A Prescriptive Approach to Business Process Modelling

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ABSTRACT

Business process modelling approaches are expected to describe business processes and prescribe advices for decision makers to implement changes to business processes for improvement or reengineering projects. Being prescriptive means that predictive advice becomes outputs to facilitate the construction of a "to-be" situation with the inputs including proposed changes and the "as-is" situation. Much effort has been made both on the descriptive ability to give a precise and close description of existing business processes and on the analysis of potential problems and changes impact. However, little work has been done to prioritise the prescriptive ability, therefore reducing stakeholders' involvements and slowing down the transition from the "as-is" situation to the "to-be" situation through change. This research proposes a prescriptive approach to business process modelling comprising a variable-oriented meta-model and an associated methodology. This approach utilizes concepts from quantitative modelling and feedback control theory to impose a systematic transformation process. A case study of an electricity distribution division illustrates the applicability of the developed approach.

1. INTRODUCTION

Business process modelling is an essential step of Business Process Improvement (BPI) and Business Process Reengineering (BPR), both of which targeting existing business processes. Given the complexity of an organization and the hefty cost incurred by the implementation of business processes, the possibility of experimenting with proposed changes to real systems is difficult to attain. This suggests research on business process modelling may be achieved from two aspects: the descriptive modelling, and the prescriptive modelling. Descriptive modelling focuses on the elicitation and the representation of business processes so that related knowledge can be understood and shared. The intention of prescriptive modelling is to provide process analytical support through modelling and facilitate process evaluation and alternative selections by giving predictive advice. Descriptive modelling approaches are favoured at the early stage of business process improvements and in reengineering projects, and at the moment proposed changes are evaluated, a prescriptive model grows more desirable, because knowing and sharing the effect a change will induce on an overall organization with stakeholders and justifying whether this effect is expected become primordial.

Recent modelling approaches offer the prescriptive ability through the addition of organizational concepts, eg. goals, and non-linear causal relationships. The use of these prescriptive elements helps to elicit the rationale of existing business processes and estimate the potential effect of a change. However, because of the qualitative expression of information, the preciseness of the analyzed results and the usefulness of justifying decisions are limited. Also, a systematic process support is missing when dealing with increased complexity.

Focusing on prescriptive ability, this research proposes a quantitative business process modelling approach comprising a variable-oriented meta-model and an associated methodology. This approach complements descriptive modelling approaches and is suitable to be applied at the stage where changes to existing business processes are to be evaluated for the construction of a "to-be" situation.

This paper gives an analytical summary of the existing business process modelling approaches in terms of their prescriptive and descriptive dimensions. The discussion is then directed to the desired properties of a business processes modelling approach owning the prescriptive ability. The variable-oriented meta-model is presented in the fourth section, followed by a description of the methodology in the fifth section. A case study is conducted with the presence of the methodology to illustrate the applicability of the proposed approach.

2. BACKGROUND

A business process is a main component of an organization. In a business process, a sequence of atomic activities is conducted to deliver a service to customers for the achievement of a goal.

Business process modelling approaches fall into three classes, descriptive, semi-prescriptive and prescriptive.

A number of modelling approaches have been developed to represent an organizational view of a business process, each one emphasizing on a given aspect. Activity-oriented approaches, eg. IDEF0 (Mayer, Benjamin et al. 1995), (IBM, 2002) highlight a specific ordering of activities in a business process. Role-oriented approaches (Ould, 1995) go beyond the mechanistic thinking in activity-oriented approaches and embrace the consideration of responsibilities undertaken by an organizational unit. A role involves a collection of responsibilities which are carried out by a set of activities (Ould, 1995). This approach brings a business process into the social context of an organization and highlights that business process redesign is not only an effort to optimise the order of activities, but also a restructuring of the organization's resources, eg. physical and human resources, and organizational hierarchies. Actor-oriented approaches make another organization concept, the actor, explicit, and introduce an aspect of implementation of a business process into process modelling. An actor is "the physical entity that personifies an instance of the role at any given moment" (Prekas and Loucopoulos, 2000). Additionally, object-oriented modelling (Wang, 1994) considers business processes as a set of objects interrelated with each other.

Some semi-prescriptive organization-oriented approaches (Yu, 1996), incorporate intentional elements into the description of a business process and provide a certain degree of analysis by offering a rationale of business processes.

