HYBRID PROCESS MODELLING WITHIN BUSINESS PROCESS MANAGEMENT PROJECTS

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Abstract
Business Process Management (BPM) is still an important research topic amongst both academics and businesses. The recent recession has forced businesses to focus on cost control and efficiency in order to better cope with the economic downturn. Many companies in this situation turn to BPM software as a means of improving their efficiency and costs by reducing aspects of the business such as process lead-times and material costs. In order to identify areas of the business and its processes which require changing the business will most likely adopt a method of modelling their business processes. Because of the large number of available techniques decision makers usually struggle to decide the best approach. Recent literature has also pointed out that prevalent modelling techniques are designed to serve one specific purpose and may not be capable of modelling the whole picture. The key relationship between the information systems and the human behaviour is one example of where existing techniques are biased towards opposite ends of the scale. This paper proposes the use of a hybrid modelling notation composed of multiple existing notations in order to bridge this. The hybrid notation was applied to a BPM project at a company in the construction industry and a case study conducted with its users.

1 INTRODUCTION

The global economic downturn has been significant in the increase in popularity of Business Process Management (BPM). As the world slipped into recession, more and more companies were urged to rethink their business processes in order to become a more streamlined, efficient and flexible organisation. The concept of BPM started in the late 1990s and has grown more and more popular throughout the early years of this millennium (Lu and Sadiq 2007, Melao and Pidd 2000). This has led to an increased focus upon business process modelling and the techniques commonly used to analyse and design business processes. Certain modelling techniques such as BPMN (Business Process Modelling Notation) and modelling families (such as UML and IDEF) have grown prevalent within the field of BPM. However concerns are beginning to emerge with regards to the usability of these notations and, as a cause of this, the model's accuracy (Fernández et al 2010, Recker et al 2006). The complex nature of certain notations means that the business analyst responsible can easily misinterpret the notation and thus model the process incorrectly. At present there appears to be a divide between informational process models, in which the notation looks to depict the information systems and logic behind a process, and behavioural models, which are aimed at modelling behavioural, human and environmental characteristics of a process. The divide between informational and behavioural business process modelling, coupled with the large amount of techniques that are available in the literature means companies are struggling to identify the notation which suits their project best.

Because of the complexity in choosing, applying and adapting existing techniques we propose the need for a new set of notation. The need for this was identified during a previous case study into a BPM project where the company faced similar problems. The notations were developed with the aims of usability and scalability in mind. The goal was that the modelling notations could be used by all levels of the business and could model the information systems and behavioural characteristics of the process in equal measure. However, due to the large number of existing techniques available within the literature (chiefly BPMN but also modelling families such as IDEF and UML and new notations such as YAWL etc), we share the belief that brand new notations would be detrimental, as stated by van der Aalst (2005). For this reason a hybrid

approach to modelling is proposed. In order to achieve this aim we take five established notations and combine their most useful components. This way the new set of notation retains an aspect of familiarity, where business users are used to most of the symbols used. In this paper we propose the basic hybrid model notation and document its application to an industrial case study.

The structure of this paper is as follows: Section 2 is a literature review where existing works in the field are discussed and the current gaps in knowledge are highlighted. Section 3 is the research methodology where the case study will be described and the plan of application will be outlined. Section 4 will introduce the hybrid model notation and explain the reasoning behind the choices made for some of its features. Section 5 will discuss the research findings which came out of the case study. Section 6 will discuss the results, highlighting those which were as expected as well as any results which were not anticipated. Section 7 is the conclusion where the findings will be synthesised against the initial literature review and any opportunities for further work will be highlighted.

2 LITERATURE REVIEW

Business Process Management (BPM) is a concept which has been rapidly growing within businesses since the late 1990s. (Lu and Sadiq 2007, Melao and Pidd 2000) BPM has become somewhat of a "buzzword" (Rausch 2006) which often gets bandied about loosely and incorrectly. One common mistake is to assume that BPM is another term for Business Process Reengineering (BPR) however the two share some differences (Armistead and Machin 1997). At a high level BPM is a methodology for improving business processes. More specifically it is a framework which is geared towards continually improving and monitoring a business process through the Business Process Lifecycle in order to enhance the quality of a product or service. The BPM Lifecycle itself is an iterative journey from process discovery/analysis, design, implementation, enactment, monitoring and evaluation/controlling see Figure 1 (Zur Muehlen et al 2006).

