

A Framework for Effort Estimation in BPMS Migration

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Abstract. Business Process management Systems (BPMS) are highly integrated in the IT of organizations. They are at the core of business. Thus, migrating from one BPMS solution to another is not a common task. However, there are forces that are pushing organizations to do this step, e.g. maintenance costs of legacy BPMS or needed additional functionality. Beforehand, risk and effort must be evaluated. This work provides a framework for effort estimation regarding the technical aspects of BPMS migration. The framework is developed starting from the question, how BPMS can be compared. Further on, the general applicability is evaluated based on a case study.

Keywords: BPMS, Migration, Effort Estimation, Workflow Management

1 Introduction

Workflow Management Systems (WMS) and the next step in the development – Business Process Management Systems (BPMS) – have their origins in the 90th. In contrast to traditionally document or data centric ERP-Systems, their main focus is the control of Business Processes. Thus, they are more flexible when enterprises develop new ways of doing business. However, like ERP-Systems they are at the core of the enterprise and hardly to replace. Furthermore, a deep integration with other systems of the enterprise can be expected [1]. With the upcoming of Service Oriented Architectures, Cloud Computing, and Continuous Delivery there is a demand to replace legacy BPMS due to the high maintenance effort. In consequence, a BPMS migration has to be considered.

The aim of this work is to examine ways to predict the effort of product migrations from one BPM system to another. The respective literature offers a wide range of information about business process management, its value and critical success factors. Compared to this, publications towards the systems which implement a key element of BPM, the process automation, are rare. In this work, a systematic literature review is used in section 2 to identify the available approaches to analyse and compare BPM systems. The gathered information will be evaluated regarding its use to estimate the effort of BPM system migration projects in section 3. The scope is to provide an

approach which supports the decision process while planning such a project and assessing alternatives.

This aim is limited to the evaluation of the effort of migration projects. Thus, the process of finding a suitable BPM product for the specific needs of a company is not the subject of matter. The assumption of this work is that the examined BPM system suits the requirement of a respective run-time scenario. The last section of this work sheds light on the validation of the proposed approach and provides an outlook.

2 Systematic Literature Analysis

So far, no work has been found that is directly dealing with the effort estimation regarding the migration of BPMS or WMS. However, having a reference for BPMS comparison could help to identify necessary tasks for the migration and thus to be able to find appropriate work packages. Each of these work packages can then be subject to effort estimation. The complexity of estimation is reduced by the divide-and-conquer principle. Since the technical aspects of migration are in focus, reference architectures for BPMS seem to be a good starting point.

2.1 Analysis Process

A literature analysis has been conducted in order to find approaches for BPMS comparison. The systematic Literature Analysis (SLA) approach by Kitchenham [2] provided guidelines for this research. Two sources have been selected for SLA:

- BPMJ is published by Emerald Group Publishing since 1995 and aims to '[...] examine how a variety of business processes intrinsic to organizational efficiency and effectiveness are integrated and managed for competitive success.' [3]
- Lustratus Research describes itself as '[...] a leading infrastructure software market analyst and consultancy firm' [4]. They provide different kinds of technical reports via their online store at www.lustratus.com.

While BPMJ is seen as source for scientific research on the area, Lustratus Research is seen as a more industry oriented source in contrast.

Overall the literature basis of this SLA consisted of 515 papers derived from these sources. The next steps according to Kitchenham are population, intervention, and union followed by the paper selection. The initial population was done by using the following search term:

'Business Process Management Systems' OR 'BPMS' OR 'BPM suites' OR 'BPM solution' OR 'BPM offering' OR 'BPM product'

The search string was applied to the title as well as to the abstract of the papers. 76 relevant papers have been identified. The intervention step is used in order to narrow down the selection of papers further on. Here the focus on BPMS comparison of the search was added. The following search term was used:

'compare' OR 'comparing' OR 'comparison' OR 'architecture'

For the reasons given in the introduction of section 2, 'architecture' was chosen as a part of the search term. 29 relevant papers have been identified in this step. The union

step forms an intersection of the result sets from population and intervention. After this step 6 papers remained. Table 1 shows the process in an overview.

