Towards Improved Organisational Decision-Making – A Method and Tool-chain

Souvik Barat[*,a], Vinay Kulkarni[b], Balbir Barn[c]

[a] souvik.barat@tcs.com, Tata Consultancy Services Research, 54 B Hadapsar Industrial Estate, Pune, India
[b] vinay.vkulkarni@tcs.com, Tata Consultancy Services Research, 54 B Hadapsar Industrial Estate, Pune, India
[c] B.barn@mdx.ac.uk, Department of Computer Science, Middlesex University, London, UK

Abstract. *Modern enterprises are large complex systems operating in an increasingly dynamic environment and are tasked to meet organisational goals by adopting suitable course of actions or means. This calls for deep understanding of the enterprise, the operating environment, and the change drivers reactive as well as proactive. Traditionally, enterprises have been relying on human experts to perform these activities. However, the sole reliance on humans for decision making is increasingly unviable given the large size of modern enterprises, fast dynamics, and the prohibitively high cost of incorrect decisions. To address this challenge, we propose a method that leverages existing enterprise modelling (EM) tools to improve the agility of organisational decision-making as well as reducing the analysis burden on human experts. The proposed method artifact employs a design science research methodology and the method is validated using a realistic industrial case to bring out its strengths as well as limitations.*

Keywords. Organisational Decision Making • Simulation-driven Method • Enterprise Modelling

Communicated by T. Clark. Received 2016-09-16. Accepted after 1 revision on 2018-01-23.

1 Introduction

Organisational decision-makers are faced with an increasingly challenging environment for making decisions. They need to continuously analyse and evaluate potential decisions in the face of intricate and time critical constraints. Technology to support such decision making contexts is consequently the subject of much research. Sufficiently good decisions are a necessary pre-requisite for organisations to remain competitive when confronted with an external, complex and turbulent environment. Support for help in making good decision is critical. Erroneous decisions can be prohibitively costly and moreover an inappropriate decision may reduce future adaptation choices (Shapira 2002). Factors such as: the context of a dynamic environment within which an organisation operates (Conrath 1967); large and complex organisational structures (McDermott et al. 2013); demands on agility and precision and multiple stakeholders with possibly conflicting viewpoints all contribute to the hard problem of organisational decision-making (McDermott et al. 2013). In this situation, those tasked with making decisions endeavour to analyse possible courses of action and select those actions that have the best potential to achieve the desired goals (Shapira 2002; Sipp and Elias 2012). In particular, the decision makers attempt to reason about the organisational status-quo (Conrath 1967; Sipp and Elias 2012) through exploration of questions such as: What are the goals of an organisation? What are the possible means of achieving an organisational goal? How do the candidate means differ quantitatively and/or qualitatively? And, what are the long-term and short-term implications of these means?

* Corresponding author.
E-mail. souvik.barat@tcs.com

Currently, the onus of decision-making lies largely with human experts (Locke 2011). Such stakeholders are expected to understand and correlate existing information about the various goals of the organisation, organisation structure and processes set up to achieve these goals. To this web are added the various change drivers and their influence on organisation goals as well as the *business as usual* (BAU) operation of the organisation. From this entailment of information, decision makers need to define possible change responses and selecting the most suitable therefrom (Shapira 2002). Typically, the technology aids that practitioners rely on for carrying out these knowledge intensive activities are mostly limited to pictorial representation of the relevant information and data computations (primarily aided by spread-sheet) (Locke 2011). As a result, they are not amenable for automated analysis that can reduce burden on human experts. The perceived view from industry reports this state-of-practice as poor with respect to agility and ineffective in addressing core organisational problems such as enterprise transformation, business-IT alignment and regulations compliance, etc. In contrast, practitioners expect an organisational decision-making approach that can reduce the excessive burden on human experts and provide a-priori indication about the efficacy of a decision in a shorter time window (Shapira 2002).

There is some evidence that suggests platform-based approaches such as simulation-aided scenario playing (Barjis 2008), artefacts that are amenable to computational analysis appear to meet these requirements (Meadows and Wright 2008; Van Lamsweerde and Letier 2004; Yu et al. 2006). At this moment, we appear to be some distance from such platform based approaches. The options available suggest that the available technological advances in enterprise modelling (notably software tools) could be used as an integrated tool-chain coupled with methodological guidance for organisational decision-making.

In recognition of this, we present a method to improve the efficacy and agility of the decision-making process using available technological advancements in Enterprise Modeling (EM) (Meadows and Wright 2008; Rolland et al. 2000; Vernadat 2002; Yu et al. 2006; Zachman et al. 1987) in the form of a tool-chain. Our approach adopts a design science research (DSR) philosophy in line with Hevner et al.'s guideline on problem relevance (Hevner et al. 2004). Very clearly, organisational decision making is critical to the profit (utility) maximisation goals of a business organisation. The problem of good decision-making is therefore relevant to the objective of design science research to develop technology based solutions to such important problems. Our DSR approach is adapted by DSR methodological innovations proposed by Pries-Heje et al. (2008) and the use of technological action research (Wieringa and Moralı 2012). Within this approach, this paper makes two key contributions. Firstly, it establishes the key tenets of an organisational decision-making method forming a contribution to the Hevner et al. notion of a knowledge-base. The principles are expressed as a conceptual model using a Unified Modelling Language (UML) based modelling approach. Secondly, as a result of the DSR approach, the research presents a design artifact in the form of a method that is able to use existing tools and technologies from enterprise modelling to support decision making.

We adopted an *Artificial* and *Ex-Post* evaluation strategy (Pries-Heje et al. 2008) to evaluate the research outcomes, i. e., conceptual model and decision-making method. Essentially, we used a reductionist abstraction from the natural setting to conceptualise a synthetic case study as recommended in (Yin 2013). Through this detailed evaluation, we outline the gaps and future research necessary for a comprehensive realisation of the proposed method.

The paper is organised as follows. Section 2 develops in more detail the organisational decision-making problem and highlights relevant industry practices. Section 3 outlines the research methodology principles we use to develop and evaluate our principal artefact. Section 4 presents a description of the proposed method along with a possible implementation using existing EM tools. Section 5 illustrates the proposed method using a realistic example from an industrial consultancy services perspective. Section 6 evaluates the proposed method and identifies future work needed to overcome some of its limitations. Finally, we conclude the paper with summary remarks in Sect. 7.

