AN EVOLUTIONARY APPROACH FOR BUSINESS PROCESS REDESIGN
Towards an Intelligent System

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Abstract: Although extensive literature on BPR is available, there is still a lack of concrete guidance on actually changing processes for the better. It is our goal to provide a redesign approach which describes and supports the steps to derive from an existing process a better performing redesign. In this paper we present an evolutionary approach towards business process redesign and explain its first three steps: 1) modelling the existing process, 2) computing process measures, and 3) evaluating condition statements to find applicable redesign "best practices". We show the applicability of these steps using an example process and illustrate the remaining steps. Our approach has a formal basis to make it suitable for automation.

1 INTRODUCTION

Although numerous papers and books on Business Process Redesign (BPR) were published during the past 15 years (e.g. (Grover et al., 1995; Kettinger et al., 1997; Al-Mashari and Zairi, 1999)), guidance for concrete process redesign is scarce. Valiris and Glykas (Valiris and Glykas, 1999) identify that "there is a lack of a systematic approach that can lead a process redesigner through a series of steps for the achievement of process redesign". This paper fits within our aim to fill this void by providing a redesign approach which describes and supports the steps to derive from an existing process a better performing one.

A key element of the approach that we propose in this paper is the generation of diagnostic information on an existing business process. Such a diagnosis is performed using so-called *process measures*, which provide a global view on the characteristics of the process. Actual values for the process measures may reveal weaknesses in the process. Identified weaknesses are removed by the application of one or more *redesign best practices*. A redesign best practice describes a well-tried way to remove a particular problem from a process to improve its performance. In our earlier work we have described 29 redesign best practices and presented a qualitative description, the potential effects and possible drawbacks for each best practice (Reijers and Limam Mansar, 2005). Finally, in our approach, the application of redesign best practices leads to one or more alternative candidates for the existing process. The evaluation of the performance of each alternative shows the best candidate process which should replace the existing one.

Our approach builds on the formal representation of a business process with Petri nets, in particular WorkFlow nets (Aalst, 1998). Some of the features of our model are inspired by the process modelling tool Protos (Pallas-Athena, 2004). Current versions of Protos are in use by thousands of organizations in more than 25 countries. In The Netherlands alone, more than half of all municipalities and insurance companies use Protos for the specification of their business processes. The focus on this real-life tool gives our approach a practical edge, while it is still easy to see how our approach can be generalized to other modelling techniques and tools (e.g. ARIS).

We envision as the ultimate goal of our research the delivery of an automated redesign tool. This tool would support all steps of the approach in an "intelligent" way. By this, we mean that the tool will not only automate the various steps of the approach, but will also interact with the redesigner. The redesigner will

be able to indicate which performance dimensions (time, costs, quality) should be improved, whether certain process characteristics should perhaps not be changed, and which promising alternatives should be combined in constructing the best alternative. Our approach is a solution that should primarily help redesign novices in finding process alternatives based on best practices. Secondly, more experienced redesigners are supported in the creation and evaluation of such alternatives in a structured and less time-consuming manner. The structure of the paper is as follows, section II describes the related work, section III details the steps of our approach using an illustrative example and section IV presents our conclusions and future work.

2 RELATED WORK

Various more structured approaches to process redesign were proposed earlier, most notably the ProcessWise methodology (Calvert, 1994) and the MIT Process Handbook (Malone et al., 2003). Also, a variety of tools is available, e.g. MIT's process recombinator tool (Bernstein et al., 1999), a number of tools that apply case-based reasoning (Ku and Suh, 1996; Min et al., 1996), and the KOPeR tool by Nissen (Nissen, 1996; Nissen, 1997; Nissen, 1998; Nissen, 2000). Many existing approaches and tools are limited in their application domain, while none of the approaches has succeeded to gain widespread adoption in industry. We have provided a more extensive literature review on this topic in (Netjes et al., 2006).