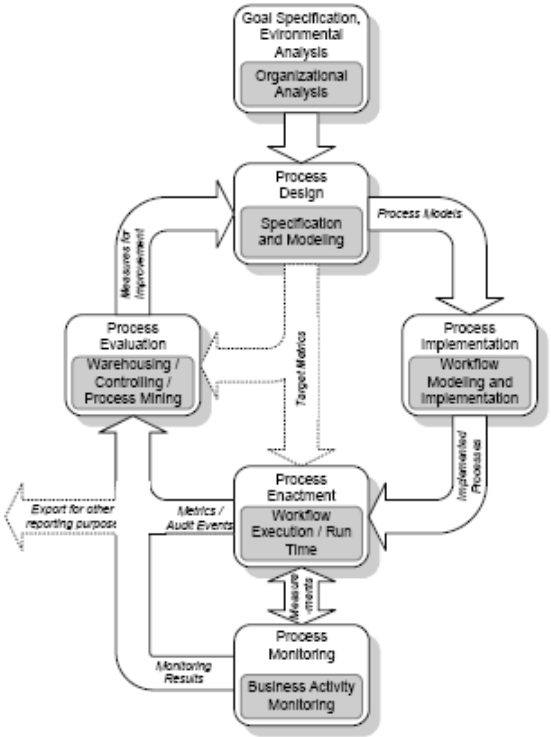


Figure 1.The Business Process Management Lifecycle (zur Muehlen and Ho 2006)

The definitions of BPM offered in the literature vary somewhat. Elzinga et al (1995) describe BPM as:
"…a systematic, structured approach to analyse, improve, control and manage processes with the aim of improving the quality of products and services."
Wil van der Aalst et al came up with the following definition:

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

Business Process Management and the concept of process innovation have been popular concepts within the literature (Serrano et al 2005, Loukis et al 2009). Investment in ICT has increased the usage and refinement of Business Process change (Elliman et al 2005). Business Process Management emerged based on Total Quality Management (TQM) and Business Process Reengineering (BPR) theories (Hammer and Champy 1990). In fact BPM is often seen a meeting in the middle of the two theories. TQM is "incremental, evolutionary and continuous" whereas BPR is "radical, evolutionary and follows a one-time approach" (Loukis et al 2009). Although a considerable number of models exist for each theory separately, they are rarely designed to integrate both aspects/theories. Serrano et al (2005) argue that "existing BP and IS design approaches are not capable of modelling this interaction". Simulation modelling is another aspect which has been traditionally associated with the manufacturing industry but, if implemented successfully, is an area from which BPM could benefit from greatly (Elliman et al 2005). Again Elliman et al (2005) argue that "despite the availability of a variety of tools for BPM, companies still face problems when trying to model in detail the way in which knowledge workers operate". So despite availability of such approaches, they seem to focus on specific issues separately.

The lack of a standard approach to workflow modelling can lead to confusion and not having a good process model can severely damage the success of a workflow project. van der Aalst (2005) stated that this lack of standardisation had created a "horses for courses" approach and indicated that a solution should use "well-established process modelling techniques". Of these "well-established" graphical techniques there are still no standard approaches. Some of the most prominent modelling approaches are Petri Nets, Business Process Management Notation, (BPMN), UML Activity Diagrams, Role Activity Diagrams (RAD), Data Flow Diagrams (DFDs), IDEF and State-Transition Diagrams (STDs) however each notation does not map a process sufficiently on its own. Notations like BPMN, UML and DFDs focus on the informational perspective of a process (e.g. the tasks, systems and information flow involved in a process). While notations such as RADs and STDs focus on the behavioural aspect of a process (e.g. concerned with how the user does something and how an action changes the state of the users and the system). A previous case study was conducted in industry where a selection of these notations were compared and contrasted with respect to their usability and accuracy (Cull and Eldabi 2009). The results of the study indicated BPMN had the most user friendly notation in the opinion of the participants of the study. The research indicated that in order to successfully create a hybrid notation, BPMN should be chosen as the foundation. The idea of standards is important. There are many ad-hoc adaptations of BPMN that can be used via annotations and comments. However annotations are generally exclusive to that person and may not appear in the same context to someone else. In the previous study we used legislation as an example. Certain companies' processes are governed by government controls such as Sarbanes-Oxley compliance. This controls how a company can design their processes as they will be subject to audit. Such control should be reflected as a part of the model, not just as an annotation. No such modelling notation has in-built standard features for aspects of compliance.