Tab. 1. Number of selected papers in SLA process

| Step | BPMJ | Lustratus | Total |
|--------------|------|-----------|-----------|
| Population | 71 | 5 | 76 |
| Intervention | 25 | 4 | 29 |
| Union | 2 | 4 | 6 |

The paper selection was done by reading the papers. One of the two sources from BMJ was considered irrelevant because it referred only to a subsystem within BPMS. The remaining one provides a pyramid architecture for BPMS from Shaw et al. [5]. The four papers originating from Lustratus Research [6, 7, 8, 9] turned out to be applications and refinements of the ‘frame of reference’ for BPMS by Craggs. The two approaches by Shaw et al. and by Craggs form as a base for the following discussion.

2.2 BPMS pyramid architecture

The approach by Shaw et al. is visualized as a pyramid of blocks with two legs. The Blocks represent BPMS core technologies while the two legs emphasize the independence between formal model constructs and software application. The arrangement of the blocks symbolizes relationships between each other. A core technology on a certain level is a prerequisite for the technologies on the next higher level in order to make it work. Within the horizontal dimension there are no interdependencies between the blocks. On top of the pyramid the *BPMS* itself is constructed on the base of all other blocks. One layer below lies the *Enactable Business Model* as the core of a BPMS. Five types of models can be distinguished: static, dynamic, passive, active and enactable [10, p. 38 - 44]. Shaw et al. define an enactable model as a '[...] composition of model constructs that is derived from the properties of the physical, hardware or software modeling medium that together naturally display characteristics that exactly replicate those of the subject abstraction.' [5, p. 5] Thus the model controls and reflects the current process states (process seen as *subject of abstraction*).

Further on, the leg of model constructs contains from top to bottom the following blocks (see figure 1): (1) *Formal Model Constructs* (2) *Formal Modeling Notation* and *Ontological Modeling Grammar* (3) *Model Abstraction* (4) *Subject Modeled* (Process).

The software application leg contains from top to bottom the blocks: (1) *Software Application* (2) *Software Language* (3) *Software Notation* and *Software Grammar* (4) *Software Formalism*, and spanning several layers (5) *Technical Infrastructure*.

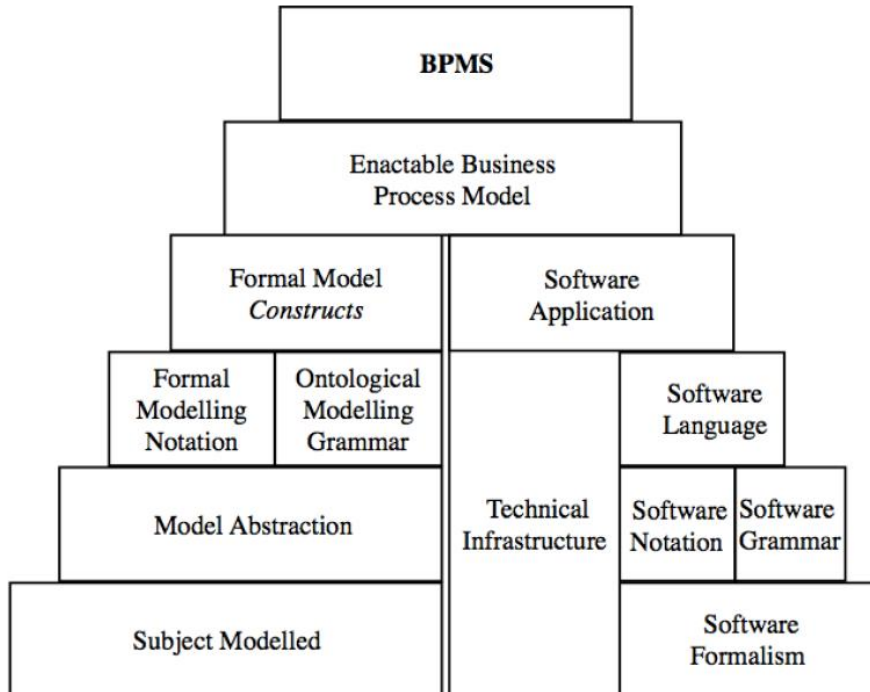


Fig. 1. BPMS Pyramid Architecture [5]