Nissen's work is most related to our approach which motivates its following deeper discussion. Its main contribution with the KOPeR tool is the construction of a set of measures that, applied to processes, would at first help to diagnose *pathologies*. The pathologies are then mapped to matching *transformations* that may be applied to the processes in order to improve their performances. Nissen used a process model based on nodes, attributes and edges (Nissen, 1998).

Nissen's work has inspired us to come up with a similar approach that nonetheless overcomes some of the KOPeR tool's shortcomings:

- On the process modelling side, the process model in use by KOPeR is yet simple and the provided examples are rather simplistic (Nissen, 1996; Nissen, 1997; Nissen, 1998). Our process model is defined as an enriched WorkFlow net allowing for the modelling of realistic, complex business processes.
- Nissen used graph-based definitions of the measures in order to operationalize them. We have noticed that the exact meaning of some of the measures is unclear. We use a formal notation to overcome this and define our measures unambiguously.
- Nissen adds an extra layer of indirection (process pathologies and process transformations). We only define a set of measures and a set of transformation rules to immediately find the applicable transformations.
- Nissen's set of presented transformation serves as an illustration and is far from a complete coverage of the spectrum of redesign options. We provide a more exhaustive list of rules based on our set of 29 best practices (Reijers and Limam Mansar, 2005).

3 EVOLUTIONARY APPROACH

In our *evolutionary* approach towards workflow process redesign we take an existing process model and improve it using redesign best practices. It is evolutionary, because an existing process is taken as starting point instead of a clean sheet. Our approach consists of six steps: 1) model an existing process (using a formal model), 2) compute process measures (which can be seen as global process characteristics. Values for the process measures are derived from the existing process model and point out weaknesses in the process), 3) evaluate condition statements to find applicable best practices (For each best practice it is known which process weaknesses it could solve and the corresponding process measures are combined in one condition statement per best practice. When a statement evaluates to true it suggests the application of the associated best practice. All condition statements are evaluated to find the best practices which are eligible to be applied to the process. We strive to include as many redesign best practices as possible in our approach and we assume that our set of best practices is complete), 4) create alternative models based on the selected best practices (The selected best practices are used to create alternative models. A best practice has essentially the following parts: some kind of construction or pattern that can be distinguished in the existing process, an alternative to be incorporated for the redesign and a context-sensitive justification for this redesign), 5) evaluate the performance of the created alternatives, and finally 6) choose the best alternative and implement the new process after comparing the performance of the various alternatives to find the best alternative model, cf. Figure 1.

Figure 1: Evolutionary approach towards redesign.

The following details the six steps we have described in Figure 1. An illustrative case study is used.

3.1 Process Model

The starting point of our evolutionary approach to workflow process redesign is the existing process model. In order to illustrate our findings we use a case study that describes the process of handling insurance claims.

Let us first describe the process: The process handles the insurance claims of both individual and business clients. The process starts when a claim is received. After receipt, the claim is classified as "individual" or "business". Then the claim is checked for validity. Three checks, *Check policy*, *Check amount* (only for business clients, requires the receipt of a damage report) and *Check legal* are performed. A check either results in OK (proceed with next check) or not OK (reject claim). Claims that pass all checks are accepted and paid. Payments are authorized at the end of each day by the finance manager. For all claims (both rejected and accepted) a letter is written and the claim is archived.

To model this process, we use the Worklow nets and we define a formal process called Proto. A workflow process is case-based, i.e. every piece of work is executed for a specific case, and make-to-order. A Petri net (Reisig and Rozenberg, 1998) which models a workflow process definition (i.e. the life-cycle of one case in isolation) is called a WorkFlow net (WF-net). In a WF-net, the workflow management concept *task* is modelled as the Petri net concept *transition*, *conditions* are modelled by *places*, and *cases* are modelled by *tokens*. For a definition of WF-nets the reader is referred to (Aalst, 1998).