Process modelling is becoming increasingly important as the focus shifts to BPM and there are so many available techniques and standards that it is difficult for businesses to determine which notation suits their needs. One influential development in the field of workflow was the identification of the "workflow patterns" proposed by van der Aalst et al (2003). These patterns focus on both imperative and optional routing constructs which can govern the path a workflow may take. They range from basic control patterns such as sequence flow and exclusive choice gateways to the more complex structural patterns such as arbitrary cycles. These patterns have become the main foundation for the development and evaluation of many new process modelling notations including, but not limited to, Business Process Management Notation and UML Activity Diagrams, two of the most popular modelling notations (White 2005, van der Aalst 2003). Any proposed notation should at least conform to the basic workflow patterns.

3 RESEARCH METHODOLOGY

The proposed methodology for the research was to undertake an action research case study in a live BPM project. In order to evaluate the hybrid notation in a business context, the same company which was the basis of the initial study into the need and feasibility for a hybrid notation (Cull and Eldabi 2009) would

be revisited. In the previous study we asked business users of all levels and experience to use existing notations and rate their usability and effectiveness. This led to the belief that the specification of the hybrid notation would best be based upon BPMN, which scored highest during the research. In this paper we document the specification of the hybrid notation, along with the justification behind the decisions involved in deciding upon the more important notations. In order to apply the hybrid model the following steps were undertaken, these steps are detailed below:

- First, we defined the business context and identify the areas of the business which cannot be addressed by existing techniques.
- Second, we selected the pilot process which we would use to apply the hybrid notation and define our evaluation criteria.
- Third, we developed a hybrid model as well as models built using prevalent methodologies for the pilot process.
- Finally we evaluated each model using the evaluation criteria in step two. To form our results we used the formally documented results from our company survey and also results of a thorough literature review. Opinions of each notation formed by both business users and reviews performed by academics were then used to formulate a ranking system whereby each model was rated against each criterion.

3.1 Business Context

The research was based at a company in the construction and mining equipment industry whose market was world wide. As the company was listed on the New York Stock Exchange they were forced to comply with the Sarbanes-Oxley Act of 2002 (Butler and Ribstein 2006, Volonino et al 2004).This forced the organisation into a full review of all of their business processes meaning that in the short term efficiency and costs would have to rise. The organisation chose to view this as an opportunity rather than a threat and installed a Workflow Management System to automate their business processes. The goal of the project was to emerge from the review before their competitors in a more flexible and efficient manner than they were before. The company brief stated the impact of SOX was "the compliant processes are cumbersome and labour intensive to operate, and as such represent a risk to the longer term competitiveness" of the company.

As the company had little experience in this kind of work they arbitrarily decided on the tools they would use based on the popularity of the theory. The end result was that processes were mapped using a perfectly good notation that was not suited to the goal of the project. They had designed what seemed to be a perfectly good workflow but during the roll-out of the process more and more problems arose.

The first was that although the process design showed what should happen, it did not reflect how things were being done in real life. This is not always a bad thing, business process management generally aims to improve the process, and so developing a bad paper system electronically is not a good idea. However the company's problem was that the process was not being followed as per the procedure. Certain members of staff, for example, were delegating responsibilities to a different department where there was a different skill set. The procedure stated they had to take an action within the process and so the information flow was documented accordingly. However such delegation activity was not formally documented within the stated process. The result was that when the process was released to the business, staff did not have the skills required. The concept of user states was not captured as part of the process. The user had to complete an action in order to move the information flow forward but when he/she received notification action they did not perform it straight away, given the lack of clarity of the flow. The information was then passed elsewhere thus making the user inactive until the other department told them what to do. Once the external task had been completed notification was sent to the user who then became active again. This shows the low level of utilisation that was created by the existing system.

The second issue which was not portrayed very well within the company's models was the communication and interaction between functional bands. Most popular modelling techniques have notations that represent functional business units or roles and allow the information flow to move between them. However one aspect that is often neglected is the types of information that is being communicated. Existing informational models show which bands an interaction involves but do not describe the nature of the information. This was imperative to the organisation in this research as they had SOX critical data being passed between functional business units at differing levels of authority. A description of the interaction between business units was required to identify what information was sent and where it went next. This

helped the developer and potentially auditors ensure that SOX critical data was being handled correctly and compliantly.

