainability*) cannot be found directly at Functionality. Functionality claims therefore can be tested using statements that are allocated to other quality attributes as well. For all claims at the other quality attributes holds that these are perfectly traceable using the proposed methodology.

5.1 Evaluation: Data-Driven Process Structures

The results from the questionnaire, directly gathered after respondents finished the tutorial, indicated that 75% of the respondent provided a score below the neutral level of three for perceived ease of use. Interestingly, the usefulness perceived for this method was rated with 75% of the scores *above* neutral level. Both are in line with the study of (Diaz Garcia, 2011), and imply that although the respondents find the method difficult in use, the according benefits of using the method are well perceived.

Using the results from the discussion and exercises, the developers' claims are tested in order to further investigate these first findings. Furthermore, statements made by the participants that cannot be directly related to the developers' claims will be addressed in the end of this section. An overview of the relations between claims made by developers and the perceptions obtained in the discussion is provided in Appendix L.

5.1.1 Functionality

D1 Data-driven modelling of large process structures; ensuring correct coordination, reducing modelling efforts, and provide mechanisms for maintenance. ●

D2 Separation of data and process logic, leading to an enactable process structure ●

D3 IT Support for automated creation and soundness checks ●

Claim **D1** states the functionality in terms of reduced modelling efforts and mechanisms for maintenance; though currently classified in the quality attributes Efficiency and Maintainability, this claim is indeed supported by the respondents. The reduced modelling efforts are realised via the reusability of models and the automated generation of a workflow, while maintainability is realised by separating data and process logic (**D2**), thereby enabling the adaptation of the model in one place and the automated translation of these adaptations to a process structure. The actual IT Support (tool support) was not evaluated, so that **D3** is neither supported nor contradicted.

5.1.2 Usability

D4 Intuitive integration of data and (sub-)processes enables users to instantiate and adapt model without process knowledge (by adapting data structure at a high level of abstraction). ●

D5 Process experts require profound domain knowledge to create data model and LCM. ●

Although participants of the workshop only have worked with the method for a short period of time, the first impression they got on usability can yield interesting results. **D5** is supported by the participants of the workshop; in addition to the profound knowledge required to *create* the models, participants however address that these models in addition are only *usable* for business analysts, as they would be too complex for managers and other users. Claim **D4** is therefore contradicted: though participants do see the benefits when users only have to instantiate a data model, they question the interpretability of the abstract models for users.

5.1.3 Efficiency

D6 Instantiating different Data Structures and generating the respective Data-Driven Process Structures ●

D7 Automated creation of Process Structure ●

D8 Standardising processing of objects in order to increase the reuse of process models and reducing modelling efforts. ●

D9 Separation of data and process logic results in a reduction of modelling efforts. ●

Regarding efficiency, **D6** and **D9** are supported: due to the separation of data and process logic, a Data Model can be used for creating different Data Structures and their corresponding Data-Driven Process Structures. The automated creation of a Process Structure based on the Data Model and the LCM, which makes the method efficient in both time and other resources, was also identified, thereby supporting **D7**. Finally, the participants identified the reusability of lifecycles and data models as one of the major contributors to the method's efficiency, which is in support of **D8**.

5.1.4 Maintainability

D10 Changes can be made at data-level and are automatically translated into corresponding adaptations of the process ●

Adjustments to a model or process can be made in a single place, and can be automatically translated to a new process structure; **D10**, that addresses both the making of changes in one place and the automated translation, is therefore supported.

5.1.5 Flexibility

D11 Usable in other environments, not specifically the engineering domain. ●

Data-Driven Process Structures is identified as a very generic approach, thereby applicable in many different environments. Although often presented in an environment in which a hierarchical structure can be identified, the method is according to the claim not restricted to such an environment; as a result, many new applications can be proposed. The method could for example be used to decompose administrative processes, thereby still reaping the benefits of the method, according to the participants. **D11** is supported.

5.1.6 Additional statements by participants

Functionality	+	Controlling workflow using data
	−	Missing details: roles, triggers, process view, origin of data
Usability	+	Hierarchy improves readability
	+	Increased understanding by using existing concepts/methods
	−	Unclear overview: large models

In addition to the statements that directly addressed one of the claims, some statements could not be allocated to one of them; these are addressed here. The additional statements regarding Functionality relate to the use of data to control the workflow (one of the strengths of a data-driven approach) as a positive aspect, and the lack of details in the used examples as a negative one. Usability is positively supported by the use of hierarchy, enabling reasoning on an abstract level, and the use of known concepts (structure similar to a Bill of Materials); it is negatively affected by the readability of the large, often chaotic Process Structures.

5.2 Evaluation: Product-Based Workflow Design

Using the results from the questionnaire (Figure 11 and Figure 12), PBWD is perceived as easy to use, having 75% of the scores above the neutral level of three. The usefulness of the method in contrast is rated with almost 75% of the scores below neutral level. The method was by some of the participants not perceived as an aid, as they perceived that the 'insights' obtainable by defining a PDM, would already be known by users. Though this statement can be (and, during the workshop, *was*) discussed, it explains the relatively low score.

Using the results from the discussion and exercises, the developers' claims are tested in order to further investigate these first findings. Appendix M provides an overview of the relation between the developers' claims and the perceptions of the participants of the workshops.

Furthermore, statements made by the participants that cannot be directly related to the developers' claims will again be addressed in the end of this section.

5.2.1 Functionality

P1	Method that (re)designs a process reasoning from the desired outcome, without directly discussing how to achieve it.
P2	Analytical, clean sheet approach: rational and quantitative way of deriving an optimised process design.
P3	PDM (in)directly used to steer a workflow: basis for process model.

The PDM used in Product-Based Workflow Design is, conform to **P1**, perceived as a good basis for redesign: it is orderless, points out process dependencies, and provides insights in important aspects of the (re)designed process. In addition, since the method is orderless and uses very explicitly defined rules, an objective (re)design can be created, supporting **P2**. **P3** was not addressed in the discussion.

5.2.2 Usability

P4	Created models are accepted by end users as valid and workable.
P5	Based on existing concept (BOM)
P6	Efforts required to collect data for PDM differs for every company.
P7	Constructing a PDM is a manual task

According to some (five) participants, a PDM model is usable for customers: especially in systems that include many rules and calculations, a PDM structure would be perfectly understandable; other participants (four in total) however perceived the PDM as too complex for customers. For **P4** therefore no consensus is reached. Similarities to a Bill of Materials are indeed identified by participants, supporting **P5**. Difficulties in *collecting* required data, as stated in **P6**, were not considered by the participants; they merely discussed difficulties in *constructing* a correct and complete PDM. The participants do indicate that the creation of a PDM is a task of a business analyst, able to derive and use abstract models. This indicates that they do see it as a manual task (**P7**).

5.2.3 Efficiency

P8	Using different optimisation criteria, different process models can be created.
P9	Algorithms and PBWS can be used to automatically generate process models or recommendations for carrying out operations.
P10	Optimisation of the process by including optimisation criteria.

Though not mentioned directly, **P8** is supported. The participants mentioned that the optimisation of the order can be based on a selected criterion: e.g. cost and time. Claim **P9** is not addressed in the discussion. **P10** on the contrary is one of the most often mentioned strengths of PBWD; it addresses its possibility to optimise processes. Since the PDM does not include any order, it can be used as objective view on the process, thereby deriving the optimal order of operations: all is in support of **P10**.

5.2.4 Maintainability

Maintainability is neither captured in a claim, nor addressed in the discussion. For PBWD, it is therefore left from the results and discussion.

5.2.5 Flexibility

P11	Restricted to fields where clear concept of the products to be delivered exists.	●

The participants of the workshop perceive the method as very broad applicable. They did not specifically mention the restriction of a process that includes a clear concept of the product as the developers did, though it was mentioned that practical problems are likely to be less straightforward, thereby more difficult to tackle using the proposed method. Combining these two statements, **P11** is supported.

5.2.6 Additional statements by participants

Functionality	–	Missing details: input, roles, triggers, different views
Usability	–	PDM does not help reasoning
	–	Difficulties in use: alternative paths, orderless, rules, tables
	–	Unclear overview: direct/alternative paths, large models

Participants addressed that the method as proposed in the tutorial lacked some important details, which are very interesting when redesigning a process. Furthermore, the PDM, which already is perceived as difficult by the participants, becomes obscured when alternative routings are included, especially in large models. Finally, using a PDM requires an alternative way of thinking (compared to activity-centric methods), which is also perceived as difficult by some of the experts; if not understood completely, a PDM does not help reasoning about optimising the process.

5.3 Evaluation: Artifact-Centric Process Modelling

While for both DDPS and PBWD the results of the questionnaire were unambiguous, the results that relate to ACPM are somewhat more centred and thereby less easy to interpret. For Perceived Ease of Use holds that the obtained value exceeds the one for DDPS. For Perceived Usefulness exactly the neutral level is obtained, which is still above the Perceived Usefulness value obtained by PBWD.

Using the results from the discussion, the developers' claims are tested in order to further investigate these first findings. In the table in Appendix N the relations between claims of developers and perceptions of participants are provided. As was done for DDPS and PBWD, this section will address statements made by the participants that cannot be directly related to the developers' claims at the end of this section.

5.3.1 Functionality

A1	Representation usable by business people to analyse, manage, and control business operations
A2	Substantial new insights can be acquired by managers
A3	Declarative approach, that incorporates formality required for rigorous design and analysis

Claim **A2** and **A3** are discussed first. Claim **A2** is supported: participants do think the method is able to provide new insights in the processes. Furthermore, using the structured approach of this method, knowledge, roles, and rules, required for rigorous design and analysis, can be captured. This all is in favour of claim **A3**, which therefore is supported. **A1** is not fully supported: though the participants stated that the combination of artifacts and lifecycles was strong and showed the interaction of different artifacts in a system, this not necessarily means it can be used to analyse, manage, and control business operations.

5.3.2 Usability

A4	Intuitive appeal to business managers, somewhat foreign to business process professionals
A5	Based on existing methods and techniques
A6	Identifying artifacts is an iterative process that requires understanding of entire business process.

Claim **A4**, that addresses the intuitive appeal of the method, is contradicted by the participants: artifacts were seen as non-intuitive (for both business users and experts), and reasoning using the proposed method was perceived confusing. Although it should be noted that the developers state the method is intuitive for business *managers* (and the participants were business professionals and students), the participants perceived the method as too complex for business managers as well. The use of existing and known methods was seen as advantage, supporting claim **A5**. Claim **A6** was not addressed; the participants neither had thorough business knowledge (of the process to be modelled in the exercises) nor time to iteratively discuss the selection of artifacts.

5.3.3 Efficiency

A7	Enabling specification of generic schema with multiple specialisations.
A8	Separation of data management concerns from process flow concerns

The reuse of artifacts and lifecycles was addressed in the discussion. The participants stated that a workflow could reuse already defined artifacts for a new purpose; though less concrete formulated than in the claim, this partly supports **A7**. The separation of data management concerns from process flow concerns (**A8**) remained unaddressed in the workshop.

5.3.4 Maintainability

A9	Changes can be made to conceptual flow and business workflow implementation, while preserving the same Business Operations Model.

Since the participants were only provided with the task of creating a Business Operations Model, both conceptual flow and business workflow implementation were not addressed in the discussion, leaving claim **A9** untested.

5.3.5 Flexibility

A10 Usable in other environments, particularly in the use of consumed and non-consumed goods. ●

The method is perceived by the participants as very broad applicable; while the developers of the method further specify this to the consumed and non-consumed goods, the participants did not further elaborate on this statement: **A10** is supported.

5.3.6 Additional statements by participants

Functionality	+	Hierarchy of artifacts possible
	−	Missing details: input, output
Usability	−	Difficulties in use: determination of artifacts, attributes, flow, and rules
Maintainability	−	Adaptation of models in several places

In addition to the interaction of artifacts and lifecycles, which are related to claim **A1**, the possibility to incorporate hierarchy in the method was mentioned as an additional strength of Functionality. A remark made to the formality currently incorporated in the method, was that additional details were required by participants of the workshops. Also with respect to Usability some negative statements were made: the models used in the method are difficult to determine, and of unclear additional value. Maintaining the models is in addition also difficult, as adaptations in artifacts or their lifecycles often result in making changes in multiple places.

6 Discussion

The results from Chapter 5 will now be discussed more in depth; an interpretation of these obtained results will be provided, that gives possible explanations for these results.

This section is structured as follows. First, in section 6.1, the methods will be discussed separately: for each of the quality attributes selected, the obtained results will be interpreted and explained. After these individual evaluations, a deliberate comparison of the methods will be made in section 6.2.

6.1 Discussion Method Evaluations

For each of the quality attributes a small interpretation of the obtained results is provided: where in the previous chapter the different claims of the developers were only tested, this section proposes possible explanations for these differences. Both statements that directly addressed developers' claims and those that did not, are taken into account in this discussion; statements that did not address claims can lead to the discovery of additional insights.

6.1.1 Data-Driven Process Structures

The focus of Data-Driven Process Structures is to a great extent on the optimisation of modelling: the creation of efficient and easily maintainable models. The method is successful in achieving this goal, which will become clear from discussing the five quality attributes.

6.1.1.1 Functionality

The main goal of DDPS is to enable the coordination of large process structures, and at the same time reduce the modelling efforts required. By separating data and process logic, changes to objects and models can be made easily (see also section 6.1.1.3). Using a high level view and generically defined objects and models, the reusability of these objects and models is enabled. Overall, an efficient and easily maintainable method is proposed.

While the used examples and exercises missed details like roles, triggers, et cetera, these models were on purpose simplified to increase understandability, and 'in practice should be enriched' (Müller, Reichert, & Herbst, 2006, p. 5). The remark that considered these missing details, is therefore at least partially due to limitations of the tutorial, and not directly related to the method.

6.1.1.2 Usability

Although the readability of the generated Process Structures might be seen as limitation of the method, this depends to a great extent on the goal of the model; a model that is used to correctly coordinate a workflow process is likely to be different from an overview model used for direct interpretation by business professionals. Furthermore, reasoning is perfectly possible on a more abstract level, using the Data Structure and the Lifecycle Coordination Model (instead of the Process Structure); a Data Structure can be used to determine *which entities* are related, and the LCM indicates *what this relation looks like*.

Some difficulties were perceived in applying the proposed method and creating the (abstract) models. The participants perceived difficulties in the creation of generic lifecycles, especially when trying to apply the method in a domain other than manufacturing. Since process experts already had difficulties using the method, these difficulties are likely to be perceived as well by business people, which often lack abstract modelling skills. Although it is stressed by the developers that business people only need to define the instantiation of the Data Model, which should be less difficult than creating the models, business users might face difficulties when trying to fit a real process or product into the abstract models.

6.1.1.3 Efficiency

The category *Efficiency* incorporates one of the main strengths of this method: the reduction of modelling efforts. Using rather abstract, generically defined objects and models, the reusability of these objects and models is facilitated; at the same time, the process of choices and checks is standardised, ensuring them to be made at exactly the right time. In addition to the reusability of models, the automated creation of Process Structures further contributes to the efficiency of this method.

DDPS makes no efforts regarding the optimisation of processes; all facets of efficiency included in the method aim at reducing modelling efforts.

6.1.1.4 Maintainability

With respect to maintainability, the Data-Driven Process Structures method provides some great functionality as well. Described as one of the main ideas behind the method, data and process logic are separated; changes to either product or process can be made in the corresponding place and, in addition, can be directly translated to the Process Structure. As changes can be made to product and process separately, and these are automatically translated to the new Process Structure, DDPS can be seen as highly maintainable.

6.1.1.5 Flexibility

The method is broadly applicable. In the examples often a BOM structure is proposed; however, complex hierarchical systems, in which objects can have multiple parents, should be possible as well. Though not claimed as a strict requirement, a hierarchical systems is required to reap the full benefits of the method. When applied in a non-hierarchical environment, the benefits mentioned at Efficiency (section 6.1.3.3) will be reduced, as the reusability of OLCs will almost certainly decrease. Nonetheless, adaptations on data and process level are still possible in a non-hierarchical environment, making the maintainability of such processes its major strength.

6.1.1.6 Strengths and weaknesses of Data-Driven Process Structures

The major strengths of this approach can be found in its efficient modelling approach and the ease with which the created objects and models can be maintained. The method focuses on the efficiency of the *modelling* of processes; no attention is paid to the *optimisation* of the processes themselves. Regarding usability, Process Structures can quickly become unreadable; however, the goal of such a model is probably not the creation of an overview. Instead, a Process Structure should function as input for a workflow system, correctly coordinating a large process. A remark regarding the reusability of models, is the use of a hierarchical system in all available examples; although not stated as a formal restriction, the benefits of the methods are reaped best in a hierarchical environment. Table 15 summaries the strengths and weaknesses of the Data-Driven Process Structures method.

Attribute	Concept	Explanation	
Usability	Understandability	Process Structure chaotic, abstract models are difficult to understand	-
	User: ease of use	Only instantiate Data Model, reasoning with abstract models difficult	±
	Expert: ease of use	Creating generic lifecycles can be difficult	±
Efficiency	Reduce modelling efforts	Reusability of models, automated generation	++
	Optimise process	No efforts regarding the optimisation of processes	--
Maintainability	Making adaptations	Separated data and process logic, easily adjusting models	++
Flexibility	Usable in other environments	Usable in all environments, hierarchical environment preferred	±

Table 15 - DDPS: Strengths and Weaknesses

6.1.2 Product-Based Workflow Design

PBWD proposes an analytical approach for business process redesign. Using an abstract model of an informational product, an optimised process can be created. Disregarding the existing order of tasks, taking only the dependencies between data elements into account, the method is able to provide insights in the optimisation of processes.

6.1.2.1 Functionality

Product-Based Workflow Design is proposed and perceived as an analytical, clean sheet approach that only considers the different data elements and the combining of these elements to achieve a value for the end product; it provides a structured overview of the data elements in a system, as well as their relations. The method uses a detailed view on the product to obtain objective insights into the optimisation opportunities of a redesign. If desired, additional details can be included to create models that better represent reality.

6.1.2.2 Usability

The main model of Product-Based Workflow Design, the PDM, is a fairly complex model. Especially when these models become larger, or incorporate more alternative routings (see for example Op2 in Figure 6), the overview of the models becomes blurred, making the models difficult to read. Different alternatives (for example use of logic, Lazy Evaluation) were suggested to reduce these alternative paths, and thereby the complexity of a PDM. When a PDM becomes easier to interpret, the usefulness of the method as a whole increases.