The process model is created based on a formal process definition called Proto net. The Proto net includes a process structure, related information and an organizational model. The process structure consists of places, transitions and flow relations just as is the case in a WF-net. The process structure is enriched with information related to transitions (such as external triggers, the type of activity to be executed, XOR-splits and -joins to model choices, responsible departments, required applications, and handled products and services). The organizational model uses roles at its foundation. A role is a collection of complementary skills. Allocating roles to transitions ensures that work is performed by the relevant person. Roles have a hierarchical relation, i.e. if two roles have the following relation (r', r) this means that role r is one step higher in the hierarchy than role r' and that role r is also able to perform the transition(s) allocated to role r'.

The Proto net is formally defined in Definition 1.

Definition 1 (Proto net) *A Proto net PN is a tuple* $(P, T, F, B, C, S, J, D, DT, E, ET, G, GT, R, H, U, A, AH)$ *with:*

- P *is a non empty, finite set of places;*
- T *is a non empty, finite set of transitions* ($P \cap T = \emptyset$)*. Task and activity are used as synonyms for transition;*
- $F \subseteq (P \times T) \cup (T \times P)$ *is a set of arcs (flow relation);*
- $B : T \rightarrow \mathcal{P}(\{time, periodic, digital, mail, telephone\})$ *relates each transition to zero, one or more trigger types;*
- $C : T \rightarrow \mathcal{P}(\{basic, communication, check, authorize, batch\})$ *relates each transition to zero, one or more activity types;*
- $S : T \rightarrow \{AND, XOR\}$ *relates each transition to a split type element;*
- $J : T \rightarrow \{AND, XOR\}$ *relates each transition to a join type element;*
- D *is a non empty, finite set of departments;*
- $DT : T \rightarrow \mathcal{P}(D)$ *relates each transition to zero, one or more departments;*
- E *is a finite set of applications (i.e. software tools);*
- $ET : T \rightarrow \mathcal{P}(E)$ *relates each transition to zero, one or more applications;*
- G *is a non empty, finite set of products and services;*
- $GT : T \rightarrow \mathcal{P}(G)$ *relates each transition to zero, one or more products and services;*
- R *is a non empty, finite set of roles;*
- $H \subseteq (R \times R)$ *is a (acyclic) set of hierarchical role relations;*
- $U \in R \rightarrow \mathcal{N}$ *is a non empty finite bag of users.* $\mathcal{N}$ *is the set of natural numbers {0, 1, 2, ...}. U is a bag, i.e., for some role r ∈ R, U(r) denotes the number of users having role r as the highest role;*
- $A : T \not\rightarrow R$ *relates each transition to zero or one roles (allocation);*
- $AH : T \rightarrow \mathcal{P}(R)$ *relates each transition to zero, one or more roles (hierarchical allocation) [Note*

that for $t \in dom(A)$: $AH(t) = \{r \in R | \ (A(t), r) \in H^*\}$ (with H^* being the reflexive transitive closure of H) and for $t \notin dom(A)$: $AH(t) = \emptyset$].

A process can be modeled according to the Proto net definition with the modelling tool Protos (Pallas-Athena, 2004). We have made several assumptions regarding the creation of a process model. In our definition of the Proto net we only take into account the structural properties of a process model and abstract from behavioral information.

Let us now use the Protos model for our insurance claim process. The model of the insurance claim process is shown in Figure 2 and is easy to understand.

