Information and Software Technology 51 (2009) 528–545

Contents lists available at ScienceDirect

Information and Software Technology

journal homepage: www.elsevier.com/locate/infsof

An approach for concurrent evaluation of technical and social aspects of software development methodologies

Damjan Vavpotic *, Marko Bajec

Faculty of Computer and Information Science, University of Ljubljana, Trzaska 25, 1000 Ljubljana, Slovenia

ARTICLE INFO

Article history:
Received 3 August 2007
Received in revised form 10 June 2008
Accepted 15 June 2008
Available online 24 July 2008

Keywords:
Software development methodology
Method engineering
Software process improvement
Methodology evaluation

ABSTRACT

The paper presents an approach for evaluation of software development methodologies (SDM) that considers the aspects of a SDM's social adoption and technical efficiency. It builds on existing evaluation models used in the field of SDM. Case study approach was used to validate the model in four software development organisations. In all four cases the management confirmed that the model provided valuable new insights into adoption and efficiency of the companies' SDM.

1. Introduction

A software development methodology (SDM) can be defined as a recommended mean to achieve the development of program systems, based on a set of rationales and an underlying philosophy. It usually includes a definition of phases, procedures, tasks, rules, techniques, guidelines, documentation and tools [1]. SDM adoption can be defined as the actual level and consistency of use of officially recommended SDM in the observed organisation. Although most organisations, involved in software development, follow certain rules and procedures during development, there is a distinction between organisations with rules and procedures written in a form of a formal SDM and organisations that rely only on informal agreements between developers on how to develop software. Different studies indicate that adoption of formal SDMs facilitate increases in productivity and quality [1–3]. However, despite the fact that formalised commercial SDMs have existed for several decades, many software development organizations do not use formal SDMs in practice. Moreover, even those that use formal SDMs, rarely follow them rigorously [4–6]. Different reasons for this situation have been identified [7,8] and different approaches to improve the level of formal SDMs adoption in organisations proposed [9,10]. The results of the formal SDMs adoption research nevertheless suggest that these efforts have been met with limited success.

Researchers found that in the context of formal SDMs non-adoption two aspects are especially significant. The first one is that formal SDMs are not tailored to specific organization and project needs. Example, formal SDMs often prescribe inappropriate techniques and methods; formal SDMs are too rigid and cannot be adapted to specific project demands, etc. [11–14]. The second one is that formal SDMs do not fit social characteristics of a development team and an organization. Example, it is difficult to introduce a rigorous SDM into an organization that has a liberal culture; an non-innovative development team will probably reject an innovative SDM, etc. [15–18]. The consequence of using a SDM that is either technically unsuitable for a project at hand, or socially inappropriate for a given development team is that even though an organisation might have invested a considerable amount of resources into the SDM, developers consider it useless and therefore reject it.

The first step to improve the aforementioned situation is to evaluate technical suitability of a particular SDM for a particular project and social suitability of the SDM for a particular development team. Even though extensive research in the field of SDMs technical aspects and in the field of SDMs social aspects exists and one of the goals of both fields is similar, i.e. to improve SDMs suitability, the two research fields remain almost completely unrelated. Researchers tend to observe SDMs from one of the two aspects only, which results in an incomplete evaluation of SDMs. We believe that in order to achieve a thorough evaluation, SDMs should be considered simultaneously from technical and social aspects.

The objective of our research is to define theoretical and empirical background for a SDM evaluation model, which will facilitate concurrent consideration of both technical and social aspects of a particular SDM and consequentially identify those parts of SDM

* Corresponding author. Tel.: +386 1 4768367; fax: +386 1 4768817.
E-mail address: damjan.vavpotic@fri.uni-lj.si (D. Vavpotic).

0950-5849/$ - see front matter © 2008 Elsevier B.V. All rights reserved.
doi:10.1016/j.infsof.2008.06.001

that are unsuitable from at least one of the two aspects. In contrast to the existing research, in which SDMs is typically observed as a whole, our model facilitates observation of a SDM on a finer scale, measuring SDMs suitability part-by-part. This allows a software development organization to identify the technically and/or socially (in)appropriate SDM parts. Based on the evaluation results the organization can prepare appropriate improvement steps for each SDM part, thus gradually bettering the SDM value.

The basic idea of the approach was first presented in [19]. Since then the model's characteristics and a detailed measurement instrument have been fully developed and the model has been tested in a real-life environment to validate its usefulness. In this paper, we present the complete model and the results of its application in several software development organizations.

The research work and the results that we present in this paper are part of a larger R&D project named MasterProc.[1] The MasterProc was conducted under the umbrella of the Centre of Excellence for Information and Communication Technologies with the aim to develop a framework and supporting tools that will help software companies in reengineering their software development methods. The framework suggests how a company can evaluate and improve its existing practice (Method Evaluation and Improvement) and how knowledge and experience of the development team can be into a formalised method (Method Construction). While the framework supports continuous improvement of the formalized method, it also gives instructions how to avoid rigidity, i.e. how to make the formalised method adaptable to particular circumstances (Method Configuration). Please note that in this paper we only focus on the approach that supports method evaluation and improvement, fundamental for method construction and its continuous evolution. For more details on the whole framework, the interested reader can refer to [20 and 21].

The paper is organised as follows. In addition to introduction (Section 1) and conclusion (Section 6), it comprises four sections. Section 2 discusses the background and theoretical foundations for the SDM evaluation model. It is followed by a detailed description of the model in Section 3, which is divided into four subsections. The first and the second subsections introduce the model and its framework, the third subsection explains the characteristics used in the model, and the last subsection presents the measurement instrument. Section 4 explains the method of application and tailoring of the evaluation model. It is followed by Section 5, which presents the approach that was used to test the model and the results of a practical application of the model in four cases. Two of the cases are discussed in detail.

2. Background and theoretical foundations

One of the important research areas that address technical aspects of SDMs tailoring is method engineering. The aim of method engineering is to construct SDMs from the SDM components or fragments [21–24]. In the context of SDMs, tailoring a special form of method engineering termed situational method engineering is particularly important. Situational method engineering deals with construction of a SDM adapted to a certain project. Different types of situational method engineering are known [25]. They vary from the relatively simple types that help choose the most suitable path through a certain SDM for a particular project, to the advanced types that support modular construction of a SDM from the suitable SDM parts and result in a SDM completely adapted to the needs of a particular project [26,27]. Although many researchers focused on the advanced types of situational method engineering, it has later been recognised that these types of situational method engineering are too complex to be widely practiced by software development organisations [28]. Situational method engineering research nevertheless offers important insights into the problem of SDMs construction and customisation. Interestingly, ideas similar to situational method engineering were reinvented with the emergence of agile methodologies that advocate the idea of SDMs adaptation for a given project [11]. Moreover, adaptation and customisation is becoming one of the important factors in some of the "off the shelf" SDMs (e.g. Rational Unified Process [29]) that were often criticised for being too rigid and inadaptable in the past [30].

The research dealing with evaluation of maturity and efficiency of SDMs is another area that addresses technical aspects of SDM. Different standards and evaluation models exist that can be used to evaluate technical aspects of SDMs and their products. These include ISO/IEC standards like ISO/IEC 15504 [31], ISO/IEC 9126-1 [32] and CMMI maturity model [33] that describe different categories and characteristics of SDMs and software quality.

While situational method engineering and SDM evaluation models consider almost every possible technical component of SDM evaluation, construction and tailoring, they almost completely omit the social and cultural aspects of SDM users. However, research has shown that it is probable that developers reject a SDM that does not suit their social needs, even if the SDM is technically suitable [3,10,18]. Therefore, considering technical aspects of SDMs only is insufficient and results in an incomplete evaluation. To obtain a complete picture of SDM value we also have to consider the aspects of its social adoption.

The research that explains social aspects of (non-)adoption in software development organisations [15,34,35] is often based on Rogers' diffusion of innovations theory (DOI) [36]. DOI is a general theory that tries to explain why certain innovations spread among their target users and others do not. Researchers in this field consider a SDM or its parts as an innovation and try to predict and explain target adopter attitudes and their innovation-related behaviour [37]. Beside DOI other innovation diffusion models and theories like the Theory of Planned Behaviour (TPB) [38], Technology Acceptance Model (TAM) [39,40], Perceived Characteristics of Innovating (PCI) [41], and the Theory of Reasoned Action (TRA) [42] can be used to predict/explain adoption of innovations in the field of SDMs. The comparison of these models shows that they all have some common characteristics that were found significant in context of SDMs adoption [3].

However, in contrast to method engineering that considers a SDM as a composition of interrelated parts, the aspects of SDM social adoption are typically observed either on the scale of the whole SDM or for a single part of a SDM only (e.g. a development tool). Furthermore, models explaining social adoption ignore technical efficiency and quality of innovation and focus only on reasons for the innovation's (non-)adoption. An additional difficulty is that these models tend to focus on reasons for (non-)adoption levels but do not measure actual levels of adoption.

3. SDM evaluation model

3.1. Introduction

The main goal of our research was to construct an approach that would better suite the needs of SDM adaptation and improvement. A comprehensive evaluation of a SDM requires an evaluation model that facilitates evaluation of SDM suitability on a social and a technical dimension. The social dimension focuses on SDM suitability to social and cultural characteristics of a development team and enables one to determine the level of SDM adoption. The

[1] The MasterProc project was co-founded by the Slovenian Ministry of Higher Education, Science and Technology, European Commission and the participating Software Companies.

technical dimension considers suitability of a SDM for technical characteristics of a project and an organisation, and helps determine the level of the SDM efficiency. The purpose of the model is to help an organisation identify less suitable parts of their SDM that need improvement.

An important aspect of such a model is that it does not only consider a SDM as a whole, but also as a composition of interconnected elements. We define a SDM element as a component of a SDM and specially focus on the SDM elements that can be formalized. Common SDM elements that can be formalized include elements like activities, roles, artefacts, techniques, templates, guidelines, recommendations, etc. [43]. The reason we decided to consider only the elements that can be formalized is that these elements can be observed and discussed on solid ground – formalized description of the element. Elements that were excluded from the evaluation deal mostly with tacit knowledge.

3.2. The evaluation model framework

The framework of the evaluation model focuses on the interaction between social and technical SDM aspects. Fig. 1 depicts the framework of the evaluation model. After an evaluation is completed, all SDM elements are positioned in a scatter chart. The chart is divided into four quadrants to facilitate differentiation between the four different types of SDM elements regarding their value:

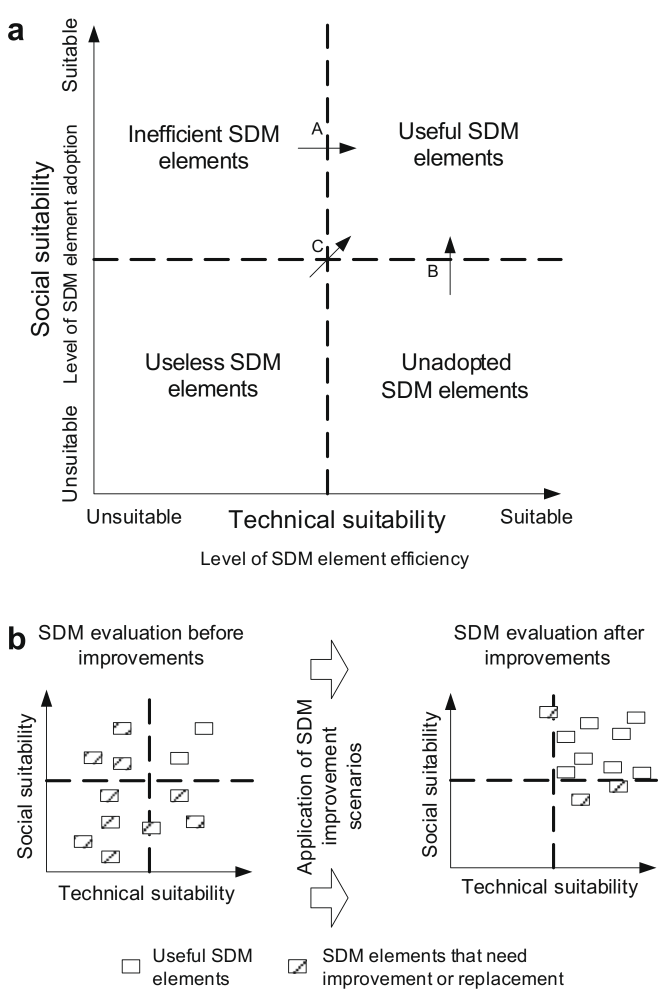

Fig. 1. The framework of the SDM evaluation model. SDM elements are positioned in one of the four quadrants to facilitate distinction between four different types of SDM elements (a). After application of SDM improvement scenarios, we expect most of the elements to move to the useful elements quadrant (b).