Especially in the application leg of the pyramid architecture some of the blocks seem to be appropriate for BPMS comparison regarding BPMS migration. However, the architecture seems to be too coarse grained.

2.3 Frame of Reference by Lustratus

As mentioned above, this frame of reference is applied by Craggs in all four reports originating from Lustratus Research between 2009 and 2012. Craggs divides the frame of reference in three main areas (see figure 2):

- (1) *Functionality* (2) *Characteristics* and (3) *Solution extensions*.

Each area summarizes a set of key categories.

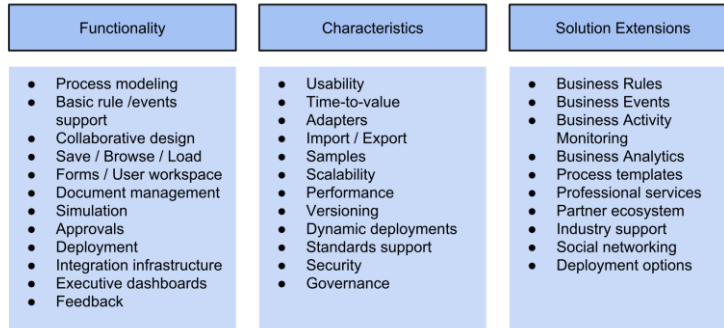


Fig. 2. Frame of reference [9]

The *Functionality* area, contains the BPMS functionalities that are considered to be “standard”. Thus, these describe the basic BPMS functionalities. It includes the core functionalities of Process Modelling, Execution and Monitoring. The *Characteristics* area aims at traditional software quality measures, representing non-functional requirements. However, there are also functionalities included. For example Import/Export, Versioning, and Governance provide means for a higher flexibility and efficiency in basic BPMS functionalities. An indirect influence on software quality is assumed here. *Solution Extensions* provide additional functionalities that are not considered as basic functionalities of a BPMS.

The framework of reference is more detailed compared to the pyramid architecture by Shaw et al. but some of the items especially in the characteristics area do not fit for the purpose of migration effort estimation. They are system inherent characteristics that should be evaluated during system selection before planning the technical implementation of a BPMS migration. Additionally, the mapping of the items to the areas changes over time as well as some the items themselves.

3 Framework Construction

The discussion of the pyramid architecture and the frame of reference showed that both give general ideas how to compare BPMS. However, they do not fit for the task of migration effort estimation. Therefore, this section introduces a framework to compare BPMSs based on the results from the previous sections. The result is shown in figure 3.