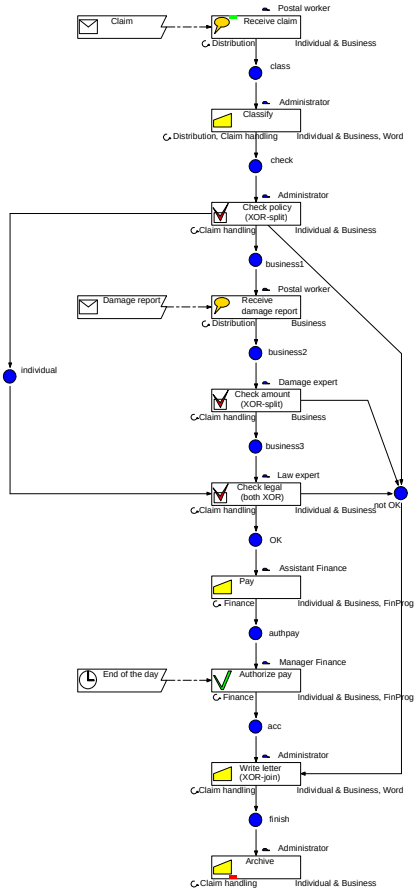

Figure 2: The existing insurance claim process.

The rectangular boxes in the process model are the transitions defined in the Proto net (T), each transition has an activity type indicated by the symbol in the box (*C*). The talking balloon indicates the activity type "communication", the trapezium indicates "basic", the check box "check", and the V-symbol "authorize". The three rectangles on the left side of the process are triggers (*B*). A trigger indicates that a certain (external) condition has to be fulfilled before the transition it links to can be executed. In this example, a "Claim", a "Damage report" and the "End of the day" are used. The split and join types are set to their values in the transition properties, but to show them in the model XOR-splits and -joins are also explicitly stated in the name of a transition. On the top right side of the transition the role allocated to the transition is indicated (For example, the first transition "Receive claim" is executed by the role "Postal worker"), on the bottom left side the related department(s) (Department "Distribution" for the transition "Receive claim"), and on the bottom right side the products / services and the required applications ("Individual and business" services for the transition "Receive claim"). The organizational model related to the process model is depicted in Figure 3 and is also created with Protos. It shows the roles and the number of resources per department.

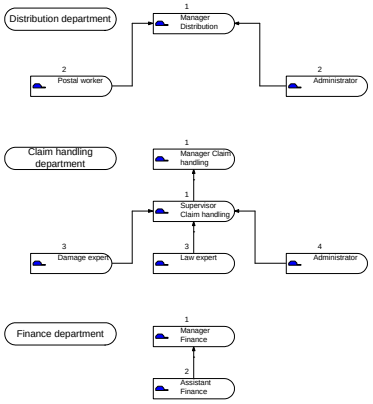

Figure 3: Organizational model of insurance claim process.

Looking at Figure 2 and 3, it is not easy to spot inefficiencies in the process. Even experienced practitioners will certainly need to use their expertise and perhaps tools such as simulation to define what will need to be improved in the process. Hence the next step of our approach, the use of process measures.

3.2 Process Measures

The second step of our evolutionary approach is the computation of the process measures for the existing process model. In this section we define our set of process measures. The starting point for the creation of the process measures has been the work of Nissen (Nissen, 1998). Nissen identified 19 (static) process measures (Nissen, 1996) of which ten appeared to be

relevant in relation to the redesign best practices. The graph-based definition Nissen presented for these measures is replaced by our formal definition because the formal definition provides a more precise and unambiguous meaning for the measures.
Besides the measures included from Nissen we developed eight new measures. These measures are all related to the additional information incorporated in the Proto net. In Table 1 the process measures are defined, their range is given and it is indicated which measures are taken from Nissen and which are new. For Table 1 we assume the following context: PN = $(P,T,F,B,C,S,J,D,DT,E,ET,G,GT,R,H,U,A,AH)$ is a Proto net.

To illustrate our results on the process measures, let us apply them to our insurance claim process. Using the set of measures defined in Table 1 we compute the process measures. The computed values are presented in Table 2. For instance, the measure *level of control* is defined as the percentage of control tasks. In the insurance claim process, there are 3 (control transitions) divided by 10 (transitions) resulting in a *level of control* of 0.3. Another measure, *knock outs*, is defined as the percentage of knock outs in the process. A knock out is a part of the process where cases are checked. The result of a check can be not OK (leading to a direct rejection of the case) or OK (leading to an acceptance of the case if all checks are OK). The knock out can be distinguished based on the presence of a special place called the knock out place. In our example process, there is one knock out place, namely "not OK", on a total of 11 places resulting in a *knock outs* measure of 0.1.