As mentioned, a PDM might be complex for users to interpretate directly. However, it could be used by process experts as an aid to identify opportunities for improvement. Furthermore, reading a PDM (after some training sessions) should be possible for business professionals, certainly when the process described is already known by these professionals.

Constructing a PDM might be fairly difficult, as all alternatives routings should be taken into account. However, a PDM can often be based on product definitions, work descriptions, et cetera. It is interesting to mention that although the participants of the workshop argued that it was difficult to create a PDM, their attempts actually resulted in quite good models.

6.1.2.3 Efficiency

Efficiency of modelling is provided only limited attention in this method. PBWD enables the use of different quality criteria to determine process models from a single PDM; the result is a number of models (one for each quality criterion selected) using the same PDM as input.

The real value for efficiency is obtained when considering the optimisation of processes. Because the PDM does not include an order of tasks (the only order included is based on dependencies between data elements), it can be used to optimise the process. Dependent on the desired optimisation criterion (cost, time, quality) an optimised process can be determined. The efficiency of PBWD thus focuses on the creation of an efficient *process*; efficiency of *modelling* is only considered by the reusability of a PDM to create different processes based using different quality criteria.

6.1.2.4 Maintainability

Maintainability is not provided any attention in PBWD. Major changes (e.g. a change in regulations) are likely to have a large effect on the PDM, forcing modellers to create an entire new version of the Product Data Model. Note that a PDM only has to be adjusted when changes to data elements or dependencies occur, as it is unrelated to changes in processes.

6.1.2.5 Flexibility

Though not indicated in the discussion, the limitation regarding usage in other environments, mentioned by the developers, is definitely important. The method is only applicable in situations where a clear concept of the products to be delivered exists: without such concepts, no structure that 'leads' to this product can be created. The proposed method could really lead to great insights in processes that do have such a structure, but reaping these benefits without such a structure will be difficult, if not impossible.

6.1.2.6 Strengths and weaknesses of Product-Based Workflow Design

One of PBWD's greatest strengths is its analytical, clean sheet approach in the (re)design of a process. Though business people might think they already know how to optimise the process, this method quantifies the different alternatives, providing insights into their costs and time. This objective view can be used in the analytical redesign.

The proposed models are created on a detailed level, which is less intuitive for business people. In addition, the created models show many dependencies and alternative paths, which obscure the overview, especially in larger systems. The final weakness considered here is the limitation of flexibility: without a clearly described product, the method has limited value.

Attribute	Concept	Explanation	
Usability	Understandability	Alternative paths not understood (alternatives proposed)	-
	User: ease of use	PDM readable when following traces	±
	Expert: ease of use	PDM based on descriptions, alternative paths difficult	±
Efficiency	Reduce modelling efforts	Creation of multiple models, using different criteria	-
	Optimise process	Optimising process using different criteria	++
Maintainability	Making adaptations	Major changes result in creation of complete new PDM	±
Flexibility	Usable in other environments	Clear description of product is required	-

Table 16 - PBWD: Strengths and Weaknesses

6.1.3 Artifact-Centric Process Modelling

Artifact-Centric Process Modelling proposes a method that can be used by business people to analyse, manage and control business operations. The method makes use of artifacts, that are concrete and self-describing business entities. Using a variety of models and tables, the method can be used to model all kinds of business processes.

6.1.3.1 Functionality

Using a declarative approach, which is based on rules and properties, a method is proposed to analyse, manage, and control business operations. Formal described rules and deliveries are used to define what is required from which employee, at what event, et cetera. Though additional details should be included, the examples used were simplified in order to increase the understandability of the models. Artifacts, lifecycles, and relations, together provide an overview of the important entities in a process, which can be used to obtain new insights. Though the ideas are promising, it unfortunately remains unclear how the method is applied best, in order to acquire the most valuable insights.

6.1.3.2 Usability

One of the major problems addressed regarding Usability was the unclarity of the added value of the created models; the participants of the study had difficulties identifying these benefits. Two possible explanations for this problem are provided. The first one considers the examples and models used in the tutorial: the focus in the tutorial is on the first, conceptual steps of the redesign process, while the method as a whole should be used to determine its added value. A second explanation for the limited added value perceived considers the broad scope used in ACPM; in contrast to the other two methods discussed, Artifact-Centric Process Modelling tries to cover all aspects of BPM. This broad scope might obscure the overview of models, and in addition the exact goal of specific models.

The identification of artifacts is a difficult task that requires profound knowledge of the process as well as an iterative identification process. Not only the creation of models is difficult; according to the participants of the workshops, interpreting the abstract models is difficult as well, especially for business users that lack abstract modelling skills. This is in contrast with the claimed intuitivity of the approach, though the effect might be reduced when the method is applied in a well-known environment (which was not the case in the workshop).

6.1.3.3 Efficiency

Concerning the reduction of modelling efforts, artifacts and their lifecycles are formulated in a generic way, which enables the reuse of common artifacts (for example 'Customer'). In addition, data management concerns are separated from process flow concerns, allowing for adaptations on separate levels. Furthermore, the developers of the method claim that generic schemas can be used to create models for multiple specialisations.

No efforts are made in ACPM that regard the optimisation of the process.

6.1.3.4 Maintainability

The maintainability of the method is seen as one of its weaknesses. As there are numerous models and tables that are all interconnected, changes made to a model or table automatically have an effect on one or multiple others. When a system has to be adjusted in several places, this requires additional resources and, in addition, makes errors more likely to occur. Although the developers of the method state that changes can be made to the conceptual flow and business workflow without changing the Business Operations Model, making desired changes to the Operations Model is perceived as fairly complex and error-prone.

6.1.3.5 Flexibility

The method is very generic, making it applicable in nearly all (if not all) domains. In all domains important artifacts can be identified and related to one another. As the method does not require any specific characteristics, it can be seen as very flexible.

6.1.3.6 Strengths and weaknesses of Artifact-centric Process Modelling

One of the major strengths of this method is the formal description of rules and deliveries, making them explicit. Defining these models is however perceived by process experts as non-intuitive, sometimes even complex and confusing. And although artifacts should be self-describing, the numerous abstract models created by experts (overviews of artifacts, their lifecycles, and rules and services) are fairly complex for business users. A major strength of the method is its flexibility; the method is applicable in every environment.

Attribute	Concept	Explanation	
Usability	Understandability	Unclear how to analyse, manage, and control	-
	User: ease of use	Abstract models difficult to use, numerous models	-
	Expert: ease of use	Difficult to determine correct and complete models	-
Efficiency	Reduce modelling efforts	Reusing artifacts	+
	Optimise process	No efforts regarding the optimisation of processes	--
Maintainability	Making adaptations	Adaptations need to be made in multiple places	-
Flexibility	Usable in other environments	Usable in (nearly) all environments	++

Table 17 - ACPM: Strengths and Weaknesses

6.2 Comparison of Methods

With an overview of all results in Chapter 5 and the discussion of these separate results in the first section of this chapter, a comparison between the three selected methods will be provided here. Using different concepts of the quality attributes, the methods can be compared, identifying relative strengths and weaknesses.

6.2.1 Functionality

The three selected data-driven methods focus on different aspects. Data-Driven Process Structures proposes a method that enables the correct coordination of large process structures, while at the same time it reduces modelling efforts and increases maintainability; the focus is thus on optimising the modelling of (large) processes structures. Product-Based Workflow Design in contrast tries to optimise the process itself, by taking an analytical, clean sheet approach that optimises the ordering of operations given a selected optimisation criteria; the focus in this approach is on the creation of an optimised redesign. The Artifact-Centric approach proposes a representation that can be used by business professionals to analyse, manage, and control business operations, incorporating the formality for rigorous design and analysis.

The three methodologies operate on different levels of abstraction. The model that uses the highest level of abstraction is DDPS: using generic structures to create an overview and coordination model for a large process. ACPM incorporates more details; concrete artifacts and their attributes are defined, and rules and services are formulated that make use of these artifacts and their attributes. Finally, PBWD uses a detailed approach, directly modelling elements of data that are of interest for the end product.

As can be seen, the goals of the three methods, as well as the chosen approach to reach these goals, differ to quite some extent. In the following sections, the other quality attributes will be discussed, in order to identify exact advantages and disadvantages of the different methods towards each other.

6.2.2 Usability

Usability is discussed using a number of concepts. The first concept considered is the understandability of the model, which addresses whether or not the general idea of the method is grasped, models are understood, et cetera. Second, the ease of use from a user perspective is discussed. This includes the tasks that should be performed by the users, and the reasoning based on the created models, for example. The final topic is similar to the second, though from an expert perspective.

6.2.2.1 Understandability

An important notion made during *all* workshop sessions was the complexity of data-centric methods, for both business users and process experts. Though process experts were able to grasp the general idea of a method or model, they doubted whether users were able to read the corresponding models and understand their added value.

Especially in large systems, the models of all methods quickly grow in size, decreasing their readability. However, for DDPS holds that reasoning is possible on an abstract level, omitting the complexity of the Process Structures. With respect to PBWD, the Product Data Model can often be 'tracked' from leafs to root element; reading it in a stepwise manner. ACPM does not include similar aspects that increase understandability. Furthermore, the added value of some of the created models is not always clear to users. The broad applicability of the method combined with the large number of models and tables, blurs the underlying idea of the individual models.

6.2.2.2 Expert: ease of use

For DDPS, the greatest difficulty perceived is the creation of the generic lifecycles, as these lifecycles should fit all objects that are allocated to the object type that is modelled. On a high level, these the processes in a single object type should be identical (e.g. test, assembly, et cetera). The creation of a PDM based on a work instruction or description of a situation was perfectly possible for experts. An unexpected difficulty perceived was the determination and use of alternative paths, though alternatives were proposed to avoid this type of routings. For ACPM, determining the required artifacts and their lifecycles is perceived as a difficulty, as is the creation of rules.

As can be seen, each of the selected methods show difficulties for experts. Further investigating these problems shows that for DDPS and ACPM these difficulties are an important step of the modelling process (determining generic models, determine artifacts and attributes), while the problems encountered for PBWD might be overcome when the concept of alternative routings is adjusted or removed. Furthermore, for all methods holds that the ease of use is likely to be increased by the use of formal training sessions; difficulties perceived after such training sessions are likely to be even more valuable for the improving of methods.

6.2.2.3 User: ease of use

The only method in which the role of the user in the creation of models is explicitly defined, is DDPS. Though the participants in the workshop had doubts whether or not a user is able to fit a product in an already defined abstract model, a user might be able to do so after a training or when done together with a process expert.

Although the creation of models is often done by process experts, the methods should be *usable* by business professionals. For DDPS holds that some of the models are fairly complex, though reasoning can also be done on lower levels. The Artifact-Centric approach states that their models are intuitively usable for business managers; although artifacts might be self-explaining, the models that include multiple related artifacts are less easily interpreted. PBWD might be difficult to understand directly for users; readability is likely to be increased when it is considered in smaller parts.

While each of the methods shows difficulties in use of the business users, it is likely that profound process knowledge reduces the encountered problems. When users of DDPS for example learn to reason in abstract models, they can use the Data Structure and LCM in reasoning. A similar statement holds for ACPM; when the models are familiar to business users, reasoning becomes possible. The method in which users encounter the most difficulties is PBWD, as PDMs quickly become large, complex models. A recently proposed initiative automatically aggregates related data elements of a (detailed, complex) PDM, resulting in a model that is easier interpretable for business users, without the loss of information (Van der Aa, 2013).

6.2.3 Efficiency

Efficiency is addressed in claims and statements using a variety of concepts. However, the used concepts can be grouped in two underlying ideas. Creating different processes from the same models, automated creation, reusability, and reducing modelling efforts all address the reduction of modelling efforts. The only concept that cannot be allocated to the reduction of modelling efforts, considers the optimisation of the process. The reduction of modelling efforts and the optimisation of processes will both be addressed here.

6.2.3.1 Reduce modelling efforts

The method that puts most emphasis on the efficiency of modelling, is Data-Driven Process Structures. The method enables the reusability of models, efficient adaptation of both data and processes, and automated creation of Process Structures, thereby providing functionality for increasing the efficiency of modelling.

Although to a lesser extent, the ACPM method incorporates some similar initiatives. The created artifacts and lifecycles can be used in other process descriptions as well, assuming the artifacts have the same lifecycle in the new model. Note that this reusability is limited when compared to the reusability of DDPS, as DDPS is able to reuse the generic models for each object of a single object type *in* a process, while ACPM is proposed the reuse of objects in *other* processes.

PBWD only facilitates the reusability of a PDM, in order to create a different process based on other quality criteria. This is hardly a real reduction of modelling efforts, making PBWD the method that performs worst for the reduction of modelling efforts.

6.2.3.2 Optimise process

Although its efforts to reduce modelling efforts are limited, PBWD instead provides opportunities to optimise the described process in an objective manner. Using optimisation criteria that can be defined by the users themselves, an optimal process order can be determined. Since users themselves can decide which criteria to include in the PDM, the optimisation of the process can be done using any desired criterion (or combinations of different criteria).

Neither DDPS nor ACPM includes similar initiatives. Their only focus regarding efficiency is based on the reduction of modelling efforts.

6.2.4 Maintainability

Regarding maintainability, DDPS exceeds the others. Data-Driven Process Structures allows for adaptations on either the data or process level; changes then are automatically translated into a new Process Structure, which incorporates the new structure or adapted processes.

The other two methods do not have such functionality. Although for ACPM it is claimed that adaptations can be made to the data or process level, these adaptations often require changes at multiple places, since all models and tables are connected to one another. For PBWD, major changes require the construction of a new PDM, since it is difficult to identify the effects of large changes in the (interconnected) data elements. However, changes in process do not apply to a PDM, as it is process independent.

6.2.5 Flexibility

All proposed methods are applicable in other environments than for which they were originally developed. However, some constraints should be taken into account. For DDPS holds that it is a very generic approach, applicable in many situations; the benefits of the approach are however obtained best when used in a hierarchical environment. In such an environment, the reusability of models is utilised best.

PBWD deals with constraints as well. While the method can be used in different domains, it is important that a clear description of the end product is available. Without such an end product, PBWD is not applicable.

Artifact-Centric Process Modelling can be applied in almost all, if not all, environments. The most important entities used in the models, artifacts, can be identified in all processes, as there are no constraints with respect to the exact contents of an artifact.

6.2.6 Schematic overview

Using the quality attributes and the corresponding underlying concepts of these attributes, here a brief overview of the findings is presented. Note that this table should only be used in combination with the above provided discussion. In addition, no 'total score' is addressed to the methods, as weights for the addressed concepts might differ for each situation.

Category	Concept	METHOD		
		DDPS	PBWD	ACPM
Usability	Understandability	-	-	-
	User: ease of use	±	±	-
	Expert: ease of use	±	±	-
Efficiency	Reduce modelling efforts	++	-	+
	Optimise process	--	++	--
Maintainability	Making adaptations to the model	++	±	-
Flexibility	Usable in other environments	±	-	++

Table 18 - Schematic Overview of Comparison of Methods

As can be seen, functionality is not taken into account in the above description. The methods all have different functionality, which cannot be expressed using the scoring method from Table 18. Which method best suits a business needs is dependent on the desired functionality (discussed in sections 6.1.1.1, 6.1.2.1, and 6.1.3.1 for DDPS, PBWD, and ACPM respectively). The methods differ for example in level of abstraction, making the selection of a method highly dependent on the desired outcome of the use of the method. It is therefore of great importance to consider not only the quality attributes and concepts defined in Table 18, but to carefully consider the functionality of the different methods as well.

7 Conclusion

In this study three data-centric process modelling methods are studied, in order to create a better understanding of both the claimed and perceived added value of these methods. The three methods that are selected are Data-Driven Process Structures, Product-Based Workflow Design and Artifact-Centric Process Modelling. Using the three research questions described in section 1.1, the findings of this study will be summarised.

First research question
The first question addresses the theoretical differences between the selected methods. After selecting five quality attributes (Functionality, Usability, Efficiency, Maintainability, and Flexibility), key articles for each of the methods are identified. Using Grounded Theory Coding, these articles are coded, and claims of the developers are determined. The result of this Theoretical Evaluation is an overview of the claimed aspects and attributes of all three methods, which is provided in Table 7. This table can be used as a basis for the comparison of the different methods.

Second research question
Rather than focusing on the theoretical similarities and differences between the methods alone, an Empirical Evaluation is conducted that identifies experts' perceptions towards the method. Three workshop sessions are conducted (one for each method), in which participating experts study the method, make exercises, and discuss their experiences. Again, Grounded Theory Coding is used; this time to extract the participants' perceptions towards the methods.

From the Empirical Evaluation it becomes clear that data-centric modelling methods are perceived as fairly difficult. Although the participants were able to apply the methods to simple examples, various difficulties were encountered. The creation of models was often perceived as complex or ambiguous, and the often abstract models were perceived as difficult to interpret for business users.

Third research question
In order to obtain the main strengths and weaknesses of this approach, the results from the Theoretical Evaluation are combined with the results of the Empirical Evaluation. In this way, claimed and perceived aspects and attributes of the methods are combined and compared, thereby identifying the strengths and weaknesses of the approaches. In the Discussion (Chapter 6), further explanations for the obtained results are provided, and the methods are compared to each other. The five selected quality attributes are used to identify the methods' strengths and weaknesses; not only can these strengths and weaknesses be used for selecting one of these data-centric methods, they can also be used for the improvement of the methods. One could for example investigate the opportunity to increase the reusability of models for the Artifact-Centric approach, by incorporating some of the aspects of DDPS. Another opportunity can be found in the flexibility of DDPS: while DDPS currently is applied in a manufacturing domain, it might be interesting to apply this method in a service domain.

This study combines insights obtained from theory, with insights obtained in an empirical setting. The results of this study therefore do not only focus on theoretical similarities and differences, but take user perceptions into account as well. In the empirical study, some interesting weaknesses were identified; these weaknesses did not only relate to individual methods, but often addressed data-centric methods in general. As data-centric methods are not widely known yet, they may encounter opposition. This study however tries to show that although adjustments might be required for all of the methods, the initiatives are interesting, often provide added value to the current activity-centric approaches, and are worth further investigation.