The final problem was that the company wanted to identify tasks as SOX critical. Certain tasks within their processes were deemed SOX critical, for example, when a process has a direct impact on financial accounts. These were tasks which, if not handled correctly, could cause a compliance issue. Most companies who need to comply with legislation such as SOX use a control methodology such as COSO or COBIT to identify and document their internal controls meaning that a company will be able to cross reference tasks which are stringently controlled. The organisation in the research found that it would have been beneficial to cross reference these controls in the model as it would have been easier at an early stage to identify tasks which were deemed important and those which were deemed unnecessary

The company identified the need for a new strategy and came up with the following mission statement:

"Develop and establish a best practice implementation strategy to enable migration of core business processes onto Business Process Management software to enforce Sarbanes-Oxley act compliance."

The brief that was given by the company stated that existing modelling notations were not:

"… reusable and scalable to a variety of other business processes. There are many methods for modelling business processes that are available in the literature, which are predominantly theoretical in nature and rarely result in real-world solutions. Secondly, existing methods are based on finding the best solution given resource constraint… [There is a need to] develop comprehensive models that link/combine the business process, information flow and customer oriented services… The project aims at developing a business process modelling methodology that is relevant to [the company], can be easily applied by other staff and delivers processes that are scalable".

3.2 Applying the Hybrid Notation

For the purpose of this project the researcher undertook the roles of process analyst and developer within the organisation. The drivers behind the majority of projects at the company were driven by the goal of compliance however some projects were chosen because of efficiency potential. The drivers for the process model were to help both analyst and developer define the process in a manner such that the models could then be used to describe the process to business users and potentially auditors. This meant that the model needed to identify inefficiencies in the process, highlight compliance issues, be scalable to a variety of processes whether clerical or production whilst retaining an easily readable and scalable notation.

With this in mind a process was selected from the company's list which had a cross-section of the majority of important features of the hybrid notation. The company's "New Hire" process was one in which there were legislative issues, parallel processing, decision points, sub processes and user state changes. This process was selected as the pilot process with which the methodology would be tested.

The process would be analysed, designed and developed using the hybrid model and rated against similar models using different techniques. There will be four evaluation criteria:

- User Feedback
  - As with our previous study, business users would be asked to rate each modelling notation as to its usability and accuracy
- Notation Perspective
  - How well the notation models the informational and behavioural aspects of the process
- Potential Scalability
  - How easily the notation can be modified for simulation/execution or for training exercises
- Usability/Familiarity
  - How popular the technique is and how easy business users found it to use.

4 HYBRID BUSINESS PROCESS MODELLING NOTATION

The specification for the informational aspects of the notation was heavily based upon BPMN. This was because the findings from the previous research study (Cull and Eldabi 2009) indicated that the majority of users were familiar with BPMN notation or similar methodologies as a method of modelling process flow. Features borrowed from BPMN include swim-lanes, tasks, subtasks and exclusive choice diamonds. One feature of BPMN which was replaced was the notation for parallel splits. Users were confused by the BPMN symbol for this and so it was replaced with the more favoured UML fork and join nodes. The

argument from the users in favour of this approach is that diamonds indicate that a choice of some kind is required whether it is an exclusive or a multiple choice gateway. The parallel split is indiscriminate and a token will be generated for each path regardless and so should not be symbolised by a diamond.

A feature which was included in the specification was a method of integrating issues such as compliance into the process model. Figure 2 shows two tasks which the organisation deemed SOX critical. Each of these tasks appeared on the company's risk control matrix and so development of these tasks must comply with the information contained within it. In order to cross-reference tasks within the process model to a company's internal controls an optional extension to the regular symbol for a task. The task is given a reference number within the model and the company's control number is cross-referenced against it. In the example in Figure 2 we can see two SOX critical tasks as well as the company's internal controls which govern them. This is useful in development, training and auditing. The company in question used this technique to identify parts of the process which had been highlighted as control risks in recent audits thus prioritising segments of the process and aiding the process of identifying areas which required improvement.