Table 2: Values for process measures.

Parallelism = 0	Department share = 0.1
Process contacts = 0.2	Process hand offs = 0.4
Batch = 0	Specialization = 0.7
Periodic = 0.1	Role usage = 0.7
Level of control = 0.3	Manag. layers = 0.3
L. of authorization = 0.1	Knock outs = 0.1
IT automation = 0.2	Process size = 10
IT communication = 0	Process versions = 2
Department inv. = 0.3	User involvement = 2

In the next step, we use and combine the set of process measures to determine condition statements per best practice. We know which weaknesses in a process a best practice would help to alleviate and we derive in the next section condition statements accordingly. Let us note that the complete set of measures has been created and defined iteratively with the development of the condition statements. Each condition statement is connected to one best practice. We assume our set of best practices is complete and in this work we include all best practices which require process, data or resource information for their selection. We hypothesize that all relevant measures which could be derived from this information and which are necessary for the condition statements are included in our set of measures.

3.3 Condition Statements

The third step of our evolutionary approach is the evaluation of condition statements to select applicable redesign best practices. For each best practice we derive one condition statement which includes one or more process measures. The application of a certain best practice should be suggested when the condition statement is fulfilled. The values used in the condition statements are based on our own redesign experience and expectation of when a certain best practice is applicable. The validation of these values will be future work.
We have created condition statements for 17 out of the 29 best practices: Task elimination, Task addition, Task composition, Task automation, Knock-out, Control relocation, Parallelism, Triage, Case manager, Split responsibilities, Numerical involvement, Specialist-generalist, Empower, Contact reduction, Case types, Technology, Case-Based Work.
Regarding the remaining 12 best practices: 1) four best practices appeared to have conditions similar to other best practices and are combined, 2) four best practices are not included because measures beyond the process level are necessary to come to a proper condition statement, 3) four best practices can not be covered due to behavioral dependencies which are not incorporated in the process definition.
For the sake of conciseness, we will only illustrate a subset of condition statements. Moreover, the examples are based on measures which were not included in Nissen's work.
For the insurance claim process 11 of the 17 condition statements we have defined evaluate to true resulting in the selection of a number of best practices that appear to be applicable to redesign this process. In what follows we describe a subset of best practices for which the condition statements evaluated to true:

Task elimination: When applying task elimination unnecessary tasks are removed (remember: task is a synonym for transition).
Condition statement: Apply task elimination IF *Level of control* > 0.2.

Table 1: Process measures.