One proposed methodology (Gong, Li et al., 2004) has a prescriptive ability by building cause and effect relationships among business process variables using the facility of causal loop diagrams, from system dynamics research (Forrester, 1961). This methodology emphasizes the significance and efficiency of utilizing cause and effect relationships in the analysis of business processes. However, its applicability is limited to guidelines, and a lack of a formalized mechanism reduces its applicability for nontrivial projects.

3. THE EXPECTED PROPERTIES OF A PRESCRIPTIVE MODELLING APPROACH

The quality of a prescriptive modelling approach depends on the quantity of trustworthy analyzed results and the degree of the controllability on a real system, gained from these results.

3.1 Quantitative Modelling

Whether a constructed model is scientific and is a close enough representation of a real system is critical to determine the degree of trust in the results. Quantitative modelling is "based on a set of variables that vary over a specific domain while quantitative and causal relationships have been defined over these variables" and its quantification is considered as a way to build a scientific model. (Bertrand, 2002).

The existence of variables is a precondition to construct a quantitative model. Research into quantitative management (Anderson, 1994) has considered that an organization is an amalgamation of variables. Furthermore, the business process level is the location of conducted activities, and data collected from this level can be used as a feed into variables in a constructed quantitative model. This ensures the model is a close representation of the organization in reality.

Generated quantitative results from the model are numerical and allow closer scrutiny than qualitative results. This helps decision makers conduct evaluations and make their decisions.

3.2 Controllability

The controllability of a prescriptive modelling approach embodies itself from two aspects.

Firstly, in models developed with this approach, the controllability is demonstrated by the ease of the traceability of the impact that a change may cause when this change is applied to such developed model. The concept of feedback loop originates from the servomechanism control theory (Porter, 1950) in the field of engineering, and is developed as a component in the research of system dynamics (Forrester, 1961) to model and analyze social systems. The use of feedback loops facilitates making both this traceability and the effect caused by changes clear. A control mechanism is built in whenever a loop is formed.

Secondly, the controllability on a real system can be secured from analyzed results. Measurements, as a quantitative utility, are recognized as an efficient management tool. The ability to measure something is a precondition to control it (Kaplan &Norton, 1992). A number of performance management frameworks based on measurements (Platts and Tan 2002), (Keegan, Eiler et al. 1989), (Cross and Lynch, 1988), (Kaplan and Norton, 1992) have been developed to enable an efficient use of data. Incorporating variables representing common characteristics of data, that are measurements collected from the business process level, into a model, enables relating analyzed results with the measurements, and corresponding variables of a model with activities that can be conducted for the implementation of changes.

4. A PROPOSED PRESCRIPTIVE BUSINESS PROCESS MODELLING APPROACH

This prescriptive business process modelling approach is developed to achieve these expected properties. This approach consists of two components, a variable-oriented meta-model and a methodology.

4.1 A Variable-Oriented Meta-Model

The developed meta-model is an abstraction over quantitative aspects of business processes and a set of developed concepts is to be used with the proposed methodology. Additionally, this meta-model also serves as a reference for the later formalization and automation of organizational knowledge management.

The concepts developed in this variable-oriented meta-model are defined here.

Variable: a symbol containing different values under different circumstances. Each variable may be refined into a strategy variable, a process variable or an operational variable.

Strategy variable: a symbol that represents a property of an organizational strategy.

Operational variable: a symbol that represents a common characteristic from a set of data which are derived from measurements of actual activities of an organization. Operational variables have actual measurements as values.

Process variable: a symbol that serves as a bridge between operational variables and strategy variables.

Value: a numerical quantity associated with a variable. A "Value" entity has two sub-entities, measured value and deferred value. These two sub-entities are, respectively, the numerical quantity obtained from organization data and the numerical quantity obtained from the transformation of a set of variables' values according to a mathematical formula.

Relationship: a quantified causal relationship between two variables. A change on a variable' value results in a change of another variable's value. This relationship is either implicit or explicit.

Mathematical functions: a mathematical function defines how a change on a variable's value will affect other variables' values.