- A *useless SDM element* is both technically and socially unsuitable. Different reasons for such unsuitability can be identified. It can for instance be caused by constant technology change that eventually renders an SDM element technically unsuitable. Consequently, developers stop using the technically unsuitable element, which finally results in its complete unsuitability. Alternatively, an element might have been technically unsuitable from the beginning and therefore never used.
- An *inefficient SDM element* is socially suitable, but does not suit technical needs of a project or an organisation. For instance, these can be SDM elements that have been technically suitable in preceding projects and have been well adopted among users, but are technically inappropriate for the current project.
- In contrast to an inefficient element, an *unadopted SDM element* is technically suitable, but its potential users do not use it because of its social unsuitability. Many reasons why potential users do not adopt a technically efficient SDM element can be identified. The element might be overwhelmingly complex, it might be difficult to present advantages of its use to the potential users, it might be incompatible with existing user experience and knowledge, etc.
- A *useful process element* is socially and technically suitable. Such SDM element is adopted among its users and suits technical needs of the project and the organisation.

This categorization of SDM elements facilitates creation of improvement scenarios for the less suitable SDM elements. We define an improvement scenario as a list of concrete actions that should be performed to improve the level of efficiency or adoption of a certain SDM element. Creation of an improvement scenario is a delicate task that is based not only on the results of the element's evaluation, but also on additional information that is gathered through observations of the element and consultations with the element's (potential) users. These observations and interviews are performed only for the elements that have been found less suitable during the evaluation. Although the scenarios typically share some common features, each scenario has to be tailored to the circumstances of the SDM element that require improvement. The detailed description of scenario creation is out of the scope of this paper, as it does not influence the evaluation itself. However, general rules considered during the creation of an improvement scenario, are as follows:

- In case of an inefficient process element (see Fig. 1a, arrow A.), we should improve element's technical and retain its social suitability. Since users already adopted the element, we should strive to modify it only to the extent that it becomes technically efficient again. An example of an inefficient SDM element could be an approach used for business modelling based on flowcharts. Such approach might be well adopted among analysts in a certain team, but technically inappropriate for a given problem, as it would not capture certain business concepts. We might identify RUP's UML business modeling approach [29] to be technically the most suitable. However, analysts would reject the RUP's approach as its philosophy differs considerably from the philosophy of the adopted approach. In this case, a socially more suitable approach that shares a similar philosophy should be considered (e.g. an approach using ARIS eEPC [44]) even though such an approach might be technically less suitable in the given context than RUP's.
- In case of an unadopted but technically suitable process element (see Fig. 1a, arrow B.), we should explore the causes for element's rejection among its potential users. We might find out that potential users lack knowledge and experience to use the element. To improve the element's adoption we might consider educating and presenting advantages of the element to its

potential users. An example of an unadopted element could be a certain modelling technique that is unused by a development team albeit obvious advantages of using such technique are reported in different publications. In this case, we should present advantages of the technique to the developers and offer them appropriate training.

- In case of a useless element (see Fig. 1a, arrow C.) that is both socially and technically unsuitable the most reasonable action would be to replace or discard it completely. We can most likely find a technically and/or socially more suitable element or perhaps the element is not needed at all.

We expect that most SDM elements will move to the useful SDM elements quadrant after application of improvement scenarios (see Fig. 1b), though some of the elements might still need further improvement or even replacement.

It is important to understand, however, that improvement scenarios cannot be applied uniformly to every SDM element and not every element can be changed to the same extent. For instance, SDM elements that are part of the SDM core can only be changed to a limited extent or not at all. In that case, only the level of the element's social adoption can be improved, but not its technical aspects. Therefore, we introduce the third dimension that has to be considered in creation of improvement scenarios – the changeability. We consider changeability in two ways, technically and socially. From technical point of view, our main concern is how to avoid changes that would lead into inconsistent methods. In our research, a method is considered to be technically inconsistent if it contains elements that are not complete or feasible, since their dependent elements have been changed or removed from the method. The approach that we use in our framework prevents such situations by special rules that are part of a base method. For more details, please see [21]. From social point of view, we take into account various aspects that influence the ability to introduce a certain innovation into a certain organisational setting like organisational culture, policies and practices. These issues have also been studied by other researchers [9,15,45].

When creating improvement scenarios changeability requires careful consideration. A detailed discussion on changeability is, however, out of the scope of this paper, as it does not influence the SDM evaluation itself.

3.3. Structure of the evaluation model

As discussed in the preceding sections, we use social and technical dimensions to determine the suitability of a SDM. The literature and the existing evaluation models were searched for measurable characteristics for each dimension. Characteristics that have been found significant in the context of SDM in the preceding studies have been selected for inclusion in the model. Characteristics of each dimension were grouped in two sets. The first set of characteristics measures the current situation, i.e. the level of social or technical suitability. The second set of characteristics measures the reasons for the current SDM element situation, i.e. the reasons for the level of technical or social suitability that was determined by the first set of characteristics. Fig. 2 shows both sets of characteristics and their relations to the dimension.

The following example illustrates the use of a model shown in Fig. 2. Suppose that by examining the set of characteristics that measures the current situation, we discovered that a certain SDM element is socially unsuitable. Although we are now aware of the element's social unsuitability, we are still unfamiliar with the reasons for its unsuitability. To determine the reasons we have to examine the second set of characteristics. Suppose that based on the second set of characteristics we determine that most of the potential users of the SDM element find the element too complex. These results lead to the conclusion that the SDM element is not used because it is perceived as being too complex. To improve the situation we can either try to simplify the SDM element so that it becomes more socially suitable, or we can try to train its potential users.

3.3.1. Characteristics of social adoption

Fig. 3 depicts a model that measures the level and the reasons for the level of social adoption. The level is determined by two characteristics.

- *Frequency of use in a case of a given opportunity* measures how often developers apply a certain SDM element in a case that an opportunity for its use arises within a certain project. It is based on a more general characteristic *frequency of use* that has been used by other researchers on the scale of a whole SDM [46,47]. We modified the more general characteristic in a way that enables us to measure the use of a single SDM element. The main difference between measuring the frequency of use of a whole SDM and of a single SDM element is that in the later case one has to consider that during a development process opportunities for use of different SDM elements are not equally frequent. Therefore, we measure the frequency of use relative to the frequency of opportunities for use. The modified characteristic enables us to gain comparable evaluations for different SDM elements.
- *Consistency of use* measures how consistently developers follow the instructions and rules of a certain SDM element. Although the developers may state that they use a certain SDM element, they may only partially follow its instructions and rules. This characteristic measures the difference between the approach developers actually apply in practice and the approach prescribed by the corresponding SDM element.

The reasons for the level of social adoption are determined by the second set of characteristics that are divided into four different groups. The characteristics are based on existing research models used in the field of SDMs and IT adoption, DOI and other studies examining the factors that influence the use of SDMs.

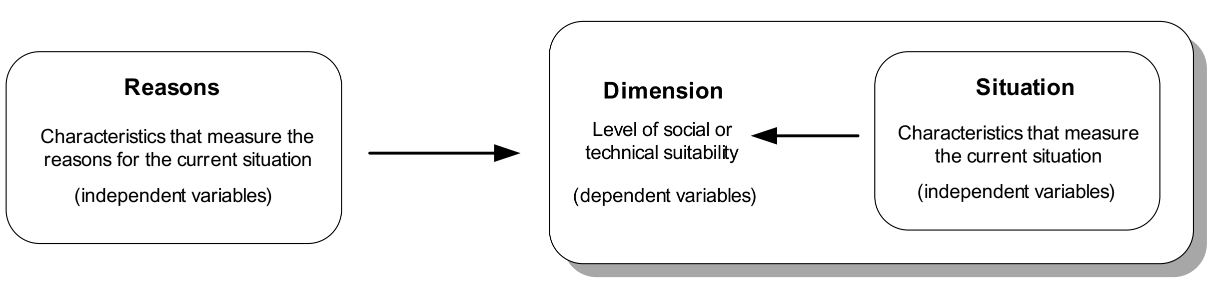

Fig. 2. The relations between a dimension, a situation and a reason for the situation.

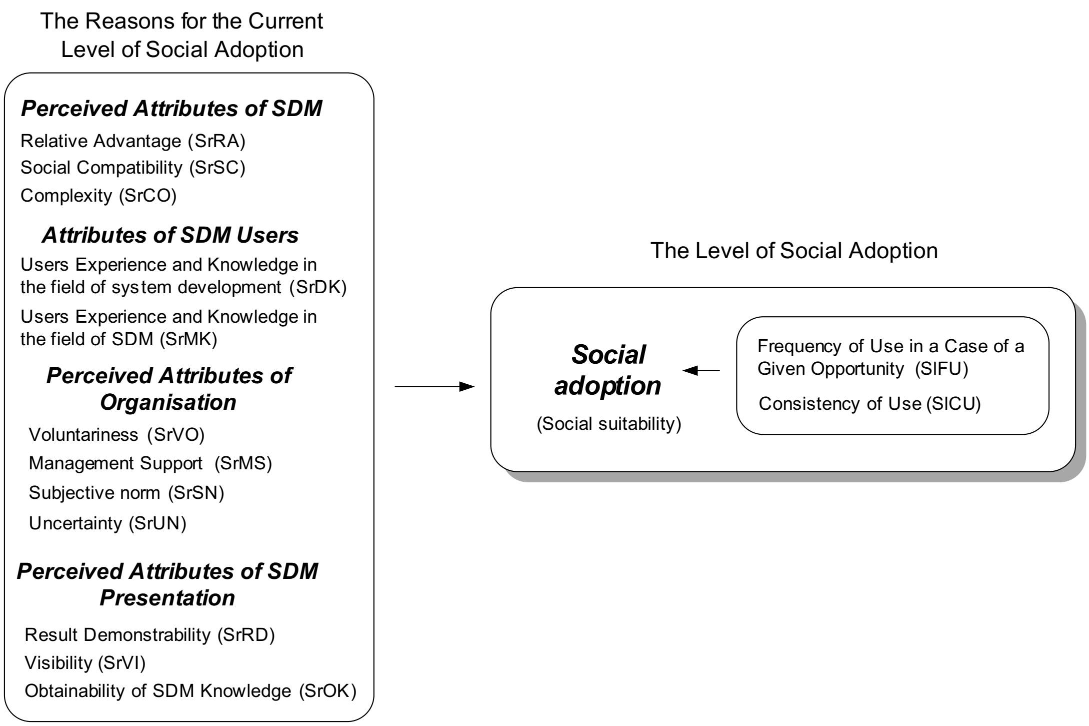

Fig. 3. The model of characteristics used to determine social adoption.

Most of these characteristics focus on users' perceptions of a SDM rather than on primary attributes of a SDM. Researchers in the field of IT innovation adoption often use perceived characteristics. According to Downs and Mohr [48] the findings of many studies, which have examined the primary characteristics of innovations, have been inconsistent, as primary attributes are intrinsic to an innovation independent of their perception by potential adopters. The behaviour of individuals, however, is predicated by how they perceive these primary attributes. Since different adopters might perceive primary characteristics in different ways, their eventual behaviours might differ.

The first group *Perceived attributes of SDM* comprises three characteristics.

- *Relative advantage* is the extent to which SDM users see the use of a certain SDM element as superior to work without using the SDM element. In some studies, relative advantage is termed Usefulness. It is based on DOI and is used in different models in the field of IT adoption like TPB, TAM and PCI. In various studies (e.g. [3,36,46]) it has been found to be one of the most significant characteristics that positively influence adoption of a SDM.
- *Social compatibility* is the degree to which SDM users perceive a certain SDM element as being congruent with their experience, knowledge and needs. It is based on PCIs *compatibility*, however, we use the term *social* to distinguish between social and technical compatibility that is also measured in the model. Studies (e.g. [3,46]) have shown that social compatibility has significant positive influence on SDM adoption.
- *Complexity* is the degree to which SDM users see a certain SDM element as difficult to use and comprehend. Some studies also use a reversed characteristic termed Ease of use. The characteristic is part of DOI and is used in TAM and PCI. Even though complexity has not been found significant in some studies [3,46], it has been found significant in others [39]. In the later studies, it has been found to negatively influence the adoption.