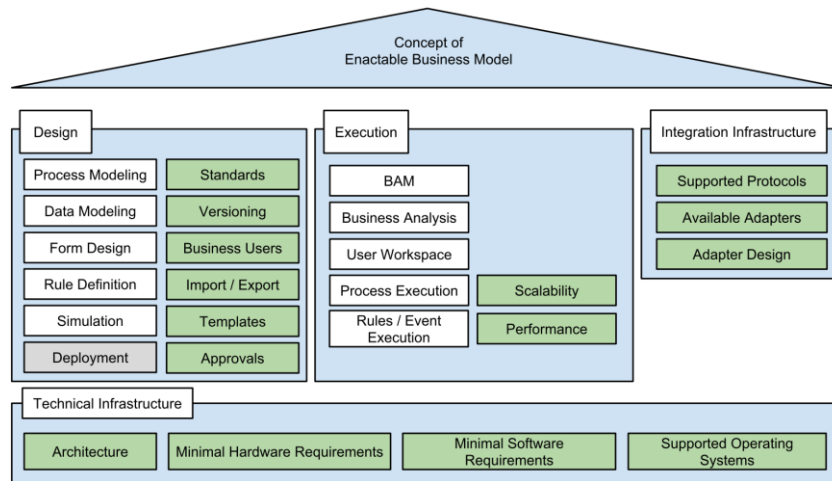


Fig. 3. Framework for BPMS comparison

3.1 View on BPMS

The framework is mainly inspired by Lustratus' frame of reference, but it is based on a new structure with a different view on BPMS. The general idea is to divide all functionalities of BPMS in four logical components. In this context logical means that the individual characteristics are considered independently from the architecture of the tools that implement them. This allows analysing BPMS in more detail without increasing the complexity of the result by including irrelevant aspects of its structure. Figure 3 illustrates the four components, which are namely *Design*, *Execution*, *Integration Infrastructure* and *Technical Infrastructure*. These divide BPMS into three main functional areas that have been derived from the investigation of existing systems like TIBCO Active matrix. *Design* tools and activities can be examined mostly independent from *Execution* regarding methodology and architecture. *Integration Infrastructure* has been seen as an important separate component. Since processes run across functional areas, integration of specialized functional oriented information systems is a main task of BPMS. The *Technical Infrastructure* represents the common system requirements in order to run a certain BPMS.

All components are seen under the umbrella of the *Concept of Enactable Business Model*. Here, an idea of the pyramid architecture has been adopted. The general question - What is included in the meta-model and what is not? - influences the complete BPMS functionality. For example TIBCO ActiveMatrix in comparison to TBCO iProcess adds organizational and inte-gration related aspects to the model.

The white boxes within the components of figure 3 represent key functionalities while relevant characteristics are displayed using green boxes. The idea behind this is to derive activities for migration from the functionalities and to derive cost drivers in the notion of Boehms work on CoCoMo [11] from the characteristics. The Technical Infrastructure is seen as a special case of a cost driver. The provision of the necessary infrastructure for a BPMS covers activities that are independent from the special task

of BPMS implementation and migration. Furthermore, a majority of the costs stems from software licenses, hardware components etc.

Applying these general ideas for example to the *Design* component of the framework, there are five functionalities considered relevant for migration effort: (1) Process Modelling (2) Data Modelling (3) Form Design (4) Rule Definition (5) Simulation. The characteristics in green boxes can be applied to all these functionalities. Deployment is not considered because most of the characteristics are not applicable. The characteristics are directly inspired by Cragg's frame of reference. Redundant aspects like collaborative design and time-to-value are removed. Collaborative design is by definition based on versioning and the support of business users. Time-to-value is indirectly influenced by all characteristics and all green boxes in the Design component effect time-to-value.

Since this BPMS concept is based on the evaluation of only two approaches, further development steps are likely. However, the general structure allows flexibility regarding future additions and changes in functionalities and characteristics.

3.2 General Questions of BPMS Migration Effort Estimation

Based on the given frame for BPMS comparison, questions (see table 2) have been formulated in order to provide a guide for migration planning and effort estimation. Each question is assigned to a label for further identification purposes. In order to avoid complex answers, the expected answer types for all questions are given in the third column.

Tab. 2. Guiding Questions

| Label | Question | Answer Type |
|------------|--|------------------------|
| <i>QD1</i> | Is an information transfer between start and target system possible using available export and import functionalities? | boolean |
| <i>QD2</i> | Does the start system provide an export functionality for the information type? | boolean |
| <i>QD3</i> | Does the target system provide an import functionality for the information type? | boolean |
| <i>QD4</i> | Is an adapter technology available? | boolean |
| <i>QD5</i> | Are the same notations used to represent the information in the start and target systems ? | boolean |
| <i>QD6</i> | Which notation is used to represent the information in the target system? | 'standard' or 'custom' |
| <i>QD7</i> | Does the target system offer interfaces for non-technical users? | boolean |
| <i>QD8</i> | Does the target systems provide templates for the business information modeled in the start system? | percentage |