7.1 Limitations and Future Research

Some limitations to this study need to be mentioned. While some of these limitations posit opportunities for further research, others are merely mentioned in order to contribute to a complete and transparent study. The limitations are divided into limitations with respect to the materials used, and limitations that consider the evaluation method.

7.1.1 Materials

Although the materials used in this study are created with great care, they are still created by a non-expert. Despite the fact that the contents of the tutorials are revised by the developers of the corresponding method, and the understandability is reviewed by two Master Students, it is still possible that the tutorials are incomplete, or somewhat unclear at given points. It might therefore be that problems perceived by the participants are caused by an error or ambiguity in the tutorial, hence not caused by limitations of the method.

Furthermore, the questionnaire could have been better matched with the contents of the workshop and its desired results. Though 'Perceived Ease of Use' and 'Perceived Usefulness' do contribute to the evaluation, questions that more specifically addressed the selected quality attributes might have provide some interesting contributions.

7.1.2 Evaluation

As the information obtained in the questionnaire and discussion all is based on the participants' perceptions, *all* information in the study can be seen as perceived information. In order to acquire some information on for example actual efficiency, one should make use of some quantitative metrics. The time required for creating a model for example, is a perfect illustration of such a quantitative metric.

Furthermore, the fairest comparison between methods would have been a comparison based on the same case. This in addition enables measuring the time required to complete the model, and can be used to evaluate the usefulness of the obtained models as well. Though in this study the use of different examples in the tutorials was well considered (optimally reaping a methods benefits), using a single case probably provides interesting insights as well.

7.2 Future Research

Future studies can try to focus on a better triangulation: integrating questionnaires, exercises, and discussion even further. When these sources are better aligned, the results actively support each other. In addition, it would be interesting to evaluate the methods using a variety of cases; cases that apply the method in environments for which it is not originally developed. Furthermore, quantitative metrics could be included, in order to obtain quantitative information as well.

Other future studies could aim at a deeper understanding of one quality attribute. While this study used a variety of quality attributes, a more in depth study would be interesting as well. One could for example select only aspects that relate to Usability, in order to obtain detailed insights on for example the understandability of models and the ease of use of the method.

Another interesting direction is to test data-centric methods in real life situations. The methods in this study often use hypothetical examples, or variations on the same example. Using the methods in a practical situation might provide some interesting insights as well, as problems and difficulties are more likely to occur in real (often complex) situations.

8 References

Bhattacharya, K., Caswell, N., Kumaran, S., Nigam, A., & Wu, F. (2007). Artifact-Centered Operational Modeling: Lessons from Customer Engagements. *IBM Systems Journal, 46*(4), 703-721.

Bhattacharya, K., Gerede, C., Hull, R., Liu, R., & Su, J. (2007). Towards Formal Analysis of Artifact-Centric Business Process Models. *LNCS*, 288-304.

CEP. (2012). *Tools, Cheetah Experimental Platform.* Retrieved from Business Process Management Research Cluster: http://bpm.q-e.at/?page˙id=56

Diaz Garcia, H. (2011). Evaluation of Data-Centric Process Modeling Approaches. *TU/e Master Thesis, BIS.*

Field, A. (2005). *Discovering Statistics Using SPSS.* London: Sage.

Flick, U. (2009). *An Introduction to Qualitative Research.* London: SAGE Publications Ltd.

Glaser, B., & Strauss, A. (1967). *The Discovery of Grounded Theory: Strategies for Qualitative Research.* Chicago: Aldine Publishing Company.

Hammer, M. (2010). *Handbook on Business Process Management 1.* Berlin Heidelberg: Springer-Verlag.

Hull, R. (2008). Artifact-Centric Business Process Models: Brief Survey of Research Results and Challenges. *Lecture Notes in Computer Science, 5332*, 1152-1163.

IEEE. (1990). *IEEE Std 610.12-1990.* New York: The Institute of Electrical and Electronics Engineers.

Kamphuis, J., Vanderfeesten, I., Reijers, H., & Van Hattem, M. (2008). From Product Data Model to Process Model. *Beta Working Paper.*

Kueng, P., & Kawalek, P. (1997). Goal-based Business Process Models: Creation and Evaluation. *Business Process Management Journal, 3*, 17-38.

Maes, A., & Poels, G. (2007). Evaluating Quality of Conceptual Modeling Scripts based on User Perceptions. *Data and Knowledge Engineering, 63*, 701-724.

Moody, D. (2003). The Method Evaluation Model: a Theoretical Model for Validating Information Systems Design Methods. *11th European Conference on Information Systems.*

Moody, D. (2005). Theoretical and Practical Issues in Evaluating the Quality of Conceptual Models: Current State and Future Directions. *Data Knowledge and Engineering, 55*, 243-276.

Müller, D., Herbst, J., Hammori, M., & Reichert, M. (2006). IT Support for the Release Management Process in the Automotive Industry. *Lecture Notes in Computer Science, 4102*, 368-377.

Müller, D., Reichert, M., & Herbst, J. (2006). Flexibility of Data-Driven Process Structures. *Lecture Notes in Computer Science, 4103*, 179-190.

Müller, D., Reichert, M., & Herbst, J. (2007). Data-Driven Modeling and Coordination of Large Process Structures. *Lecture Notes in Computer Science, 4803*, 131-149.

Müller, D., Reichert, M., & Herbst, J. (2008). A New Paradigm for the Enactment and Dynamic Adaptation of Data-Driven Process Structures. *Lecture Notes in Computer Science, 5074*, 48-63.

Nigam, A., & Caswell, N. (2003). Business Artifacts: An Approach to Operational Specification. *IBM Systems Journal, 42*(3), 428-445.

Pinggera, J., Zugal, S., & Weber, B. (2010). Investigating the Process of Process Modeling with Cheetah Experimental Platform. *22nd International Conference on Advanced Information Systems Engineering* (pp. 19-24). Hammamet, Tunisia: CEUR Workshop Proceedings.

Qu, S., & Dumay, J. (2011). The Qualitative Research Interview. *Qualitative Research in Accounting & Management, 8*(3), 238-264.

Redding, G., Dumas, M., Ter Hofstede, A., & Iordachescu, A. (2008). Transforming Object Oriented Models to Process-oriented Models. *BPD'07*, (pp. 132-143). Brisbane, Australia.

Reijers, H., Limam, S., & Van der Aalst, W. (2003). Product-Based Workflow Design. *Journal of Management Information Systems, 20*(1), 229-262.

Strauss, A., & Corbin, J. (1998). *Basics of Qualitative Research.* London: SAGE Publications Ltd.

Van der Aa, J. (2013). *Automated Activity Composition in Product-Based Workflow Design.* Master Thesis (work-in-progress), Eindhoven University of Technology, Eindhoven.

Van der Aalst, W., Ter Hofstede, A., & Weske, M. (2003). Business Process Management: a Survey. *Lecture Notes in Computer Science, 2678*, 1-12.

Vanderfeesten, I., Reijers, H., & Van der Aalst, W. (2008). Product-Based Workflow Support: Dynamic Workflow Execution. *Lecture Notes in Computer Science, 5074*, 571-574.

Vanderfeesten, I., Reijers, H., & Van der Aalst, W. (2011). Product-Based Workflow Support. *Information Systems, 36*(2), 517-535.

Vanderfeesten, I., Reijers, H., Van der Aalst, W., & Vogelaar, J. (2010). Automatic Support for Product-Based Workflow Design: Generation of Process Models from a Product Data Model. *Lecture Notes in Computer Science, 6428*, 665-674.

Venkatesh, V., Morris, M., Davis, G., & Davis, F. (2003). User Acceptance of Information Technology: Toward a Unified View. *MIS Quarterly, 27*(3), 425-478.

Wolcott, H. (1990). On Seeking and Rejecting: Validity in Qualitative Research. In W. Eisner, & A. Peshkin, *Qualitative Inquiry in Education: The Continuing Debate* (pp. 121-152). New York: Teachers College Press.

Appendices

Appendix A. Tutorial: Data-Driven Process Structures

Data-driven Process Structures

Data-driven Process Structures is a modeling methodology that proposes a separation of the data structure on one hand from process logic on the other. Changes made to the product therefore do not automatically imply a complete redesign of the process structure, but are driven by changes of the product's data structure; these changes are automatically mapped to adaptations of the corresponding process structure, thereby saving efforts when evolving the process instance structure. In addition, data-driven process structures can easily contain many elements as they are constructed automatically.

Overview

In an overview of the methodology, four steps can be identified; two steps in the (abstract) *model level*, and two on the *instance level* (i.e. concrete examples). The first two steps are very abstract and are defined by domain experts. The domain experts create a meta-model, a framework, which can be used to create models for real instances. The two steps on the instance level, step 3 and 4, show such an instantiation; step 3 is a manual step that can be performed by users, while the model shown in step 4 is generated automatically, based on the defined meta-models and the provided instantiation.

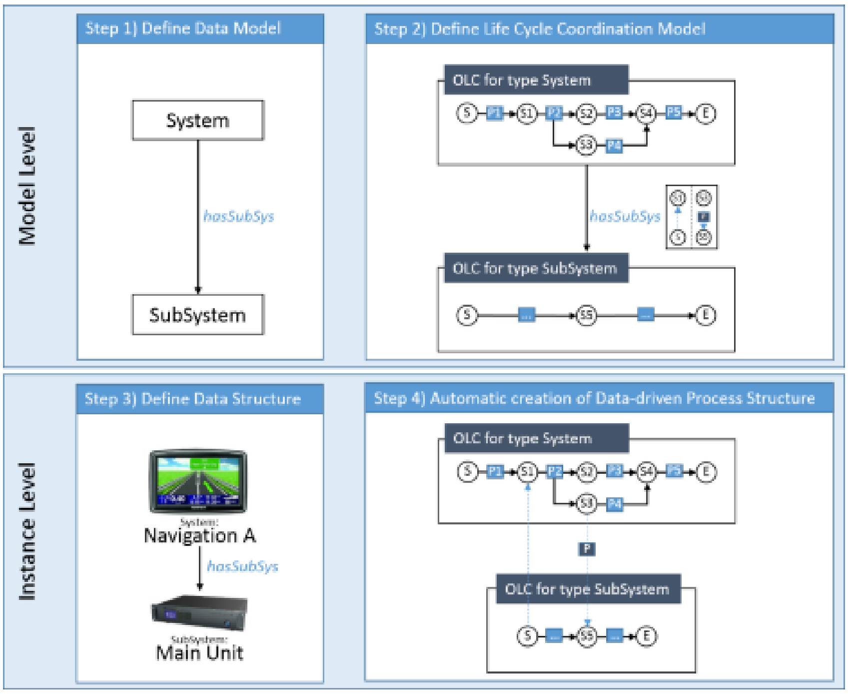


Figure 1 - Overview of Data-driven Process Structure methodology

Step 1. Definition of the Data Model
Step 2. Definition of the Life Cycle Coordination Model
} Model level (abstract)

Step 3. Definition of Data Structures
Step 4. Automatic creation of Data-driven Process Structures
} Instance level (concrete example)

Note that the first two steps are performed by domain experts, and are usually done only once for an entire domain. Step 3 can be performed by users and is unique in every project. Step 4 is performed automatically, based on the (user defined) data structure and the OLCs.

Main entities

In data-driven process modeling there is a separation of the model level and the instance level. The main entities in the model level are the data model and the corresponding life cycles of data objects. On the instance level, these models are instantiated, adding concrete names to the data objects. Since all these instantiated structures follow the abstract structure defined before, the final model (a data-driven process structure) can be determined automatically.

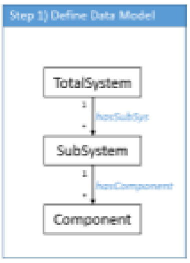


Figure 2 - Data Model

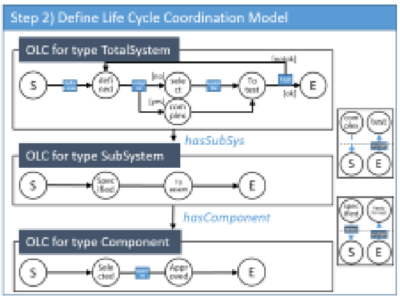


Figure 3 - Life cycle Coordination Model

Figure 4 - Data Structure

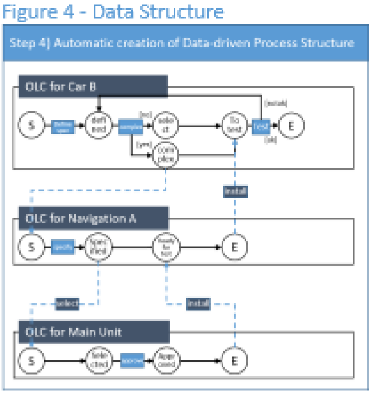


Figure 5 - Data-driven Process Structure

Data model: The data model includes all important *object types* (see Figure 2: “System”, “SubSystem” and “Component”) and their *relation types* (Figure 2: “hasSubsys”). Object types represent abstract or physical components that are part of the logical structure of the product; *relation types* or ‘dependencies’ describe the relation between different objects (including cardinalities).

Life Cycle Coordination Model: For each data object different *states* (e.g. defined, selected, tested) can be defined. Together with *internal state transitions*, which define how different states are connected, these states and internal transitions form *object lifecycles* (OLCs). In Figure 3 the OLCs for *TotalSystem*, *Subsystem* and *Component* are provided; all have a *starting state* ***S***, an arbitrary number of intermediary *states* ***Sx***, and an *end state* ***E***; different states are linked by sub-processes ***Px***. Object lifecycles often interact with other OLCs using *external state transitions*; a Lifecycle Coordination Model maps these states and transitions.

Data Structure: a data structure provides an instantiation of the *data model* (see Figure 2). Instead of mentioning *System*, *Subsystem*, and *Component*, the names of the represented objects are used. Note that although only one SubSystem (“Navigation A”) is defined in Figure 4, a system can include any number of SubSystems, due to the cardinality specified in Figure 2.

Data-driven process Structure: The previous step showed how a data structure is derived from a data model. In this step an OLC is automatically created for each object instance, based on this data structure and the OLCs as provided in the Life Cycle Coordination Model. In addition, the relations between OLC instances are automatically created as well, resulting in the creation of a Data-driven Process Structure.

In the first step of the model level, domain experts define a domain specific *data model*, consisting of object and relation types. This data model can be instantiated by users to obtain a *data structure* (step 3), consisting of objects and relations; the general terms are replaced with specified objects. On the right-hand side of Figure 6, the object types are enriched with *Object Life Cycles* (OLCs) that define the coordination of sub-processes and states associated with a particular object type (Step 2). For each different level of hierarchy (in the example this is two), a lifecycle needs to be defined. The lifecycles

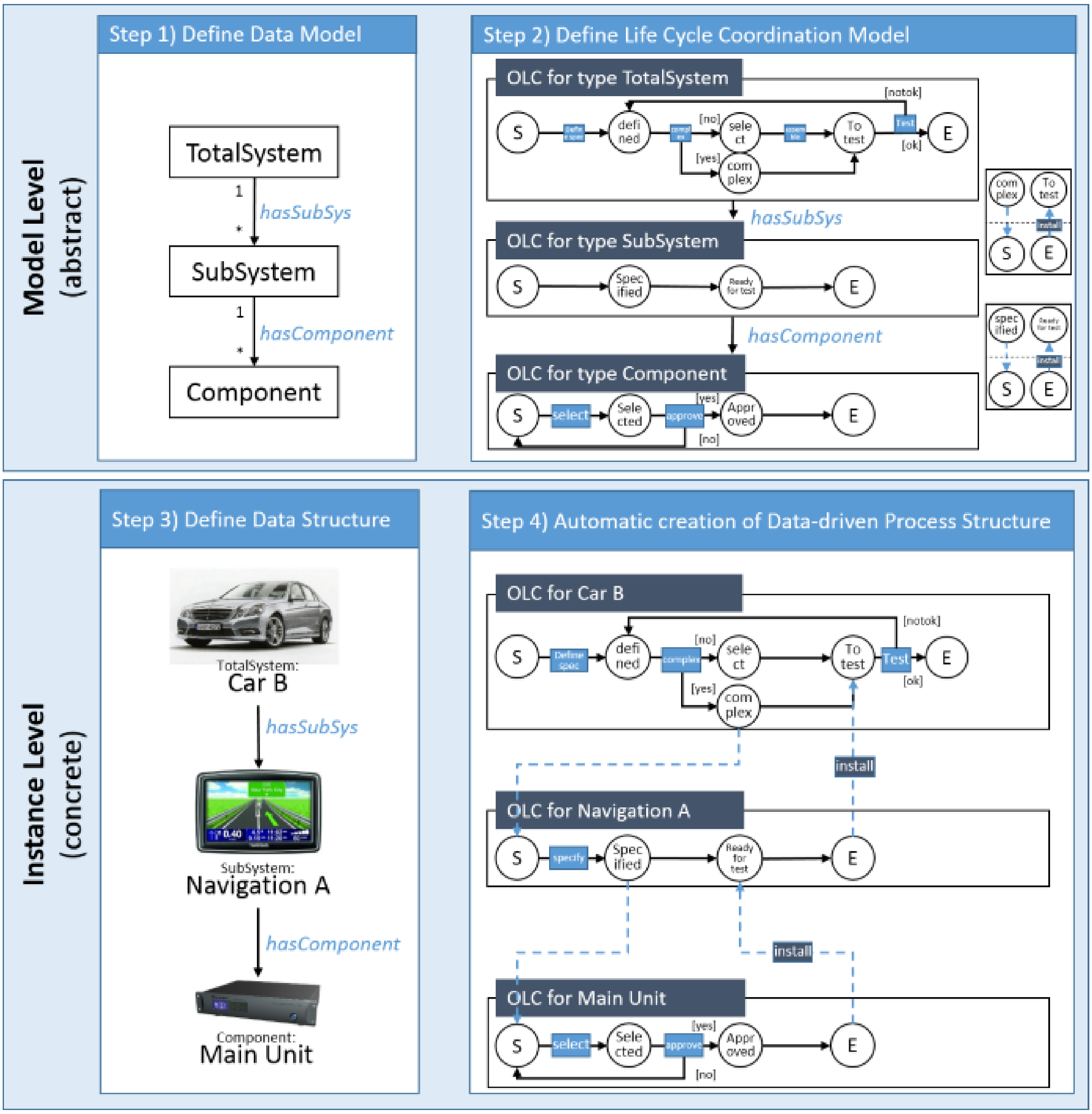


Figure 6 - Overview of Data-driven Process Structures

differ only per *object type*; for example, all SubSystems have identically structured OLCs. In addition to *internal state transitions* that consider the sub-processes and states of a single object, dependencies between sub-processes associated with different object types exist as well (so called *external state transitions*); an external state transition could for example describe that a specific process of a subsystem (e.g. 'testing') should be completed before continuing with the process of total system.