2 Theoretical Foundations for Organisational Decision-making and State of the Practice

In this section, we utilise existing research literature to outline the key tenets for organisational decision-making. Typically, an organisational decision-making problem starts with a broad definition of organisational goals or objectives, and ends with a set of means that have the best potential to achieve the goals (Shapira 2002; Sipp and Elias 2012). Using UML as a representational tool, the core concepts for describing organisational decision-making along with the relevant relationships are depicted as a meta model in Fig. 1 where a decision-making problem can be described using three key concepts: *Goal*, *Means* and *Contextual Information*. The *Goal* represents the desire or intention of an organisation, *Means* are the potential course of actions that an organisation considers in a decision-making process, and *Contextual Information* is information about the organisation necessary for decision-making. The *Contextual Information* may take several forms, for instance, a historical Trace comprising the side effects of business as usual (BAU) operation of the organisation and/or popular Enterprise models such as goal models (Yu et al. 2006), process models (Barjis 2008), system dynamic models (Meadows and Wright 2008) etc. A more elaborated conceptual model has been described elsewhere (Barat et al. 2017a,b). Recent research output from Bock (2015) delineates organisation decision making as operating decisions that are *taken routinely*, administrative decision that *coordinate the operating decisions* and strategic decision processes that are seen to be concerned with the problems *characterized by novelty, complexity, and open endedness*. It is these latter decisions that we are address here. Bock's main contribution is an elaborated meta model for supporting these various decision making categories. In contrast, we provide a practical application of an existing set of tools to support decision making.

Organisational decision-making process is about finding the best possible set of *Means* for achieving the desired *Goals* of the organisation (Shapira 2002). This endeavour is accomplished by performing multiple decision-making activities that include *Goals* decomposition or elaboration, listing down all possible *Means*, evaluations of the candidate *Means*, and pruning out and selection of suitable *Means*, etc. In practice, these activities are performed by questioning a specific organisational element (i. e., *Goals* or *Means*) to arrive at an answer by analysing *Contextual Information*. Finding an answer to a goal-related question helps to decompose the *Goal* further whereas finding an answer to a means-related question helps to select or prune out a set of candidate *Means*. An *Answer* can be qualitative or quantitative. An *Answer* can trigger a further set of elaborating *Questions* (known as decision loop (Mintzberg et al. 1976)), can lead to a new *Question* corresponding to a new *Goal* or *Means* (known as decision interruption (Langley et al. 1995)), and a set of *Answers* to a set of related *Questions* can result into an *Answer* (known as snowballing (Langley et al. 1995)).

The efficacy (i. e., the utility of a decision) and agility (i. e., ability to quickly arrive at a specific conclusion) of organisational decision-making are both largely dependent on two principal factors: i) a structured method for performing decision-making activities and ii) a capability of analysing contextual information. The latter is further reliant on the chosen analysis technique and structural representation of *Contextual Information*. The rest of this section highlights the state-of-the-practice of organisational decision-making processes and techniques for representing and analysing *Contextual Information*.

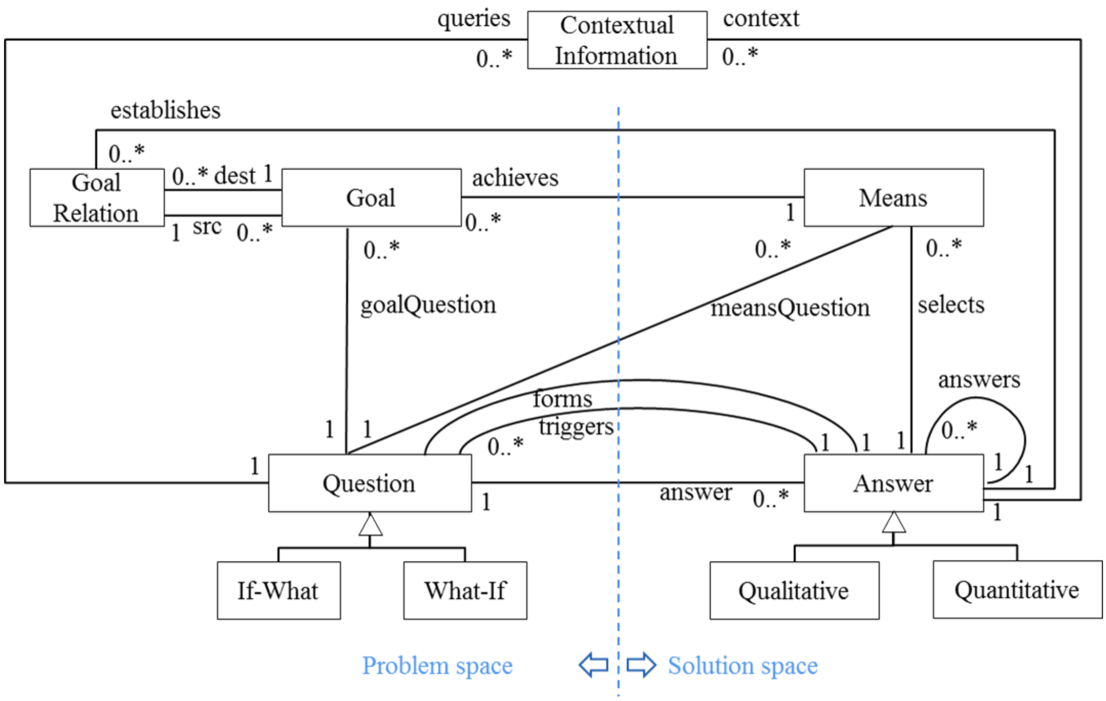

Figure 1: Meta model of organizational decision-making

2.1 Organisational decision-making processes

Management literature proposes multiple method templates or styles (Anderson et al. 2015; Cohen et al. 1972; Cyert and March, James G 1963; Langley et al. 1995; Mintzberg et al. 1976; Rolland et al. 2000) for decision-making in general. Majority of the existing styles have emerged from one of the four approaches namely, Management science (Anderson et al. 2015), Carnegie model (Cyert and March, James G 1963), Incremental process model (Mintzberg et al. 1976) and Garbage Can model (Cohen et al. 1972). These decision-making styles advocate the order in which the decision activities need to be performed. For example, the Incremental process model starts with high-level *Goals* and finally reaches to a consensus decision (Harnett 2011) about *Means* by iterating over decision activities such as goal elaboration, means identification, and evaluations of identified means. In contrast, the Garbage Can model or anarchy style does not recommend a specific sequence i. e., *Goals* and *Means* evolve and are evaluated simultaneously.