| | | |
|--------------|--|---------|
| $QD9_{Form}$ | Does the target system provide automatic form generation? | boolean |
| QI | How much of the integration adapters required by the project are available by the vendor of the target system? | percent |
| $QT1$ | Do the start and the target system share a design tool? | boolean |
| $QT2$ | Do the start and the target system share an integration tool? | boolean |
| $QT3$ | Do start and target system share the execution environment? | boolean |
| QC | Are the concepts of the enactable business model from the start and the target system compatible? | boolean |

All questions QD deal with the *Design* component. While $QD9_{Form}$ deals with the forms functionality only, the other eight questions are applicable to all the relevant design time functionalities depicted in figure 3. The first four refer to the technical support of design information transfer between start and target system. As a result of answering these questions, one of three action scenarios (AS) can be identified: information transfer using export and import functionalities ($AS1$, $QD1$ true), information transfer possible using an adapter technology ($AS2$, $QD1$ false and $QD2-4$ true), information transfer requires manual recreation of the information objects in the target system ($AS3$, $QD1$ false and one of $QD2-4$ false). The migration effort $f(x)$ differs between the scenarios: $f(AS1_i) < f(AS2_i) < f(AS3_i)$; $i \in \{Process, Data, Form, Rule, Simulation\}$.

The remaining questions related to the design component ($QD5$ to $QD9_{Form}$) in table 2 aim at estimating the effort in the $AS3$ situations, which means a transfer of information of an object by recreating it within the target system, e.g. remodelling a process model. Therefore, $QD5$ and $QD6$ refer to the notation of respective models. If the start and the target system use different notations for the same information type the migration requires the acquisition of know-how related to the notation of the target system. Commonly, this is possible by either hiring further experts or training the available staff. Furthermore, it can be assumed that knowledge about a standard notation can be acquired easier compared to custom notations. This assumption is based on the fact that a larger number of experts for standard notations as well as training offerings are available on the market since standards are not limited to a single vendor. In consequence, different Knowledge Demands (KD) generating different effort are identified: the same notation in source and target system ($KD1$, $QD5$ true), Different notations and standard notation in target system ($KD2$, $QD5$ false and $QD6 = 'standard'$), Different notations and custom notation in target system ($KD3$, $QD5$ false and $QD6 = 'custom'$). General assumptions regarding effort are: $f(KD1_i) < f(KD2_i) < f(KD3_i)$; $i \in \{Process, Data, Form, Rule, Simulation\}$.

$QD7$ evaluates if there is support for non-technical users. Craggs [6] argues that non-technical users such as business analysts provide the knowledge of the business case that should be automated by the BPMS. In $AS3$ scenarios this knowledge needs to be remodelled. Non-technical user interfaces, such as drag-and-drop capabilities, allow storing business information into a BPMS without expert knowledge about the used notation. This decreases the migration effort for two reasons: the number of required technical users can be minimized by including business analysts in the migration

process and less know-how about the notation of the target is needed. This decreases the knowledge acquisition costs.

QD8 aims to include the influence of industry knowledge provided by the BPMS vendor on the migration effort. As mentioned in the application of the frame of reference by Lustratus [7], some vendors of BPMS offer industry knowledge in the form of templates, e.g. business process model templates for common business cases. The answer of QD8 should state how much information does not need to be recreated manually in the target system because of templates that cover this information. Since this statement needs to be relative to the overall size of the information of a certain migration project, it is given in percentages.

QD9_{Form} assesses the existence of generators that can create forms automatically based on data objects. These forms still require customization to be used in production environments, but it can be assumed that form generators decrease the migration effort related to forms. The impact of form generators depends on their quality, thus some measure regarding the generator quality needs to be included in effort estimation.