These Object Life Cycles and their external state transitions together form the Life Cycle Coordination Model (LCM). An instantiated version of an LCM, which is created automatically based on the LCM and the definition of the data structure, is called a Data-driven Process Structure (Step 4). Note that, since the data-driven process structure is created automatically, this is also possible when dealing with a large number of objects).

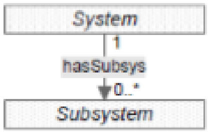
Example: Car Navigation System

MÜLLER, D., REICHERT, M., HERBST, J. (2008). A NEW PARADIGM FOR THE ENACTMENT AND DYNAMIC ADAPTATION OF DATA-DRIVEN PROCESS STRUCTURES, LECTURE NOTES IN COMPUTER SCIENCE, 5074, 48-63.

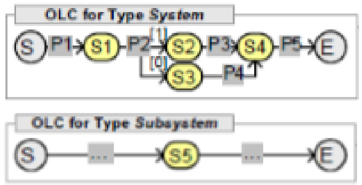
The example described below considers the navigation system of a car. The release management (RLM), which systematically tests and releases different systems and subsystems, requires several processes to be executed for each electrical component. These processes should be synchronized with processes of other components (test an assembly only after its components are tested individually). Note that there can be differences between navigation systems (e.g. a more luxurious car series can have an extensive navigation system); different data structures and therefore process structures can be created.

The four different steps in creating Data-driven Process Structures are described below.

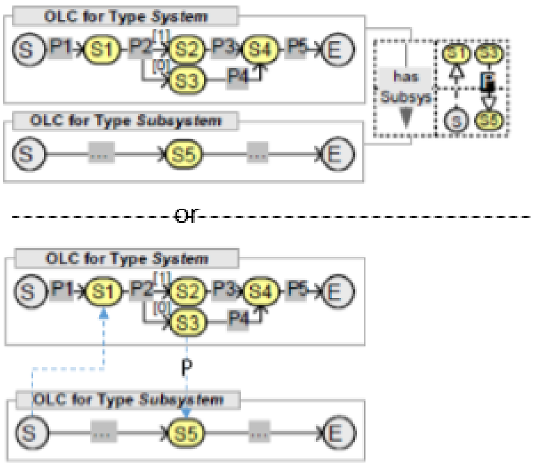
1. First a Data Model needs to be defined. The *System* that is created is the navigation system, which consists of an arbitrary number of *Subsystems* (see cardinalities).



2. The second step is to create the lifecycles of the different objects; the individual object lifecycles (OLCs) can be created first; as can be seen, the states as well as the processes are formulated in a very general manner.



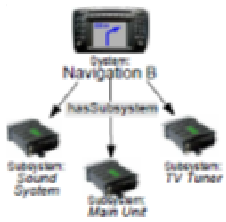
   The individual OLCs can then be internally linked following the Data Model as defined in the first step. In this example, *System* in the Data Model will be replaced with the *OLC of System*; *Subsystem* will be replaced with its OLC in the same way. Linking related states of different OLCs using *external state transitions* (see "hasSubsys") results in the Lifecycle Coordination Model (LCM). Note that, the external transitions can be represented either by a box that shows which states are related (❶), or by incorporating these transitions directly in the object lifecycles (❷).



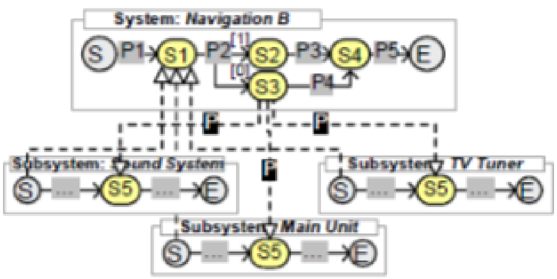
❶

❷

3. The main difference between the data model (created in the first step) and the data structure created here, is that in the latter a concrete instance is described. A *Data Structure* includes name and version numbers of the actual system (e.g. Bose 5.1, v 2.13)



4. When all desired *Subsystems* are added, the Data-driven Process Structure can be derived automatically. Note that there is no difference between the creation of a *System* with one *Subsystem* and a *System* with three *Subsystems*: since all *Subsystems* are related to the main *System* in an identical way, the same step will be repeated three times (in the figure the three OLCs of the *Subsystems* are identically structured and related to the *System*).



The overview below (Figure 7) provides a nice example of the use of the abstract Model Level (Data Model, LCM) and the specified Instance Level (Data Structure, Data-driven Process Structures). In the first example in the instance level (block C and D) a navigation system only has one subsystem; in the second example (block E and F) the navigation system has three subsystems. As can be seen, the process structure of the second example also includes the OLCs of the other subsystems; the lifecycle of Subsystem is multiplied for each of the three subsystems, and connected to the System in an identical way.

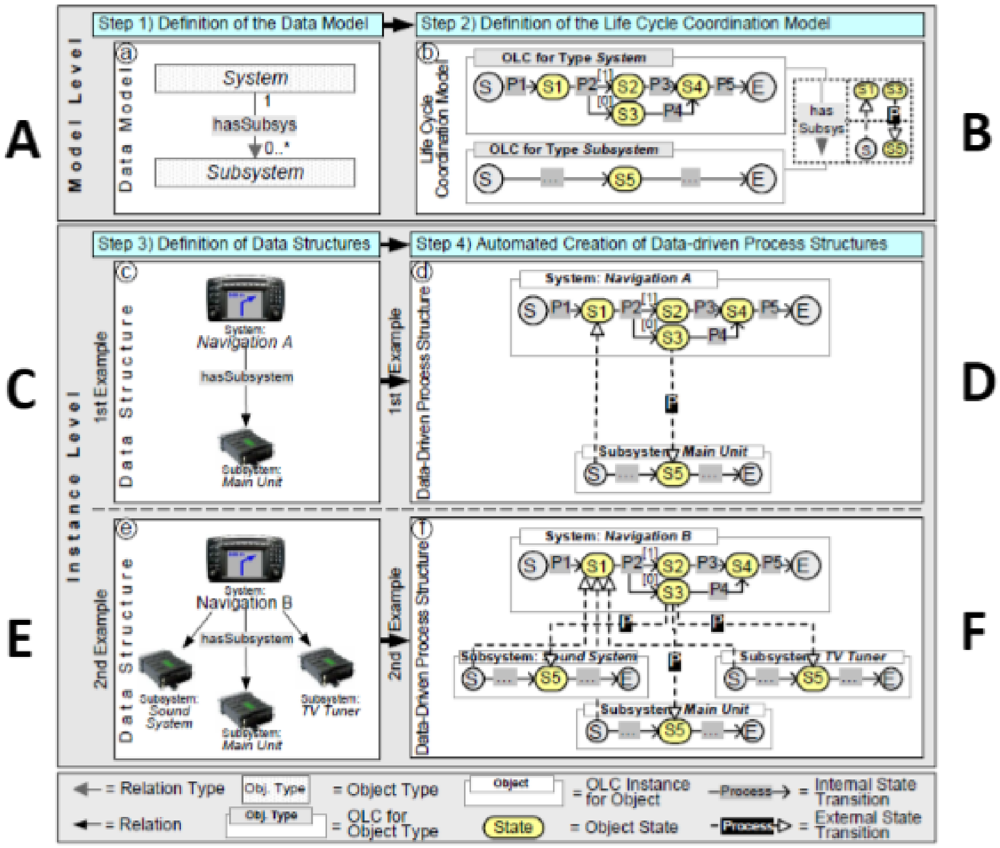


Figure 7 - Two examples of Data-driven Process Structures

Exercise

This exercise is about the Telematics System in a car (which can be considered top level). The system consists of different SubSystems, from which we will consider two: the Display Unit (V3.14) and the TV Tuner (V2.15). The Display Unit is actually a part of the Telematics System, while the TV Tuner is not an actual part, but merely a subsystem used by the Telematics System. The Data Model is already provided by domain experts.

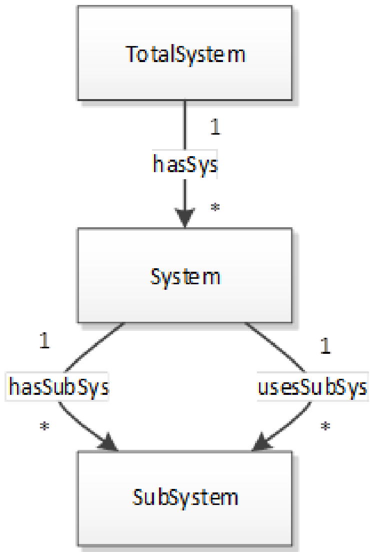
In order to test drive a car, first all systems and subsystems should be tested separately. After suppliers are selected for the different parts of a system, the specifications of a subsystem are sent to the suppliers and parts are ordered. When all subsystems meet the specified criteria, the system can be assembled. If all systems included in the total system are checked and approved, the prototype can be prepared and tested. Note that when systems and subsystems do not meet the criteria, a part of the process is performed again.

Step 1: Provide the Data Model

The Data Model is provided below. Three different levels of hierarchy can be distinguished:

- TotalSystem, which includes the complete final product (in the example a car);
- System, which includes a complete system that is used in the final product;
- SubSystem, which includes smaller systems that are part of or used by a System.

As can be seen, a SubSystem can be linked in two different ways to System: when a SubSystem is only *used* by a System, one should select the *usesSubSys* relation; when the SubSystem is part of the System, one should use both *hasSubSys* and *usesSubSys.*



Step 2a: Provide the Object Lifecycles

TotalSystem

System

SubSystem

Step 2b: Create the according Lifecycle Coordination Model

When defining the LCM, the different states of and Object Lifecycle are connected to each other. Use one of the two methods explained in Step 2 on page 6 to create an LCM.

Step 3: Create the Data Structure

Step 4: Automatic Creation of Data-driven Process Structure

This step is based on the Lifecycle Coordination Model (LCM) and Data Structure, and will be shown in the Proposed Solutions of the exercise.

Appendix B. Tutorial: Product-Based Workflow Design

Product-Based Workflow Design

Product-Based Workflow Design (PBWD) is a method based on similar concepts as used for optimization in industry. Based on a technique comparable to the Bill of Materials (BOM) used in manufacturing, which links different parts and components in an organized manner, a Product Data Model (PDM) is used to identify and link data objects in an organized way, thereby creating a foundation for the redesign. By using a true clean sheet approach, the created process is very lean and provides an optimized solution for the redesign.

Main entities

The most important entity used in PBWD is the Product Data Model. The PDM identifies and links different data objects to each other. In many cases the information of different objects can be combined to create a value for another object.

Figure 1 - Data element

Data element: main objects which contain specific information. Some elements are determined by the external environment ('leaf elements'), while other elements are determined by combining information of other objects. Note that data elements cannot be updated in PBWD; once determined, data elements have fixed values.

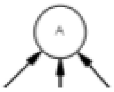


Figure 2 - Top data element

Top data element: specific instance of a data element; this is the data element for which the eventual outcome is to be determined, it is the end product/final decision.

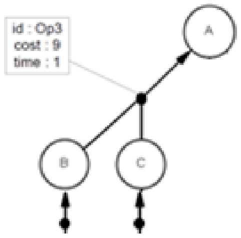


Figure 3 - Production Rule

Production rule: a production rule (represented by a black dot) is used to combine information of data elements to create a value for another element. In the provided example, information of data elements B and C is combined to create a value for data element A. Rules are either concrete or abstract; for both types an example is provided.

- Concrete A = 3 * B + C
- Abstract Human judgment on suitability A based on both elements B and C

Figure 4 - Attributes

Attributes of production rule: provides information about other characteristics of executing the production rule. In the example an identifier, cost and time are provided, but more could be added (e.g. probability of success).

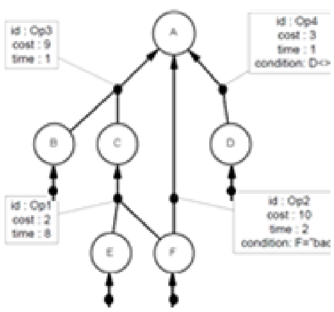


Figure 5 - Product Data Model

Product Data Model (PDM): This is the main entity of PBWD. It provides a complete overview of the different objects and their relations, as well as the according production rules.

In the example, A is the top element for which a decision should be made. B, D, E, and F are all examples of leaf elements. C is the only element (not considering the top element) which can be created using the information of E and F and the according production rule (Op1). As can be seen, the according cost (2) and time (8) have to be spent.

Product Based Workflow Design (PBWD), the methodology that makes use of the PDM, is especially useful for processes that combine different pieces of information to make a single decision. For example insurance claims (pay/no pay) or mortgage processes (reject/accept request); a final decision can be made based on different elements of data.

Production rules, as mentioned earlier, can have different characteristics. These characteristics can differ in terms of costs, time, probability of success, et cetera. Dependent on the selected performance indicator, the best possible solution can be picked.

Example: Helicopter pilot

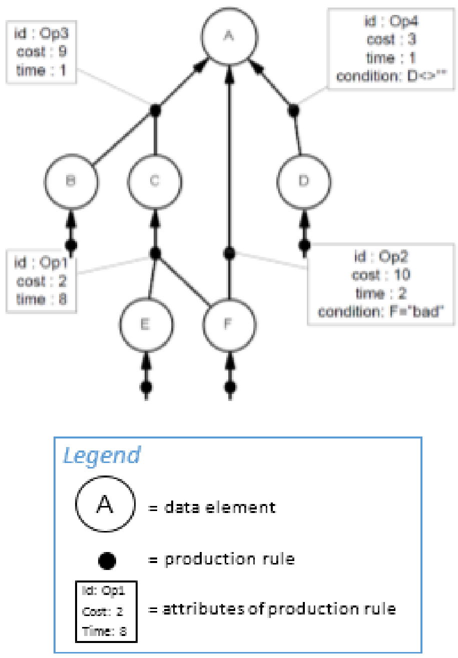
REIJERS, H.A., LIMAM, S.,VAN DER AALST, W.M.P. (2003). PRODUCT-BASED WORKFLOW DESIGN, JOURNAL OF MANAGEMENT INFORMATION SYSTEMS, 20 (1), 229-262.

This example shows the product data model that describes the process to determine someone's suitability to become a helicopter pilot. The top element is ***A***, which corresponds to the suitability to become a helicopter pilot. Decisions are based upon psychological fitness, physical fitness (***B*** and ***C***), latest results of a suitability test from the last two years (***D***), and the quality of reflexes and eyesight (***E*** and ***F***).

As can be seen from the arrows leading directly to ***A***, a decision can be made based upon a combination of psychological and physical fitness {***B***,***C***}, results of a previous test {***D***}, or {***F***} quality of eyesight. In a similar way, a value for ***C*** can be obtained using the results from {***E***,***F***}.

A decision (either positive or negative) can be made using one of the above described sets of data elements. However, to be able to choose the optimal path, additional information is required about time and cost.

Using the model and its constraints, the best solution with respect to a performance indicator (cost, time) can be selected. For the leaf elements in this example (elements that are acquired from external environment) no attributes of the production rules are specified; one can consider the cost and time for creating these elements to be zero.



ID	*x*	*constr(x)*	*cost(x)*	*time(x)*
Op1	(c, {e,f})	True	2	8
Op2	(a, {f})	F = bad	10	2
Op3	(a, {b,c})	True	9	1
Op4	(a, {d})	D <>""	3	1

Figure 6 - Helicopter Pilot Example

Exercise

The next example describes the calculation of the maximum amount of mortgage a bank is willing to loan to a client. When a new client that is going to apply for a new mortgage loan enters the bank, he first has to provide some information about his gross income and the specifications of previous mortgage offers made in the last six months (if any); previous offers that are made in the last 6 months can be used directly to determine the maximum amount. When no such offers exist, the bank employee checks the client's credit registration at the Central Credit Register, to ensure the client has no insurmountable debts. When the results of this test are positive (no overwhelming debts), the bank employee combines the credit registration and gross income with the percentage of income a client is allowed to spend on the mortgage, to determine the annual budget spent on the mortgage. Hereafter he selects, together with the client, the term of the mortgage. Based on the client's annual budget to spend on the mortgage, the term of the mortgage, and the percentage of interest, the employee is able to determine the maximum amount the bank is willing to loan.

Step 1: Select all important data elements

Step 2: create the product data model

Step 3: Create some Production Rules (provided)

Production rules are either concrete or abstract rules; in a single PDM, both concrete and abstract rules can be used. Although a table that consists all production rules of a PDM model is not obligatory, it can be used to further specify the model and rules. An example of such a table is provided in Table 1.

	(Creates, {requires})	*Cost*	*Time*	*Description*
Op1	(A,{B})	2	2	If offer is placed in lasts 6 months, then A=B
Op2	(A,{F})	9	3	If F = not OK, then A=0
Op3	(A,{C,D,E})	5	1	Employee determines maximum amount based on annual budget spend, term of mortgage, and percentage of interest.
Op4	(B,{})	1	1	
Op5	(C,{})	0	0	
Op6	(D,{F,G,H})	5	4	Employee combines credit registration info with gross income and percentage a client is allowed to spend, to determine the maximum amount the bank is willing to loan.
Op7	(E,{})	0	0	
Op8	(F,{})	3	10	
Op9	(G,{})	0	2	
Op10	(H,{})	0	0	

Table 1 - Production Rules

Exercise 2

When applying for a citizenship, applicants have to meet some predefined requirements. The next example shows the requirements that applicants should meet to be qualified for acquiring the Dutch citizenship. This exercise does not focus on the *identification* of data elements (which will be provided) but on the *creation of production rules* and different *routing opportunities*.