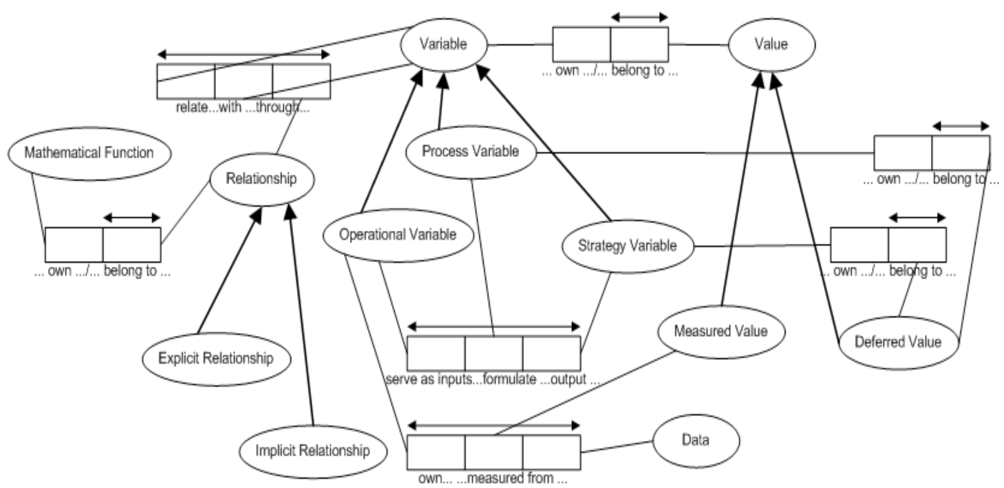
Explicit relationship: when a relationship between two variables is deferred from available knowledge, this relationship is explicit.

Implicit relationship: when two variables relate with each other in a way which cannot be derived from available knowledge, this relationship is implicit.

Operational variables have measured values while strategy variables and process variables have deferred values. The values of operational variables serve as inputs to calculate values of process variables, which themselves are used as inputs into strategy variables.

This meta-model presents the quantitative aspects of business processes and yet it is not purely mathematical as these variables are classified in an organizational context. By integrating concepts from organization management (Loucopoulos, 2003), variables, scattered in an organization, are shelved at three levels: the operational level, the service level, and the strategy level. Operational variables belong to the operational level, where business processes are conducted as sequences of atomic activities. Process variables belong to the service level, at which business processes deliver services. These two levels contribute to the achievement of organizational strategies at the strategy level which accommodates strategy variables. It is prescriptive in that variables at the three levels are interrelated in a logical "input-process-output" order (Platt &Tan, 2002). The achievement of organizational strategies is justified by the values of strategy variables outputted

Figure 1. Variable oriented meta-model



from the transformation of values of operational variables through process variables. Values of operational variables are collected from data gathered from real happenings of business processes, as this ensures the validity of the justifications and enhances the efficiency of control.

4.2 A Methodology

This methodology provides process support to instantiate concepts developed in the meta-model and presents the way in which the prescriptive ability is achieved in four steps. This methodology complements qualitative modelling approaches and is applied at the later stage of business process analysis when changes are proposed and evaluated.

The presentation of this methodology is accompanied with the conduction of a case study to illustrate its applicability. The background of this case study is set in the distribution division in an electricity group. This division is responsible for the transportation and delivery of electricity to consumers. With the opening of the European electricity market, the monopoly position of this division is challenged by future competitors. The distribution division responds to these challenges by a redesign of its business processes through a customer-oriented perspective. Research work (Kavakli & Loucopoulos, 1999), (Prekas & Loucopoulos, 2000), has been done to describe existing business processes, analyze the factors which have led to changes, and propose changes to these existing processes. This current research builds on this previous work and plans to apply the proposed approach as a further step in the transition to a "to-be" situation.

Step 1: Represent an Organization with a Generic Set of System Variables

The generation of a set of system variables is the process of representing a quantitative view of a whole organization. This step is necessary in that having a set of system variables is a precondition to fit variables, introduced by changes, into a global view of an organization and thus observe the changes effect in the context of the organization rather than within the limits of local areas where these changes occur.