QI aims at the *Integration Infrastructure*. *QI* refers to the available adapter components for the integration of existing information systems. The estimation is based on the ratio of existing adapters to the total number of needed adapters. There is a base effort for adapter configuration. However, effort increases if adapters need to be newly designed and implemented. BPMS support for this task may differ. The supported protocols of the Integration Infrastructure are not further considered since these are reflected in the available adapters and of course are important for strategic decisions.

Architecture is a relevant characteristic of the *Technical Infrastructure* component. The example of TIBCO iProcess and TIBCO ActiveMatrix BPM shows that two different BPMSs can share design and integration tools. Thus, these BPMS parts do not need to be migrated. A big amount of migration effort can be avoided. *QT1* to *QT3* assesses the possibility of shared BPMS components. The other characteristics of the *Technical Infrastructure* like hard and software requirements are not further considered regarding migration effort because this is not a special issue of BPMS but rather a standard problem of IT management.

However, even if core components are shared between BPMS, a migration remains necessary when the start and the target system do not share the same concept of an enactable business model. This essential aspect is covered in question *QC*. With the respect to a BPMS migration, different concepts of enactable business models means different demand of information for the start and the target BPMS (cf. section 2.2). Therefore, an additional effort needs to be considered that covers the acquisition and implementation of these business information.

The overall effort of a migration project is based on two main aspects: the effort for transferring the all business information from the start to the target system and the effort of integrating all the required business software into the target system. Moreover, overall effort of a migration project needs to include the installation of the design tools, the integration infrastructure and the tools related to Execution component such as the process engine, analysis tools and additionally business rules or event engine. Another aspect that has not been discussed in the context of this framework is the training effort for the different user groups. Only the costs of knowledge acquisition effort regarding different notations are covered. However, the technical users, the non- technical users and the end user need to become familiar with the respective user interfaces of the target

system. In case certain components are shared the training effort for these components would be reduced.

3.3 Operationalization of the Cost Drivers

After discussing the general influences on BPMS migration effort based on the provided framework, cost drivers need to be operationalized in order to provide metrics for a calculation of the estimated effort. For reasons of brevity not all of the provided calculation schema can be discussed in detail here. However, the complete set is depicted in the figures 4 and 5.

The total effort f_{total} is a function of the information sets X_i (Data, Process, ...) that need to be migrated between the BPMS, the vector of involved BPMS bv , the set of available adapters for information transfer A , and the number of users u (u_t = technical users and u_{non-t} = non-technical users like business analysts) involved.

$f_{information}$ calculates the effort of transferring all information of a certain type, which basically means that one of three sub-efforts needs to be determined. f_{import} represents the effort of ($AS1_i$), $f_{indirect}$ is related to the effort of ($AS2_i$) and $f_{recreate}$ calculates the effort of ($AS3_i$). For the $AS1_i$ situations (which mean that matching import and export functionalities are provided by the start and the target systems) the effort can be identified by multiplying the size of a set of information with the sum of the average costs of exporting a single element of this set (t_{ex}), copying it to the target system (t_{cp}) and importing it (t_{im}). In case the respective tools of both BPMS allow importing all elements of a certain information type at the same time, f_{import} can be described as the sum effort of these single $export(\kappa_{ex})$, $copy(\kappa_{cp})$ and $import(\kappa_{im})$ processes.