Statute Law on Dutch Citizenship, art. 8

1. For grant of the Dutch citizenship is only qualified the applicant
   a. Who is of age,
   b. Against whose permanent stay in the Netherlands, Netherlands Antilles or Aruba no objections exist,
   c. Who has had admittance and main residence in the Netherlands, Netherlands Antilles or Aruba, for at least five years immediately preceding the request, and
   d. Who can be seen as adapted to the Dutch, Dutch-Antillean or Aruban society based on the fact that he has sufficient level of knowledge of the Dutch language [...] as well as sufficient knowledge about the Dutch constitution and society [...].

Step 1: Select all important data elements (provided)

A. Applicant is entitled to Dutch citizenship
B. Objections exist against permanent stay of applicant
C. Applicant has allowance and main residence in the Netherlands, Netherlands Antilles or Aruba for at least five years immediately preceding the request
D. Age of applicant
E. Applicant can be seen as naturalized
F. Knowledge of the Dutch language
G. Knowledge of the Dutch constitution and society

Step 2: Create the Product Data Model

Hint: different paths to the end decision can have different costs; make sure to include all possible paths.

Step 3: Create Production Rules

Although no statements are made for time and cost, try to think of some production rules that enrich the model, in order to make the model suitable for optimization. Adding this information to production rules, the costs of alternative paths can be calculated.

Operation	*Creates,* *{Requires}*	*Time*	*Cost*	*Description*
Op1				
Op2				
...				

Appendix C. Tutorial: Artifact-Centric Process Models

Artifact-centric Process Modeling

The artifact-centric approach is developed as an aid to analyze, manage, and control business operations. As already introduced by the name, artifacts play an important role in this method. Artifacts are key entities that combine data and behavioral properties; together with their life cycles and relations to each other, artifacts can offer models that provide a complete overview of the business process.

Main entities

There are different steps one should follow when creating an artifact-centric process model. First the key data objects and their dependent objects need to be identified; from a business perspective, these so-called business artifacts manifest operational goals. Next, detailed specifications of the data objects are defined, as well as the tasks and relations that are associated with the artifacts. In addition, rules are defined that specify the links between services and artifacts.

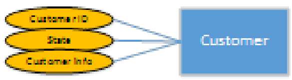


Figure 1 - Business Artifact

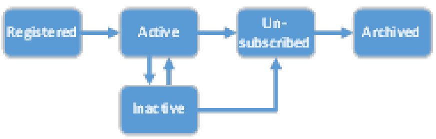


Figure 2 - Artifact Life cycle

Service	Generate_Production_Order
Inputs	- Artifact: Order
Outputs	- Artifact: Order - Artifact: Production Order
Pre-conditions	Order is evaluated and accepted.
Conditional Effect	If the Order is evaluated and accepted, then: - Define Scheduled Date of *Production Order* - Define Product Details of *Production Order* - Define ID of *Production Order* - Define state of *Production Order* (Scheduled)

Table 1 - Service

Rule 11	Create Production Order
Events	Order enters state **InProcess**
Conditions	(none)
Actions	invoke Generate_Production_Order
By	

Table 2 - Association

Business artifact: Concrete, self-describing, and unique entity that corresponds to a key data object. Artifacts include all information required for executing business processes. In addition, artifacts have a unique identity (ID) that cannot be changed; the other *attributes* of artifacts can be changed at will. An example of an artifact could be a customer (Figure 1) or a task.

Business artifact (macro-level) life cycle: The lifecycle of an artifact provides its end-to-end process; it describes the states of an artifact from creation to disposal. Artifacts may have different life expectancies: some live short, others long, while still others are essentially permanent.

Service: unit of work that is meaningful to the business process. Services make changes to one or more artifacts; these changes are transactional; the service has exclusive control over the involved artifacts when making changes. Each service can be decomposed in four properties, which define the actual service in a structured manner. The four key aspects are Inputs, Outputs, Pre-conditions, and Effects (IOPE). For all changes that need to be made, the artifact(s) and attribute(s) that are changed are specified. When an artifact changes states as a result of the service, this is defined here as well (e.g. the *Production Order* will be placed in state '**Scheduled**' of its lifecycle).

Association: changes made by services to artifacts are subject to a number of constraints. These constraints can be procedural (order of execution) or declarative (based on rules and properties). *Association rules* capture these constraints by defining at which *Event*, given defined *Conditions*, a certain *Action* should be performed (ECA). When required, the person performing the action can be added as well ('by').

These entities together form BALSA^{basic} (Business Artifacts with Life cycles, Services, and Associations), and can be used to formulate business processes.

The artifact-centric approach defines the following steps to acquire insights in one's processes:

1. *Business Artifacts Discovery*
   a. *Identify critical artifacts for the business process and identify relations between artifacts*
   b. *Discover key states of artifacts' life cycles from the scenario-based requirements*
2. *Design of Business Operations Model (BOM)*
   a. *Logical design of artifact schemas*
   b. *Specify services for artifacts needed for moving artifacts through the life cycles*
   c. *Develop Event-Condition-Action rules that specify the links between services and artifacts*
3. *Design of Conceptual Flow Diagram*❶
4. *Workflow Realization*❶

❶ The final two steps can be performed to create actual processes. However, as this study focuses on the creation of new insights instead of on the creation of new processes, these steps are beyond the scope of this study and are therefore excluded.

Example: Distributed Enterprise Services (DES)

BHATTACHARYA, K., HULL, R., SU, J. (2009). A DATA-CENTRIC METHODOLOGY FOR BUSINESS PROCESSES. IN J. CARDOSO AND W. VAN DER AALST, EDITORS, HANDBOOK OF RESEARCH ON BUSINESS PROCESS MANAGEMENT.

The following example considers the company Distributed Enterprise Services (DES), an IT service provider that provides IT services to one or more enterprises, each of which comprise a large number of locations; one could think for example of a chain of restaurants that has several locations throughout the country. The company provides provisioning, installation, maintenance and general support to all of the enterprises' locations. Due to the highly distributed nature of the problems, DES often makes use of subcontracted vendors to provide the IT services.

The main goal of DES is to complete services or an installation at a location. The services are organized using elaborate schedules, that contain planned and actual content of the installation project (for example a set of tasks that should be performed). In this example a business process is defined that concerns the main operational goal (completing services and installations at sites) using the artifact-centric modeling approach. First a brief description of the process is provided.

When a location faces a problem or requires a new installation, they contact DES. DES has a structured set of services they provide (known as Offered DES Services); from the problem description, they are able to point out the specific set of tasks that should be performed. For each of the selected generic tasks DES has the knowledge to provide the service, or knows which subcontractor is able to provide it; a schedule is created in which all required tasks, including time schemes and vendor, are specified.

Step 1a: Identify critical artifacts for the business process and identify relations between these artifacts

The first step in artifact-centric process modeling is to identify the different artifacts that can be distinguished, and create a schedule that shows how they are linked to one another (Step 1a). An Entity

Relationship (ER) model is used to capture the most important artifacts and their relations (including cardinalities).

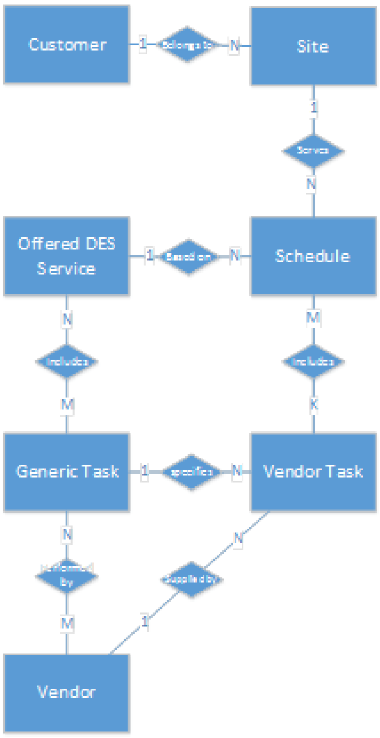


Figure 3 - Identify Critical Artifacts (Step 1a)

On the right hand side of Figure 3 one of the most important artifacts of this process is described: the *Schedule*. It contains the planned and actual content of the installation project plan. A *Schedule* consists of an arbitrary number of *Vendor Tasks*, which correspond to individual tasks that should be performed by DES or one of their subcontracted vendors. While these kinds of artifacts contain very concrete information of the task that should be performed, some artifacts include a more general description of the services and tasks. The *Offered DES Service* for example contains the templates for the different services (sets of tasks) that can be provided by DES, while *Generic Task* holds the general descriptions of the tasks that can be performed (as part of a DES service), as well as information of the vendors that are able to perform these tasks. Three artifacts in the figure contain background information, representing the *Customers*, their *Sites*, and the various *Vendors* (the subcontractors).

Step 1b: Discover key states of artifacts' life cycles from the scenario-based requirements

With the artifacts defined and linked, the Business Artifact Life Cycles can be formulated. Figure 4 provides the life cycle for the artifact class *Schedule*: there are six different states in this life cycle (rounded rectangles). The planning should be approved before executing; when approved, only minor revisions can be made directly; for major revisions the schedule needs to be re-approved.

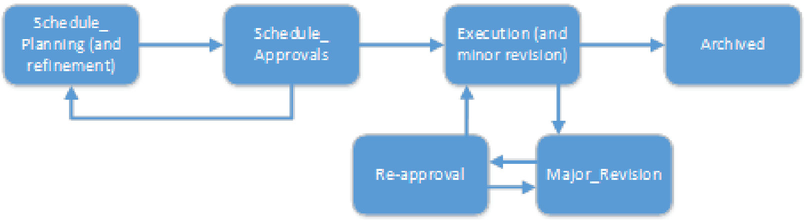


Figure 4 - Identify Critical states in the Artifact's Lifecycle (Step 1b)

Step 2a: Logical design of artifact schemas

With the key artifacts as well as their life cycles defined, various attributes of the artifacts can be added. For *Schedule,* for example the state, planned start and end date, and the revision checklist are important. Although many differences exist between the attributes of different artifacts, all receive a unique identification, which thereby makes each artifact unique as well (see for example *Schedule ID, Generic task ID*).

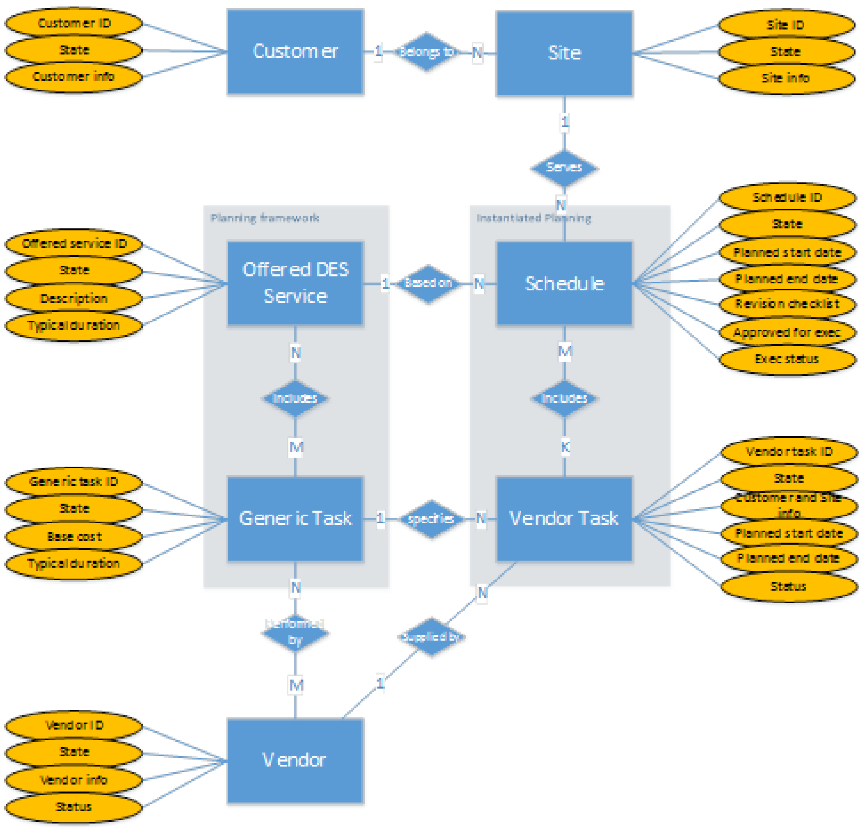


Figure 5 - Create a Logical Design of Artifact Schemas (Step 2a)

Step 2b: Specify services for artifacts to enable state transitions

Next, different tasks (or 'services') need to be defined. As specified earlier, there are four important aspects of a service: Input, Output, Pre-conditions, and Effects. For the *Create_Schedule* service, the artifacts *Offered DES Service, Customer, and Site,* are required inputs. The output of this service is the actual *Schedule* and the linked *Site*. Furthermore, the pre-condition is checked (using information from the input artifacts) and information about the conditional effect, the effect that applying the service will have, is provided. The specification of the service *Create_Schedule* can be found in Table 3.

Service	Create_Schedule
Inputs	- Artifact: Offered DES Service - Artifact Customer - Artifact: Site
Outputs	- Artifact: Schedule - Artifact: Site
Pre-conditions	The infrastructure and value of the *Offered DES Service* should be compatible with the infrastructure and needs of the *Site*.
Conditional Effect	If the infrastructure and value of the *Offered DES Service* are compatible with respectively the infrastructure and needs of the *Site*, then: - Define Schedule_ID - Define state of Schedule (**Schedule_Planning**) - Define state of Site (**Being_Served**)

Table 3 - Specify Services for Artifacts (Step 2b)

Step 2c: Develop Event-Condition-Action rules for specifying associations between services and artifacts

The next step in creating an artifact-centric process model is the specification of Event-Condition-Action (ECA) rules; they state how services are associated to artifacts. ECA rules are structured as follows: whenever an *Event* occurs that meets predefined *Conditions*, the corresponding *Action* is performed. Some rules have no *Event* specified, which means that they can be initiated any time.

R1	Initiate Schedule
Events	Request by *Performer* to create a *Schedule* instance for *Offered DES Service, Customer*, and *Site*
Conditions	the appropriate non-disclosure agreements (NDAs) are in place for *Customer*
Actions	**invoke** Create_Schedule

Table 4 - Develop ECA Rules that enable Artifacts progress through their lifecycles (Step 2c)

Given the example of the *Schedule*, it should be initiated at a given point in time. When at a given point in time the *Performer* places a request that a *Schedule* should be created (including information about the Offered DES Service, Customer, and Site artifacts) rule R1 checks whether all appropriate documents, in this case the NDAs, are in place; if this is indeed the case, the service *Create_Schedule* is invoked, thereby creating a Schedule and defining the according attributes (for description of the *Create_Schedule* service, see Table 4). If the conditions are not met, the according action is simply not performed.

Exercise

A small case is created here, to practice with the explained methodology. As the case description is very brief, it might very well be that information is missing; own insights and ideas can be used to overcome the lack of information. Note that the general idea is to get some hands on experience using the methodology and its techniques; one should not spend too much time creating models that reflect reality.

This exercise is about ordering a meal in a restaurant. The restaurant offers a menu consisting of different meal options (e.g. pasta, pizza), thereby offering the opportunity to select options for each type of meal. Since the specified meals can be very diverse, the required ingredients are not always directly available; unavailable ingredients should be prepared first (e.g. cutting vegetables). For each customer the restaurant keeps a Guest Check, on which the different ordered goods and their prices are listed.

Step 1a: Identify all important artifacts and show their relations (including cardinalities)

Step 1b: Provide a lifecycle for the artifacts *Customer* and *Specified Meal*

Step 2a: create a logical design of the artifact schemas (including their attributes)

Step 2b: specify services for the creation of a new Customer and the registering of a new Guest Check.

Service	
Input	
Output	
Pre-condition	
Effects	

Service	
Input	
Output	
Pre-condition	
Effects	

Step 2c: Develop a rule that enables the creation of a Customer.