The second group *Attributes of SDM users* consists of two characteristics.

- *Users experience and knowledge in the field of system development* is the level of knowledge and experience that a SDM user has in the field of programming tools, platforms, technologies, program languages, etc. Studies (e.g. [49]) suggest that inexperienced developers are more likely to use SDM and that existing experience has negative influence on SDM adoption. Users evaluate their experience and knowledge in the context of evaluated SDM element only.
- *Users experience and knowledge in the field of SDM* is the level of knowledge and experience that a SDM user has in the field of development processes, standards, etc. Researchers have found significant positive relation between user experience in the field of SDM and SDM adoption [50]. Users evaluate their experience and knowledge in the context of evaluated SDM element only.

The third group *Perceived attributes of the organisation* comprises four characteristics.

- *Voluntariness* is the extent to which SDM users see the adoption of a certain SDM element to be optional. The characteristic is part of extended TAM and PCI. Studies suggest that unless management prescribes the use of SDM or other IT innovation, developers often do not adopt it. Consequentially, significant negative relation between voluntariness and SDM adoption has been detected [3,51,52].
- *Management support* is the degree to which management actively supports introduction and use of a certain SDM element on projects. Management support has been found to have significant positive influence on SDM adoption [36,46].
- *Subjective norm* is the degree to which SDM users think that others, who are important to them, think they should use a certain SDM element. It is based on TRA and is also used in extended TAM and TPB. This characteristics has been found to significantly influence adoption of tools [40] and SDM [3].

- *Uncertainty* is the extent to which potential adopters of SDM think the future of their organisation is uncertain and are therefore unwilling to support new initiatives, i.e. adopt SDM. Uncertainty has been found to have significant negative influence on SDM adoption [46,53].

The fourth group *Perceived attributes of SDM presentation* consists of three characteristics.

- *Result demonstrability* is the degree to which the benefits of use of a certain SDM element are tangible. The characteristic is part of DOI and is used in PCI. Studies suggest that the characteristic has positive influence on adoption of IT innovations [41]. However, studies in the field of SDM adoption typically have not found significant influence on adoption [3,46]. Nevertheless, we decided to include the characteristic in the evaluation model, as we expect that it could have significant influence on the adoption of some specific SDM elements like tools and SDM products.
- *Visibility* is the degree to which others can observe SDM users using a certain SDM element. The characteristic is part of DOI and is used in PCI. Visibility is suggested to have positive influence on adoption of IT innovations [41]. The motive to include the characteristic is the same as for Result demonstrability.
- *Obtainability of SDM knowledge* is the extent to which it is easy for SDM users to acquire knowledge of a certain SDM element. Users obtain SDM knowledge from different sources like trainings, books, web resources, etc. Studies emphasise the importance of SDM training that facilitates adoption and use of SDM [54].

3.3.2. Characteristics of technical efficiency

Compared to social adoption characteristics, characteristics of technical efficiency are of more objective nature. Evaluation models that consider the technical aspects of a SDM [32,43,55] therefore usually measure its primary attributes that do not leave much room for subjective (perceptual) interpretation (e.g. lines of code produced in a man-week, number of critical errors per thousand lines of code, etc.). There are, however, also evaluation models that focus on perceptions of SDM users to evaluate technical aspects [6].

We decided to focus on perceptions of SDM technical efficiency rather than on its primary attributes. The reason that led us to this decision was, that it is necessary for an organisation to have a well-established measurement system in order to acquire objective measurements of primary attributes of a SDM in such an organisation. Unfortunately, many organisations do not systematically measure their development process and it is usually these organisations that call for process evaluation and improvement.

Nevertheless, use of perceptual characteristics creates the problem of objectivity, as it is difficult to eliminate the influence of the respondent's subjective views of SDM technical efficiency. To mitigate the impact of perceptual characteristics on objectivity, only a selected group of SDM users answered to the questions about technical efficiency. The formation of the group is discussed in the following section.

Fig. 4 shows the model that measures the level and the reasons for the level of technical efficiency. To determine the level we use the following characteristics:

- *Frequency of opportunities for use* measures how frequently an opportunity for application of a certain SDM element arises regardless of the fact if this SDM element is actually used by its potential users. It complements the characteristic frequency of use in a case of a given opportunity and is similarly based on a more general characteristic frequency [46,47].

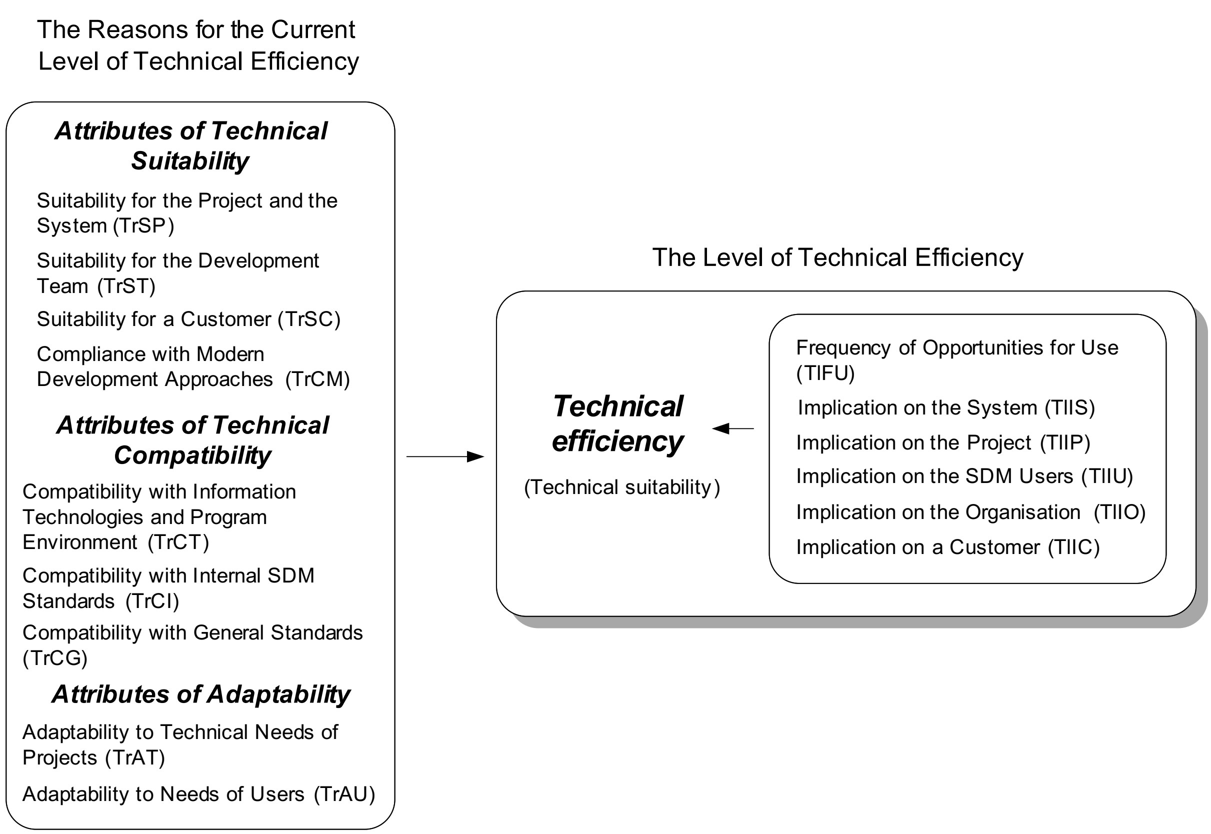

Fig. 4. The model of characteristics used to determine technical efficiency.

- Characteristics concerning *implication of a certain SDM element* on different aspects of the development are based on existing models and standards that can be applied to determine the quality of the development process [6,31,55]. SDM elements that have positive implication are considered technically suitable and vice versa. The characteristics have been modified to support perceptual measuring.

Characteristics concerning *implication of a certain SDM element* focus on following aspects of the development:

- *Implication of SDM element on system to be implemented* – completeness, coherence, usability, reliability, maintainability, portability, efficiency and reusability of the new system.
- *Implication of SDM element on project* – time consumption, project costs, project control, quality of project plans, traceability of a project, estimation of project risks and different other problems that arise during project.
- *Implication of SDM element on SDM users* – ambiguity of communication, facilitation of cooperation, understanding of responsibilities and duties and support for training.
- *Implication of SDM element on organisation* – facilitation of standardisation, organisation goal achievement and improvement of organisation's reputation.
- *Implication of SDM element on customers* – improvement in customers' trust in organisation, improvement in customers' overview of progress, improvement in general satisfaction with the organisation.

The second set of characteristics is used to determine the reasons for the level of technical suitability. Characteristics are based on existing models and standards [11,13,32,55] that enable us to determine suitability, compatibility and adaptability of the development process.

The first group *Attributes of technical suitability* comprises four characteristics.

- *Suitability for the project and the system* is the degree to which a certain SDM element suits different project and system parameters like size, complexity, priority, type, etc.
- *Suitability for the development team* is the extent to which a certain SDM element suits the experience and knowledge of the development team. Even though this characteristic covers a rather similar field as some of the social suitability characteristics, the main difference is that it measures suitability from a more objective perspective.
- *Suitability for the customer* is the degree to which a certain SDM element suits predefined requirements and needs of the customer. This characteristic is relevant especially when the customer has special demands regarding the SDM element (e.g. use of a special tool).
- *Compliance with modern development approaches* is the extent to which a certain SDM element is kept up-to-date with current technologies, techniques and recommendations in its field.

The second group *Attributes of technical compatibility* consists of three characteristics.

- *Compatibility with information technologies and the program environment* is the degree to which a certain SDM element is compliant with technologies and program environments used for system development on a certain project. Some SDM elements may be closely related to technologies and therefore less useful when unsupported technologies are applied on a project.
- *Compatibility with the internal SDM standards* is the degree to which a certain SDM element complies with internal SDM standards and common standards of other SDM elements. The characteristic measures SDM internal integrity.
- *Compatibility with general standards* is the degree to which a certain SDM element complies with generally defined standards in its field like modelling techniques, coding standards, architecture standards and patterns, etc.

The third group *Attributes of adaptability* comprises two characteristics.

- *Adaptability to technical needs of projects* is the degree to which a certain SDM element can be tailored to technical needs of a certain project.
- *Adaptability to needs of users* is the extent to which a certain SDM element can be tailored to suit the level of knowledge and experience of each SDM user. This kind of adaptability is especially important when knowledge and experience of team members varies.

3.4. The measurement instrument

To evaluate the characteristics of social adoption and technical efficiency we developed the measurement instrument that is shown in Tables 1–4. Several questions are posed for each characteristic. Most of the social adoption items used in the instrument are adopted from existing studies and models and are only slightly modified to suit specific requirements of the model. The references are noted in Tables 1 and 2. The items used to determine technical efficiency build on the existing evaluation models and studies [6,29,31–33]. However, most of them had to be modified, to focus on perceptions rather than on primary attributes.

The measurement instrument mostly consists of close-ended questions using a seven-point Likert scale. In case, when other types of questions and scales are used, that is noted in Tables 1–4 in square brackets.

The appropriateness and the validity of the measurement instruments were pilot tested in a company dealing with software development. The results of pilot testing led to slight rephrasing of some items.

The tests showed that in case of certain SDM element types some characteristics tend to be more important than others . This has to be considered during interpretation of the results and creation of the improvement scenarios. For instance, in the context of visibility, it is typically easier to observe the use of a development tool than to observe execution of a certain activity. In the latter case, visibility is considered less important during the construction of the improvement scenarios.