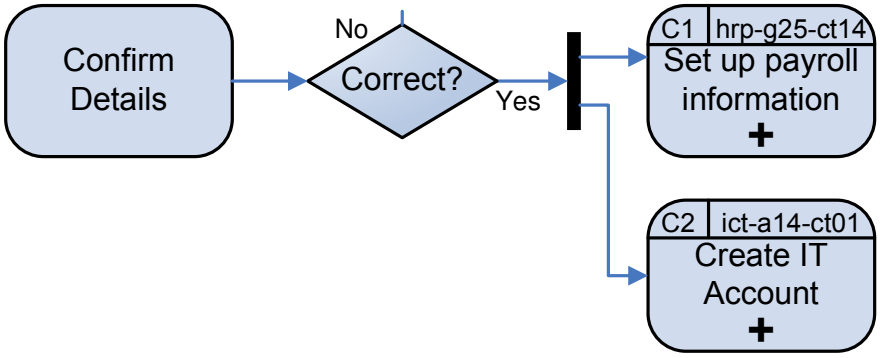


Figure 2 .Exclusive choice and parallel split showing SOX critical sub-processes

The next important concept which was introduced to the business was the concept of user states. Users can be active or inactive within a process. If the user is active it means they are required to perform an action to move the process to the next stage. When they are inactive they may not have a physical item of work but they still do something outside of the system which has an impact on another part of the process. The example in Figure 3 demonstrates an instance like this. Once a department manager creates a new hire form he/she sends it for approval and does not receive it back until the new member of staff has been created in payroll and IT. During this period of time the manager does not disappear, he/she still has duties within the business, some of which have an impact on this process. In fact it is the manager's responsibility to prepare for the new arrival by ensuring there is an available desk, freeing up time in his diary for the employee's induction and making the department aware of their responsibilities on the start date. These actions are not physical parts of the workflow but are important aspects of the process which potentially could highlight a missing step or inefficiency in a process. The notation used to symbolise user states was similar to that of IDEF object level states and activity cycle diagrams. The transition from an active to an inactive state is depicted using a dashed line instead of the solid line which shows a user action or interaction.

Figure 3 also shows the notation for an interaction description. Interactions can be used to define what information is passed from stage to stage. This is useful as it helps to identify the required inputs and outputs to and from each task. This information can be used to demonstrate what changes and transformations are imposed upon the information flow as well as showing which business functions can view what data. SOX critical interactions or interactions which require encryption, such as communicating passwords, can be depicted as a jagged line. The use of user states and interaction descriptions help show how people do what they do while the informational symbols show what happens.

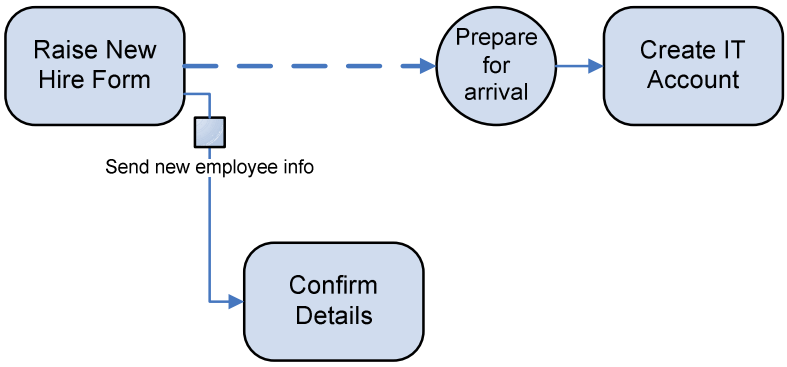


Figure 3. Notation for state changes and interactions

Some of the notations discussed, such as the interaction descriptions and headings for SOX controls, can be handled in BPMN as informal annotations so it could be argued that these additional notations proposed are not needed. However the problem with using such informal methods for documenting business processes is that the methods and techniques used by different people will differ and because of this each model loses accuracy and requires further documentation and explanation. As we strive towards standards and best practice such informal annotations should be forgotten about and, where possible and where useful, replaced with standard notations.

In addition, some existing features of BPMN, such as the AND-SPLIT notation, have been replaced with features of other frameworks. The decision to remove the AND-SPLIT symbol was one based upon a small research group but based upon valid and logical reasoning. Experienced users are comfortable with using the AND-SPLIT for multiple choice gateways and so there is no problem. However the goal was to create a methodology that is easy to use for all level of user and making the diamond available solely for use in discriminate decisions means that there is less room for confusion. Users of the proposed framework will know as soon as they see a fork or join node that there is an indiscriminate split and that if they see a diamond that the decision is discriminatory. The basic notations are described in Table 1 and example of its application to the pilot process can be found in Figure 4.