Process measures with range [0, ..., 1]		
Parallelism*	=	$\frac{\lvert T_{par}\rvert}{\lvert T\rvert}$, perc. of parallel tasks[1]
Process contacts	=	$\frac{\lvert\{t\in T\mid communication\in C(t)\}\rvert}{\lvert T\rvert}$, perc. of communication tasks
Batch	=	$\frac{\lvert\{t\in T\mid batch\in C(t)\}\rvert}{\lvert T\rvert}$, perc. of batch tasks
Periodic	=	$\frac{\lvert\{t\in T\mid periodic\in B(t)\}\rvert}{\lvert T\rvert}$, perc. of periodic tasks
Level of control	=	$\frac{\lvert\{t\in T\mid check\in C(t)\}\rvert}{\lvert T\rvert}$, perc. of control tasks
Level of authorization	=	$\frac{\lvert\{t\in T\mid authorize\in C(t)\}\rvert}{\lvert T\rvert}$, perc. of authorization tasks
IT automation*	=	$\frac{\alpha\cdot\lvert\{t\in T\lvert ET(t)\neq\emptyset\wedge t\notin dom(A)\}\rvert+\beta\cdot\lvert\{t\in T\lvert ET(t)\neq\emptyset\wedge t\in dom(A)\}\rvert}{(\alpha+\beta)\cdot\lvert T\rvert}$, perc. of (semi-)automated tasks
IT comm.*	=	$\begin{cases}\frac{\lvert\{t\in T\lvert digital\in B(t)\wedge communication\in C(t)\}\rvert}{\lvert\{t\in T\lvert communication\in C(t)\}\rvert} & , \ for\ \{t\in T\lvert communication\in C(t)\}\neq\emptyset \\ 1 & , \ for\ \{t\in T\lvert communication\in C(t)\}=\emptyset\end{cases}$
Department involvement*	=	$\frac{\lvert D\rvert}{\lvert T\rvert}$, perc. of departments
Department share	=	$\frac{\lvert\{t\in T\mid \lvert DT(t)\rvert\geq 2\}\rvert}{\lvert T\rvert}$, perc. of tasks shared by departments
Process hand offs*	=	$\frac{\lvert\{t_1,t_2\in T\mid t_1\bullet\cap\bullet t_2\neq\emptyset\wedge AH(t_1)\cap AH(t_2)=\emptyset\}\rvert}{\lvert\{t_1,t_2\in T\mid t_1\bullet\cap\bullet t_2\neq\emptyset\}\rvert}$, perc. of work that is handed over to another role
Specialization*	=	$\frac{\lvert\{A(t)\mid t\in dom(A)\}\rvert}{\lvert T\rvert}$, specialization of roles (with a higher perc. meaning more specialists)
Role usage*	=	$\frac{\lvert\{A(t)\mid t\in dom(A)\}\rvert}{\lvert R\rvert}$, perc. of actively involved roles
Managerial layers*	=	$\frac{\lvert lrp\rvert}{\lvert R\rvert}$, perc. of hierarchical layers[2]
Knock outs	=	$\frac{\lvert\{p\in P\mid \lvert\bullet p\rvert>1\wedge(\forall_{t\in\bullet p}\ check\in C(t)\wedge S(t)=XOR\wedge\lvert t\bullet\rvert>1)\wedge(\exists ep\in EP_{PN}\mid \bullet p\subseteq\lvert\lvert ep\rvert\rvert)\}\rvert}{\lvert P\rvert}$, perc. of k.outs[3]

			Range
Process size*	=	$\lvert T\rvert$, the number of transitions	[1, 2, ..., number of transitions]
Versions	=	$\lvert G\rvert$, the number of products and services	[1, 2, ..., number of products and services]
User involvement*	=	$\frac{\lvert U\rvert}{\lvert T\rvert}$, the average number of users per task	[0, ..., 1, ..., number of users]

* = measure taken from Nissen (Nissen, 1996)

1. A parallel transition, T_{par}, is defined as $T_{par}\subseteq T$ such that $t\in T_{par}$ if and only if there exist two elementary paths that both start in an AND-split and end in an AND-join, t is on only one of these two paths, and the AND-split and AND-join are the only two nodes these paths have in common.
2. A role path, rp, in PN is defined as a nonempty sequence $r_k...r_1$ of roles which satisfies $(r_k,r_{k-1}),...,(r_2,r_1)\in H$. Let RP_{PN} be the set of all role paths in PN. Then a longest role path, $lrp\in RP_{PN}$, is defined as a role path which satisfies $\forall_{rp\in RP_{PN}}\ \lvert lrp\rvert\geq\lvert rp\rvert$.
3. An elementary path, ep, in PN is defined as a nonempty sequence $a_1...a_k$ of nodes which satisfies $(a_1,a_2),...,(a_{k-1},a_k)\in F\wedge\forall_{1\leq i<j\leq k}\ a_i\neq a_j$. Further, let EP_{PN} be the set of elementary paths in PN and let $\lvert\lvert ep\rvert\rvert$ be the set of all nodes in the elementary path ep.

Knock-out:When applying knock out tasks resulting in a knock out are re-ordered.
Condition statement: Apply knock-out IF *Knock outs* > 0.