Management Science approach uses statistical analysis, data analytics and Business Intelligence (BI) techniques extensively to make sense of resultant data from BAU operation i. e., *Trace*. The approach assumes that *Trace* is the necessary and sufficient *Contextual Information* for evaluating *Questions*. However this assumption holds true only for a class of decision-making problems where the *Goals* and *Means* are fixed thus putting a bound on evolution of the organisation. In contrast, the Carnegie model (where the problem space is not known a-priori), Incremental Process (where the problem space is known but solution space is not known a-priori), and Garbage Can model (where both problem space and solution space are unknown) require both enterprise models and historical Trace for analysis while relying principally on human experts for analysis).

The next sub-section reviews the state of the art and practice of enterprise model representation and their analysis capabilities in the context of organisational decision-making.

2.2 Enterprise modeling languages and analysis techniques

The Zachman Framework (Zachman et al. 1987) recommends six interrogative aspects namely – *why*, *what*, *how*, *who*, *where*, and *when* for capturing information about an organisation for its comprehensive understanding. We argue that these dimensions constitute complete *Contextual Information* for organisational decision-making (Barat et al. 2016). The ArchiMate (Iacob et al. 2012) and UEML (Vernadat 2002) enable specification of the four aspects but lack in the necessary qualitative and quantitative analysis support. The BPMN (OMG 2011), KAOS (Van Lamsweerde and Letier 2004), i* (Yu et al. 2006), BMM (OMG 2015) and Stock-and-Flow (SnF) (Meadows and Wright 2008) enable specification of only one aspect but provide good analysis support. Recent work conducted by Overbeek et al. (Overbeek et al. 2015) elaborate a goal modelling domain specific language for managing multiple perspectives using the MEMO (Multi-perspective enterprise modeling) technology (Frank 2002). The multiple perspectives support the notion that there is unlikely to be one single language that is capable of specifying <*what, why, how, who*> aspects of enterprise in analysable form.

Therefore, a set of EM tools need to be used in a coherent manner so that contextual information is captured completely to be analysed later (Kulkarni et al. 2015b). For instance, a tool-chain combining i*, SnF and BPMN is capable of modelling and analysing the *why*, *what*, *how* and *who* aspects of an organisation. However, paradigmatically diverse modelling languages and the non-interoperable nature of the tools makes the task of constructing the desired tool-chain an intellectually demanding endeavour (Chen et al. 2008). We address this need by proposing a method that enables coherent use of EM tools in a systematic and judicious manner towards improving the agility of the organisational decision-making process. The proposed method also results in reduction of the analysis burden of the decision-maker.

3 Methodology

This paper posits that organisational decision-making is both difficult and largely intuitive being based on the experiential knowledge of decision makers. Technologies that can support such stakeholders could therefore play a significant role in meeting the needs of an organisation and its desire to achieve utility (profit and/or other goals) from its core activities. Such a rationale lends itself to a design science research methodology. To that end, we draw upon the DSR process proposed by Peffers et al. (2007) and execute three essential activities from their nominal process to realise three design science research cycles namely *relevance cycle, design cycle and rigor cycle* recommended by Hevner (2007):

- Identify Problem and Motivate: justification of the problem existence
- Design and Development (of the artefact)
- Evaluation of the usage of the artefact (using a synthetic case study).

Identify Problem and motivate activity defines the research problem and justifies the value of a solution (Peffers et al. 2007). Typically, the researchers explore theoretical bases that improve the rigour or consider practical relevance that improve the situation on ground as the basis for identifying the problem. We combine both the objectives as the basis for identifying our problem statement. As discussed in the introduction section, our objective is to improve the state of the practice of decision making in terms of efficacy and agility without compromising the methodological rigour discussed in management literature (presented in Sect. 2). We adopt conceptual modelling technique (presented in Fig. 1) and literature review (an overview is presented in Sect. 2.1 and Sect. 2.2) to justify the problem statement for a class of decision problems. The conceptual model defines the class (i. e., decision problems that start with *Goals* and a solution can be reached by iterating over possible *Means* in an arbitrary complex manner), the literature review of management literature establishes the practical needs and the literature review on enterprise modelling languages and analysis techniques helps in identifying the gaps that needs to be addressed to solve practical problem. These three activities define the *relevance cycle* of our research.

Design cycle essentially deals with *Design and Development of artefacts* and *Evaluation of the usage of the artefacts* activities. For the evaluation activity, several authors such as Hevner et al. (2004) and Prat et al. (2014) define a number of criteria for evaluation purposes. The latter, in particular, collate a set of criteria following a review of literature. We select a subset of criteria for evaluation based on our understanding of the problem definition. These criteria are: *efficacy* – the degree to which the artefact achieves its desired effect; *completeness* – akin to and amounts to functionality; and *homomorphism* – the correspondence of a structure with another model, in essence, the fidelity with respect to the environment. In addition to the criteria, we position our evaluation strategy as one that is *Artificial* and *Ex-Post* (Pries-Heje et al. 2008). It is *Ex-Post* as the evaluation is taking place after the design of the artefact. It is *Artificial* in that we are using a case study and a simulation across the tool-chain to provide our evidence. The research reported here is part of a wider agenda and here we are using this experiment to provide requirements to our broader research aims in developing a rich tool based environment to support organisational decision-makers. Hence, this stage can be seen as an example of technical action research (Wieringa and Moralı 2012).

Finally, as part of *rigor cycle* we establish the connection between the design science activities and the knowledge base by conducting a meta-analysis on research outcomes (as discussed in Sect. 6).

4 Proposed Solution

We propose a method that realises the conceptual decision-making models discussed in Sect. 2.1. The stages of the proposed method are ordered and can be prescriptive leading to a repeatable decision-making endeavour. The degree of sophistication of analysis support dictates the precision of the recommendations. Importantly, as the analysis techniques deployed in the method are generally supported in popular EM tools and hence largely familiar, the cognitive burden of learning new techniques is reduced.

Therefore, the proposed method can improve the efficacy and agility of organisational decision-making process while reducing dependence on human intuition.

4.1 Method

Figure 2 describes the 3-step method for organisational decision-making. The *Preparatory* step tries to make the problem space bounded and manageable for iteration. It performs two kinds of activities: i) elaboration of high-level organisational goals into precise goal statements that are more concrete and amenable to be measured using quantitative or qualitative metrics, and ii) identification of alternate Means that may help to achieve these goals. The output of this step is a table structure (termed as decision table) where the rightmost column of decision table represents a goal, intermediate columns represent its identified sub-goals, and rows represent the identified means of achieving the goal. Each cell of this matrix captures a decision point that can be expressed as a what-if question e. g., what is the impact on a goal if this means is selected? The goals and means can be prioritised by ordering them appropriately in the decision table.

