A METHODOLOGY FOR ICT IMPACT ANALYSIS BASED ON SEMANTIC PROCESS MODELS

Lars Baacke¹, René Fitterer², Tobias Mettler¹, Peter Rohner¹

Abstract – In today’s fast changing public sector environment, administrative decision makers increasingly demand that information and communication technology (ICT) investments demonstrate business value through measurable results. While costs are easy to track, measuring tangible benefits such as quality improvements and utility potentials of ICT takes considerable effort. Hence, simultaneously with a multitude of eGovernment initiatives, ICT evaluation methods have been developed. As the great part of these initiatives exclusively focuses on the electronic delivery of governmental services, predominantly the end-user perspective is used for evaluation thus leaving behind the impact of ICT on the back-office of a public administration. For this reason a fundamental methodology for administration-wide ICT impact analysis is presented. This methodology consists of two phases: semantic modelling of administrational processes (phase 1) and computer-assisted analysis of ICT impact (phase 2). For both phases, the respective specifications are explained and their applicability is demonstrated with a real-world example.

1. Introduction

At present, public administrations (PAs) are faced with complex and comprehensive changes [1]. Rising expectations of constituents, increasing regional competition, as well as the pressure on costs and efficiency require fundamental improvements of organisational and procedural structures including the introduction of new and the integration of existing ICTs [2, 3]. However, and in contrast to other industries, a necessary prerequisite, the formalised documentation of internal procedures is almost absent [4]. In many cases this can be attributed to the hierarchical and function-oriented production of public sector services resulting in decentralised responsibilities and fragmented processes [5, 6]. Considering the high number and increasing complexity of public sector services [2], the identification of potential ICT support and the analysis of expected impacts of new (often cross sectional) services are nearly impossible within such an undocumented process landscape [1].

This lack of transparency is one reason for resistance to change [7]. It can be reduced by diffusing easily usable process modelling techniques in PAs which consider the specific characteristics of public service production [4]. Based on such formalised process knowledge, organisational deficiencies and appropriate support of ICT can be identified. Although the efforts of introducing and operating ICT can be well calculated already today, the actual impacts of new ICT (positive and negative) are barely analysed [8].

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In this contribution a methodology is presented that on the one hand enables a distributed documentation of processes based on semantically standardised process building blocks (PBBs). The resulting homogeneous levels of detail and abstraction facilitate the integration of the distributed modelled processes. On the other hand the PBB-based modelling approach provides the foundation for pattern-based identification of organisational weaknesses and potential ICT support as well as for qualitative and quantitative analysis of ICT impacts. Thus, the developed methodology targets internal and external users who are concerned with issues of reorganisation as well as ICT investment decisions.

In this contribution, after the initial overview of the state of the art in the subsequent section, the research approach will be briefly described in Section 3. The two phases of the methodology, the semantic process modelling and the ICT impact analysis are presented in Section 4. To prove the practical applicability of the methodology in PAs, a real-world example for both parts of the methodology is illustrated, too. In Section 5 the main results are summarised and an outlook on obtainable potentials and further research is provided.

2. State of the Art

Although a large number of ICT evaluation methods have been developed for the private sector, few methods have been designed specifically for application in public sector organisations. These have emerged during the last decade in line with the multitude of eGovernment initiatives and have been developed both by commercial and privately subsidised organisations [9, 10] as well as governmental authorities [11-13]. The majority of the identified methods only have a limited view on eGovernment, focusing exclusively on the electronic delivery of government services using web portals, and not on a broader spectrum of ICT use such as document management, workflow systems, and optical archives inside the PA. Hence, the focus is primarily on the analysis of the impact of ICT on the end-users (e.g. citizens) rather than the back-office environment. However, those methods considering the impact of ICT on the back-office side (e.g. including operational efficiency measures) do not address the impact of ICT on the processes of a PA in adequate detail.

Along with the development of new methods for ICT evaluation, a range of initiatives to manage and improve the processes for both public and private participants were developed [14, 15]. Although at least in other industries there is extensive knowledge about documenting business processes with syntactically formalised modelling notations, semantics are not formalised [14]. Thus, there is a considerable heterogeneity with regards to terminology, detail and abstraction of process documentations in PAs [4]. Comprehensibility and comparability of the existing models in particular for an overall analysis of a process landscape is rather difficult and depends to a large extent on the modellers’ perception and experience. Therefore, considerable manual effort has to be accomplished when using non-semantic process models (e.g. when searching for organisational improvements). On that basis, automation of semantic consistency validation or weakness analysis is impossible.