4. Method of application of the evaluation model

Prior to application, in an organisation, the evaluation model has to be adapted to the specifics of the organisation's SDM and

Table 1
The measurement scales of the level of social adoption

Frequency of use in a case of a given opportunity – SlFU (based on [52]):
1. Given the opportunity to use the part of the SDM, how often do you use it? (never, in up to 20% of opportunities, in 20–40% of opportunities, in 40–60% of opportunities, in 60–80% of opportunities, in more than 80% of opportunities but not always, always)
2. Use of the part of the SDM is encouraged as a normal activity
3. Use of the part of the SDM is routine and is used at every opportunity
Consistency of use – SlCU (based on [52]):
1. I consistently follow the instructions of the part of the SDM, when I use it
2. Instructions of the part of the SDM precisely describe my work in this field

Table 2
The measurement scales of the reasons for the current level of social adoption

Perceived attributes of SDM

Relative advantage – SrRA (based on [3,39]):
1. Using the part of the SDM improves my job performance
2. Using the part of the SDM increases my productivity
3. Using the part of the SDM enhances the quality of my work
4. Using the part of the SDM makes it easier to do my job
5. The advantages of using the part of the SDM outweigh the disadvantages
6. The part of the SDM is useful in my job

Social compatibility – SrSC (based on [3,41]):
1. The part of the SDM is compatible with the way I develop systems
2. Using the part of the SDM is compatible with all aspects of my work
3. Using the part of the SDM fits well with the way I work

Complexity – SrCO (based on [3,39]):
1. Learning the part of the SDM was easy for me
2. I think the part of the SDM is clear and understandable
3. Using the part of the SDM does not require a lot of mental effort
4. I find the part of the SDM easy to use
5. The part of the SDM is not cumbersome to use
6. Using the part of the SDM does not take too much time from my other duties

Attributes of SDM users

Users experience and knowledge in the field of system development – SrDK (partially based on [46]; note that survey participants were instructed to evaluate their experience and knowledge in the field of the evaluated SDM element):
1. How many years of experience in system development do you have? (years)
2. Mark those concepts from the field of system development, to which you are familiar (different concepts – depends on a particular requirements of an organisation and field of work of the user)
3. Evaluate your own knowledge in the field of system development (marks form 1– poor to 5 – excellent)

Users experience and knowledge in the field of SDM – SrMK (partially based on [46]; note that survey participants were instructed to evaluate their experience and knowledge in the field of the evaluated SDM element):
1. How many years of experience in SDM do you have? (years)
2. Mark those concepts from the field of SDM, to which you are familiar (different concepts – depends on a particular requirements of an organisation and field of work of the user)
3. Evaluate your own knowledge in the field of SDM (marks form 1 – poor to 5 – excellent)

Perceived attributes of organisation

Voluntariness – SrVO (based on [3,41]):
1. Although it might be helpful, using the part of the SDM is certainly not compulsory in my job
2. My supervisor does not require me to use the part of the SDM
3. My use of the part of the SDM is voluntary

Management support – SrMS (based on [52]):
1. Organisation's top management supports use of SDM
2. IT department's management supports use of SDM

Subjective norm – SrSN (based on [3,46]):
1. People who influence my behaviour think I should use the part of the SDM
2. People whose opinion is important to me think I should use the part of the SDM
3. Co-workers think I should use the part of the SDM

Uncertainty – SrUN (based on [46]):
1. It is probable that the IT department will dismiss some of its employees in near future
2. The future of the IT department (or organisation) is uncertain

Perceived attributes of SDM presentation

Result demonstrability (SrRD) (based on [3,41]):
1. I would have no difficulty telling others about the results of using the part of the SDM
2. I believe I could communicate to others the consequences of using the part of the SDM
3. The results of using the part of the SDM are apparent to me
4. I would have no difficulty explaining why the part of the SDM may or may not be beneficial

Visibility – SrVI (based on [3,41]):
1. The part of the SDM is very visible at the organisation
2. It is easy for me to observe others using the part of the SDM
3. I have had plenty of opportunity to see the part of the SDM being used
4. I can see when others use the part of the SDM in my department

Obtainability of SDM knowledge – SrOK (partially based on [52]):
1. I have enough opportunities for gaining knowledge in the field of the part of the SDM (in-house training, self-study, vendor courses, etc.)
2. The quality of available sources of knowledge (training, courses, literature, internet sources, etc.) is suitable
3. The available sources of knowledge (training, courses, literature, internet sources, etc.) are suitable for my level of knowledge; they are neither beyond my comprehension nor too simple

the organization itself. The size of the SDM and the number of SDM users involved in the evaluation are the two most important factors that have to be considered. The size of the SDM is determined by the number of SDM elements it contains. A simple SDM can contain as few as 20 elements whereas a complex one can have hundreds or even thousands of SDM elements. Clearly, an evaluation of a SDM comprising a few hundreds SDM elements is far more complex and time-consuming than the evaluation of a SDM comprising 20 elements. The complexity of the evaluation is further affected by the number of SDM users and other organisation specifics. For instance; an organisation may find that some parts of its SDM are more critical for the success of its projects, those parts should

Table 3
The measurement scales of the level of technical efficiency

Frequency of opportunities for use (TIFU):
1. How often does an opportunity arise to use the part of the SDM (regardless it is actually used or not)? (never, very rarely, rarely, sometimes, often, almost always, always – during the whole development)

Implication of SDM element on system to be implemented (TIIS):
1. The part of the SDM helps to develop a more complete system (more aligned with requirements)
2. The part of the SDM helps to develop a system that is more coherent (more aligned with standards)
3. The part of the SDM helps to develop a more usable system (easier to use)
4. The part of the SDM helps to develop a more reliable system
5. The part of the SDM helps to develop a more maintainable system
6. The part of the SDM helps to develop a more portable system
7. The part of the SDM helps to develop a more efficient system
8. The part of the SDM helps to develop a system that reuses existing components (designs, code) and new components of which can be reused

Implication of SDM element on project (TIIP):
1. The part of the SDM helps to decrease the time needed to complete a project
2. The part of the SDM helps to decrease the costs of a project
3. The part of the SDM helps to improve control over a project
4. The part of the SDM helps to improve the quality of project plans
5. The part of the SDM helps to improve the documentation and traceability of a project
6. The part of the SDM helps to better estimate project risks
7. The part of the SDM helps to reduce number and impact of different problems at the project

Implication of SDM element on SDM users (TIIU):
1. The part of the SDM facilitates unambiguous communication between SDM users
2. The part of the SDM facilitates cooperation between SDM users
3. The part of the SDM helps to lessen the number of conflicts concerning SDM users' responsibilities and duties
4. The part of the SDM facilitates better understanding of SDM users' duties and responsibilities
5. The part of the SDM helps to improve training of new SDM users

Implication of SDM element on the organisation (TIIO):
1. The part of the SDM facilitates standardisation in the organisation
2. The part of the SDM helps the organisation in achieving its goals
3. The part of the SDM helps to improve organisation's reputation of excellent work

Implication of SDM element on a customer (TIIC):
1. The part of the SDM helps to improve a customers' trust in organisation
2. The part of the SDM helps to improve a customers' overview of the progress on project
3. The part of the SDM helps to improve general satisfaction of a customer with the organisation

Table 4
The measurement scales of the reasons for the current level of technical efficiency

Attributes of technical suitability

Suitability for the project and the system (TrSP):
1. The part of the SDM is suitable for the project size and complexity (number of developers, number of organisations involved, etc.)
2. The part of the SDM is suitable for the system to be implemented (size and complexity of subsystems, number and complexity on interactions between subsystems, integration of legacy applications, etc.)
3. The part of the SDM is suitable for project type (new development, upgrade, renovation, etc.)
4. The part of the SDM is suitable for project priorities (productivity, traceability, etc.)
5. The part of the SDM is overall suitable for work on the project and the system

Suitability for the development team (TrST):
1. The part of the SDM is suitable for the level of knowledge and experience of the development team
2. The development team has no difficulty in understanding and using the part of the SDM

Suitability for a customer (TrSC):
1. The part of the SDM is aligned with the demands of the customer
2. The part of the SDM suits real needs of the customer

Compliance with modern development approaches (TrCM):
1. The part of the SDM is aligned with modern trends and approaches in its field
2. The part of the SDM is aligned with current standards in its field in case standards exist

Attributes of technical compatibility

Compatibility with information technologies and program environment (TrCT):
1. The part of the SDM is aligned with the development tools used in the development team and facilitates their use
2. The part of the SDM is aligned with the information technologies used in the development team and facilitates their use
3. The part of the SDM is aligned with the program languages used in the development team and facilitates their use

Compatibility with internal SDM standards (TrCI):
1. The part of the SDM is compatible with other parts of SDM that are of the same type
2. The part of the SDM is compatible with internal standards of the SDM
3. The part of the SDM is compatible with the results of other parts of the SDM that it needs for its execution (e.g. input artefacts)
4. The results of the part of the SDM are compatible with other parts of the SDM that use them (e.g. output artefacts)

Compatibility with general standards (TrCG):
1. The part of the SDM is compatible with general standards in its field (e.g. standardised notation, languages, techniques, etc.)
2. The part of the SDM does not prescribe a very different way of work from way of work generally performed (e.g. at other organisations) or taught (e.g. at schools or trainings) in its field

Attributes of adaptability

Adaptability to technical needs of projects (TrAT):
1. It is possible to tailor the part of the SDM according to the size and complexity of the project
2. It is possible to tailor the part of the SDM according to the type of the project (new development, upgrade, renovation, etc.)
3. It is possible to tailor the part of the SDM according to the project priorities (productivity, traceability, etc.)

Adaptability to needs of users (TrAU):
1. It is possible to tailor the part of SDM to suit different levels of experience and knowledge of SDM users
2. The part of the SDM is designed in a way that it allows more experienced SDM users to use it in a different way than less experienced users do

hence be evaluated more precisely; an organisation may be willing to invest more time and effort in the evaluation than another one may, etc. Therefore, it is important to find the right balance between the evaluation precision, the organisation's requirements and the time required to implement the evaluation. To support this adaptation we created a procedure that comprises five steps.

The first step is the analysis of the basic features of the SDM and the organisation. Different aspects of the organisation should be considered, like: which parts of the organisation's development process are formalised and how precisely, how many developers work in the organisation, what kind of projects does the organisation deal with, what is the general attitude of developers towards the organisation's SDM, are the developers willing to participate in the evaluation, etc. The analysis shows whether it is rational to apply the evaluation model in the organisation and helps define the scope of the evaluation (evaluation can be performed for the whole SDM or only for particular parts of the SDM).

The second step is the identification of roles and SDM users that perform these roles. A role is a concept that defines the behaviour and responsibilities of an individual, or a set of individuals working together as a team, within the context of a software development organization [43]. Typical roles include programmers, analysts, designers, testers, etc. Even if a certain SDM does not contain formally defined roles, it is usually possible to categorize different sets of activities and responsibilities that individuals perform during software development. These sets of activities and responsibilities are than assigned to a certain role. Subsequently, each SDM user that participates in the evaluation is matched to one or more roles that he performs. It is thus precisely determined who is supposed to use a certain SDM element and is therefore responsible for its evaluation. Fig. 5 shows SDM users who perform different roles and therefore use different SDM elements. They evaluate only the elements they use in the context of their roles.