The *Analysis* step iterates over a finite number of decision points for finding possible answers. Thus, the analysis step comprises of several micro-steps. A micro-step finds an *Answer* to a *Question* by one of the three possible ways: i) analysing the relevant *Contextual Information* i. e., analysis decision point; ii) interpreting a series of other answers i. e., snowballing decision point, or iii) delegating to another decision-making process i. e., nested decision point.

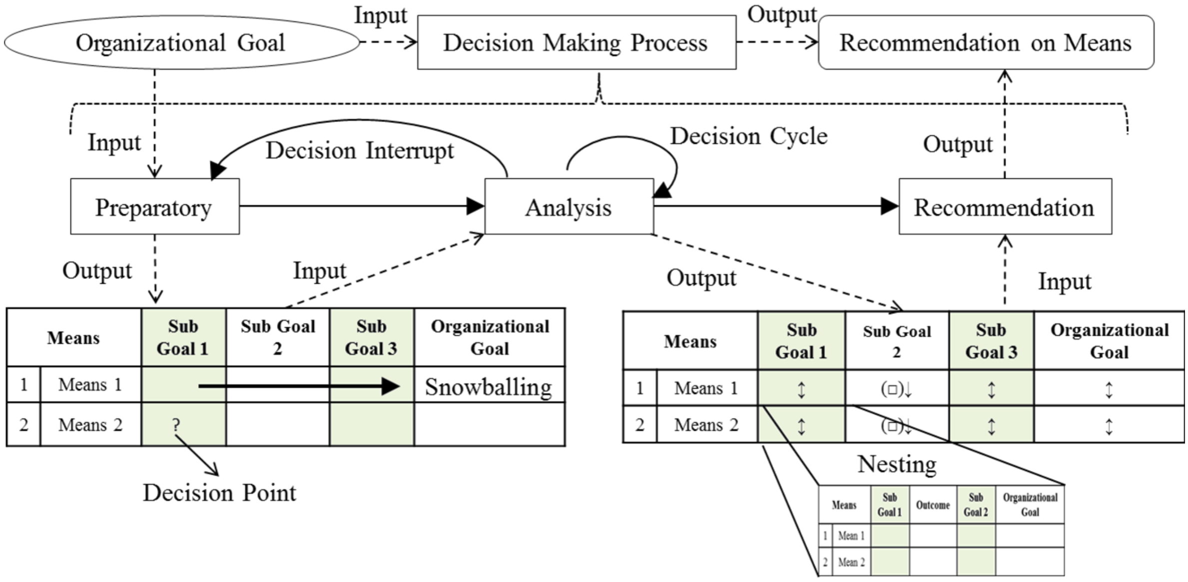

Figure 2: Method for organisational decision making

We further classify an analysis decision point into three types: algorithmic decision point that is answerable using a specific algorithm on Trace; contextual decision point that is answerable by analysing *Enterprise Models*; and anarchical decision points where the *Contextual Information* is either missing due to lack of knowledge or there is high degree of uncertainty about this information. A series of answers snowballing (Langley et al. 1995) into a major decision is termed as a snowballing decision point. A snowballing decision point is used for deducing the goal (i. e.., rightmost column) from its sub-goals (i. e., decision points that exist in a row).

The decision points can be visited from left-to-right and top-to-bottom based on their priority. However, one may loop back to previous decision points in case of disagreement among decision makers or inability to identify a feasible recommendation. Or, one may loop back to preparatory step in case of appearance of a new alternative means or consideration of new goal or objective. Looping back to a previous decision point is termed as decision cycle (Mintzberg et al. 1976) and looping back to a preparatory step is termed as a decision interrupt (Langley et al. 1995). These two feedback paths make the method iterative thus helping a consensus decision (Harnett 2011) to be arrived and/or decision conflicts (Amason 1996) to be resolved by iterating over decision points through decision cycles. They also address decision mistakes (Langley et al. 1995) of earlier step and the decision anarchy (Cohen et al. 1972) of the decision-making process.

The *Recommendation* step uses the learning of earlier steps and recommends a set of means that outscore others. A better recommendation can be provided when convincing numbers of means are evaluated using decision point analysis, decision loops, decision interrupts and snowballing.

4.2 Implementation

We explored Trace analysis and Enterprise models analysis as possible implementation avenues for the proposed method. The Trace analysis ranges from simple data computation to complex data analytics. The enterprise model analysis involves qualitative and quantitative analysis of *why, what, how and who* aspects of the organisation. We propose to capture the information required for analysis in the form of models that are amenable to computational analysis. We consider i*, SnF and BPMN models as collectively as a tool chain, they are capable of specifying the core aspects and are amenable for qualitative and quantitative analyses.

5 IIlustrative Example

Consider a software service provisioning organisation that earns revenue by developing bespoke software for its customers. The organisation bids for software projects in response to request for proposals (RFPs). Once a bid is won, the organisation initiates and executes projects using tried-and-tested process leading to successful completion. This BAU scenario, as depicted in Fig. 3, is driven by organisation goals that are accomplished by several means.

Consider a goal of securing leadership position in terms of business volume, profitability and customer satisfaction. Several means or strategies are available to the organisation for achieving this goal. Some strategies focus on introducing local fixes through improving operational efficiency while keeping structural as well as process aspects of organisation unchanged. For instance, one can think of increasing number and skill-level of resources, obtaining a predictive handle on demand, reducing resource attrition, reducing delays in recruitment, training, relocation etc. Some means might be more disruptive as they introduce changes in organisation structure and/or operational processes. For example, one can think of creating a unit specialising in creation of developer productivity improvement tools which necessitates change in project execution process as well in skill-set of project team. An organisation decision-maker would like to know a-priori which of these strategies would turn out better both in qualitative as well as quantitative terms

The use of a range of tools in a form of tool-chain is common practice in software development practice. Historically, such tool chains then became integrated using a range of approaches such as method integration, syntax integration and semantic integration (Asplund and Törngren 2015; Brown and McDermid 1992). In our example, we use i* model to specify organisational goals, SnF model to specify high level dynamics, BPMN model to specify operational processes, i* model simulation for qualitative analysis, and SnF and BPMN model simulations for quantitative analysis.