Split responsibilities: When applying split responsibilities the responsibility for a task will be given to one department.
Condition statement: Apply split responsibilities IF *Department share* > 0.

Case types: When applying case types new workflow processes and product types are distinguished.
Condition statement: Apply case types IF *Process versions* > 1.

Case-Based Work: When applying case-based work each case is handled individually.
Condition statement: Apply case-based work IF *Batch* > 0 OR *Periodic work* > 0.

It is straightforward, using Table 2, to check that these condition statements are true for the insurance claim process.

3.4 Alternative models

The fourth step of our approach derives new process models based on the selected best practices. At this stage our approach does not support an automatic identification of where in the process a best practice should be applied. This is included in our future work. However, for the sake of completeness, we here illustrate the remainder of the approach for the insurance claim process. Hence the following list of the 5 selected best practices for which the condition statements evaluated to true, including a possible application:

- Task elimination: eliminate the control task *Check legal* and ask the client to indicate whether (s)he or some one else was responsible for causing the damage.
- Knock out: perform *Check amount* and *Check legal* in a different order if *Check amount* requires longer service times and / or has a lower rejection probability than *Check legal*.
- Split responsibilities: give the responsibility for the task *Classify* solely to the Distribution department.
- Case types: distinguish one workflow process for the individual claims and one for the business claims.
- Case-based work: remove or change the periodic activity *Authorize pay* which should reduce waiting times.

3.5 Evaluation of Alternatives and New Process Model

In the final steps of our approach, the performance of the various alternatives is evaluated and one redesign alternative is selected for implementation. For the evaluation, performance data (time, cost and quality indicators) are necessary. Evaluation can be done by simulating the model or (in simple processes) with calculation. The alternative that provides the best performance is selected. We have earlier found that 11 condition statements (thus best practices) evaluated to true for the insurance claim process (and we only illustrated five of them). Implementing the best practices separately would lead to 11 redesign alternatives for the insurance claim process. Each redesign project has goals (for instance improvement on throughput time or operational costs) and project risks (Limam Mansar et al., 2006) which makes some alternatives more promising than others. For the insurance claim process an improvement in throughput time will be achieved with the application of *Task elimination*. An improvement on costs could result from the use of the *Knock out* best practice. A careful evaluation with performance data is necessary to see which alternative will indeed be the best and should replace the existing insurance claim process.

At this point in time our approach ends with the selection of the best practices that seem fruitful for application to the existing process. Based on the description of the best practices it is straightforward to come up with possible applications of the best practices as we showed in our illustration. It should give a redesign novice enough input to create an alternative that will perform better than the existing process. In the future our approach and the supporting redesign tool should provide redesign alternatives which are based on the selected best practices and evaluate the alternatives to find the best one. This would support both redesign novices and experts.

4 CONCLUSION AND OUTLOOK

In this paper we describe and illustrate a six steps evolutionary approach towards workflow process redesign. Our contribution in this paper focuses on the first three steps leading to suggesting applicable best practices. This suggestion will already help redesign

novices with the creation of redesign alternatives. We introduced a formal process definition suitable for modelling realistic, complex business processes. Our process measures have a clear and unambiguous meaning because of their formal notation. Furthermore, our process measures are directly related to the redesign best practices with condition statements.

Our current work holds limitations that we will be addressing in the future. One direction for future research is the extension of the current process definition, for instance with performance information about historic process instantiations, to be able to set up condition statements for all redesign best practices (steps 1, 2 and 3). Another important direction will be the exact place in the process model where a suitable best practice should be applied and the derivation of the alternative model (step 4). We also aim at automating our approach with a highly interactive redesign tool. In addition to merely generating process alternatives on the basis of an existing model, such a tool will be able to process the preferences of the redesigner for a subset of the alternatives to continue its search for a satisfying design (steps 5 and 6). The interaction with the redesigner and the advanced support will hopefully make our tool a truly "intelligent" system for BPR.

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