The varieties of organizations and the complexity of variables result in the difficulty of generating a method with which such a set of variables can be developed. The concept of system variables is a reminder that a high level view should be taken in the extraction of these variables, as plunging too early into specifics risks missing a global view. The developed four levels view helps to discriminate system variables and to serve as a guidance to extract the proper ones. These four levels are business process implementation dependent, business process design dependent, organization dependent, application domain dependent. At the business process implementation dependent level, each atomic activity of a business process is conducted and thus variables from this level are the most specific. System variables should be elicited from a unique level, this level being higher than the business processes implementation dependent level. It is recommended to extract variables by starting from the highest level and going down to the suitable level of interest. This top to bottom method has the advantage of building a global but simplified view at the beginning and gives the possibility of zooming into a specific picture later. Figure 2 gives examples of variables at each level.

In this case study, system variables from a distribution division are elicited as listed in Figure 3 at the organization dependent level. These variables represent main states of main objects in this division.

Figure 2. Variables in the four levels view

Application domain dependent level	Eg. the number of customers
Organization dependent level	Eg: the number of customers who contact with PPC office
Business process design dependent level	Eg: the number of customers who visit PPC office personally
Business process implementation dependent level	Eg: the number of customers who visit PPC office personally during January 2006

Figure 3. Elicited system variables from the electricity distribution division

System Variables at the organization dependent level	
Object: Customers	The number of potential customers
	The number of customers who apply for connections
	The number of customers who sign contracts
	The number of customers who get connected
	The number of customers who get disconnected
Object: Electricity	Electricity in demand
	Electricity available to be distributed (network capacity)
	Electricity ready to be used
	Electricity measured
	Network capacity used
	Network capacity unused
Object: Material	Material in use
	Material in inventory
	Material in construction
	Material idling
Object: Payment	Payments billed
	Payments made
	Payments recorded

Step 2: Transform Changes to Variables

The second step consists in transforming changes into variables. Changes are proposed and expressed in the format of goal hierarchies which consist of strategy goals, sub-goals and operational goals (Kavakli & Loucopoulos, 1999). Changes might be limited to the operational level in order to improve existing business processes; alternatively, changes might occur across the operational level, the service level and the strategy level, because organizational strategies are shifted to new ones. Updated strategy goals usually underlie expected states of objects. Because these states are observable and quantifiable, they are used as labels of variables to represent the changed strategies. Sub-goals bridge strategy goals with operational goals and they achieve strategies by relating to a business process or to a service. Process variables are elicited from these sub-goals. The labels given to these process variables vary with the characteristics of these sub-goals. They might be strategy variables associated with a business process or a service. They also might be properties of the transition between two states of an object. When a sub-goal refers to a service, its variables can be extracted from possible criteria to justify this service. Operational variables are elicited from these operational goals and they represent either properties of an atomic activity or common properties of several atomic activities. When an operational goal involves more than one atomic activity, the use of process variables at the business process design-dependent level narrows the gap between process variables from sub-goals and operational variables, and also eases the communication and understanding of the relationships among variables, although using these intermediary process variables is not necessary.

Changes in this distribution division not only take place at the operational level but also reach the strategy level; therefore, the transformation is conducted at the three levels of the organization. The figure 4 shows examples of each used heuristics including elicited variables and their corresponding goals. When operational variables are elicited from the operational level, corresponding atomic activities are identified for the later specification of relationships among variables.

Step 3: Specify Cause and Effect Relationships Among Variables

This step involves two tasks. The first task is to locate variables causally related and the second task is to quantify these relationships with mathematical functions.

There are three ways to trace the causal relationships among variables. Firstly, deduced goal hierarchy from qualitative analysis (Kavakli & Loucopoulos, 1999), (Yu, 1996) is a resource to relate operational variables with strategy variables

Figure 4. The transformation of changes to variables

The level where changes take place	The classes of goals where changes occur	Heuristics used in the transformation	Examples
Strategy Level	Strategy goals	Expected states of an object	Goal: improve customer satisfaction Variable: customer satisfaction
Service Level	Sub-goals	Expected states of an object	Goal: improve load forecasting methods Variable: the preciseness of forecasted load
		Expected states of an object and related business processes	Goal: improve customer satisfaction for new installation requests Variable: customer satisfaction for new installations
		Properties of a transition between two states of an object	Goal: improve load increase satisfaction Variable: load increase satisfaction
Operational Level	Operational goals	Properties of an atomic activity	Goal: Minimise the waiting period for new installations Variable: the time of installation construction when customers ask for new installations
		Common properties of several atomic activities	Goal: Minimise the waiting period for new installations Variable: the waiting time for a new installation which involves the atomic activities, "installation construction", "service order creation", "the communication between service Dept. and studies. Dept."

through process variables. This resource offers an initial sketch of relationships among variables. Secondly, the identification of atomic activities that operational variables share enables building possible links among the related variables. The third way is to fit system variables into a network of elicited variables, ensuring that all system variables are embedded into such a variable network and that this network is a comprehensive view of the organization. In this network, system variables play the role of process variables or strategy variables.