5.1 Preparatory step

The Preparatory step elaborates the high-level goal of 'securing leadership position' into precise goal statements that can be measured using quantitative or qualitative metrics. This step also specifies possible means for achieving the goals. We use the OpenOME tool to specify a goal, its constituent subgoals, and possible means for achieving them as an i* model. The root organisational goal of 'secure leadership position' is elaborated into three sub-goals namely, 'improve customer satisfaction', 'increase business volume', and 'improve profit margin'. Each of the three is further elaborated into sub-goals for fine-grained qualitative and quantitative measurements. The quantitative goals of 'business volume' (i. e., number of active business opportunities) and 'profitability' are represented as hard-goals. The 'customer satisfaction' goal that can only be qualitatively assessed as a function of operational certainty and service quality is represented as soft-goal. The model also captures several means of achieving these goals as tasks. We consider five specific means namely, 'Increase win rate', 'Create new opportunity stream', 'Increase resource strength', 'Improve resource skills', and 'Utilize tools' for illustration purpose. Table 1 depicts key guidelines for constructing i* model. Thus, it can be said that i* model is a structured, semantically rich, and machine processable representation of the structure of decision table (i. e., the rows and columns without cell values) described in Tab. 2. Organisational goal column corresponds to the root goal, intermediate columns correspond to [sub-] goals, and means of achieving the principal goal correspond to the tasks. We use Tab. 2 whose each cell corresponds to a decision point to drive the next step.

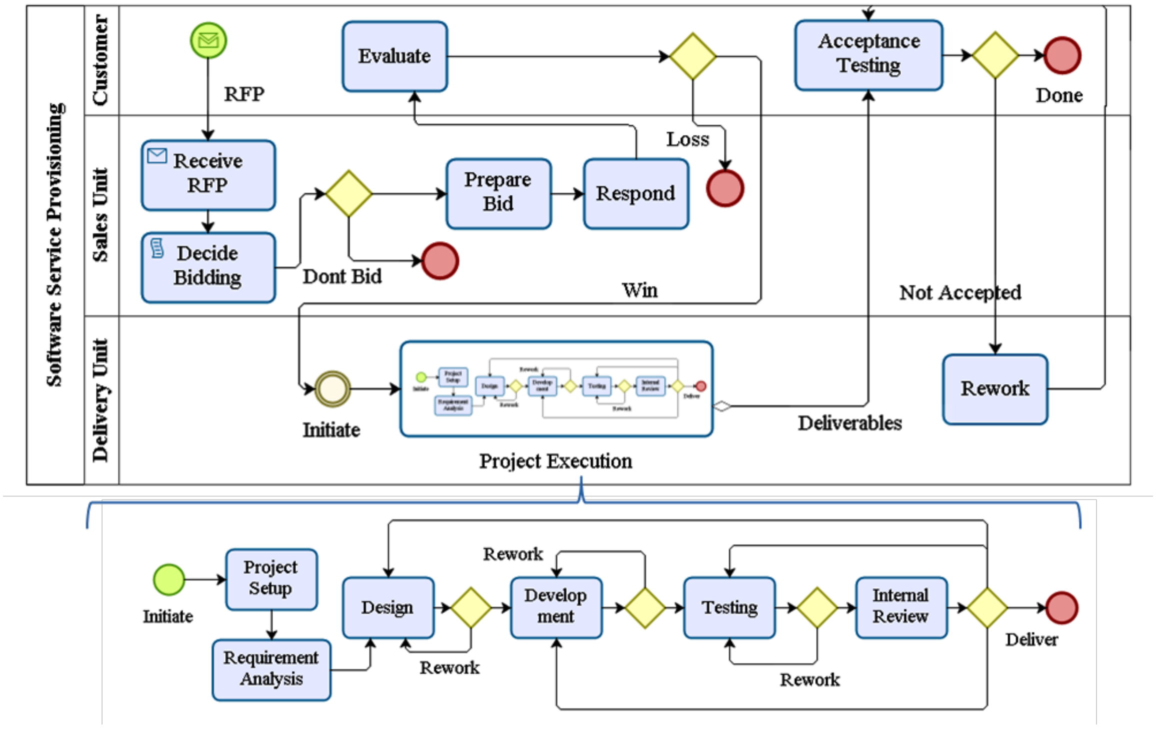

Figure 3: Business process for software provisioning

5.2 Analysis step

The analysis step tries to find answers for decision points identified one row at a time from left to right. First, algorithmic decision points are evaluated using forward propagation algorithm of i* model. This expects the necessary contextual information to be present as a strategic rationale model. Each row of Tab. 2 corresponds to the result of qualitative analysis, conducted using forward evaluation of i* model, of impact of a mean on goals and sub-goals. For example, 'Increase Win Rate' mean will: i) positively impact 'Business Volume', 'Revenue' and 'Expense' goals, ii) Negatively impact 'Operational Certainty', 'Service Quality' and 'Customer Satisfaction' goals, and iii) is inconclusive about 'Profitability' goal. Thus, Tab. 2 clearly identifies which decision points are left unaddressed. Also, a decision maker would like to have a quantitative feel for some of the qualitatively arrived at decisions. This constitutes the next iteration of Analysis step.

In next iteration, we use either SnF or BPMN models to find answers for contextual decision points of Tab. 2. We use iThink and Bizagi for SnF and BPMN modelling respectively. For example, decision points DP1 and DP2 of Tab. 2 are addressed using SnF models 'Model1' and 'Model2' respectively. SnF model 'Model1' is essentially business process model of 3 augmented with resource dynamics and accounting process. Simulation of Model1 with suitable data leads to computation of impact of 'Increase Win Rate' means on 'Profitability' goal as shown in Fig. 4(a). Model2 represents a service provider organisation that is capable of exploring 'New Opportunity Stream'. Essentially, Model2 is an extension over Model1 wherein the extension represents the behaviour associated with 'New Opportunity Stream'. Simulation of Model2 with suitable data leads to computation of impact of 'New Opportunity Stream' means on 'Profitability' goal as shown in Fig. 4(b). As can be seen from Fig. 4, profitability drops initially but improves over time

Table 1: Guidelines for constructing i models*

Organisational Concepts	i* concept	Organisational Concepts	i* concept
Organisational Unit	Agent	Unit level Delegation	Strategic Dependency
Qualitative goals and sub-goals	Softgoal	Quantitative goals and sub-goals	Hardgoal
Positive Influence	Make	Quantitative goals and sub-goals	Hurt
Moderate Influence	Some+	Eventual Influence	Help
Means	Task	What-if analysis	Forward Propagation

Table 2: Results of what-if analysis using i model*

	Operational Strategy	**Goal, Sub-goals and other outcomes** (symbols :- ✓ - Satisfied, ✓• - Partially Satisfied, ✗• Partially Denied, ⚡ Conflict)							**Principal Goal**
		Business Volume	*Revenue*	*Expense*	*Profitability*	*Operational Certainty*	*Service Quality*	*Customer Satisfaction*	*Secure Leadership Position*
1	Increase Win Rate	✓	✓	✓•	⚡ DP1	✗•	✗•	✗•	⚡
2	New Opportunity Stream	✓	✓	✓•	⚡ DP2	✗•	✗•	✗•	⚡
3	Improve Resource Skill	-	-	✓	✗•	✓	✓	✓	⚡
4	Increase Resource Strength	-	-	✓	✗•	✓	✓	✓	⚡
5	Utilize Tool	-	-	✓	✗•	✓	✓	✓	⚡

leading to positive impact for both the means. We further observe the profit for 'Increase Win Rate' is almost immediate but marginal whereas profit for 'new opportunity stream' kicks in late but is more significant.