Rule 1	
Events	
Conditions	
Actions	

Appendix D. DDPS: Claims from Developers

Category	Concept	Code	Claim	Year	Pg.	Quote
Efficiency	Automated creation	Automated Creation	D7	2007	3	automated creation of process structures based on data structures
Efficiency	Automated creation	Automated Creation	D7	2007	4	Concept must enable automated creation of data-driven process structure
Efficiency	Automated creation	Automated Creation	D7	2007	5	LCS can be automatically generated based on inputs
Efficiency	Automated creation	Automated Creation	D7	2007	18	automated creation of process structures based on data structures
Efficiency	Automated creation	Automated Creation	D7	2008	2	when changing product data structure at buildtime, related process structure can automatically be recreated
Efficiency	Automated creation	Automated Creation	D7	2008	4	Based on object types and relationships, process structures can be specified at model level and automatically instantiated
Efficiency	Automated creation	Automated Creation	D7	2008	6	corepro allows to instantiate different data structures and automatically create related process structures
Efficiency	Automated creation	Automated Creation	D7	2008	10	data structure changes should be automatically transformed into corresponding process structures
Efficiency	Multiple instantiations of models	Instantiate different Data Structures	D6	2007	18	instantiation of different data structures
Efficiency	Multiple instantiations of models	Instantiate different Data Structures	D6	2008	4	for models with same behavior, one OLC is modelled (which can instantiated multiple times)
Efficiency	Multiple instantiations of models	Instantiate different Data Structures	D6	2008	6	Different process structures can be automatically created by instantiating respective data structures
Efficiency	Reduce modeling efforts	Reduce modeling efforts	D9	2007	1	Method reduces modeling efforts significantly
Efficiency	Reduce modeling efforts	Reduce modeling efforts	D9	2007	2	Reduce modeling efforts for DDPS
Efficiency	Reduce modeling efforts	Reduce modeling efforts	D9	2007	4	In order to reduce efforts, model and instance level are separated
Efficiency	Reduce modeling efforts	Reduce modeling efforts	D9	2008	15	approach reduces modeling efforts for large process structures
Efficiency	Reusability	Reduce modeling efforts: Reusability	D8	2007	2	increasing reusability
Efficiency	Reusability	Reduce modeling efforts: Reusability	D8	2008	5	procedures for modifying different objects might slightly differ (eg different testing procedures for Sound System and TV Tuner)
Flexibility	Other environments	Use in other environment	D11	2007	18	presented concept is not specific to the engineering domain
Functionality	Goal of method	Data-driven specification	D1	2007	1	Data-driven modeling of large process structures, reducing modeling efforts and provide mechanisms for maintenance
Functionality	Goal of method	Data-driven specification	D1	2007	3	data-driven specification of process structures at model level
Functionality	Goal of method	Data-driven specification	D1	2007	4	Corepro supports the definition of the product data structure
Functionality	Goal of method	Data-driven specification	D1	2007	5	Process structure describes dynamic aspects of given data structure
Functionality	Goal of method	Data-driven specification	D1	2008	15	approach ensures correct coordination of processes
Functionality	Goal of method	Modeling, enactment, adaptation	D1	2008	2	COREPRO provides techniques for modeling, enactment, (dynamic) adaptation of process strucutres based on data structures
Functionality	Goal of method	Modeling, enactment, adaptation	D1	2008	3	corepro addresses full lifecycle of data driven process structures including modeling, enactment, (dynamic) adaptation
Functionality	How to achieve goal	Separate data and process logic	D2	2007	5	Corepro enables definition of dynamic aspects of object and relations at model level
Functionality	How to achieve goal	Separate data and process logic	D2	2007	18	model driven design in combination with instantiation mechanism For DDPS
Functionality	How to achieve goal	Separate data and process logic	D2	2008	3	When changing, benefit from strong linkage between process structure and product data structure
Functionality	How to achieve goal	Separate data and process logic	D2	2008	4	corepro follows model-driven (respectively data-driven) approach by differing between model and instance level
Functionality	IT Support	Soundness checks	D3	2007	11	Corepro enables checking soundness on model level
Functionality	IT Support	Soundness checks	D3	2007	11	corepro guanrantees soundness for every data-driven process structure based on sound LCM
Functionality	IT Support	Soundness checks	D3	2008	6	COREPRO allows for checking soundness on model level
Functionality	IT Support	Soundness checks	D3	2008	10	for static changes: soundness can be ensured if underlying LCM is sound
Functionality	IT Support	Soundness checks	D3	2008	15	Corepro disallows dynamic changes of process structures which would lead to an inconsitent runtime situation
Maintainability	Changing models	Data-driven adaptation	D10	2007	1	Provides mechanisms for maintaining DDPS
Maintainability	Changing models	Data-driven adaptation	D10	2007	2	increasing maintainability
Maintainability	Changing models	Data-driven adaptation	D10	2007	3	data-driven adaptation of process structures to deal with real world changes
Maintainability	Changing models	Data-driven adaptation	D10	2008	9	COREPRO allows to insert objects and object relations into a given data structure as well as to remove them
Maintainability	Changing models	Data-driven adaptation	D10	2008	10	COREPRO provides basic operations for inserting and deleting OLC instances as well as OLC dependencies
Maintainability	Changing models	Data-driven adaptation: automatically translated	D10	2007	14	changes can be specified at data level and are automatically translated into corresponding adaptations, reducing efforts
Maintainability	Changing models	Data-driven adaptation: automatically translated	D10	2008	3	data structure changes can automatically be translated into adaptations of the corresponding process structure
Maintainability	Changing models	Data-driven adaptation: automatically translated	D10	2008	9	users adapt data structure, and these changes are automatically translated into corresponding adaptations of process structure
Maintainability	Changing models	Data-driven adaptation: automatically translated	D10	2008	10	data driven process structures have to be dynamically adapted when related data structure is changed
Maintainability	Changing models - runtime	Changing (dynamically)	D10	2008	1	new techniques for (dynamically) adapting data driven process structures
Maintainability	Changing models - runtime	Changing (dynamically)	D10	2008	1	COREPRO provides new paradigm for changing data-driven process structures at runtime, reducing costs of change
Usability	Expert: ease of use	Profound domain knowledge required	D5	2007	4	subprocess dependencies have to be defined
Usability	Expert: ease of use	Profound domain knowledge required	D5	2007	4	definition of data model requires profound domain knowledge
Usability	Expert: ease of use	Profound domain knowledge required	D5	2007	4	Process experts describe dynamic aspects of each object type
Usability	Expert: ease of use	Profound domain knowledge required	D5	2007	5	Data model, Data structure, LCM are generated manually
Usability	User: ease of use	Changes at high level of abstraction	D4	2008	3	changes can be introduced at high level of abstraction, reducing cost and complexity
Usability	User: ease of use	Changes at high level of abstraction	D4	2008	9	Users must be able to perform changes at a high level of abstraction
Usability	User: ease of use	Changes at high level of abstraction	D4	2008	15	approach enables adaptations of process structures at both build- and runtime at a high level of abstraction
Usability	User: ease of use	Users can instantiate	D4	2007	3	intuitive and product-related integration of data and (sub-)processes
Usability	User: ease of use	Users can instantiate	D4	2007	4	instantiation can be done by users
Usability	User: ease of use	Users can instantiate	D4	2007	18	integrating data and process, allowing user without process knowledge to adapt process structure by adapting data structure
Usability	User: ease of use	Users can instantiate	D4	2008	2	enable users to adapt complex process structures

Used articles
2007: Müller, D., Reichert, M., & Herbst, J. (2007). Data-Driven Modeling and Coordination of Large Process Structures. *Lecture Notes in Computer Science, 4803*, 131-149.
2008: Müller, D., Reichert, M., & Herbst, J. (2008). A New Paradigm for the Enactment and Dynamic Adaptation of Data-Driven Process Structures. Lecture Notes in Computer Science, 5074, 48-63.

Appendix E. PBWD: Claims from Developers

Category	Concept	Code	Claim	Year	Pg.	Quote
Efficiency	Automated creation	Automated creation of PM	P9	2011	30	in some cases the PDM can be converted into procedural model
Efficiency	Automated creation	PDM itself as vehicle to steer WF execution	P9	2011	32	instead of deriving a WF design that in general is the best way to generate info-product, PDM itself is used to steer WF execution
Efficiency	Multiple instantiations of models	Optimizing: create different models	P8	2003	31	Based on a cost optimal plan and PDM, all execution sequences of prod. rules can be derived that have positive prob. to deliver value for top element
Efficiency	Optimizing process	Optimizing: order	P10	2003	3	Proposed method uses product specification to derive minimal number of required tasks to produce product
Efficiency	Optimizing process	Optimizing: order	P10	2003	3	principles of optimally ordering tasks can be integrated
Efficiency	Optimizing process	Optimizing: quality	P10	2003	12	quality is defined as the probability that an acceptable value of the top element can be determined
Efficiency	Optimizing process	Optimizing: quality, cost, time	P10	2003	12	consider three important design criteria: quality, cost, time
Flexibility	Other environments	Use in other environments	P11	2003	9	applicability of PBWD relies heavily on the ability to collect the type of data that is part of the PDM
Flexibility	Other environments	Use in other environments	P11	2003	32	PBWD is restricted to fields where a clear concept of the products to be delivered exists.
Flexibility	Other environments	Use in other environments	P11	2003	32	Deloitte applied the method four times in client engagements (minimum of 50% cost and 30% flow time reduction)
Flexibility	Other environments	Use in other environments	P11	2011	2	focus on design of processes that deliver informational products
Flexibility	Other environments	Use in other environments	P11	2011	2	adopted by various consultancy and service companies to improve the performance of various business processes in service domain
Flexibility	Other environments	Use in other environments	P11	2011	4	product of a workflow process is an informational product, e.g. A decision
Flexibility	Other environments	Use in other environments	P11	2011	6	information needed to construct PDM can be obtained from rules, work instructions, forms, descriptions, information systems, etc
Functionality	Goal of method	Analytical redesign	P1	2003	2	method to design or redesign administrative business processes
Functionality	Goal of method	Analytical redesign	P1	2011	3	Rigorous approach for business process improvement
Functionality	Goal of method	Analytical redesign	P1	2011	4	Based on (client) input, process constructs the end product step-by-step
Functionality	Goal of method	Analytical redesign	P1	2011	6	PDM is used as basis for designing process that respects dependencies between various data elements
Functionality	Goal of method	Analytical redesign	P1	2011	7	PDM is used as basis for designing process that provides an attractive walk through along various required operations
Functionality	Goal of method	Analytical redesign	P1	2011	1	initiatives exist that allow end users to flexibly decide on best possible way to create an informational product within limits of regulations and logical c
Functionality	How to achieve goal	Analytical, clean sheet	P2	2003	1	the product specification and three design criteria as starting point to derive favorable new design of WF process
Functionality	How to achieve goal	Analytical, clean sheet	P2	2003	2	Proposed method is analytical and clean sheet, in order to counter problems of prevailing practice
Functionality	How to achieve goal	Analytical, clean sheet	P2	2003	3	stimulate more rational and quantitative ways of process design
Functionality	How to achieve goal	Analytical, clean sheet	P2	2003	4	carefully fix boundaries of the workflow to be redesigned
Functionality	How to achieve goal	Analytical, clean sheet	P2	2003	31	No fair comparison with results of a participative redesign
Functionality	How to achieve goal	Analytical, clean sheet	P2	2003	32	formal model, notion of conformance, possible quantification of design criteria
Functionality	How to achieve goal	Analytical, clean sheet	P2	2011	2	method for process design that is repeatable, objective, and effective
Functionality	How to achieve goal	Analytical, clean sheet	P2	2011	2	develop deep understanding of characteristics of informational product that is to be delivered
Functionality	How to achieve goal	Analytical, clean sheet	P2	2011	2	attention to what is desired outcome, without directly discussing how to achieve it
Functionality	How to achieve goal	Analytical, clean sheet	P2	2011	7	availability of various alternatives to achieve a particular outcome is exploited
Functionality	How to achieve goal	Analytical, clean sheet	P2	2011	32	separation of concerns: PDM is based on functional requirements, while selected strategy focuses on performance
Functionality	IT Support	Basis for process model	P3	2011	3	Product data model itself is proposed as the vehicle to steer a WF execution
Functionality	IT Support	Basis for process model	P3	2011	3	do not aim at design of generic process, but provide a business user with direct support for delivering individual informational products
Functionality	IT Support	Basis for process model	P3	2011	3	PBWS: business user determes on case-by-case basis the best possible way to create an informational product in accordance with PDM
Functionality	IT Support	Basis for process model	P3	2011	3	IT tools have been developed to support administration of PDM, as well as algorithms that automatically generate WF designs based on PDM
Usability	Expert: ease of use	Efforts for collecting data differ	P6	2003	9	Needed effort to collect this type of data differs from company to company; dependent on available data sources
Usability	Expert: ease of use	Manually constructed models	P7	2011	3	Manually translating PBWD into PM is time consuming and error prone
Usability	Expert: ease of use	Manually constructed models	P7	2011	6	construction of a PDM is a manual task
Usability	Understandability	Based on existing concept	P5	2003	2	Inspired on manufacturing principles (BOM)
Usability	Understandability	Based on existing concept	P5	2011	5	PDM is described by tree-like structure similar to a Bill of Material
Usability	User: ease of use	Accepted by users	P4	2003	32	accepted by end users as valid and workable
Usability	User: ease of use	Accepted by users	P4	2011	10	PBWS: an end user is supported on a case-by-case basis with recommendations on the most suitable way to carry out available operations in PDM

Used articles
2003: Reijers, H., Limam, S., & Van der Aalst, W. (2003). Product-Based Workflow Design. Journal of Management Information Systems, 20(1), 229-262.
2011: Vanderfeesten, I., Reijers, H., & Van der Aalst, W. (2011). Product-Based Workflow Support. Information Systems, 36(2), 517-535.

Appendix F. ACPM: Claims from Developers

Category	Concept	Code	Claim	Year	Pg.	Quote
Efficiency	Multiple instantiations of models	Generic schemas for multiple customizations	A7	2007	4	the abstraction of artifacts and services facilitate customization of services flows
Efficiency	Reduce modeling efforts	Separate Data and Process logic	A8	2007	16	Separation of data management concern from process flow concerns
Flexibility	Other environments	Use in other environments	A11	2003	1	used in internal processes as well as for use with customers
Flexibility	Other environments	Use in other environments	A11	2003	2	particularly in the use of consumed and nonconsumed goods
Flexibility	Other environments	Use in other environments	A11	2007	3	artifact centric approach has been applied in various internal and external IBM client engagements
Functionality	Goal of method	Analyze, manage, control business	A1	2003	1	representation that business people could use to analyze, manage, and control day to day business operations
Functionality	Goal of method	Analyze, manage, control business	A1	2003	2	create a discription of a business that will be used by business people to manage the business
Functionality	Goal of method	Analyze, manage, control business	A1	2003	2	real value comes from ownership, design, analysis of models by business owners
Functionality	Goal of method	Analyze, manage, control business	A1	2003	2	value of arifact centric thinking lies in creation of a manageble, analyzable, flexible model, from perspective of a business person
Functionality	Goal of method	Analyze, manage, control business	A1	2007	1	useful for designing the detailed operation of business processes for enterprises
Functionality	Goal of method	Analyze, manage, control business	A1	2007	1	Business artifacts are information entities that capture process goals and allow for evaluating how thoroughly these goals are achieved
Functionality	Goal of method	Analyze, manage, control business	A1	2007	3	artifact is an information record that allows for measuring whether or not the business is on track to achieve their business goals
Functionality	Goal of method	Analyze, manage, control business	A1	2007	5	ACPM has been used for both business analysis and business driven development engagements
Functionality	Goal of method	Analyze, manage, control business	A1	2007	24	enable managers to understand, design, and adapt their business operations
Functionality	Goal of method	Analyze, manage, control business	A1	2007	24	Remain confident that managers' goals are accurately reflected in IT level WF
Functionality	Goal of method	New insights	A2	2003	17	Operational models also provide a concrete underpinning to which strateg, organization, and application, issues can be connected
Functionality	Goal of method	New insights	A2	2007	3	business artifacts are an abstraction to focus businesses on not just any information, but on the core entities
Functionality	Goal of method	New insights	A2	2007	5	ACPM can be valuable for business transformations, as it makes key data in processes visible
Functionality	Goal of method	New insights	A2	2007	2	using the framework, properties of process models are studied that concern both information perspective and control flows
Functionality	How to achieve goal	Declarative approach (based on rules + properties)	A3	2007	1	at logical level this workflow model is largely declarative
Functionality	How to achieve goal	Declarative approach (based on rules + properties)	A3	2007	1	services and associations are described in a declarative manner
Functionality	How to achieve goal	Declarative approach (based on rules + properties)	A3	2007	2	business rules are specified in declarative languages, and easy to modify
Functionality	How to achieve goal	Formal structure for rigorous design and analysis	A3	2003	1	based on formal structure suitable for use in rigorous design and design analysis
Functionality	How to achieve goal	Formal structure for rigorous design and analysis	A3	2003	2	Operational model retains formality needed for reasoning and where applicable automated implementation
Functionality	How to achieve goal	Formal structure for rigorous design and analysis	A3	2003	2	created models contain enough information for implementation teams
Functionality	How to achieve goal	Formal structure for rigorous design and analysis	A3	2003	11	Operational model when fully developed has all info needed for creating an automation system
Maintainability	Changing models	Flexibility in evolution of process	A10	2003	12	Additional information can be easily added to artifacts
Maintainability	Changing models	Flexibility in evolution of process	A10	2007	16	support rich flexibility in the creation and evolution of business processes
Maintainability	Changing models	Manage applications: reusability	A10	2007	24	realization independence (changes to conceptual flow and business workflow implementation while preserving same BOM)
Maintainability	Changing models	Manage applications: reusability	A10	2007	24	separation into levels makes it easier to manage mappings between levels and reduce complexity of making changes at BOM level
Usability	Expert: ease of use	Identifying artifacts: iterative process	A6	2003	9	Iteration steps to identify all artifacts
Usability	Expert: ease of use	Identifying artifacts: iterative process	A6	2003	13	choice of key artifacts may require extended and animated discussion
Usability	Expert: ease of use	Identifying artifacts: iterative process	A6	2007	5	Any process modeling engagement is iterative
Usability	Expert: ease of use	Profound domain knowledge required	A6	2007	2	a technical challenge is to properly chain the services together or evolve the current WF of services to adapt for new business requirements
Usability	Expert: ease of use	Profound domain knowledge required	A6	2007	6	identifying artifacts requires an understanding of the whole business process
Usability	Understandability	Based on existing techniques and methods	A5	2003	2	approach is inspired by IDEF0
Usability	Understandability	Based on existing techniques and methods	A5	2003	2	superset relation to activity flow diagrams in UML
Usability	Understandability	Based on existing techniques and methods	A5	2003	2	Zachman's information systems architecture
Usability	Understandability	Based on existing techniques and methods	A5	2007	5	BALSA uses ER-model to specify format of artifacts
Usability	Understandability	Intuitive for business people	A4	2003	1	key operation is recognition rather than classification
Usability	Understandability	Intuitive for business people	A4	2003	1	amenable to business people and intuitive for business communications
Usability	Understandability	Intuitive for business people	A4	2003	2	operation model is targeted at business user
Usability	Understandability	Intuitive for business people	A4	2003	3	concept of artifacts appeared somewhat foreign to business process professionals
Usability	Understandability	Intuitive for business people	A4	2003	3	operational business people grasped the concept quite fast
Usability	Understandability	Intuitive for business people	A4	2007	4	business stakeholders can describe macro-level lifecycles

Used articles
2003: Nigam, A., & Caswell, N. (2003). Business Artifacts: An Approach to Operational Specification. IBM Systems Journal, 42(3), 428-445.
2007: Bhattacharya, K., Gerede, C., Hull, R., Liu, R., Su, J. (2007). Towards a Formal Analysis of Artifact-Centric Business Process Models. Lecture Notes in Computer Science, 4714, 288-304.