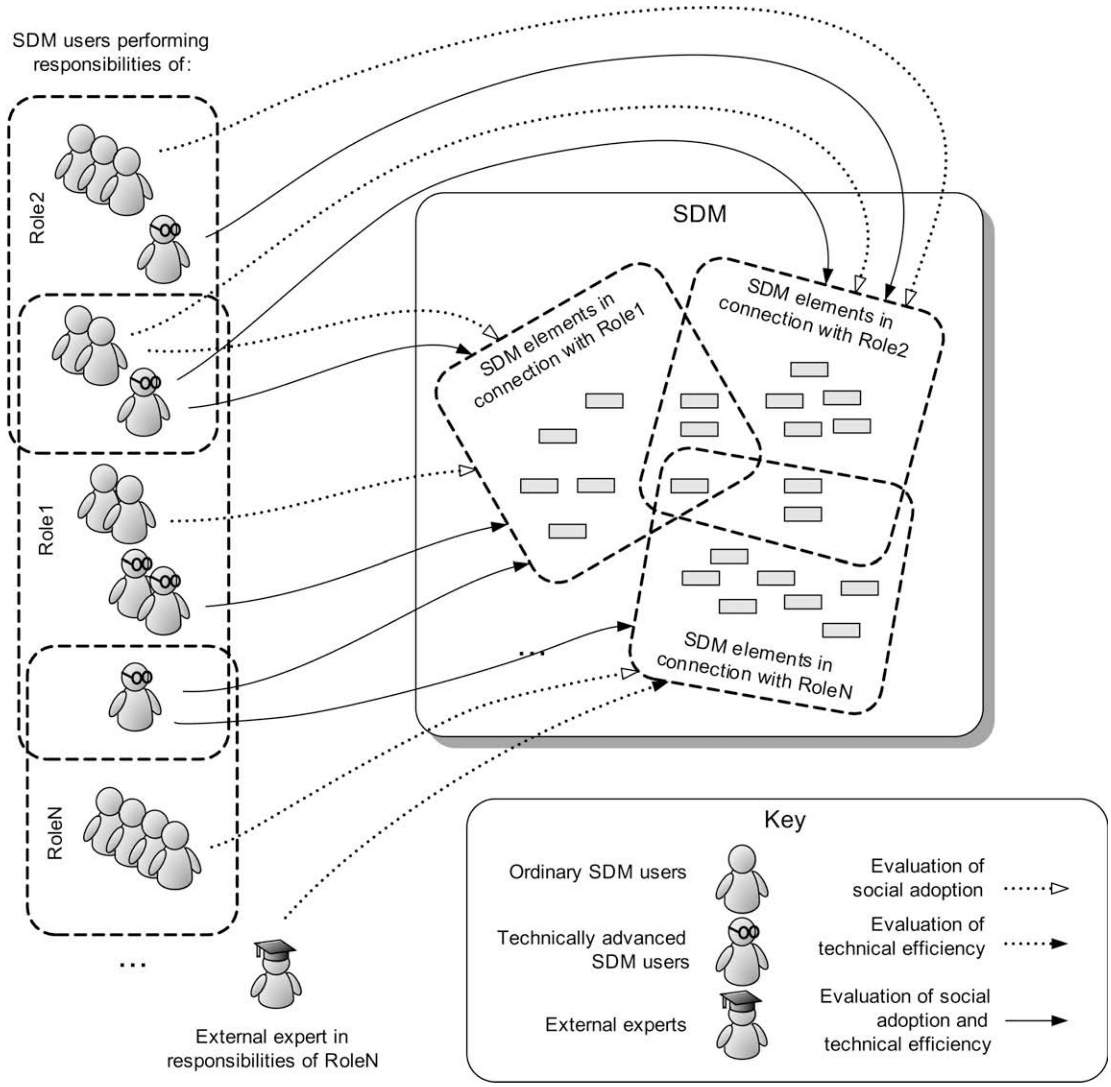

Fig. 5. The roles of different types of survey participants. The participants in the survey evaluate only SDM elements that are part of their responsibilities in the context of their roles. All SDM users evaluate the level of social adoption, but only technically advanced SDM users evaluate the level of technical efficiency.

The third step is the identification of technically advanced SDM users. These users should not only be knowledgeable in the context of their SDM roles, but should also understand a broader perspective of SDM. They should be familiar with the current trends in the field of their expertise and should be able to assess technical efficiency of the SDM objectively. In cases, when technically advanced SDM users cannot be identified for a certain SDM role, external experts are engaged to assure objective evaluation of the SDM's technical efficiency. Fig. 5 depicts that the responsibility of the technically advanced users is to evaluate both technical efficiency and social adoption whereas ordinary users evaluate only social adoption. External experts can also be engaged to help evaluate technical efficiency.

In the fourth step, we define the basic evaluation units for different parts of the SDM. The evaluation on the scale of a single SDM element enables the most accurate assessment of the SDM's technical efficiency and social adoption; however, it can be a very time-consuming procedure. Therefore, one could choose to evaluate only the most critical parts of a SDM on the scale of a single SDM element, whereas less critical parts would be evaluated on the scale of larger evaluation units that encompass several SDM elements. For instance, an evaluation unit can consist of SDM elements like: an activity, all artefacts used in the activity, all artefacts produced in the activity and all tools used during the activity. Although such evaluation is less precise, it is also less time-consuming.

In the fifth step, we select characteristics of the evaluation model that will be used in the evaluation. In the preceding sections, we presented the complete list of characteristics that can be used in an evaluation. It is often not rational to use all of these characteristics. For instance, if we are only interested in the level of SDM social adoption and technical efficiency, but not in the reasons for this level, all characteristics that determine the reasons can be omitted. Another possibility for simplification of the model is to omit characteristics that can be determined upfront. E.g., it is not rational to evaluate a well-known commercial SDM's compatibility with internal SDM standards, as this compatibility is already assured by the provider of the SDM. Based on the chosen characteristics, we customise the measurement instrument and prepare questionnaires for the evaluation.

Finally, evaluation is performed. It is important that the SDM users are motivated to participate in evaluation. They should understand that evaluation is the key to the improvements of their SDM that will positively affect the way they perform their work.

5. Tests of the evaluation model in a real-life environment

5.1. Test design

The main research question during testing was how the evaluation model performs in real life environment i.e. organisations dealing with software development. The aim of the tests was therefore to verify the model's usefulness as a tool for identification of less suitable SDM elements. We formed the following propositions:

- P1: The evaluation model will enable acquisition of nontrivial information about the SDM technical and social suitability that was previously unknown to people responsible for the organisation's SDM.
- P2: The combined analysis of social and technical suitability will enable people responsible for the organisation's SDM to take better decisions in the context of the SDM improvement compared to measurement of only technical or only social suitability.
- P3: The evaluation on the level of SDM elements will enable people responsible for the organisation's SDM to take better decisions in the context of the SDM improvement compared to evaluation on the level of a whole SDM.
- P4: The SDM elements that will be improved based on the results of evaluation and introduced to the SDM users will be re-evaluated as generally more suitable than the original SDM elements.

To answer the research question and verify the propositions we decided to use the case study research strategy as defined by Yin [56]. A holistic multiple-case design was used and three software development organisations and one organisation unit served as units of analysis.

The test procedure in each case (unit of analysis) started with adaptation of the evaluation model to case specifics as discussed in Section 4. Next, presentations were held to explain the adapted measurement instrument to the evaluation participants. Execution of the evaluation followed and after it was completed, the results were analysed.

To verify the prepositions P1, P2 and P3, we discussed the analysis results and the prepositions with each organisation's key employees i.e. the management and the employees in charge of an organisation's SDM. Initially, reports were prepared that were sent to the key employees. After one to two weeks, during which the key employees examined the reports, a meeting was held to additionally explain the results and to interview the key employees.

A different approach was used to verify the preposition P4. SDM improvements that were based on the preceding SDM evaluation were created. These improvements were implemented and the improved SDM was later re-evaluated. This verification was performed in one organisation.

5.2. Test cases

We tested the SDM evaluation model in four different cases: two different software development companies that produce their own pre-packaged business solutions for small companies, a software development company that develops custom software solutions, and an IT department of a mid-sized bank. In the following sections, there are detailed descriptions of two of the four cases and a short summary of the other two cases.

5.3. Case A

5.3.1. Case description

Case A is a company that develops its own ERP solution for small businesses. It uses object-oriented program languages and a self-developed SDM that contains 21 elements. These elements are best described as comprehensive activities that also include simple descriptions of documents produced in the activities, roles that perform the activities and prescribed development tools. The SDM is only used to develop a single product, so there is not much need for SDM tailoring for different projects. Nevertheless, the SDM is constantly updated and improved. As a result, the SDM is relatively inadaptable, but optimized for work at the company. Therefore, we anticipated that most SDM elements would be evaluated as quite suitable in both technical and social dimension.

5.3.2. Evaluation

Ten SDM users participated in the evaluation, seven of which were considered as technically advanced users, and thus they evaluated technical efficiency as well. SDM users had a positive attitude towards the evaluation and there was strong management support for the evaluation. This enabled the use of a comprehensive questionnaire, which included most of the evaluation model characteristics and measurement items. However, some of the characteristics and items were left out, as they were irrelevant in the context of the organisation or the SDM users were unwilling to answer the questions regarding the items. For instance, characteristics regarding adaptability were excluded, as there is almost no need for SDM tailoring.

Paper questionnaires were distributed among the 10 survey participants. Each participant was asked to evaluate only SDM elements he/she was using in the context of his/her roles. In total 70 questionnaires were returned, but four of them remained partially unanswered or were considered invalid. Verification of the questionnaires showed that 66 of 70 evaluations of social adoption and all 49 evaluations of technical efficiency were valid.

Cronbach alpha coefficients and corellations of all constructs used in the evaluation are provided in Table 6. All constructs were well within the limits of acceptable internal consistency [57]. As expected, the constructs were correlated to a certain extent, however, their correlations were generally significantly lower than internal correlations of constructs' items.

Results of the evaluation showed that all SDM elements except one (element C) were inside the useful SDM elements quadrant. Favourable results were expected, as SDM was optimised and the development process did not require much tailoring. Fig. 6 shows the results of the evaluation. Spikes connect each SDM element's evaluation to a centroid.

To demonstrate the detailed analysis of the evaluation results, we focus on two elements that have the largest negative horizontal and vertical distance from the centroid: element B termed *Addition of new system functions and change of existing system functions on analysis level* and element C termed *Addition and change of program code or user interface*. Two reference points were additionally selected to compare the results of the evaluation: the mean evaluation of all SDM elements (centroid) and element A that has the largest positive distance from the centroid. Diagram in Fig. 7 shows the evaluations of reason characteristics of elements B and C, and of the two reference points. As expected, most evaluations of elements B and C are lower than of element A and many are also below average. We focused especially on characteristics whose evaluations are considerably different from the average and are on "disagree" part of the scale.

The characteristic that clearly steps out of element B's average is Management support (SrMS). Its evaluation indicates that its users believe that management does not support the use of the element. Consultation with the element's users revealed that new system functions were usually added into the analysis model, but the model was only rarely updated to reflect changes that occurred during implementation. The management considered updating

Table 5
The test cases summary

Organisation	Case and evaluation summary	Summary of the evaluation results
Case A		
A company developing pre-packaged business solutions (1)	• A SDM developed completely inside the organisation, improved and optimised regularly	• Almost all SDM elements were evaluated as technically and socially suitable
	• An evaluation of 21 comprehensive SDM elements	• Based on the differences between the SDM elements' evaluations several improvement opportunities were identified which company management was previously unaware of
	• Most of the evaluation model characteristics were applied	• Key employees confirmed prepositions P1, P2 and P3
Case B		
A company developing custom software solutions	• Specifically tailored SDM based on Rational Unified Process and Information Engineering	• Although the SDM was specifically tailored for the needs of the company, several SDM elements were identified that required improvement
	• Evaluation of 113 well-defined SDM elements	• Improvements to SDM were implemented that were based directly on the results of the evaluation
	• Only the characteristics that measure the level of social and technical suitability were applied, however, users were asked to additionally comment their evaluations	• Re-evaluation showed that efficiency and adoption of the improved SDM elements generally bettered; preposition P4 was confirmed
	• Re-evaluation of the improved SDM elements	• Key employees confirmed prepositions P1, P2 and P3
Case C		
A company developing pre-packaged business solutions (2)	• A SDM partially based on Information Engineering and partially developed inside the organisation	• Only six areas were evaluated as technically and socially suitable of which two were marginally suitable
	• An evaluation of 11 areas of the SDM	• Although the company's management was already aware of many of the deficiencies of their SDM, the evaluation helped them to delineate the reasons for the deficiencies and identify additional problems
	• Most of the evaluation model characteristics were applied	• The results of the analysis were used in the creation of a new SDM that partially integrated suitable elements of existing SDM • Key employees confirmed prepositions P1, P2 and P3; a more detailed evaluation would be advantageous
Case D		
An IT department of a mid-sized bank	• SDM mainly developed inside the organisation	• Six of 16 areas were evaluated as technically and/or socially unsuitable
	• Evaluation of 16 areas of the SDM	• The identification of the reasons for their unsuitability was based on the results of the evaluation
	• Most characteristics of the evaluation model were applied	• The results were used to improve some parts of the SDM • Key employees confirmed prepositions P1, P2 and P3

Table 6
The Cronbach alpha coefficients and inter-correlations for each construct used in the evaluation

	SlFU	*SlCU*	*SrRA*	*SrSC*	*SrCO*	*SrMS*	*SrRD*	*SrVI*	*SrOK*
Characteristics of social adoption									
SlFU	1.000								
SlCU	0.402[b]	1.000							
SrRA	0.175	0.011	1.000						
SrSC	0.463[b]	0.213[a]	0.395[b]	1.000					
SrCO	0.370[b]	0.221[a]	0.033	0.294[b]	1.000				
SrMS	0.390[b]	0.409[b]	0.039	0.183	0.287[b]	1.000			
SrRD	0.299[b]	0.110	0.474[b]	0.353[b]	0.035	0.197	1.000		
SrVI	0.359[b]	0.297[b]	0.477[b]	0.347[b]	0.078	0.260[a]	0.480[b]	1.000	
SrOK	0.280[a]	0.298[b]	0.409[b]	0.204	0.451[b]	0.157	0.210[a]	0.365[b]	1.000
Cronbach's alpha	0.812	0.801	0.851	0.913	0.801	0.932	0.888	0.881	0.853
Number of items	3	2	4	3	3	2	3	2	3

Characteristics of technical efficiency

	TlFU	*TlIS*	*TlIP*	*TlIU*	*TlIO*	*TrSP*	*TrST*	*TrCM*	*TrCT*	*TrCI*	*TrCG*
TlFU	1.000										
TlIS	−0.038	1.000									
TlIP	0.134	0.366[b]	1.000								
TlIU	−0.023	0.282[a]	0.413[b]	1.000							
TlIO	0.027	0.244[a]	0.507[b]	0.398[b]	1.000						
TrSP	−0.011	−0.023	0.317[a]	0.200	0.539[b]	1.000					
TrST	0.134	−0.318[a]	−0.045	−0.258[a]	0.057	0.209	1.000				
TrCM	0.068	0.001	0.007	−0.037	0.352[b]	0.483[b]	0.209	1.000			
TrCT	0.063	0.021	0.143	−0.096	0.234	0.403[b]	0.225	0.441[b]	1.000		
TrCI	0.322[a]	−0.032	0.334[b]	−0.078	0.152	0.365[b]	0.296[a]	0.160	0.288[a]	1.000	
TrCG	0.363[b]	−0.041	−0.083	−0.218	−0.127	−0.263[a]	0.070	−0.059	−0.058	0.324[a]	1.000
Cronbach's alpha	–	0.803	0.895	0.820	0.842	0.899	0.781	0.819	0.926	0.815	0.798
Number of items	1	5	7	5	3	5	2	2	2	4	2

[a] $p < .05$.
[b] $p < .01$.