On similar lines, all quantitative goals are analysed using simulation leading to results shown in Tab. 3. For example, 'Increase Win Rate' means has positive quantifiable impact on 'Business Volume' sub-goal, marginal positive impact 'Revenue', 'Expense' and 'Profitability' sub-goals, negative impact on 'Operational Certainty' sub-goal, delayed but substantial negative impact on 'Service Quality' and 'Customer Satisfaction' sub-goals. Thus, it is difficult to say about quantitative impact of 'In-crease Win Rate' means alone on the overall goal of 'Secure Leadership Position'. As can be seen from Tab. 3, none of the identified means alone are able to achieve the overall goal. Therefore, one would like to try out possible combinations of means as a solution for achieving the overall objective i. e., a new decision interrupt.

Row 6 of Tab. 3 corresponds to combining together 'Increase Win Rate', 'New Opportunity Stream' and 'Increase Resource Strength' means. We use the combined SnF model for computing impact of this combination on goals and sub-goals. As can be seen from row 6 of Tab. 3, this combination leads to positive impact on all sub-goals and hence on the overall goal. Initial result of the simulation is shown in Fig. 4(c). If unsatisfactory, one can keep on modifying values for the three constituent means until desirable impact is achieved in an iterative process. For instance, Fig. 4(d-f) depict the impact of 'Increase Resource Strength' means in this combination. Increased value of this means leads to increased 'Profitability' as seen in Fig. 4(d) and Fig. 4(e). However, further increase in the value of 'Increase Resource Strength' leads to reduced 'Profitability' as seen in Fig. 4(f). Such an iterative decision loop

Table 3: Results of what-if analysis using simulation model

	Means	**Goal, Sub-goals and other Outcomes** (symbols :- ↑ - increase, ↓ - decrease ,↕ - unknown, □ - eventually, Δ - delta)							**organization Goal**
		Business Volume	*Revenue*	*Expense*	*Profitability*	*Operational Certainty*	*Service Quality*	*Customer Satisfaction*	*Secure Leadership Position*
1	Increase Win Rate	↑	(Δ)↑	(Δ)↑	(□Δ)↑	↓	(□)↓	(□)↓	?
2	New Opportunity Stream	↑	(□)↑	↑	(□)↑	↓	(□)↓	(□)↓	?
3	Improve Resource Skill	–	–	(Δ)↑	(□Δ)↓	(Δ)↑	↑	(Δ)↑	?
4	Increase Resource Strength	–	–	↑	↓	↑	(□)↑	↕	?
5	Utilize Tool	–	–	↑	↓	↑	↑	↑	?
6	M 1 + M2 + M4	↑	↑	↑	↑	↑	↑	↑	↑

leads to identification of locally optimal solution. The output of this step is the evaluation results of sufficient number of *Means* in a decision table form as depicted in Tab. 3. Though this example illustrates implementation of the proposed method using i* and SnF models (and associated tools), any other EM tool can be used with appropriate analysis technique.

5.3 Recommendation step

This step involves discussions, bargaining and negotiation among the coalition of stakeholders. For example, discussion could be around temporal ordering of *Means* e. g., should 'Increase Win Rate' be explored before considering 'New Opportunity Stream'. Also, sales unit head would pitch in for *Means* such as 'Increase Win Rate', 'New Opportunity Stream' and 'Increase Resource Strength' whereas COO would not tolerate compromise on *Means* such as 'Operational Certainty' and 'Service Quality'. Moreover, these relationships change over time and can change rather fast. As a result, notion of uncertainty is an intrinsic element of the problem space which needs to be addressed. Work is needed to apply well-established ideas from fields such as agent based systems, graph theory, stochastic systems, psychology, management etc.

6 Evaluation and Future Work

The proposed method uses a separation of concerns principle to break down decision-making problem into sub-problems each addressable using suitable specification language and tool. It uses the existing schema of decision tables supported by method primitives such as snowballing, decision loop, and decision nesting to integrate and/or interpret the part solutions obtainable from multiple tools into a consistent whole. Existing tools such as AnyLogic[1] and AA4MM (Siebert et al. 2010) also advocate a similar multi-modelling co-simulation based approach but they use predefined protocols to establish the correlations between the inputs and outputs of different tools. The Unified Enterprise Modelling Language (UEML) initiative (Vernadat 2002) aims to integrate existing Enterprise Modelling Languages using a meta-modelling framework. Our earlier work (Kulkarni et al. 2015a,b) also tries to establish interoperability between a fixed set of EM languages and tools, i. e., <i*, OpenOME>, <SnF, iThink>, and <BPMN, Bizagi>, using model mapping techniques. However, the language/tool integration approach is still some distance away as regards robustness, scalability and usability. In contrast, a method enabling concerted use of existing EM tools in a systematic manner seems pragmatic. With EM tools witnessing reasonable adoption by industry, the proposed method is likely to be met with easier adoption by practitioners. Moreover, the proposed method is not tied down to any specific EM tool, and a new <language, tool> tuple