$$\begin{aligned}
f_{total}(X, bv, A, u) &= \neg g(QT1, bv) * \left(\sum_i f_{information}(X_i, bv) + \zeta_{design} \right) \\
&\quad + \neg g(QT2, bv) * (f_{adapters}(A, bv) + \zeta_{integration}) + \zeta_{execution} \\
&\quad + f_{user}(u, bv) + \neg g(QC, bv) * (\theta_{bv} + f_{create}(X_{unknown}, bv)) \\
f_{information}(X_i, bv) &= g(QD1_i, bv) * f_{import}(X_i) \\
&\quad + g(QD2_i, bv) * g(QD3_i, bv) * g(QD4_i, bv) * f_{indirect}(X_i) \\
&\quad + \neg(g(QD2_i, bv) * g(QD3_i, bv) * g(QD4_i, bv)) * f_{recreate}(X_i, bv) \\
f_{import}(X_i) &= |X_i| * (\iota_{ex} + \iota_{cp} + \iota_{im}) \\
f_{indirect}(X_i) &= |X_i| * (\kappa_{ex} + \kappa_{cp} + \kappa_{im}) \\
f_{recreate}(X_i, bv) &= f_{transfer}(X_i) + f_{knowledge}(X_i, bv) \\
f_{create}(X_{Unknown}, bv) &= f_{transfer}(X_{Unknown}) + f_{knowledge}(X_{Unknown}, bv) \\
&\quad + g_{collect}(X_{Unknown}) \\
f_{user}(u, bv) &= u_t * \eta_{t,bv} + u_{non-t} * \eta_{non-t,bv} + u_{end} * \eta_{end,bv} \\
f_{adapters}(A, bv) &= \left(\frac{g(QI, bv)}{100} * |A| * \epsilon + \left(1 - \frac{g(QI, bv)}{100} \right) * f_{develop}(A, bv_{target}) \right) \\
f_{develop}(A, bv_{target}) &= \sum_{j=1}^{|A|} g_{adapter}(a_j) * \epsilon_{target} \\
f_{transfer}(X_i, bv) &= \left(1 - \frac{g(QD8_i, bv)}{100} \right) * f_{manual}(X_i) + \frac{g(QD8_i, bv)}{100} * \gamma_i * |X_i| \\
f_{manual}(X_i) &= \sum_{j=1}^{|X_i|} g_{complex}(x_j) * \beta_i \\
f_{generate}(X_{Form}, bv) &= g(DR9_{Form}, bv) * \delta_{target} * f_{manual}(X_{Form}) \\
f_{transfer}(X_{Form}, bv) &= \left(1 - \frac{g(QD8_i, bv)}{100} \right) * f_{generate}(X_{Form}, bv) \\
&\quad + \frac{g(QD8_i, bv)}{100} * \gamma_{Form} * |X_{Form}| \\
f_{knowledge}(X_i, bv, u) &= g(QD7_i, bv) * g_{tech}(X_i)^{\frac{u_{non-t}}{u_t}} * f_{acq}(bv, u, i) \\
&\quad + \neg g(QD7_i, bv) * f_{acq}(bv, u, i) \\
f_{acq}(bv, u, i) &= \neg g(QD5_i, bv) * u_t * \alpha_{notation} \\
notation &= g(QD6_i, bv)
\end{aligned}$$

Fig. 4. Estimated Effort Calculation

$f_{adapters}$ calculates the effort for integration. This includes the effort for integration adapter development $f_{develop}$. $f_{transfer}$ calculates the effort for the manual transfer of information from source to target BPMS. This includes effort savings depending on the existence of templates. Additionally, in the case of forms information, the influence of form generators needs to be considered. $f_{knowledge}$ addresses the need of knowledge acquisition by the users involved in BPMS migration. As stated in the previous section, this effort depends on the existence of interfaces for non-technical users and of course

on the number of users. The calculations are based on several values that need expert estimation from past experiences with BPMS maintenance, implementation and use. These values are treated as constants in the calculation model (see figure 5). A special function $g(Q^*,bv)$ operationalizes the answers to the questions. A special information type *unknown* has been added for the case that the concepts of the enactable business model differ.