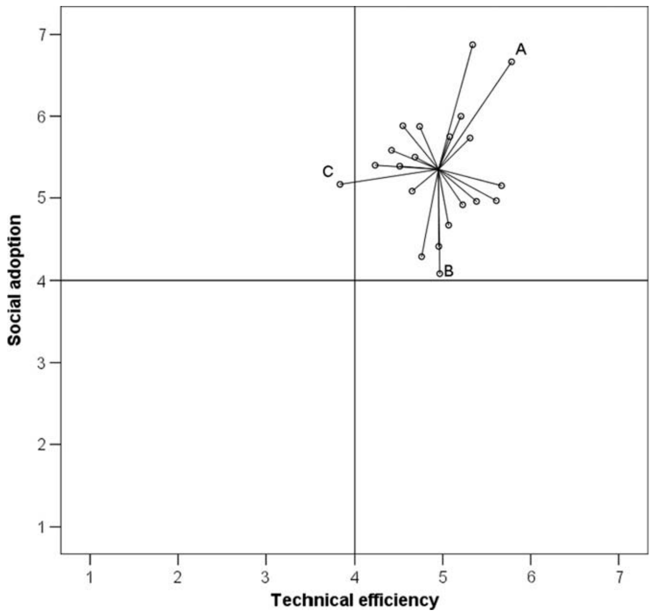

Fig. 6. The results of Case A evaluation.

the analysis model unnecessary, which consequentially resulted in relatively low adoption. Nevertheless, the element was evaluated as rather technically efficient, which indicated that the cause for low adoption was not the element itself.

The most noticeable characteristics of the element C are the Suitability for a project and a system (TrSP) and the Compliance with modern development approaches (TrCM). The prescribed development tool and accompanying technologies that were of an older generation and did not support new trends in the field of software development were found to be the critical part of the element. Even though the tool was relatively well adopted and used regularly, technically advanced SDM users were well aware of its deficiencies.

Other SDM elements that had evaluations below the average were analysed in a similar way and opportunities for their improvements identified.

5.3.3. Discussion

Initial consultations with the company's key employees did not reveal any significant deficiencies in the SDM. Therefore, the main challenge of the evaluation was to answer whether the SDM is actually adopted and efficient as much as it was believed to be. The results of the evaluation confirmed that SDM is quite suitable generally, yet distinctions between more and less suitable SDM elements, have clearly been recognized. The main contribution of the evaluation was the identification of improvement opportunities, which the company management was previously unaware of. The company's key employees who were in charge of the SDM confirmed our findings and prepositions P1, P2 and P3.

5.4. Case B

5.4.1. Case description

Case B is a company that develops custom software solutions in an object-oriented way using Java development platform. It has its own SDM that is based on the principles of Rational Unified Process and Information Engineering and is specifically tailored to the company's needs. The SDM has moderate possibilities for adapting to projects specifics, as some activities are optional and some steps of the SDM are executed only in case of certain project types. The SDM consists of the following SDM elements types: processes, activities, roles, documents (artefacts) and templates. Altogether, the SDM contains 113 well-defined SDM elements, which represented basic evaluation units during the evaluation. The SDM is stored in a form of a web site so that the users can easily access SDM through organisation's intranet. At the time of the evaluation, the company employed 28 people that were actual or potential users of the SDM. All of them were invited to participate in the survey and 13 responded. Five were technically advanced users and eight were ordinary users. To ease their participation in the survey, a web survey application was created. We integrated the application into the web-based SDM, which allowed survey participants to access questionnaires directly from their SDM web pages.

The test was divided into three phases: initial evaluation, improvement and re-evaluation.

5.4.2. Evaluation

Because of the scale of the evaluation, the model used in the survey was simplified. In the questionnaires, only the characteris-

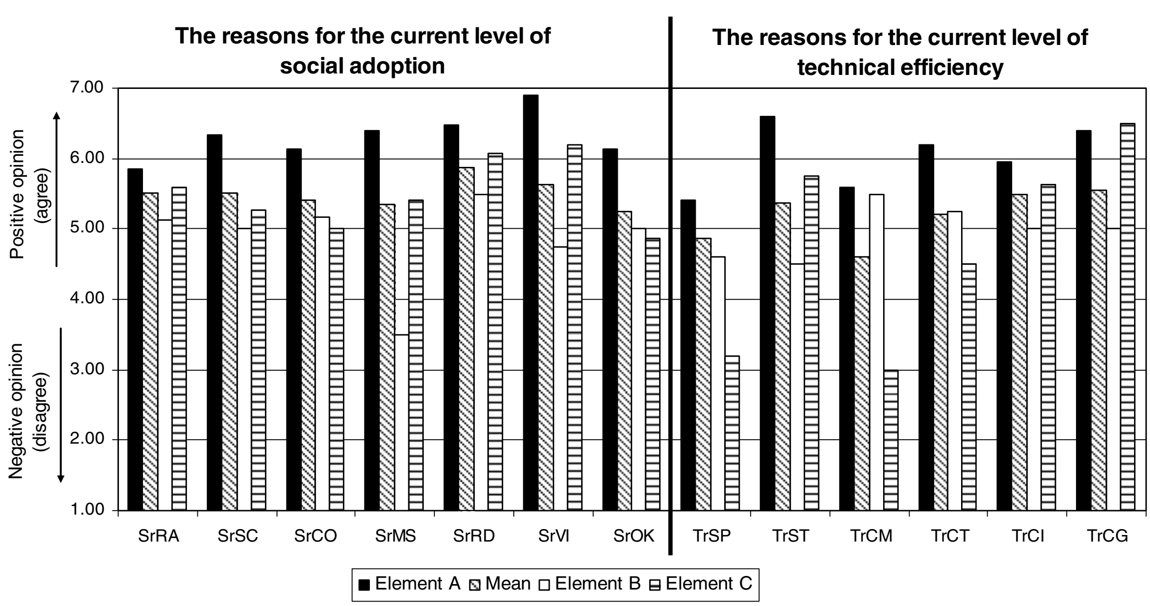

Fig. 7. The comparison of evaluations of reasons for the current level of social adoption and technical efficiency for elements A, B, C and mean.

tics for evaluation of the level of social adoption and technical efficiency were used, but not the characteristics for evaluation of the reasons for these levels. This simplification was necessary as SDM users were not prepared to fill in extensive questionnaires for each SDM element. Nevertheless, the survey participants were encouraged to make short comments on reasons for their evaluation. These comments proved very valuable during the improvement phase.

The number of questionnaires that a SDM user had to fill in was relatively high as a typical role was connected to at least five other SDM elements and each user performed two or more roles. Each SDM user had to fill in approximately 15 questionnaires. Not only it was unlikely that SDM users would be willing to complete all questionnaires at the same time, but it was also probable that their answers would be distorted because of the time shortage. For that reason, we decided that SDM users should be able to answer to a survey during a longer period, while simultaneously using the SDM to work on projects.

In the first phase, an initial evaluation of all SDM elements was conducted. The survey participants were given one and a half months to evaluate the SDM elements. Although they were allowed to evaluate the SDM elements anytime during that period, they were encouraged to evaluate them while applying them on real projects, as we wanted their answers to be based on their immediate experiences with the SDM elements. The survey participants were allowed to correct their answers. In total, we received 225 answers of which 168 were valid. The remaining 57 were either corrected by later answers (43 answers) and were therefore discarded or were invalid (14 answers).

Of 113 elements, 20 SDM elements remained completely unevaluated. As we discovered later, five of these elements dealt with database administration and database reviewing, that nobody of the survey participants felt responsible for, and 15 of the unevaluated elements dealt with business modelling, which was not performed in the organisation at the time. The remaining 93 elements (see Table 7) were evaluated as follows: 60 were evaluated in both dimensions; the remaining 33 were evaluated only in the dimension of social adoption, as we could not identify technically advanced users who would be competent to evaluate their technical efficiency.

The measurement instrument was tested for its validity. Cronbach alpha coefficients of the constructs, used in the evaluation model, ranged from .69 to .93, indicating acceptable internal consistency [57]. The constructs were correlated to a similar extent as in Case A and their correlations were generally lower than internal correlations of constructs' items.

The scatter chart in Fig. 8 shows the results of the initial evaluation. The dots on the scatter chart indicate positions of SDM elements. The vertical position represents the level of element's social adoption and the horizontal position the level of element's technical efficiency. Larger points indicate that more elements are in the same position, as they have the same average evaluation of both dimensions.

Most of the elements that were evaluated in both dimensions are in the upper right quadrant i.e. the useful elements quadrant. Elements that were not evaluated in the technical dimension are shown in the left side of the scatter chart.

Table 7
List of all evaluated SDM elements in Case B

D Act: 2.0 Create initial requirements document	D Doc: Source code commenting standards
D Act: 2.1 Determine and structure requirements	D Doc: Source code design by contract
D Act: 2.2 Develop prototype	D Doc: Standards violation document template
D Act: 2.3 Validate requirements	D Doc: Standards violation notification
D Act: 3.0 Choose initial software architecture	D Doc: System architecture and logical structure 1
D Act: 3.1 Define architecture	D Doc: System architecture and logical structure 2
D Act: 3.2 Define logical structure	D Doc: System deployment
a D Act: 3.3 Review software architecture	D Doc: System deployment template
D Act: 4.1 Design database	D Doc: System test case
D Act: 4.3 Implement database	D Doc: System test case template
D Act: 5.0 Define object model	D Doc: System test report
D Act: 5.1 Plan integration and Setup required development environment	D Doc: System test report template
D Act: 5.2 Design features	D Doc: Unit tests
D Act: 5.3 Develop unit tests	D Doc: Unit tests description
D Act: 5.4a Implement features (client side)	D Ovr: Overview – development
D Act: 5.4b Implement features (server side)	D Ovr: Overview – many elaboration iteration process
D Act: 5.5 Execute unit tests	D Ovr: Overview – single elaboration iteration process
D Act: 5.6 Revise unit	D Rol: DB designer
D Act: 5.7 Unit review	D Rol: End user
D Act: 5.8 Assure compliancy with standards	D Rol: Implementer
D Act: 6.0 Integrate subsystem	D Rol: Software architect
D Act: 6.1 Develop subsystem Tests	D Rol: SW architecture reviewer
D Act: 6.2 Execute subsystem Tests	D Rol: System analyst
D Act: 6.3 Revise subsystem integration	D Rol: System deployer
D Act: 7.1 Deploy system	D Rol: Tester
D Act: 7.2 Execute system tests	Ovr: Overview – Complete SDM process[a]
D Act: 7.3 Revise system integration	PM Act: 1.1 Initiate new project
D Act: 8.1 Develop system approval tests	PM Act: 1.2 Develop initial project plan
D Act: 8.2 Execute system approval tests	PM Act: 1.3 Evaluate project risks
D Doc: Application	PM Act: 1.4 Plan next iteration
D Doc: Approval test document	PM Act: 1.5 Manage iteration
D Doc: Approval test document template	PM Act: 1.6 Evaluate project risks and a
D Doc: DB design and object mapping	PM Act: 1.7 Close-out phase
D Doc: DB Design and object mapping template	PM Act: 1.8 Close-out project
D Doc: Detailed design	PM Doc: Minutes of a meeting
D Doc: ER model	PM Doc: PMD 1 document
D Doc: Fine tuned physical DB	PM Doc: PMD 2 document
D Doc: Integrated system	PM Doc: PMD 3 document
D Doc: Object model	PM Doc: PMD 4 document
D Doc: Physical DB	PM Doc: PMD 5 document
D Doc: Requirements document 0	PM Doc: PMD 6 document
D Doc: Requirements document 1	PM Doc: PMD 7 document
D Doc: Requirements document template	PM Doc: PMD 8 document
D Doc: SALSD template	PM Doc: PMD template
D Doc: Selected initial architecture	PM Ovr: Overview – project management process
D Doc: Source code	PM Rol: Project manager
D Doc: Source code coding standards	

[a] Actual SDM name was replaced by acronym "SDM".