[1] www.anylogic.com/

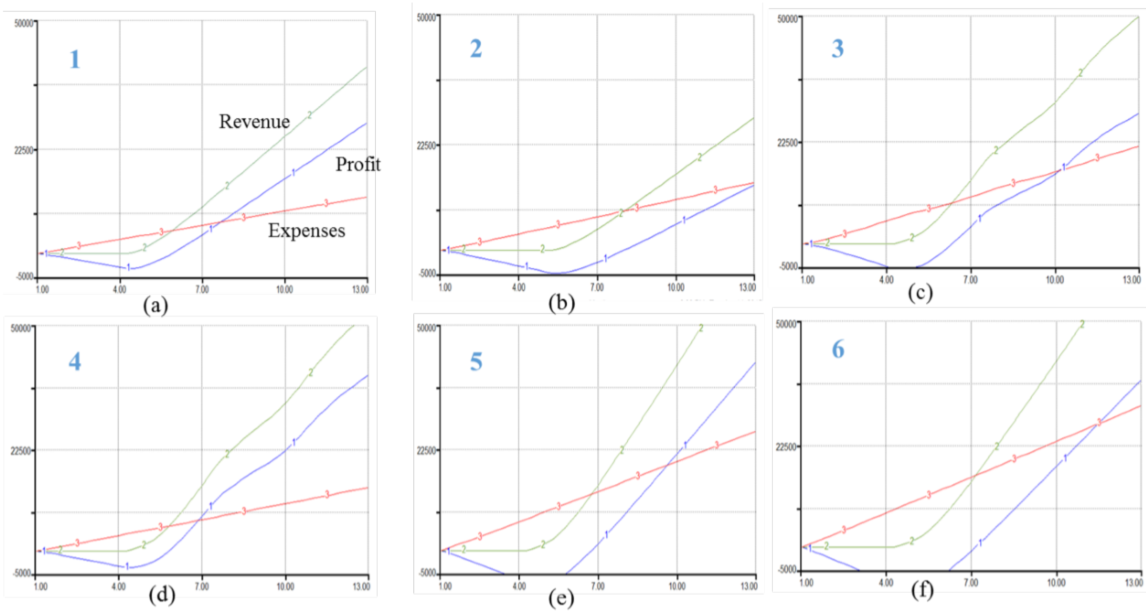

Figure 4: Quantitative analysis using Stock-and-Flow model for profitability

can be easily accommodated. Table 4 describes advantages of the proposed method over current state of practice from the viewpoint of efficacy.

As can be seen above, current practice relies entirely on human experts for doing the right things, in the right order and the right way. Typically, available help is limited to documented guidelines and best practices. The proposed method demonstrates increased efficacy in several ways: Firstly, the approach supports human experts by leveraging existing support for enterprise modelling, analysis and simulation in a prescribed and organised manner. Further work could attempt to ascertain whether this leads to improved efficiencies in decision making through the use of controlled experiments. A second benefit is derived from the availability of a simulation capability from the supporting tools that may also lead to improving the agility of a decision-making process.

From a *completeness* perspective, the various decision activities identified as part of the proposed method are mostly addressed by the integrated tool chain to some extent apart from the formation of what-if and if-what questions which remains a manual process. Key decisions around potential suggestions or final conclusions are also manual but, importantly, are able to be supported by simulation results. Hence, at least, the decision maker is not operating on intuition alone.

The *Homomorphism* aspects of the structure of the artefact is demonstrated by the correspondence of the method constructs with other models. In particular, the goal model constructs in the method correspond to the use of the goal constructs from the i* method. Further homomorphism is evidenced by our tool-chain usage. Tool chains imply an underlying concept integration, where concepts are mapped from one semantic domain to another (Asplund and Törngren 2015; Brown and McDermid 1992). Else where we have documented a comprehensive meta model of the underlying concepts required for decision making along the lines described in Barat et al. (2017b).

Though the proposed method identifies the right things to do and advocates the right order in which they need to be done, it leaves many challenges unaddressed. We discuss a few of them in brief:

Navigating the design space: Decision-making involves navigation in a multi-dimensional space

Table 4: Advancement over current state of practice

Decision Activities	Current Practice	Advancement using proposed method
Goal specification and elaboration	Manual	Tool (i*)
Means specification	Manual	Tool (i*)
Contextual information specification	Data Analysis for Trace and Documents for Organisation	Model based – i*, SnF, BPMN
Formation of if-what and what-if questions	Manual	Manual
Finding Answers	Automated for Trace related question-answers and manual for other Questions	Tool assisted – Simulation and other qualitative and quantitative analysis
Suggestion or Conclusion	Manual	Manual but backed by analysis and simulation results

that has peaks and troughs corresponding to several local optima and one global optima. Topology of the space means the starting point of analysis/simulation has a significant bearing whether global optima can be reached or which of the several local optima can be reached. Today, a decision maker has no help to decide with certainty whether an additional decision cycle is required (i. e., local optima is reached) or no more decision interrupts are required (i. e., global optima is reached).

Applying proven ideas from diverse fields: Enterprises are socio-technical systems where agents are automatons (i. e., automation systems) and humans. Human decisions are not always rational and are influenced by several factors. Also, in today's connected world, the enterprise is best viewed as part of an ecosystem comprising competitors, collaborators, suppliers, consumers, partners so the notion of a system boundary is much more flexible. Moreover, these relationships change over time and can change rather fast. As a result, uncertainty is an intrinsic element of the problem space which needs to be addressed. Work is needed to apply well-established ideas from fields such as agent based systems, graph theory, stochastic systems, psychology, management etc. We have began that process.

7 Summary

It is becoming increasingly apparent that coming up with a decision in appropriate time and making a priori assessments of its likely efficacy is critical for modern large enterprises. It is arguable that current Information Systems Development practice is able to address this challenge. We have proposed a method to improve agility of the decision-making process and validated it on a sample but realistic example. The method uses a tool chain of several existing EM tools in an integrated and coordinated fashion to provide a relatively complete coverage for automation support. The method also reduces analysis burden on human experts but is constrained by the level of sophistication of analysis support available in existing EM tools. As part of the evaluation, we outlined several limitations of the current state of art and practice of enterprise modelling to support agile decision-making with enhanced certainty. As the proposed method leaves these limitations largely untouched, we believe the proposed method can at best be seen as an an important step towards a solution. However, we think, due to its reliance on popular EM tools and support for the established organisational decision-making approaches, the proposed method is sufficiently attractive for practitioners to consider adoption in their needs. Unsurprisingly, more work is needed on the robustness aspect to make the proposed method a compelling choice for the practitioners. We intend to take up this activity next.