3. Research Method

As the development of a sophisticated, computer-assisted approach for ICT impact analysis is a rather pertinent and practical endeavour, engaged research is needed in order to provide rigorous solutions for this relevant problem. A theoretical basis that serves both relevancy and rigour is that of design research. The design research process aims at building and evaluating
innovative artefacts, in order to extend existing capability limitations [16]. Hence, it is considered a problem-oriented approach [17].

But what is meant by “artefact”? Artefacts represent the final results of a design process. They can be characterised as constructs, models, methods or instantiations [16]. In this case a multitude of artefacts have been developed. Starting point was the definition of the essential constructs for semantic modelling and for impact analysis and the description of the relationships in a corresponding meta-model (cp. Figure 1 and Figure 3). This served as basis for the construction of the overall methodology which has been prototypically implemented in form of an instantiation (i.e. software tool). As the development of the artefacts has been discussed in [18] already, this contribution focuses on the demonstration of the functional capability of the artefacts, keeping in mind that further evaluation has to be conducted.

4. Methodological Framework

The overall objective of the presented methodology is the identification of potential fields of usage of new ICT as well as the quantitative and qualitative impact analysis of its deployment in an organisation. Prerequisite for such analyses is extensive knowledge about internal organisational and procedural structures which can be represented by process models. Thus, the approach can be divided into two phases: model and analyse. Initially, the as-is situation of a process landscape is captured through respective models (phase 1). Subsequently potential sources of inefficiency are identified through measurement on the captured process landscape. Furthermore, beneficial ICT is identified and analysed with respect to its impact (phase 2). For that purpose, the subsequent sections explain the specifications developed for the two phases and exemplify their applicability in a brief real-world scenario.

4.1 Phase 1: Semantic Modelling with Standardised Process Building Blocks

In order to obtain formalised process descriptions which can be analysed automatically in phase 2, the main objective of the first phase is semantically annotated process modelling. Considering the characteristic of PA’s service delivery that a high number of various processes usually consist of a much smaller number of recurring activities, the bottom-up approach of PBB composition was selected [4]. Thereby, recurring activities are depicted by an adequate set of PBBs whose composition results in complete process chains. A challenge was the identification of a minimised number of generic PBBs that enable the semantically standardised depiction of typical administrational processes. The first attempt of an inductive identification based on existing process models failed as a large number of very heterogeneous and in parts similar PBB candidates were found, such as activities named “receive a message”, “take an application form” or “incoming mail”. In order to reduce the high number of PBB candidates, heterogeneous terminology as well as the differing levels of detail and abstraction had to be standardised. As the analysis within the second phase of the methodology requires rather detailed information, a high level of detail was selected. In order to reduce the number of PBBs, a higher level of abstraction was needed which has been reached by generalising PBB candidates. This generalisation was achieved by distinguishing between the core activity and the information object that is processed by the activity [18]. An example is the PBB candidate “send an approval” that was divided into the activity “send” and the processed object (PO) “approval”. After having extracted all activities from the PBB candidates, in the second step same or similar activities were joined. Furthermore, all PBBs have been extensively evaluated and reengineered wherever necessary. This approach finally resulted in a set of 37 generic PBBs (cp. Table 1).
Table 1: List of process building blocks

<table>
<thead>
<tr>
<th>Category</th>
<th>Process building blocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initiation</td>
<td>[produce/create/generate], [capture/enter], [start/open], [receive], [take from], [take notice/to be informed]</td>
</tr>
<tr>
<td>Processing</td>
<td>[retrieve/gather/enquire], [check/verify], [examine/analyse], [register], [decide], [document], [change/update/complete], [demand sth./follow up], [discuss], [consult], [sign], [certify/legalise], [invalidate], [pay], [encash], [reserve/book], [calculate], [scan], [print], [copy], [wait until], [on-site visit], [coordinate]</td>
</tr>
<tr>
<td>Completion</td>
<td>[send/give], [forward/delegate], [assign], [notify], [publish], [close], [dispose/delete], [archive]</td>
</tr>
</tbody>
</table>

Each PBB is described in more detail. The specification of the example PBB “receive” is presented in Table 2.