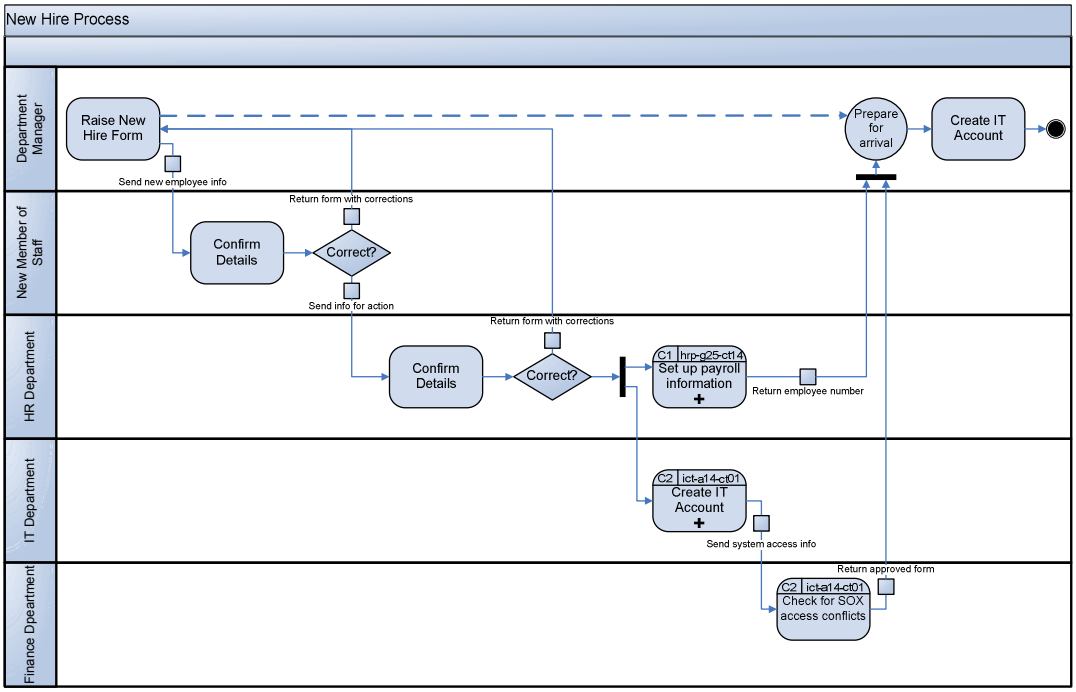
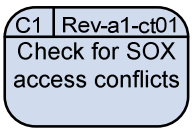
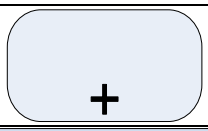
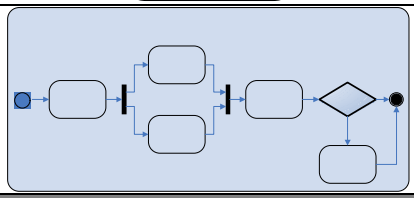
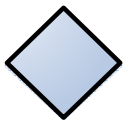
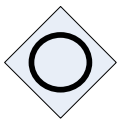
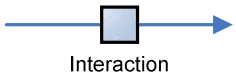
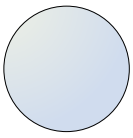


Figure 4.Hybrid Notation applied to pilot case study process

Events			
Element	Description	Notation	Parent Notation
Start	An event which determines where the process will start		BPMN
Intermediate	An intermediate event happens between a start and end event, influencing the process flow but not starting or ending it		BPMN
End	An event which determines where the process will end		BPMN
Message	Event is triggered by receipt of a message		BPMN
Timer	Event is triggered by meeting a certain time		BPMN
Error	Event is triggered by an error		BPMN
Cancel	Indicates the transaction should be cancelled		BPMN
Terminate	All instances of the process should be terminated without compensation		BPMN
Activities			
Element	Description	Notation	Parent Notation
Task	A task is an atomic activity and will be used where the component of the process is not broken down into finer detail		BPMN
SOX Controlled Task	An atomic activity which is governed by legislation. The task is formally annotated with control detail		N/A
Sub-Process	A task which can be broken down into a finer level of detail		BPMN
Expanded Sub-Process	The sub-process is the finer level of detail described above encased in the sub-process boundary.		BPMN
Gateways			
Element	Description	Notation	Parent Notation