$\alpha_{notation}$: average effort to train a technical user in a certain notation
 g_{tech} : share of technical information inside a set of information
 β : effort to recreate a single information element with a complexity equals 1
 $g_{complex}$: function to determine the average complexity of an information element
 γ : average effort of apply a template of a certain information type
 δ : quality of a form generator in terms of proportional effort of customizing a generated form compared to creating it without generator
 ϵ : average effort to set up available adapters
 ε : effort to develop an adapter with a complexity equals 1
 $g_{adapter}$: function to determine the complexity of an adapter
 $\zeta_{design}, \zeta_{execution}, \zeta_{integration}$: effort to set up the tools that implement the functionalities of the design, execution and integration components
 $\eta_t, \eta_{non-t}, \eta_{end}$: average effort to train technical, non-technical and end-users
 θ : effort to get the additional information required by the concept of enactable BPM of the target system
 l_{ex}, l_{cp}, l_{im} : average effort to directly export, copy and import a single information element
 k_{ex}, k_{cp}, k_{im} : average effort to export, copy and import a single information element using an adapter tool

Fig. 5. Cost Drivers for Effort Estimation

The framework has been evaluated by using it for a migration scenario having TIBCO iProcess as source BPMS. TIBCO Active Matrix BPM and jBPM have been used as target systems. Migration was done for a small process. A comparison of effort estimated by the framework and of actual effort has been done. However, not all aspects and variables could be evaluated. For example, no training costs have been considered. At the end, the absolute differences of actual and estimated values have been in the range between 2 and 5 hours. Nevertheless, the total migration efforts were too small (13 hours and 9 hours) to allow any interpretation regarding the quality of the estimation. The framework however has been considered useful by the project responsible.

4 Conclusion and Outlook

The framework for effort estimation has been proven generally applicable for its purpose based on a small case study evaluating a BPMS migration scenario. The framework is open for additional information sets. One set that needs to be added looking at the case study using TIBCO iProcess and Active Matrix BPM is organizational information. The comparison of BPMS based on the framework is bound

to the purpose of migration. Other frameworks may fit better for example if the task of BPMS selection is considered. Effort is strictly related to the technical effort of migration. Maintenance is not being considered. The training costs are only calculated for the staff that is involved in migration. Since the BPMS in the case study did not share execution components (see *QT3*) this aspect has not been investigated further in the calculations. However, based on existing executable process model standards like BPEL or XPD L there may be the case of a shared execution engine of different BPMS. Overall, the framework provides guidelines and ideas for the estimation of BPS migration effort. However further steps of refinement and validation are necessary. Regarding experience, more functional dependencies may be derived for the data which has been considered as constant here.

Regarding validity of the presented results, there is a limitation due to the small number of publications found. Furthermore, the architecture of more BPMS should be compared to the presented framework and a bigger case study is suggested.

References

1. Karagiannis, D. (1995). BPMS: business process management systems. ACM SIGOIS Bulletin, 16(1), 10-13.
2. B. Kitchenham. Procedures for Undertaking Systematic Reviews. Computer Science Department, Keele University and National ICT Australia Ltd, 2004.
3. Emerald - business process management journal. URL: <http://www.emeraldgroupublishing.com/products/journals/journals.htm?id=BPMJ> [cited 7.7.2017].
4. Lustratus research limited [online]. URL: <http://www.lustratus.com> [cited 7.7.2017].
5. Duncan R. Shaw, Christopher P. Holland, Peter Kawalek, Bob Snowdon, and Brain Warboys. Elements of a business process management system. Business Process Management Journal, 13(1):91-107, 2007.
6. S. Craggs. Comparing bpm from appian, oracle and ibm. Lustratus Research, 2012.
7. S. Craggs. Comparing bpm from pegasystems, ibm and tibco. Lustratus Research, 2011.
8. S. Craggs. Comparing bpm from ibm, oracle and sap. Lustratus Research, 2009.
9. S. Craggs. Comparing bpm from ibm, software ag and pegasystems. Lustratus Research, 2010.
10. B. Warboys, P. Kawalek, I. Robertson, and M. Greenwood. Business Information Systems: A Process Approach. McGraw-Hill, New York, 1999.
11. Boehm, B. W., Madachy, R. & Steece, B. (2000). Software cost estimation with Cocomo II with Cdrom. Prentice Hall PTR.