Table 2: Specification of an example PBB

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name / Synonyms</td>
<td>Receive</td>
</tr>
<tr>
<td>Definition</td>
<td>This PBB describes the activity of receiving a message, document or dataset (by different mediums and different channels). The PBB also includes that someone physically accepts documents.</td>
</tr>
<tr>
<td>Category</td>
<td>Initiation</td>
</tr>
<tr>
<td>Examples</td>
<td>Receive an application form; Receive a complaint</td>
</tr>
<tr>
<td>Overlapping</td>
<td>RPB-20 [Take notice/To be informed]</td>
</tr>
<tr>
<td>Status of evaluation</td>
<td>Accepted</td>
</tr>
<tr>
<td>Attribute(s)</td>
<td>Processing time [0..1] &lt;minutes&gt;</td>
</tr>
<tr>
<td></td>
<td>Communication Channel [1..n] &lt;list&gt;</td>
</tr>
<tr>
<td></td>
<td>Sender [1..n] &lt;relation&gt;</td>
</tr>
</tbody>
</table>

However, information limited on activities is not sufficient to create automatically analysable processes. In fact, after having chosen suitable PBBs during the modelling phase, specialisation is needed. One possibility to detail PBBs is the specification of attributes (cp. Table 2) such as processing time, sender and communication channel (for the PBB “receive”), or number of copies (for the PBBs “copy” and “print”). Also POs can be specified by further attributes such as media (e.g. paper-based or electronically) and number of pages. An initial list of attributes is presented in Table 3.

Table 3: Exemplary attributes for PBB and PO

<table>
<thead>
<tr>
<th>Attribute type</th>
<th>Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>PBB attributes</td>
<td>Communication channel, processing time, transport time, time limitations, template support, relation, number of copies, sender, receiver</td>
</tr>
<tr>
<td>PO attributes</td>
<td>Medium, structuredness, need for signature, document type, confidentiality, number of pages</td>
</tr>
</tbody>
</table>

In addition to PBBs, POs and their attributes, in most process models the responsible organisational unit (e.g. department, office, or position) is specified in order to identify organisational interfaces. Such interfaces are often considered a potential weakness that can be well supported by ICTs. For the described methodology responsibilities are moreover important because this approach also allows distributed modelling. On the basis of semantically standardised PBBs and respective standardised interfaces resulting process fragments are compatible to each other and can be joined to form a whole process. This enables inexperienced people to model only those process parts they are responsible for. In addition, already existing ICT has to be analysed too and, thus, it can also be assigned to a respective activity. The derived components of a semantic process model as well as their interrelations are summarised in Figure 1.
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Figure 1: Essential components for the composition of PBB-based process models

As the developed modelling approach is not limited to a specific notation, a broad and flexible usage by different organisations and in various tools is enabled. So far, about 200 processes have been modelled by different PAs on the basis of PBBs. The results indicate that PBBs improve both quality and efficiency of process modelling. A concrete part of an example process (car registration) which shows a typical process fragment is presented in Figure 2.

Figure 2: PBB-based process model fragment – a real-world example

The information documented in this part of the process model provides the foundation for measurement and analysis described in the subsequent section.

4.2 Phase 2: Qualitative and Quantitative Analysis of Potential ICT Support

Based upon the captured process flow resulting from phase 1, process characteristics can be measured and respective potential weaknesses can be identified. The measurement is thereby not limited to the scope of individual processes; instead the analysis can be carried out over the whole process landscape which allows for prioritisation of ICT investments based on indicators such as process complexity, number of organisational interfaces or media breaks. Such rankings also enable prioritisation of concrete modernisation projects. The focus of the methodology hereby lays on the elimination of weaknesses in processes through the support of ICT. Weaknesses are considered inefficiencies (e.g. media breaks or inefficient communication channels). Using the concept of weakness patterns which consist of a combination of the previously described semantic elements to depict processes (PBBs, POs, Attributes, Organisational Units and existing ICTs), inefficiencies can be flexibly defined with this methodology. In order to identify respective ICT support for weaknesses in the models of the as-is processes of public administrations, concrete ICT services need to be related to the weaknesses. Therefore, a set of generic front-office and back-office related ICT functionality groups (ICT FGs) were developed as part of the methodology that categorise and group related ICT services and describe the respective usage conditions [19].
For the quantification of ICT potential with regards to a certain weakness, an analysis of the impact of new ICT has been designed based on existing approaches for ICT value measurement and investment analysis [9, 20]. Two dimensions of impact (qualitative and quantitative) as well as respective indicators were defined which are used to analyse the impact of new ICT [18] (cp. Table 4 for an overview of potential ICT benefits).