Appendix G. Questionnaire

Vraag	
Geslacht	❑ Man ❑ Vrouw
Leeftijd	❑ Jonger dan 25 jaar ❑ 25-34 jaar ❑ 35-50 jaar ❑ Ouder dan 50 jaar
Beroep	❑ Consultant ❑ Bedrijfsanalist ❑ Software Engineer ❑ Academicus ❑ Student ❑ Anders: ....
Hoe zou u uw ervarenheid in business process modelling en conceptueel modelleren beoordelen?	❑ Beginner ❑ Gevorderde ❑ Expert
Hoeveel jaar ervaring heeft u met process modelleren?	❑ 0 – 1 jaar ❑ 2 – 4 jaar ❑ 5 – 10 jaar ❑ 11 – 20 jaar ❑ Meer dan 20 jaar
Hoeveel procesmodellen heeft u geanalyseerd of gelezen in de laatste 12 maanden? (een jaar heeft ongeveer 250 werkdagen; wanneer u één model per dag zou lezen, zou dit gelijk staan aan 250 modellen per jaar)	.... modellen
Hoeveel modellen heeft u gemaakt of aangepast in de laatste 12 maanden?	.... modellen
Hoeveel activiteiten hadden deze modellen gemiddeld?	.... activiteiten
Hoeveel werkdagen met formele training heeft u gevolgd in de laatste 12 maanden? (dit omvat cursussen, colleges, etc. 15 weken een college van 90 minuten somt op tot 3 werkdagen).	.... werkdagen
Hoeveel werkdagen heeft u zelf gebruikt in de laatste 12 maanden om te leren proces modelleren? (dit omvat het oefenen met modellen, verplicht werken met modellen, zelfstudie, gebruik van tekstboeken, etc.)	.... werkdagen
Met welke van de volgende methoden bent u bekend? Meerdere antwoorden zijn mogelijk.	❑ BPMN ❑ Protos ❑ Petri-netten ❑ Unified Modeling Language (UML) ❑ IDEF0 ❑ BPM—one ❑ Anders:................................... ❑ Geen van deze methoden
Met welke van de hiernaast gegeven methoden bent u bekend? Meerdere antwoorden zijn mogelijk.	❑ Product-Based Workflow Design ❑ Data-driven Process Structures ❑ Artifact-Centric Process Modelling ❑ Geen van deze methoden

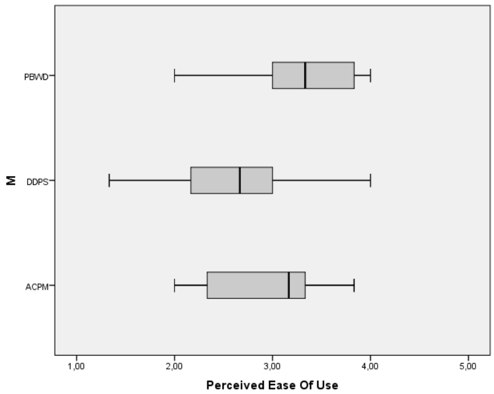
		Helemaal oneens	Oneens	Noch eens, noch oneens	Eens	Helemaal eens
PEOU1	Ik vond de procedure van toepassing van de methode complex en lastig te volgen	❑	❑	❑	❑	❑
PU1	Ik denk dat deze methode de benodigde inspanning voor het documenteren van grote modellen zal verminderen.	❑	❑	❑	❑	❑
PU2	Grote modellen gemaakt met deze methode zijn lastiger te begrijpen voor gebruikers	❑	❑	❑	❑	❑
PEOU2	Al met al vond ik de methode lastig in het gebruik	❑	❑	❑	❑	❑
PU3	Deze methode maakt het voor gebruikers gemakkelijker te verifië ren of modellen correct zijn	❑	❑	❑	❑	❑
PEOU3	Ik vond de methode gemakkelijk te leren	❑	❑	❑	❑	❑
PU4	Al met al vond ik de methode nuttig	❑	❑	❑	❑	❑
PU5	Het gebruik van deze methode maakt het onderhouden van grote modellen moeilijker	❑	❑	❑	❑	❑
PEOU4	Ik vond het moeilijk de methode toe te passen op het voorbeeldmodel	❑	❑	❑	❑	❑
ITU1	Ik zou deze methode zeker niet gebruiken om grote procesmodellen te documenteren	❑	❑	❑	❑	❑
PEOU5	Ik vond de regels van deze methode duidelijk en gemakkelijk te begrijpen	❑	❑	❑	❑	❑
PU6	Al met al denk ik dat deze methode geen effectieve oplossing geeft voor het representeren van grote modellen.	❑	❑	❑	❑	❑
PEOU6	Ik ben niet overtuigd dat ik competent ben deze methode in de praktijk toe te passen	❑	❑	❑	❑	❑
PU7	Al met al denk ik dat deze methode een verbetering geeft ten opzichte van de alternatieven	❑	❑	❑	❑	❑
ITU2	Ik zou deze methode de voorkeur geven boven standaard procesmodellen wanneer ik moet werken met grote data modellen in de toekomst	❑	❑	❑	❑	❑

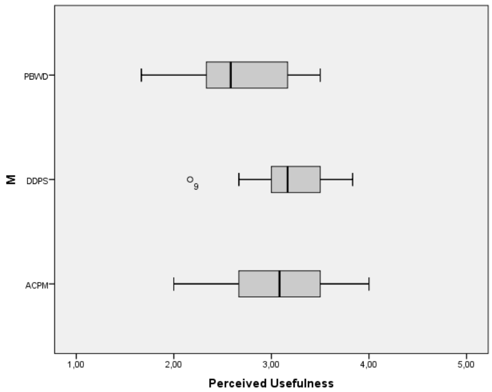
Eventuele opmerkingen:

....
....
....
....
....
....
....
....

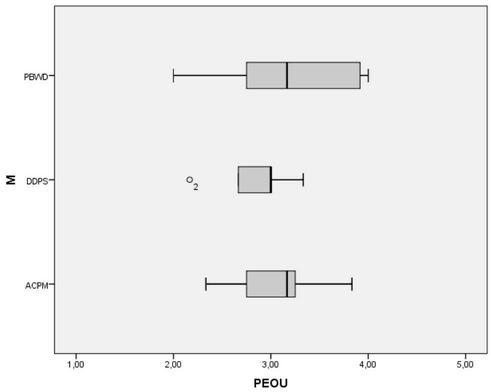
Appendix H. Boxplots from Questionnaires

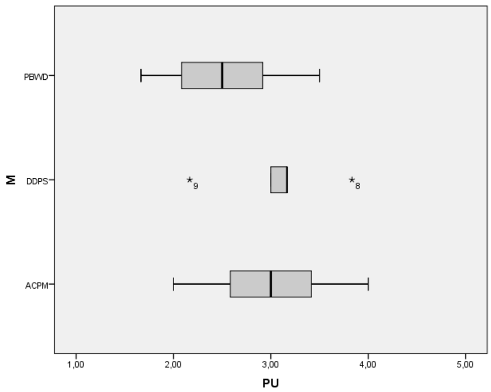
Total



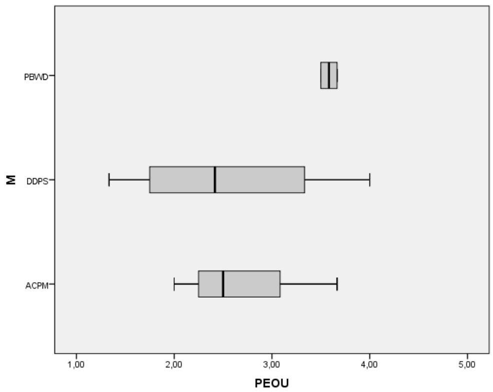


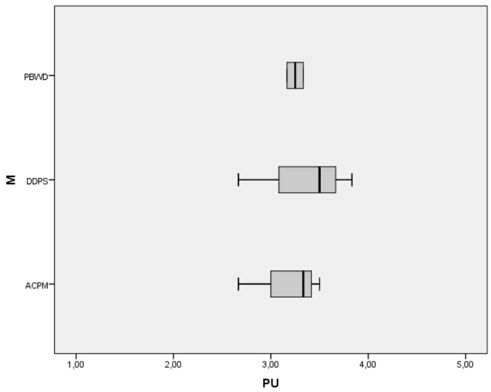
Professionals





Students





Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	90% Confidence Interval of the Difference Lower	Upper
PEOU	Equal variances assumed	2,241	0,178	-0,541	7	0,605	-0,29167	0,5391	-1,31303	0,72969
	Equal variances not assumed			-0,492	3,751	0,65	-0,29167	0,59229	-1,57882	0,99549
PU	Equal variances assumed	0,018	0,897	0,826	7	0,436	0,30833	0,37309	-0,39852	1,01518
	Equal variances not assumed			0,845	6,961	0,426	0,30833	0,36474	-0,38327	0,99993

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	90% Confidence Interval of the Lower	Upper
PEOU	Equal variances assumed	2,316	0,167	0,701	8	0,503	0,375	0,53522	-0,62026	1,37026
	Equal variances not assumed			1,396	7,94	0,201	0,375	0,26865	-0,12506	0,87506
PU	Equal variances assumed	1,549	0,249	1,603	8	0,148	0,72917	0,45495	-0,11683	1,57516
	Equal variances not assumed			3,138	7,999	0,014	0,72917	0,23239	0,29702	1,16132

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	90% Confidence Interval of the Difference Lower	Upper
PEOU	Equal variances assumed	0,948	0,359	-0,743	8	0,479	-0,3254	0,43813	-1,14012	0,48932
	Equal variances not assumed			-0,609	2,721	0,59	-0,3254	0,53458	-1,63793	0,98714
PU	Equal variances assumed	0,565	0,474	0,374	8	0,718	0,16667	0,44544	-0,66164	0,99498
	Equal variances not assumed			0,454	6,235	0,665	0,16667	0,36732	-0,54231	0,87564

Interpretation:

1. For all tests holds that Levene's test for equality of variances is not significant; the null hypothesis of equal variances cannot be rejected;
2. For all methods, the two-tailed significance (equal variance assumed) is above 0,10;
3. Therefore, for all methods the means for students do not significantly differ from the means obtained for professionals;
4. The boxplots that include both students and professionals will be used in the evaluation.

Appendix I. DDPS: Quotes from Discussion

	Category	Code	Quote	#
1	Usability	Abstract models for analysts: too complex for users	Vrij complex om snel te leren	1
2	NA	NA	Niet altijd een activiteit tussen verschillende states	1
3	Usability	Abstract models for analysts: too complex for users	Onderscheid abstracte/concrete model lastig	1
4	Usability	Abstract models for analysts: too complex for users	Doelgroep begrijpt abstracte model niet	1
5	Flexibility	Use in other environments - Generic model	Generiek model, gebruiken in andere situaties	1
6	Usability	Abstract model should fit concrete situations	Concrete model moet altijd passen in abstracte model	1
7	Usability	Abstract models for analysts: too complex for users	Abstracte modellen zijn voor ontwerpers, analisten	1
8	Usability	Abstract models for analysts: too complex for users	Gebruik van generiek model om concreet model aan user te laten zien	1
9	Usability	Abstract model should fit concrete situations	Sprake van een fit van modellen	2
10	Usability	Abstract model should fit concrete situations	Goed abstract model geschikt voor elke concrete uitvoering	1
11	Maintainability	Adaptation of model in one place	1 model onderhouden	1
12	Functionality	Controlling workflow using data	Executie vindt plaats ahv abstracte model	1
13	Usability	Abstract model should fit concrete situations	Hoe weet je dat je de juiste fit hebt	1
14	Usability	User only has to instantiate Data Model	User definieert alleen data structure	1
15	Efficiency	Automated generation of workflow	Data Structure + LCM = process structure	1
16	Usability	User only has to instantiate Data Model	Voor user is het relatief eenvoudig	1
17	Usability	Abstract model should fit concrete situations	Complex om modellen te maken die overal op toepasbaar zijn	1
18	NA	NA	Waar start je nu?	1
19	Usability	Abstract models for analysts: too complex for users	User kan niet in abstracte modellen denken	1
20	Usability	User only has to instantiate Data Model	User moet alleen een structuur geven van het product	1
21	Usability	Abstract model should fit concrete situations	User moet product passen in abstract model	1
22	Usability	Business Analyst requires profound business knowledge	Verondersteld wordt dat analist business kennis heeft	1
23	Usability	Business Analyst requires profound business knowledge	Abstracte model moet aangepast worden aan de situatie	1
24	NA	NA	Automatisch begin je in relaties te denken	1
25	Usability	System boundaries should be clearly defined	Het moet duidelijk zijn was Sys, SubSys, etc zijn	1
26	Flexibility	Use in other environments	Lifecycles buiten hierarchische structuur mogelijk	1
27	Functionality	Controlling workflow using data	Automatisch flow aansturen aan hand van kenmerk	1
28	Functionality	Controlling workflow using data	Methode universeler toepasbaar door gebruik van states	1
29	Efficiency	Reusability of models	Hergebruik van lifecycles	1
30	Maintainability	Adaptation of model in one place	Veranderingen zijn eenvoudig op 1 plek door te voeren	1
31	Usability	Hierarchy improves readability	Hierarchie is goed in complexe systemen (anders onoverzichtelijk)	1
32	Usability	Fit between completeness and readability	Links tussen niveaus zijn lastig (hoeveel, welke niveaus)	1
33	Usability	Fit between completeness and readability	Afweging tussen niveaus/links en overzichtelijkheid	1
34	Usability	Unclear overview	Vrij snel onoverzichtelijke modellen	1
35	Usability	Unclear overview: connexions	Connecties tussen objects worden snel onduidelijk	2
36	Functionality	Controlling workflow using data	Keuze maken tussen twee processen	1
37	Usability	Unclear overview: large models	Model wordt in grote systemen onoverzichtelijk	2
38	Functionality	Controlling workflow using data	Als computer een WF maakt is onoverzichtelijkheid geen probleem	1
39	Usability	System boundaries should be clearly defined	Ontbreken richtlijnen voor afbakenen systemen en componenten	1
40	Usability	Unclear overview	Onoverzichtelijkheid wordt snel slechter	1
41	Usability	Fit between completeness and readability	Afweging tussen volledigheid/overzichtelijkheid	1
42	Efficiency	Reusability of models	Model mooi door herbruikbaarheid	1
43	Efficiency	Reusability of models	Efficient model	2
44	Efficiency	Separation of data and process logic	Hergebruik binnen een model (alleen input veranderen)	1
45	Functionality	Missing details - Process view	Hoe geef je volgorde weer?	1
46	Usability	Increased understanding by using existing concepts/methods	Structuur lijkt op bill of materials	1
47	Usability	System boundaries should be clearly defined	Hoe worden system boundaries bepaald	1
48	Functionality	Hierarchy	Handig om eerst individuele componenten te testen	1
49	Usability	System boundaries should be clearly defined	Mis de exacte definities	2
50	Flexibility	Use in other environments - Generic model	De methode is breed inzetbaar omdat hij erg generiek is	1
51	Usability	Hierarchy improves readability	De methode is erg overzichtelijk	1
52	Usability	Unclear overview: complex models	Niet toepasbaar voor complexe data modellen	2
53	Usability	Hierarchy improves readability	Gelaagdheid	1
54	Efficiency	Automated generation of workflow	Stap 4 (creeren model) kan volledig automatisch worden doorlopen	1
55	Maintainability	Automatically translate adaptations	Het model is door automatic creation eenvoudiger te bewerken	1
56	Functionality	Missing details - Process view	Sterk op definitie product gericht; stappen van produceren ontbreken	1
57	Maintainability	Adaptation of model in one place	Processen veranderen; modellen moeten gemakkelijk aan te passen zijn	1
58	Maintainability	Automatically translate adaptations	Proces hoeft niet noodzakelijk op de schop, bij verandering product	1
59	Efficiency	Reusability of models	Herbruikbaarheid van (deel)processen	1
60	Usability	Increased understanding by using existing concepts/methods	Aansluiting bij PBS/WBS; begrijpbaar voor projectmanagers	1
61	Flexibility	Use in other environments	Administratieve processen op deze wijze eenvoudig ontleed	1
62	Efficiency	Automated generation of workflow	Geautomatiseerd genereren van Process Structure	1
63	Usability	Abstract models for analysts: too complex for users	Conceptuele stap niet voor iedereen te begrijpen	1
64	Functionality	Missing details - Roles	Hier is niet te zien wie wat doet	1
65	Functionality	Missing details - Triggers	Triggers ontbreken	1
66	Functionality	Missing details - Data origin	Belangrijk te weten waar de betreffende data vandaan komt	1
67	Functionality	Missing details - Process view	Datamodel als leidraad voor procesmodel	1