5.4.3. Improvement

In the second phase, we focused on the improvement of 15 SDM elements that were evaluated in both dimensions and were positioned outside the useful SDM elements quadrant on the evaluation scatter chart (see Fig. 8). Three SDM elements were found to be redundant and were therefore discarded. Five elements remained unchanged as they were either already technically efficient, or no suitable alternatives were available. The remaining seven elements were improved in accordance with the SDM user comments and evaluation. After improvement, they were integrated into the web-based SDM.

To illustrate how the improvement was performed, we focus on three of the seven improved elements. Elements are marked with letters A, B and C in Fig. 8.

The element A is a document named *Detailed Design Document*. Its purpose is to provide a precise description of a part of an information system under development. It serves as a basis for coding.

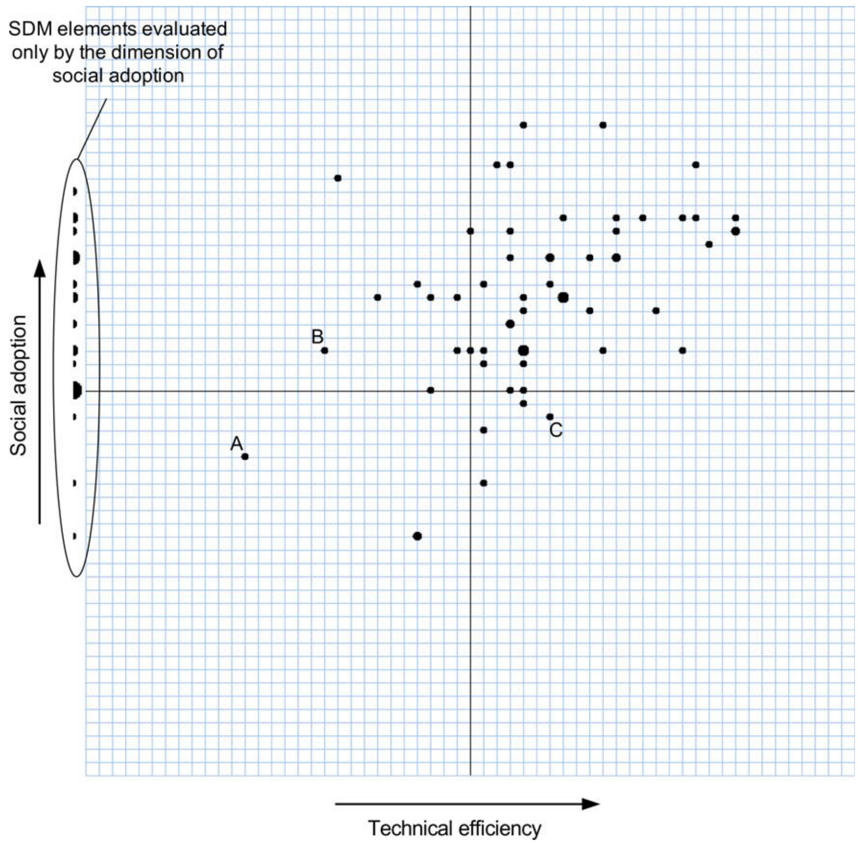

Fig. 8. The results of the initial evaluation of Case B.

The element was evaluated as less suitable in both technical and social dimension. Although the results of the evaluation suggested that the proper action would be to discard the element, we decided to try to improve it. SDM users' comments indicated that the main problem was the low level of element's adaptability to different types of projects and its high complexity. Thus, the improvement focused especially on improving the element's adaptability and reducing its complexity. Parts of the element were made optional and changes were made to allow the use of less rigorous techniques in the creation of the document in case of smaller projects. A simple decision table was introduced to help users decide, which parts of the document and techniques to use.

The element B is an activity named *Execute Subsystem Tests*. The activity is performed after the integration of a subsystem. Its purpose is to validate that the newly integrated subsystem is operating correctly. The element was evaluated as technically unsuitable, but socially suitable. The comments of technically advanced users pointed out that activity did not produce any formal reports of the results of the tests. The results of the tests were formally registered and reported only after the final system integration. The lack of formal reporting made supervision impossible, which led to superficial execution of subsystem tests. However, ordinary SDM users adopted the element and were relatively content with its performance. The improvement therefore focused on an establishment of a formal reporting mechanism. Subsystem test reports were introduced to systematize subsystem testing.

The element C is a template named *Software Architecture and Logical Structure Document Template*. The template is used in a creation of *Software Architecture and Logical Structure Document*. Interestingly however, the document itself was evaluated as socially and technically quite suitable, while the document's template was evaluated as socially unsuitable. Users' comments revealed that the template was unpopular because of its rigidness. As a result, most users preferred ad hoc approaches in creation of the document, rather than using the template. To improve the template, an analysis of the ad hoc documents created by SDM users was performed. The results of the analysis showed that users often used informal techniques and models to describe system architecture. Although the document permitted the use of informal techniques, the template did not. Hence, the template was extended to allow the use of informal techniques and at the same time, parts of the template were made optional.

5.4.4. Re-evaluation

In the third phase, the improved SDM elements were re-evaluated. The re-evaluation was performed about three months after the SDM improvements were introduced, which gave SDM users some time to familiarise with the changes. The same configuration of the evaluation model as in the initial evaluation was used. The scale of the evaluation was much smaller, however, as only the seven improved SDM elements were re-evaluated. In addition to the improved elements, three SDM elements that remained unchanged during the improvement phase were also re-evaluated. The three elements served as control elements to verify whether the changes in the evaluation of the seven improved elements were actually the result of the improvements, or were caused by external factors. During the re-evaluation, the participants were allowed to access their answers from the initial evaluation and were asked to correct these answers only if their perception of any of the 10 SDM elements changed. We received 23 valid answers.

Scatter chart in Fig. 9 shows the results of the re-evaluation. Black dots mark the initial positions of the 15 less suitable SDM

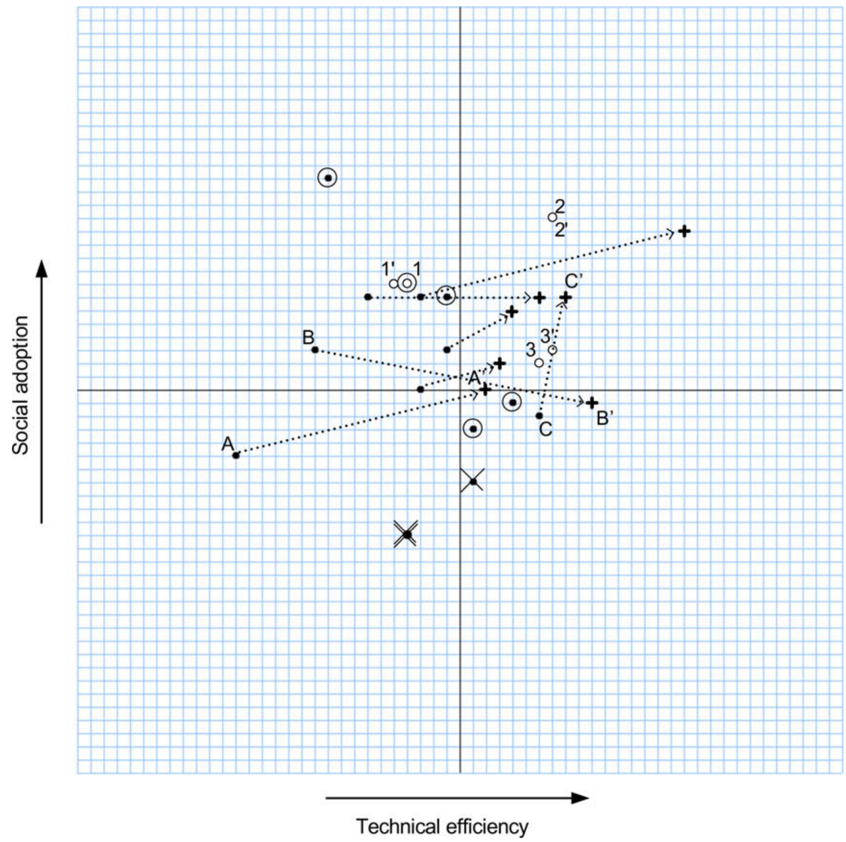

Fig. 9. The results of the re-evaluation of Case B after the improvement of the less suitable SDM elements.

elements (except control element 1) of which the five SDM elements that remained unchanged and were not re-evaluated are encircled, and the three SDM elements that were discarded are crossed out. Arrows indicate to which positions the seven SDM elements moved after the improvement. New positions are marked with crosses. Letters A, B and C mark initial positions of the three SDM elements, depicted in the previous subsection, while their new positions are marked with letters A′, B′ and C′. White dots mark the three control elements. Numbers 1, 2 and 3 mark their initial positions and 1′, 2′ and 3′ are their positions after re-evaluation.

5.4.5. Discussion

The initial evaluation showed that the SDM was generally suitable. The result was expected, as the SDM was specifically tailored to the company's needs. However, it also revealed that several SDM elements were in need of improvement.

The results of the initial evaluation were used in creation of improvement scenarios for the seven SDM elements. The process of creation of improvement scenarios proved relatively lengthy. However, this was not an obstacle as only seven scenarios were created. Generally, the scenarios proved to be effective as social and technical suitability of most of the improved elements increased noticeably. The three control elements moved only slightly (elements 1 and 3) or not at all (element 2), which signifies that the changes in the evaluation were not influenced by external factors.

We believe that one of the reasons for effectiveness of the improvements was that they were based on the comments of SDM users. After the users realised that the SDM was improved according to their comments, they were more eager to adopt and use the improved elements. However, social adoption of SDM element B decreased. The main reason for this was that some of the element's users rejected the use of formal subsystem test reports, and consequentially did not adopt the improved element B′. Further improvements of element B should therefore focus mainly on proper presentation of the element to SDM users.

The key employees responsible for SDM validated the results of evaluation and re-evaluation and confirmed the prepositions P1, P2 and P3. In their opinion, it was especially important to perform the evaluation on the level of a SDM element, as it enabled the creation of focused improvement scenarios. The re-evaluation of the improved SDM confirmed the preposition P4.

5.5. Summary of cases C and D

The general course of the evaluation for the cases C and D was similar. In both cases, larger areas of custom-made SDMs were evaluated and the evaluation showed that many of the areas needed improvements. In case C, the results were used in creation of a new SDM that partially integrated suitable elements of the existing SDM and in case D, the results were used to improve parts of the existing SDM. In both cases, the key employees agreed the results gave them new insights into their SDM, and generally confirmed the prepositions P1, P2 and P3. In case C they, however, suggested that a detailed analysis would be more beneficial as the analysis on the level of larger SDM areas gave them only general directions on how to improve the SDM, but was too coarse to create focused improvement scenarios.

5.6. Discussion

Table 5 summarises the characteristics of the four cases, and the evaluation results. In all four cases, the same pattern emerged, i.e. the key employees confirmed that: the evaluations provided new valuable insights into their SDMs; it was important to consider technical and social aspects to create suitable improvement scenarios; and the evaluation on the level of SDM elements was more beneficial than evaluation of larger areas of SDM, as it facilitated creation of focused improvement scenarios. An important finding was that in case of evaluation on the level of SDM elements and use of the simplified evaluation model (Case B), users' comments provided enough information to create efficient improvement scenarios. We speculate that in case of SDM evaluation on the level of SDM elements, the use of simplified questionnaires as in Case B generally suffices. Further investigation is needed to confirm this speculation.