XOR-Split (Exclusive)	An XOR-Split restricts the flow so that only one of a given set of outcomes can be realised		BPMN
OR-Split (Inclusive)	An OR-Split is different to an XOR-Split in that one or all of the potential outcomes may be realised.		BPMN
AND-Split (Parallel)	Creates a parallel flow where all potential outcomes are realised in each iteration of the process.		UML Activity Diagrams
Complex	Complex gateways are used for situations which are not easy to model through use of the others		BPMN
Sequence Flow			
Element	Description	Notation	Parent Notation
Uncontrolled Flow	Standard Process flow, unaffected by conditions		BPMN
Conditional Flow	Used if sequence flow leaving an activity has conditions upon it.		BPMN
Message Flow (Passive)	Shows flow of messages between entities		BPMN
Interaction Description (Active)	Used to describe the nature and content of an interaction between two entities, driven by the activity from which the interaction is leaving.		Role Activity Diagram
Sensitive Data Flow	Used in the event of data or messages being passed between entities where the content of the flow is sensitive or its handling controlled by legislation		N/A
Behavioural Elements			
Element	Description	Notation	Parent Notation
User State	Describes the state of the entity whether active or passive within the process. Identifies the human behaviour within the automated workflow		Activity Cycle Diagram/ IDEF3

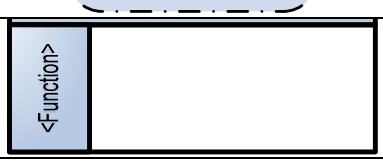
Activity Group	Groups a set of activities for documentation or analytic purposes		BPMN
Role	Represents a participant or entity within the process		BPMN/ UML Activity Diagrams

Table 1: Basic specification for the Hybrid model

5 RESULTS

The notations proposed in Table 1were applied to the new "hire process" introduced in section 3 (Figure 4) and passed to users within the project team, each with varying backgrounds and capabilities. Models for the same process were created using BPMN, UML Activity Diagrams, IDEF 3 (Mayer et al 1995), Activity Cycle Diagrams and Role Activity Diagrams. The names were removed from each of the models and users were asked to compare and rank each of the models according to their preference. The study was done behind closed doors and no one knew the results of each others rankings. For each user the highest ranked process was given 3 points, the second ranked was given 2 points and the third placed model was given 1 point. All of these scores were then compiled to give an overall preference within the company. In total ten people took part in the research; 1 director, 1 manager, 1 project manager, 2 seniors, 1 analyst, 1 developer, 2 end users and 1 academic. This meant a diverse set of opinions and ideals were contributing to the research. The results of the study indicated that the hybrid notation was a success within the project team as it scored higher than the rest. Unsurprisingly BPMN, upon which the hybrid notation was heavily based, was ranked second. The other notations were ranked fairly similarly. The reasoning behind this when asked afterwards seemed to be that the style of the notation BPMN adopts is most like what people expect when they this of a process model. Another interesting point is that informational modelling notations seemed to score higher than behavioural ones. This is possibly because at a glance users just want to see what happens and not necessarily how. The behavioural models were most likely scored higher by analysts and developers who need to see the process in more detail. A full list of the results can be found in Table 2.

IDEF3	4
Role Activity Diagram	4
Activity Diagram	6
Hybrid	25
Activity Cycle Diagram	4
Business Process Diagram	17

Table 2: Results of research into application of hybrid model to the pilot process

6 EVALUATION

The results in section 5 indicate that the hybrid model was well received within the company in the case study. The notations used were essential in helping the company identifying their SOX controls and highlighting potential compliance risks. The only components that were used during the project were those detailed in Section 5. This was enough for a basic project as the existing notation allows for all basic process modelling constructs. However the need to expand the notation became apparent as larger projects were discussed. The expansion of the notation and its application to other projects is outside of the scope of this paper but the need to refine the methodology to meet the more complex workflow patterns is recognised. Interaction with external bodies, complex routing constructs and iterative, repeating actions were some of the features that were discussed with the company for future projects but were not considered in great deal within this paper. However BPMN already offers graphical elements which are capable of handling such scenarios. Such constructs were listed in the specification in table 1 but were not applied to a business scenario so have not been tested as such. As we are using an existing, well supported notation it is easy to assume that integrating these notations would work just as well.

In Section 3, three evaluation criteria were defined. These were:

- Notation Perspective
  - How well the notation models the informational and behavioural aspects of the process
- Potential Scalability
  - How easily the notation can be modified for simulation/execution or for training exercises
- Usability/Familiarity
  - How popular the technique is and how easy business users found it to use.

The next step is to evaluate the hybrid model and the other four models discussed in this thesis against these criteria to see if the development of the notation met the criteria. The results of the evaluation can be found in Table 3.