Appendix J. PBWD: Quotes from Discussion

	Category	Code	Quote	#
1	Usability	Difficulties in use: alternative paths	Lastig alternatieve paden te bepalen	1
2	Usability	Unclear overview: direct/alternative paths	Zonder shortcuts blijft de boom veel netter, overzichtelijker	1
3	Usability	Alternative approaches could reduce complexity of PDM	Logica zou shortcuts overbodig maken	1
4	Usability	Fit between completeness and readability	Nuttig om alle paden te modelleren indien automatiseren niet kan	2
5	Usability	Alternative approaches could reduce complexity of PDM	Alternatieven om aantal kruisende lijnen te verminderen	1
6	NA		Waar komt input vandaan	2
7	Functionality	Missing details: triggers	Hoe wordt het model getriggerd?	1
8	Functionality		Leaf elements geven maken van info aan	1
9	Usability	Difficulties in use: orderless	Lastig om niet te denken in processen	1
10	NA		Data is interessant; traject voor leaf elements hier minder interessant	2
11	Flexibility	Practical problems less straightforward	Praktijkproblemen lijken minder goed aan te sluiten	1
12	Flexibility	Practical problems less straightforward	Onduidelijk hoe praktijkproblemen aan te moeten pakken	1
13	Usability	Business analyst creates PDM	PDM wordt gemaakt door analist	1
14	Functionality	PDM basis for redesign	PDM als basis voor herontwerp	1
15	Efficiency	Optimising: order	Optimale volgorde kan worden beredeneerd	1
16	Efficiency	Optimising: cost, time	PDM helpt om achter snelste/goedkoopste stappen te komen	1
17	Efficiency	Optimising: order	Bij PBWD hoeven niet per se alle stappen doorlopen te worden	1
18	Efficiency	Optimising: order	Redeneren vanuit benodigdheden naar proces	1
19	Usability	PDM doesn't help in reasoning	PDM helpt niet bij redeneren	1
20	Efficiency	Optimising: cost	PDM helpt bij redeneren over kosten	1
21	Functionality	PDM is no end product	PDM is geen procesmodel	3
22	Functionality	PDM basis for redesign	PDM geeft procesafhankelijkheid aan	1
23	Efficiency	Optimising: cost, time	Relatief goedkope stappen met hoge knockout eerst	1
24	Efficiency	Optimising: order	PDM helpt bij redeneren over volgorde (want volgorde onafhankelijk)	1
25	Usability	PDM doesn't help in reasoning	Structuur van PDM helpt momenteel nog niet bij denkstappen	1
26	Functionality	PDM basis for redesign	Met tabellen erbij zou dit prima zijn voor redesign	1
27	Functionality	PDM basis for redesign: Orderless	Objectieve manier van aangeven wat gevolgen zijn van volgorde	1
28	Functionality	PDM basis for redesign: Orderless	Inzichten alleen verkregen als je volgorde eerst helemaal los laat	1
29	Functionality	PDM basis for redesign: Orderless	De methode is volgorde onafhankelijk	1
30	Usability	Unclear overview: direct/alternative paths	Expliciet modelleren van niet paden maakt model complex	1
31	Usability	Fit between completeness and readability	Model moet wel volledig blijven	1
32	Usability	Abstract models for analysts: too complex for users	PDM kun je niet gebruiken bij de klant	2
33	Functionality	PDM basis for redesign	PDM kan prima worden gebruikt als input voor procesmodel	1
34	Functionality	PDM is no end product	PDM is geen eindproduct	1
35	Usability	PDM understood by customer	In omgeving met regels en rekenregels snapt klant dit wel	1
36	Usability	PDM understood by customer	Klant kan eenvoudig volgen en nalopen (controleren)	1
37	Usability	Abstract models for analysts: too complex for users	Meer tekst en uitleg voor de klant is noodzakelijk	1
38	Flexibility	Usable in other environments	De methode is overal toepasbaar	1
39	Functionality	PDM is no end product	Methode moet geintegreerd worden met procesmodelleren	1
40	Functionality	Missing details: input	Ontbreekt waar processen, data, regels vandaan komen	1
41	Functionality	Explicitly defined rules	PDM maakt regels expliciet	1
42	Efficiency	Optimising: order	Optimale volgorde kan worden beredeneerd	1
43	Usability	Difficulties in use: alternative paths	Lastig alternatieve paden te bepalen	1
44	Usability	Abstract models for analysts: too complex for users	Effect van data-waarde op het te volgen pad is niet direct duidelijk	1
45	Functionality		In regels kun je het effect van gegevens op het te volgen pad meenemen	1
46	Usability	Alternative approaches could reduce complexity of PDM	Vaak zijn waarden automatisch interpreteerbaar; nettere boom	1
47	Usability	Difficulties in use: tables	Tabel is snel te technisch, houd hem makkelijk voor de klant	1
48	Usability	Alternative approaches could reduce complexity of PDM	Tabel kun je veel in kwijt	1
49	Usability	Alternative approaches could reduce complexity of PDM	Boxjes zijn snel interpreteerbaar	1
50	Functionality	Missing details: Quality	Kwaliteit wordt niet behandeld in het model?	1
51	Functionality	Missing details: Quality	Kwaliteit hoeft niet meegenomen te worden in dit model	1
52	Usability	Unclear overview: direct/alternative paths	Alternatieve paden maken het model minder leesbaar	2
53	Usability	Fit between completeness and readability	Alle negatieve paden meenemen houdt het model compleet	1
54	Usability	Unclear overview: large models	PDM wordt snel wirwar van pijlen, overzicht raakt kwijt	2
55	Usability	Alternative approaches could reduce complexity of PDM	Lazy evaluation ipv alternative paths	1
56	Usability	Unclear overview: large models	Grote modellen zijn niet leesbaar voor klant	1
57	Usability	Unclear overview: large models	Clusteren oid om leesbaar te houden noodzakelijk	1
58	Functionality	PDM basis for redesign: complex processes	Het kan voordelen opleveren bij grote complexe processen	1
59	Usability	Difficulties in use	Modelleur en lezers hebben opleiding nodig in gebruik	1
60	Usability	Increased understanding by using existing concepts/methods	Vanuit een BOM naar product of dienst werken	1
61	Usability	Abstract models for analysts: too complex for users	Methode is niet snel te begrijpen	1
62	Functionality	Missing details: roles	Ontbreken van gegevens zoals uitvoerende, verantwoordelijke	1
63	Usability	Difficulties in use: rules	Opstellen van regels moeilijk	1
64	Functionality	PDM basis for redesign	Methode met name geschikt voor procesverbeteringsanalyse	1
65	Functionality	Missing details	Voor inzichtelijk maken van proces voor uitvoerende te weinig details	1
66	Functionality	PDM basis for redesign	Inzicht in belangrijke beslismomenten	1
67	Efficiency	Optimising: cost, time	Mogelijkheid tot verbeteren van efficiency van een proces	1
68	Functionality	Extend to existing methods	Mogelijk aanvulling op Lean methodiek	1
69	Functionality	Missing details: roles	Ontbreken van actoren en karakteristieken	1
70	Flexibility	Usable in other environments	Methode breed inzetbaar	1
71	Usability	Increased understanding by using existing concepts/methods	Vanuit een BOM naar product of dienst werken	1
72	Functionality	PDM basis for redesign: indirect processes	Waarde van indirecte processen in kaart brengen	1
73	Functionality	Explicitly defined rules	Concreet maken van business rules	1
74	Functionality	Missing details: views	Ontbreken van verschillende views voor verschillende doeleinden	1

Appendix K. ACPM: Quotes from Discussion

	Category	Code	Quote	#
1	Usability	System boundaries should be clearly defined	Wat is precies een artifact	1
2	Usability	System boundaries should be clearly defined	Waar houd je op met een lifecycle	1
3	Usability	System boundaries should be clearly defined	Wat is de gedetailleerdheid van artefacten	1
4	Usability	Difficulties in use: artifacts	Gewend onderwerpen aan te kruisen, niet alles in tekst	1
5	Usability	Difficulties in use: artifacts	Wat zit er in een proces? Dat zijn je artefacten	1
6	Usability	System boundaries should be clearly defined	Duidelijk definieren welk niveau gewerkt wordt	1
7	Usability	Abstract models for analysts: too complex for users	Uitvoerende partij kan niks met het model	1
8	Functionality	New insights in process	Software ontwikkelaar die kijkt naar functioneren syst heeft hier iets aan	2
9	Maintainability	Adaptation of models in several places	Als iets verandert moet dit op verschillende punten doorgevoerd worden	1
10	Maintainability	Adaptation of models in several places	In grote systemen worden aanpassingen alleen lastiger	1
11	Functionality	New insights in process	Software ontwikkelaar heeft voordeel bij manier van modelleren	1
12	Functionality	Structured method: rules	Regels en voorschriften leiden tot gestructureerde methode	1
13	Usability	Abstract models for analysts: too complex for users	Alleen laatste stappen, flow, bruikbaar voor iedereen	1
14	Usability	Abstract models for analysts: too complex for users	Artifact models meer voor de techneuten	1
15	Functionality	Structured method: roles	Formeel opstellen van regels: Wie doet Wat	1
16	Functionality	Structured method: knowledge	Vastgelegde regels beter dan kennis in hoofden werknemers	1
17	Usability	Limited understandability: what is added value	Toegevoegde waarde states en lifecycles niet helemaal duidelijk	1
18	Functionality	Interaction of artifacts and lifecycles	Totaalproces moet hier nog boven, koppelen van lifecycles	1
19	Functionality	Interaction of artifacts and lifecycles	Aangegeven hoe objecten communiceren met elkaar	1
20	Functionality	Interaction of artifacts and lifecycles	Workflow stuurt artefacten	1
21	Efficiency	Reusability of artifacts and lifecycles	Andere workflow die gebruik maakt van dezelfde artefacten	1
22	Usability	Limited understandability: confusing reasoning	Moeilijke manier van redeneren, verwarrend tov process	1
23	Usability	Difficulties in use: flow	Moeilijk om alles weer in een flow te krijgen	1
24	Functionality	Interaction of artifacts and lifecycles	Verschillende lifecycles van artefacten laten samenwerken in systeem	1
25	Usability	Limited understandability: artifacts not intuitive	Niet echt intuitief om in artefacten te denken	2
26	Functionality	Hierarchy of artifacts possible	Hierarchie van artefacten is mogelijk	1
27	Usability	System boundaries should be clearly defined	Concrete afspraken mbt level of detail	1
28	Functionality	New insights in process	Inzichten in het proces worden verkregen	1
29	Functionality	Interaction of artifacts and lifecycles	Lifecycles bepalen hoe rules en services gestructureerd worden	1
30	Maintainability	Adaptation of models in several places	Veranderingen doorvoeren in grote modellen is complex	1
31	Usability	Difficulties in use: rules	Toepassen van rules is lastig	1
32	Flexibility	Usable in other environments	De methode is breed inzetbaar	1
33	Functionality	Structured method	Methode is gestructureerd en specifiek	1
34	Usability	Difficulties in use: attributes	Benodigde eigenschappen van artefacten lastig te bepalen	1
35	Usability	Limited understandability: artifacts not intuitive	Mix van artefacten en lifecycles was lastig	1
36	Functionality	Missing details	Te weinig info om methode te gebruiken bij systeemontwikkeling	1
37	Flexibility	Usable in other environments	De methode is redelijk breed inzetbaar	1
38	Usability	Limited understandability: method not self-explaining	De methode is niet zozeer zelf uitleggend	1
39	Functionality	Interaction of artifacts and lifecycles	De combinatie van artifacten en lifecycles is erg sterk	1
40	Functionality	Missing details: input, output	Ondergeschiktheid van input en output	1
41	NA		Eenvoud van de methode	1
42	NA		Start en Endstate zijn niet herkenbaar	1
43	Usability	Limited understandability: method not self-explaining	Services niet gealloceerd op arcs van lifecycles, niet direct duidelijk	1
44	Flexibility	Usable in other environments	Methode is breed inzetbaar	1
45	Usability	Increased understanding by using existing concepts/methods	Methode is herkenbaar door gebruik van bestaande technieken	1
46	Functionality	New insights in process	Focus is op kritieke procesovergangen ipv op een gehele flow	1
47	Usability	Difficulties in use: Missing tooling	Ontbreken van tooling om het modelleren te vergemakkelijken	1

Appendix L. DDPS: Linking Claims and Statements

	METHODS		
	Positive	**Negative**	**Undecided**
FUNCTIONALITY -Goal of method (D1)	Reusability of models Separation of data and process logic Adaptation of model in one place		
-How to achieve (D2)	Controlling workflow using data		Abstract model should fit concrete situations
-IT Support (D3)		Missing details: roles, triggers, process view, origin of data	
USABILITY -Understandability	Hierarchy improves readability Increased understanding by using existing concepts/methods		Fit of completeness and readability
-User: ease of use (D4)	User only has to instantiate data model	Unclear overview: large models Abstract models for analysts: too complex for users	
-Expert: ease of use (D5)		Unclear overview: large models Business analyst requires profound business knowledge	System boundaries should be clearly defined
EFFICIENCY -Multiple instantiations of models (D6)	Reusability of models		
-Automated creation (D7)	Automated generation of workflow		
-Reusability (D8)	Reusability of models		
-Reduce modelling efforts (D9)	Reusability of models Separation of data and process logic		
-Optimising process			
MAINTAINABILITY -Changes (D10)	Adaptation of model in one place Automatically translate adaptations into a new process		
FLEXIBILITY -Other environments (D11)	Generic model Use in other environments		

Appendix M. PBWD: Linking Claims and Statements

	METHODS		
	Positive	**Negative**	**Undecided**
FUNCTIONALITY -Goal of method (P1)	PDM basis for redesign: orderless, insights in indirect processes, and benefits in large processes		PDM is no end product
-How to achieve (P2)	Explicitly defined rules		
-IT Support (P3)		Missing details: input, roles, triggers, different views	
USABILITY -Understandability (P4, P5)	Increased understanding by using existing concepts/methods	PDM does not help reasoning	Fit between completeness/readability Alternative approaches could reduce complexity of PDM
-User: ease of use	PDM understood by customer	Abstract models for analysts: too complex for users Difficulties in use: alternative paths, orderless, rules, tables Unclear overview: direct/alternative paths, large models	
-Expert: ease of use (P6, P7)		Difficulties in use: alternative paths, orderless, rules, tables Unclear overview: direct/alternative paths, large models	Business analyst creates PDM
EFFICIENCY -Multiple instantiations of models (P8)			
-Automated creation (P9)			
-Reusability			
-Reduce modelling efforts			
-Optimising process (P10)	Optimising: order, cost, and time		
MAINTAINABILITY -Changes			
FLEXIBILITY -Other environments (P11)	Usable in other environments	Practical problems less straightforward	

Appendix N. ACPM: Linking Claims and Statements

	METHODS		
	Positive	**Negative**	**Undecided**
FUNCTIONALITY -Goal of method (A1, A2)	Structured method: capturing knowledge, roles, and rules New insights in process		
-How to achieve (A3)	Interaction of artifacts and lifecycles: communication, workflow Hierarchy of artifacts possible		
-IT Support		Missing details: input, output	
USABILITY -Understandability (A4, A5)	Increased understanding by using existing concepts/methods	Limited understandability: artefact not intuitive, unclear added value, confusing reasoning, and non self-explanatory method.	
-User: ease of use		Abstract models for analysts: too complex for users	
-Expert: ease of use (A6)		Difficulties in use: determination of artifacts, attributes, flow, and rules	System boundaries should be clearly defined
EFFICIENCY -Multiple instantiations of models (A7)			
-Automated creation			
-Reusability	Reusability of Artifacts and Lifecycles		
-Reduce modelling efforts (A8)			
-Optimising process			
MAINTAINABILITY -Changes (A9)		Adaptation of models in several places	
FLEXIBILITY -Other environments (A10)	Usable in other environments		

Appendix O. Descriptives of Participants

		DDPS	PBWD	ACPM	Total
Sex	Male	9	9	9	27
	Female	0	1	1	2
Age	<25	2	2	2	6
	25-34	3	5	3	11
	35-50	0	3	3	6
	>50	4	0	2	6
Profession	Consultant	4	4	5	13
	Business Analyst	0	1	1	2
	Software Engineer	0	2	1	3
	Process Analyst	0	1	0	1
	Process Architect	1	0	0	1
	Student	4	2	3	9
Skill level	Novice	3	4	2	9
	Intermediate	5	6	4	15
	Expert	1	0	4	5
Years of experience	0-1	2	2	0	4
	2-4	2	6	3	11
	5-10	4	2	4	10
	11-20	0	0	3	3
	>20	1	0	0	1
Models read/analysed	Min	0	0	0	0
	Mean	68,89	82,50	64,00	71,90
	Max	250,00	200,00	150,00	250,00
Models created/adjusted	Min	0	0	0	0
	Mean	37,44	123,30	24,90	62,72
	Max	200,00	1000,00	60,00	1000,00
Number of activities	Min	5,00	10,00	5,00	5,00
	Mean	18,00	130,88	24,13	57,67
	Max	60,00	650,00	100,00	650,00
Days of formal training	Min	0	0	0	0
	Mean	1,83	8,60	0,80	3,81
	Max	5,00	25,00	3,00	25,00
Days of self-education	Min	0	0	0	0
	Mean	11,56	5,70	27,70	15,10
	Max	88,00	35,00	250,00	250,00
Known methods/tools	BPMN	6	5	7	18
	Protos	4	2	7	13
	Petri-nets	6	5	8	19
	UML	5	7	7	19
	IDEF0	5	2	3	10
	BPM|one	1	4	4	9
	PBWD	4	4	5	13
	DDPS	2	3	1	6
	ACPM	0	0	1	1

Appendix P. Overview of Claims and their support

		Data-driven Process Structures		Product-Based Workflow Design		Artifact-Centric Process Modelling
FUNCTIONALITY -Goal of method	**D1** ● (green)	Data-driven modelling of large process structures; ensuring correct coordination, reducing modelling efforts, and providing mechanisms for maintenance.	**P1** ● (green)	Method that (re)designs a process reasoning from the desired outcome, without directly discussing how to achieve it.	**A1** ● (yellow) **A2** ● (green)	Representation usable by business people to analyse, manage, and control business operations Substantial new insights can be acquired by managers
-How to achieve	**D2** ● (green)	Separation of data and process logic, leading to an enactable process structure	**P2** ● (green)	Analytical, clean sheet approach: rational and quantitative way of deriving an optimised process design.	**A3** ● (green)	Declarative approach, that incorporates formality required for rigorous design and analysis
-IT Support	**D3** ● (grey)	IT Support for automated creation and soundness checks	**P3** ● (grey)	PDM used to steer a workflow execution: basis for a process model.		
USABILITY -Understandability			**P4** ● (yellow) **P5** ● (green)	Created models are accepted by end users as valid and workable. Based on existing concept (BOM)	**A4** ● (red) **A5** ● (green)	Intuitive appeal to business managers, somewhat foreign to business process professionals Based on existing methods and techniques
-User: ease of use	**D4** ● (red)	Intuitive integration of data and (sub-)processes enables users to instantiate and adapt model without process knowledge (by adapting data structure).				
-Expert: ease of use	**D5** ● (green)	Process experts require profound domain knowledge to create data model and LCM.	**P6** ● (grey) **P7** ● (green)	Efforts required to collect data for PDM differs for every company. Constructing PDM is manual task	**A6** ● (grey)	Identifying artifacts is an iterative process that requires understanding of whole business process.
EFFICIENCY -Different processes from same models	**D6** ● (green)	Instantiating different data structures and generating the respective data-driven process structures	**P8** ● (green)	Using different optimisation criteria, different process models can be created.	**A7** ● (yellow)	Enabling specification of generic schema with multiple specialisations.
-Automated creation	**D7** ● (green)	Automated creation of Process Structure	**P9** ● (grey)	Algorithms and PBWS can be used to automatically generate process models or recommendations for carrying out operations.		
-Reusability	**D8** ● (green)	Standardising processing of objects in order to increase the reuse of process models and reducing modelling efforts.				
-Reduce modelling efforts	**D9** ● (green)	Separation of data and process logic results in a reduction of modelling efforts.			**A8** ● (grey)	Separation of data management concerns from process flow concerns
-Optimisation			**P10** ● (green)	Optimisation of the process by including optimisation criteria.		
MAINTAINABILITY -Changes	**D10** ● (green)	Changes can be made at data-level and are automatically translated into corresponding adaptations of the process			**A9** ● (grey)	Changes can be made to conceptual flow and business workflow, while preserving the same Business Operations Model.
FLEXIBILITY -Other environments	**D11** ● (green)	Usable in other environments, not specificly the engineering domain.	**P11** ● (green)	Restricted to fields where clear concept of the products to be delivered exists.	**A10** ● (green)	Usable in other environments, particularly in the use of consumed and nonconsumed goods.