Several particularities need to be considered during practical application of the model. First, the population of SDM users in an organisation is often relatively small. On one hand, this hinders the application of many common statistical protocols, but on the other, it enables us to sample most of the population and gain relevant results in the context of the company. Second, perceptual questions are used in the model to evaluate technical efficiency. To gain objective evaluation of the SDM technical dimension, a group of technically advanced SDM users has to be formed. Although in most cases, the formation of the group was unproblematic, in some cases, we were not able to identify the technically advanced users for particular SDM elements, which therefore remained unevaluated from the technical perspective. It is also important to note, that as different groups respond to social and technical aspects, there is a possibility that the group means might be different. Third, the evaluation is relatively extensive and time consuming, especially if performed on a scale of a single SDM element. It is therefore important to tailor the model to specific requirements of the organisation and users to avoid redundant work. Finally, it is important to motivate SDM users who participate in the evaluation. They need to understand that evaluation is the key for SDM improvements that will positively affect the way they work.

In all four cases, the evaluation was performed in smaller organizations or organisational units that were motivated to improve and/or standardise their development processes and practices. Although the results validated our initial prepositions, we are aware of the validity and reliability threats posed by relatively small number of test cases. Unfortunately, due to complexity of the evaluation and limited resources, we were unable to perform tests in more organisations so far. On the other hand, according to Yin [56] more than two cases can make a strong argument already. In our opinion, the repeated positive response of the key employees in the four companies provides strong indication that the model will generally provide useful results for similar companies. Additional research is needed to verify whether the model can also be successfully applied in larger organisations.

6. Conclusion and further work

In this paper, we have presented an approach for SDM evaluation. Although various SDM evaluation methods exist, the proposed approach has several distinctive qualities. First, it considers both social and technical suitability of a SDM; second, it supports evaluation on a scale of single SDM elements; and third, it measures the level of SDM adoption and efficiency and the reasons for SDM adoption and efficiency. These allow a software development organization to observe the value of its SDM in detail, identify technically and/or socially inappropriate parts of the SDM, and create customized improvement scenarios based on the evaluation of each SDM part.

The proposed evaluation model builds on existing models that have been checked for their validity and reliability. The model has been applied in four companies dealing with software development. In all four cases, the evaluation gave valuable insights into SDM adoption and efficiency and validated our prepositions. The re-evaluation in one of the companies proved the efficiency of SDM improvement scenarios that were based on the initial evaluation.

In the following step of our research, we intend to focus on the simplified evaluation model and validate its effectiveness on additional cases. Next, we intend to develop a support for semi-automated creation and selection of SDM improvement scenarios. The tests of the evaluation model showed that the creation of improvement scenarios on a scale of single SDM elements is time consuming. However, the tests also showed that improvement scenarios often share several common features, even though they are created to improve different parts of a SDM. Therefore, we plan to create templates that will speed up the creation of improvement scenarios. To facilitate selection of the templates we intend to create a semi-automated decision system that will help a SDM expert to choose the suitable template for each SDM element and lessen the work required to create an improvement scenario, consequentially enabling more frequent SDM improvements.

References

[1] D.E. Avison, G. Fitzgerald, Information Systems Development: Methodologies, Techniques and Tools, McGraw-Hill, London, 2003.

[2] B. Fitzgerald, Am empirical investigation into the adoption of systems development methodologies, Information & Management 34 (1998) 317–328.

[3] C.K. Riemenschneider, B.C. Hardgrave, F.D. Davis, Explaining software developer acceptance of methodologies: a comparison of five theoretical models, IEEE Transactions on Software Engineering 28 (2002) 1135–1145.

[4] I. Aaen, Software process improvement: blueprints versus recipes, IEEE Software 20 (2003) 86–93.

[5] B. Fitzgerald, Formalized systems development methodologies: a critical perspective, Information Systems Journal 6 (1996) 3–23.

[6] M. Huisman, J. Iivari, Deployment of systems development methodologies: perceptual congruence between IS managers and systems developers, Information & Management 43 (2006) 29–49.

[7] M. Khalifa, J.M. Verner, Drivers for software development method usage, IEEE Transactions on Engineering Management 47 (2000) 360–369.

[8] J.L. Wynekoop, N.L. Russo, Systems-development methodologies – unanswered questions, Journal of Information Technology 10 (1995) 65–73.

[9] R. Agarwal, M. Tanniru, D. Wilemon, Assimilating information technology innovations: strategies and moderating influences, IEEE Transactions on Engineering Management 44 (1997) 347–358.

[10] M. Niazi, D. Wilson, D. Zowghi, A maturity model for the implementation of software process improvement: an empirical study, Journal of Systems and Software 74 (2005) 155–172.

[11] A. Cockburn, Agile Software Development, Addison-Wesley, Boston, 2002.

[12] B. Fitzgerald, N.L. Russo, T. O'Kane, Software development method tailoring at motorola, Communications of the ACM 46 (2003) 64–70.

[13] S. McConnell, Rapid Development: Taming Wild Software Schedules, Microsoft Press, Redmond, WA, 1996.

[14] G. Low, R. Looi, An investigation of client/server application development methodologies, Journal of Information Technology 12 (1997) 187–196.

[15] M.J. Gallivan, The influence of software developers' creative style on their attitudes to and assimilation of a software process innovation, Information & Management 40 (2003) 443–465.

[16] G.C. Green, R.W. Collins, A.R. Hevner, Perceived control and the diffusion of software process innovations, Journal of High Technology Management Research 15 (2004) 123–144.

[17] P. Rawstorne, R. Jayasuriya, P. Caputi, Issues in predicting and exploring usage behaviours with the technology acceptance model and the theory of planned behaviour when usage is mandatory, in: Proc. of the Twenty first International Conference on Information Systems, Brisbane, Australia, 2000.

[18] S. Sharma, A. Rai, An assessment of the relationship between ISD leadership characteristics and IS innovation adoption in organizations, Information & Management 40 (2003) 391–401.

[19] D. Vavpotic, M. Bajec, M. Krisper, Measuring and improving software development methodology by considering technical and social suitability of its constituent elements, in: O. Vasilecas, A. Caplinskas, W. Wojtowski, W.G. Wojtowski, J. Zupancic, S. Wrycza (Eds.), Proc. of the Thirteenth International Conference on Information Systems Development, Technika, Vilnius, Vilnius, 2004.

[20] M. Bajec, D. Vavpotic, F. Stefan, M. Krisper, Software process improvement based on the method engineering principles, in: J. Ralyte, S. Brinkkemper (Eds.), Situational Method Engineering: Fundamentals and Experiences, Proc. of the IFIP WG 8.1 Working Conference, Springer, Berlin, 2007.

[21] M. Bajec, D. Vavpotic, M. Krisper, Practice-driven approach for creating project-specific software development methods, Information and Software Technology 49 (2007) 345–365.
[22] B. Henderson-Sellers, Method engineering for OO systems development, Communications of the ACM 46 (2003) 73–78.
[23] J. Ralyte, R. Deneckere, C. Rolland, Towards a generic model for situational method engineering, in: Proc. of the 15th International Conference on Advanced Information Systems Engineering, 2003.
[24] S. Brinkkemper, M. Saeki, F. Harmsen, Meta-modelling based assembly techniques for situational method engineering, Information Systems 24 (1999) 209–228.
[25] F. Harmsen, S. Brinkkemper, H. Oei, Situational Method Engineering for information system project approaches, in: Proc. of the IFIP WG8.1 Working Conference on Methods and Associated Tools for the Information Systems Life Cycle, Elsevier, Amsterdam, 1994, pp. 169–194.
[26] F. Karlsson, P.J. Agerfalk, Method configuration: adapting to situational characteristics while creating reusable assets, Information and Software Technology 46 (2004) 619–633.
[27] I. Mirbel, J. Ralyte, Situational method Engineering: Combining Assembly-based and Roadmap-driven Approaches, Projet EXECO, Rapport de recherche, 2004.
[28] H.A. Hofstede, T.F. Verhoef, On the feasibility of situational method engineering, Information Systems 22 (1997) 401–422.
[29] Rational Unified Process v 7.0.1 (IBM Rational Method Composer plugin), IBM Corp., 2006.
[30] S.W. Ambler, R. Jeffries, Agile Modeling: Effective Practices for Extreme Programming and the Unified Process, Wiley, New York, 2002.
[31] ISO/IEC-15504, Information technology – software process assesment, 1998.
[32] ISO/IEC-FCD-9126-1, Software product quality – Part 1: Quality model, 1998.
[33] CMU/SEI-2002-TR-029, Capability Maturity Model ® Integration (CMMISM), Version 1.1, SEI, 2002.
[34] G.C. Green, A.R. Hevner, R.W. Collins, The impacts of quality and productivity perceptions on the use of software process improvement innovations, Information and Software Technology 47 (2005) 543–553.
[35] M. Huisman, J. Iivari, The organisational deployment of systems development methodologies, in: Advances in Methodologies, Components, and Management, Kluwer Academic Publishers, Dordrecht, 2003, pp. 87–99.
[36] E.M. Rogers, Diffusion of Innovations, Free Press, New York, 2003.
[37] M.J. Gallivan, Organizational adoption and assimilation of complex technological innovations: development and application of a new framework, The DATABASE for Advances in Information Systems 32 (2001) 51–85.
[38] I. Ajzen, The theory of planned behavior, Organizational Behavior and Human Decision Processes 50 (1991) 179–211.
[39] F.A. Davis, Perceived usefulness perceived ease of use and user acceptance of information technology, MIS Quarterly 8 (1989) 318–339.
[40] V. Venkatesh, F.D. Davis, A theoretical extension of the technology acceptance model: four longitudinal field studies, Management Science 46 (2000) 186–204.
[41] G. Moore, I. Benbasat, Development of an instrument to measure the perceptions of adopting an information technology innovation, Information Systems Research 2 (1991) 192–222.
[42] M. Fishbein, I. Ajzen, Belief, Attitude, Intention, and Behavior: An Introduction to Theory and Research, Addison-Wesley, Reading, MA, 1975.
[43] P. Kruchten, The Rational Unified Process, Addison-Wesley, Reading, MA, 1999.
[44] R. Davis, Business Process Modelling with ARIS: A Practical Guide, Springer, Berlin, 2001.
[45] K.J. Klein, J.S. Sorra, The challenge of innovation implementation, Academy of Management Review 21 (1996) 1055–1080.
[46] M. Huisman, J. Iivari, The Individual Deployment of Systems Development Methodologies, Lecture Notes in Computer Science, Springer, Berlin, 2002. pp. 134–150.
[47] I.R. McChesney, D. Glass, Post-implementation management of CASE methodology, European Journal of Information Systems 2 (1993) 201–209.
[48] G.W. Downs Jr., L.B. Mohr, Conceptual issues in the study of innovation, Administrative Science Quarterly 21 (1976) 700–714.
[49] D.B. Tesch, G. Klein, M.G. Sobol, Information-system professionals attitudes – development tools and concepts, Journal of Systems and Software 28 (1995) 39–47.
[50] D. Leonard-Barton, Implementing structured software methodologies: a case of innovation in process technology, Interfaces 17 (1987) 6–17.
[51] G. Green, A.R. Hevner, Perceived control of software developers and its impact on the successful diffusion of information technology, Software Engineering Institute, Carnegie Mellon University, Pittsburgh, 1999.
[52] J. Iivari, Why are CASE Tools not used?, Communications of the ACM 39 (1996) 94–103
[53] A. Rai, G.S. Howard, Propagating CASE usage for software development: an empirical investigation of key organizational correlates, OMEGA 22 (1994) 133–147.
[54] J.M. Fernandes, F.J. Duarte, Using RUP for process-oriented organisations, product focused software process improvement, in: Proc. of the 5th International Conference, Springer, Berlin, 2004.
[55] N. Bevan, Quality in use: meeting user needs for quality, Journal of Systems and Software 49 (1999) 89–96.
[56] R.K. Yin, Case Study Research: Design and Methods, Sage, Thousand Oaks, CA, 2003.
[57] J.C. Nunally, Psyhometric Theory, McGraw-Hill, New York, 1978.