<table>
<thead>
<tr>
<th>Quantitative benefits</th>
<th>Qualitative benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduction of processing time, idle time, transport time, consumables, response time</td>
<td>Legal compliance, ability for audit trail, information quality, information integrity, availability of services, availability of information, data protection, data security, accessibility, redundancy reduction, error reduction, customer satisfaction, authenticity</td>
</tr>
</tbody>
</table>

Some qualitative benefits also have impact on measurable indicators. An example is error reduction which improves the quality of information and reduces processing time required for rework on resulting objections (e.g. number of objection cases and related processes). The development and evaluation activities carried out as part of the research produced an initial set of twelve typical weaknesses that are specified in weakness profiles (cp. Table 5).

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weakness name</td>
<td>Use of inefficient communication channels</td>
</tr>
<tr>
<td>Description</td>
<td>Communication channels are specified by the corresponding attributes of those PBBs which depict a PO transfer, e.g. “send” or “forward”. Mail is considered such an inefficient channel as it causes high costs and requires long transport times. Depending on the position of the receiver (internal or external) different ICT will be recommended.</td>
</tr>
</tbody>
</table>
| Related ICT FGs | - If receiver is an external actor: “eMail Service”
- If receiver is an internal actor “Object Management Service”
- If transferred PO needs to be signed: “Electronic Signature Service”
- If transferred PO is confidential: “Encryption Service” |
| Related quantifiable benefits | - Reduction of transport times
- Reduction of transport costs (e.g. postage, envelope, address label)
- Reduction of resource costs, such as paper and printing
- Reduction of processing time and, thus, personnel costs |
| Related qualitative benefits | - Increasing receiver’s satisfaction because of faster responding time
- If “Object Management Service” is recommended: Redundancy reduction because duplication of information is avoided by central information availability and distributed access
- If “Electronic Signature Service” is recommended: Improvement of data integrity and authenticity
- If “Encryption Service” is recommended: Improvement of data protection |

If applied to the example from Section 4.1, three weaknesses can be detected. The previously shown weakness of using an inefficient communication channel for internal communication can be identified by use of a paper-based mail as channel of the activity “forward”. This weakness is addressed by the ICT functionality groups eMail Service and Encryption Service. Their introduction results in a reduction of transport time and an improvement of data protection. The same ICT also removes the weakness media break, which is represented by the activity “print”. The removal results in a reduction of used consumables and processing time. Manual, paper-based signatures which are also part of the exemplary process shown in Figure 2 can also be defined as a weakness as data integrity and authenticity may be considerably improved by using an Electronic Signature Service. The respective quantification of benefits for the examples mentioned such as reduced use of consumables is possible by multiplying paper costs, number of printed pages per process and number of processes where the weakness of a media break has been identified. Similarly quantification
of transport time reduction is possible by measuring the related attribute values of the respective PBB (e.g. “forward”). The conceptualisation of the resulting overall methodology that integrates the previously described two phases is shown in Figure 3.

![Figure 3: Meta model of the ICT impact analysis](image)

### 5. Conclusion and Outlook

In this contribution a methodology for ICT Impact Analysis Based on Semantic Process Models is described which consists of two phases: the semantic modelling of processes on the one side and the weakness-based analysis of potential ICT support and impact on the other side. After an introduction to the state of the art and the research approach, both phases have been specified and applied to a real-world example to demonstrate the applicability of the theoretical foundation in practice. As the presented weaknesses and benefits represent only an initial set, the methodology allows extensive modifications, e.g. the removal or adoption of existing and the definition of new rules, which ensure flexibility and sustainability. Summarising, it can be stated that the availability of standardised process building blocks for modelling and techniques for measurement and analysis lays the foundation for justification of tangible ICT investment decisions and the development of sound ICT strategies as the developed methodology makes it possible to answer questions like: Which ICT has potentials to support PAs’ processes by elimination or reducing a weakness? Where (within the whole process landscape) is a specific ICT needed? How will an organisation-wide deployment of a specific ICT have impact on PAs’ services? Using the presented methodology, public administrations are not only supported in recognising potential ICT but also in generally identifying current weaknesses whose elimination (with or without ICT) is considered to increase efficiency and effectiveness. As the methodology promises automation of impact analysis, the modelling and analysis specifications have consequently been implemented in a prototypical instantiation. This prototype enables a dialogue-oriented capturing of semantic process models on the one side. Using ontology reasoning mechanism on the other side, it realises the automated process analysis based on weakness profiles and generates goal-driven reports for PAs’ decision makers. The prototype provides a valuable foundation for disseminating the achieved results to a broader community as well as for further developments which conforms to the design-oriented research approach.

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References