	Notation Perspective		**Potential Scalability**			**Usability/Familiarity**	
Model	Information flow	User/System Behaviour	Simulation	Execution	User Training	Popular Technique	Easy to Use
UML Activity Diagrams							
BPMN							
Activity Cycle Diagrams							
Role Activity Diagrams							
Hybrid Model							

	Scored Highly
	Scored Average
	Scored Badly

Table 3: Each model measured against evaluation criteria

Each model was rated during the research both by literature and during the empirical research during the case study. Where a model scored highly, they are given a dark grey mark, average was given grey and poor was given light grey. Table 3 shows similar results to the feedback given during Section 5. Of the existing methodologies, BPMN was deemed the most suitable while the hybrid methodology received the best feedback of all of them when it was applied in Section 5. By looking at Table 3 we can say that the hybrid notation meets the requirements of this thesis.

7 CONCLUSIONS

This paper investigated the suitability of existing modelling techniques for use in modelling business processes in BPM projects and proposes the use of a hybrid modelling notation. This was based upon a previous study (Cull and Eldabi 2009) where popular techniques were identified and applied to a case study BPM project where existing techniques were assessed. The results indicated that no technique can adequately handle both the informational and behavioural aspects of a process. This led to the proposal of creating extensions to existing notations and combining their most useful aspects into one hybrid notation.

The hybrid notation was heavily based upon BPMN which scored highest during the survey. Its informational notation is one which is familiar to most business users and is already a prevalent technique used both in literature and business. The BPMN notation was merged with different symbols from the other reviewed techniques to create a more flexible extended version of BPMN. Things such as SOX controls and interaction descriptions now have a formal notation which can be recognised by all business users. Previous such components of a process were possible to model in BPMN using informal annotations however it was believed that such informal text should be avoided and where possible a standard symbol should be used.

The hybrid notation was then applied to a BPM project at Komatsu UK Ltd and reviewed with a project team of varying skill levels and experiences.

BPM projects with the driver of SOX compliance are an area which has received little attention in the literature. Most BPM projects, and indeed BPM itself, are geared towards improving efficiency, lead-times and cost. While these are all important factors of the BPM lifecycle the goal of SOX compliance is not a long-term goal which the company hopes to achieve, it is a short term necessity the company *must* achieve. Because the drivers of the project are different, so are the objectives and thus it is important to assess whether existing tools within the field are applicable. The aim was to define a process modelling methodology to be used in such situations. The thesis proposes a hybrid modelling methodology in order to solve this aim. It was deemed that no one existing process modelling notation could fully and adequately model SOX compliant processes so the decision was taken to merge these techniques in order to solve the research problem. The new hybrid notation offers formal descriptive elements to capture SOX restrictions and sensitive information flow.

This is not to say that the notations proposed in Section 4 can be generalised. The survey conducted was very small and will need to be expanded to refine the methodology. The point is not the notations proposed but the benefits of using hybrid modelling to solve a problem such as this. Whether or not the specification of this hybrid model is applicable outside of the scope of this case study is unknown as yet, but the main contribution is that by combining and refining existing techniques in an incremental fashion it is possible to solve the problems that are being faced, maybe better than by creating a brand new methodology.

This research was an empirical study at a business struggling to meet the objectives described above using existing techniques. BPM literature often lacks empirical business studies. The theoretical foundation of the modelling techniques described in this paper is sound but when applied to the case study in practice it did not meet their objectives. This paper identifies the problems which companies implementing BPM with the goal of SOX compliance may come across and aims to solve them through slightly adapting existing practices. By adapting these existing methodologies we are basing decisions upon highly regarded techniques and theory and moulding them to fit a new objective.

The main limitation with this research is that its scope is very small. The surveys conducted were limited to two companies and only a small number of people were directly involved with the research. Ideally the sample would have been a lot larger in order to gain a broader spectrum of opinion. However the results of each survey can be backed up by other literature where notations such as BPMN are being championed and the informal interviews with Metastorm were based upon a larger sample of users. Another limitation is that this paper only covers the first two parts of the BPM lifecycle. The techniques proposed were concerned only with business process modelling and not the other factors that are problematic within SOX driven BPM projects such as process identification, selection and development. This paper has only looked at analytical and specification modelling. As the notation is based upon existing methods such as BPMN, it is based upon proven theories and parts of its notation are already popular both in the literature and in industry. This also means that as BPEL (Business Process Execution Language) evolves the hybrid notation can be adapted to suit this need and the process level models discussed earlier can be converted to an executable level model. This is potentially an area for future research.

The next step however is to refine the methodology and apply it to more case studies within industry to gain a more in depth evaluation of its usefulness. The notation, as it stands, should conform to the 20 mandatory workflow patterns (Russell et al 2006) however further study should formally test the hybrid modelling specification against these and the additional twenty-three.

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