The relationships among variables should be quantified. Explicit relationships are quantified by using available knowledge. Implicit relationships, often appearing with the introduction of new variables, exist because of common sense, intuition and experience. The transformation of implicit relationships to explicit relationships is a process of proving them scientific. The feasibility of the transformation resides in the presence of data, either gathered from history or collected from experiments.

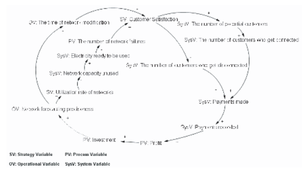
Figure 5 gives a partial view of the identified causal relationships.

Step 4: Causal Loop Analysis

A loop is a set of variables linked together by a circular dependency chain. This step consists of highlighting loops and checking whether variables expected to be controlled belong to a loop or relate themselves with variables belonging to a loop. As a loop is a control mechanism on system behaviours, this step, in essence, is a way to identify or introduce control mechanisms. The observation of the loops helps to check the effect of changes and impose control to adjust unexpected effects. When a loop contains variables linked by decision information flow, the control is enabled through decisions from human beings and thus requires human beings' interventions. Variables linked by decision information flow are only causally related when a decision is made. When options exist for making a decision, multiple decision information flows can be built to form loops. These related variables, as controllable variables, should be emphasized because they are the places where human beings have the ability to affect system behaviours.

In the case study, causal loops are identified to analyze the effect of changes and where controls are imposed to limit unexpected effect. The distribution division expects to obtain information of which proposed changes will bring most benefit

Figure 5. Causal relationships among elicited variables



and also be compatible with investment capabilities. The "investment" variable is therefore considered as a decision variable, and decision information links connect "investment" with other variables representing proposed changes. The observation of these loops shows the way each proposed change affects the achievements of organizational strategies, but also how each proposed change affects each other. For example, when the investment is made to improve "network forecasting preciseness", the chance of network modification will be reduced when customers apply for new installations. Consequently, customer satisfaction will be improved because of the reduction of the waiting time for network modification, and this will lead to the increase of the number of customers who get connected, and thus increase the revenue. However, this investment also improves the utilization rate of electricity networks and thus the reduced available electricity load could be a cause to network failures at peak time. This will negatively affect customer satisfaction and eventually reduce revenue. These two loops, as shown in figure 5, will therefore balance each other and likely lead to a stable situation.

This methodology takes qualitative results from qualitative modelling approaches as inputs, processes them through four steps, and outputs a model containing variables representing a quantitative view of business processes. Data collected from the implementation level is fed into the model to output the values of the variables of interest. This enables a quantitative observation of system behaviours and paves the road toward the evaluation of proposed changes.

This case study illustrates the applicability of the proposed approach. In this case applied with the developed approach, the effect of changes on an organization is observed quantitatively and the trace of implemented changes at the operational level affecting organizational strategies becomes explicit.

6. CONCLUSION

The developed prescriptive approach to business process modelling, incorporating concepts from quantitative modelling and control theory, enables a quantitative modelling of business processes with variables, and provides a systematic process of taking qualitative inputs to outputting quantitative outputs. In contrast with current modelling approaches, it represents a complete shift from the emphasis on the descriptions of business processes to the prescription and facilitates the transformation from a situation with proposed changes to a "to-be" situation; it takes a quantitative view and represents organization-oriented concepts with variables; it provides a systematic process to support the quantitative transformation from qualitative knowledge of business processes; it has a certain formalism that increases the possibility of automated analysis to tackle complicated applications.

Future work will focus on the evaluation of change effects and the construction of a "to-be" situation. Also, the development of automated support tools is planned in order to increase the applicability of this approach.

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