References

Amason A. C. (1996) Distinguishing the effects of functional and dysfunctional conflict on strategic decision making: Resolving a paradox for top management teams. In: Academy of management journal 39(1), pp. 123–148

Anderson D., Sweeney D., Williams T., Camm J., Cochran J. (2015) An introduction to management science: quantitative approaches to decision making. Cengage Learning, Boston, USA

Asplund F., Törngren M. (2015) The discourse on tool integration beyond technology, a literature survey. In: Journal of Systems and Software 106, pp. 117–131

Barat S., Kulkarni V., Clark T., Barn B. (2016) Enterprise modeling as a decision making aid: A systematic mapping study. In: IFIP Working Conference on The Practice of Enterprise Modeling. Springer, pp. 289–298

Barat S., Kulkarni V., Clark T., Barn B. (2017a) A domain specific language for complex dynamic decision making. In: ESM 2017: 31st Annual European Simulation and Modelling Conference, pp. 135–142

Barat S., Kulkarni V., Clark T., Barn B. (2017b) A Model based Realisation of Actor Model to Conceptualise an Aid for Complex Dynamic Decision-making.. In: MODELSWARD 2017, pp. 605–616

Barjis J. (2008) Enterprise, organization, modeling, simulation: putting pieces together. In: Proceeding of EOMAS, pp. 1–5

Bock A. (2015) Beyond narrow decision models: toward integrative models of organizational decision processes. In: 2015 IEEE 17th Conference on Business Informatics Vol. 1. IEEE, pp. 181–190

Brown A. W., McDermid J. A. (1992) Learning from IPSE's Mistakes. In: IEEE software 9(2), pp. 23–28

Chen D., Doumeingts G., Vernadat F. (2008) Architectures for enterprise integration and interoperability: Past, present and future. In: Computers in Industry 59(7), pp. 647–659

Cohen M. D., March J. G., Olsen J. P. (1972) A garbage can model of organizational choice. In: Administrative Science Quarterly 17(1), pp. 1–25

Conrath D. W. (1967) Organizational decision making behavior under varying conditions of uncertainty. In: Management Science 13(8), pp. 487–500

Cyert R., March, James G (1963) A behavioral theory of the firm. Prentice-Hall, Englewood Cliffs, NJ, USA

Frank U. (2002) Multi-perspective enterprise modeling (memo) conceptual framework and modeling languages. In: System Sciences, 2002. HICSS. Proceedings of the 35th Annual Hawaii International Conference on. IEEE, pp. 1258–1267

Harnett T. (2011) Consensus-Oriented Decision-Making. Canada New Society Publishers, Gabriola Island, BC, Canada

Hevner A. R. (2007) A three cycle view of design science research. In: Scandinavian journal of information systems 19(2), pp. 87–92

Hevner A., March S. T., Park J., Ram S. (2004) Design science in information systems research. In: MIS Quarterly 28(1), pp. 75–105

Iacob M., Jonkers D. H., Lankhorst M., Proper E., Quartel D. D. (2012) ArchiMate 2.0 Specification: The Open Group. In: Van Haren Publishing http://doc.utwente.nl/82972/

Kulkarni V., Barat S., Clark T., Barn B. (2015a) A Wide-Spectrum Approach to Modelling and Analysis of Organisation for Machine-Assisted Decision-Making. In: Enterprise and Organizational Modeling and Simulation. Springer, pp. 87–101

Kulkarni V., Barat S., Clark T., Barn B. (2015b) Toward overcoming accidental complexity in organisational decision-making. In: Model Driven Engineering Languages and Systems (MODELS), 2015 ACM/IEEE 18th International Conference on. IEEE, pp. 368–377

Langley A., Mintzberg H., Pitcher P., Posada E., Saint-Macary J. (1995) Opening up decision making: The view from the black stool. In: organization Science 6(3), pp. 260–279

Locke E. (2011) Handbook of principles of organizational behavior: Indispensable knowledge for evidence-based management. John Wiley & Sons, New Jersey, USA

McDermott T., Rouse W., Goodman S., Loper M. (2013) Multi-level modeling of complex sociotechnical systems. In: Procedia Computer Science 16, pp. 1132–1141

Meadows D. H., Wright D. (2008) Thinking in systems: A primer. Chelsea Green Publishing, Vermont, USA

Mintzberg H., Raisinghani D., Theoret A. (1976) The structure of" unstructured" decision processes. In: Administrative science quarterly, pp. 246–275

OMG (Jan. 2011) Business Process Model and Notation (BPMN), Version 2.0. http://www.omg.org/spec/BPMN/2.0

OMG (Jan. 2015) Business Motivation Model (BMM) Version 1.3. http://www.omg.org/spec/BMM/

Overbeek S., Frank U., Köhling C. (2015) A language for multi-perspective goal modelling: Challenges, requirements and solutions. In: Computer Standards & Interfaces 38, pp. 1–16

Peffers K., Tuunanen T., Rothenberger M. A., Chatterjee S. (2007) A design science research methodology for information systems research. In: Journal of management information systems 24(3), pp. 45–77

Prat N., Comyn-Wattiau I., Akoka J. (2014) Artifact Evaluation in Information Systems Design-Science Research-a Holistic View.. In: PACIS. Citeseer, pp. 1–16

Pries-Heje J., Baskerville R., Venable J. (2008) Strategies for design science research evaluation. In: ECIS 2008 proceedings, pp. 1–12

Rolland C., Nurcan S., Grosz G. (2000) A decision-making pattern for guiding the enterprise knowledge development process. In: Information and software technology 42(5), pp. 313–331

Shapira Z. (2002) Organizational decision making. Cambridge University Press, Cambridge

Siebert J., Ciarletta L., Chevrier V. (2010) Agents and artefacts for multiple models co-evolution: building complex system simulation as a set of interacting models. In: Proceedings of the 9th International Conference on Autonomous Agents and Multiagent Systems, pp. 509–516

Sipp C. M., Elias C. (2012) Real Options and Strategic Technology Venturing: A New Paradigm in Decision Making Vol. 31. Springer Science & Business Media

Van Lamsweerde A., Letier E. (2004) From object orientation to goal orientation: A paradigm shift for requirements engineering. In: Radical Innovations of Software and Systems Engineering in the Future. Springer, pp. 325–340

Vernadat F. (2002) UEML: towards a unified enterprise modelling language. In: International Journal of Production Research 40(17), pp. 4309–4321

Wieringa R., Moralı A. (2012) Technical action research as a validation method in information systems design science. In: International Conference on Design Science Research in Information Systems. Springer, pp. 220–238

Yin R. K. (2013) Case study research: Design and methods. Sage publications, London, UK

Yu E., Strohmaier M., Deng X. (2006) Exploring intentional modeling and analysis for enterprise architecture. In: Enterprise Distributed Object Computing Conference Workshops, 2006. EDOCW'06. 10th IEEE International. IEEE, pp. 32–32

Zachman J. et al. (1987) A framework for information systems architecture. In: IBM systems journal 26(3), pp. 276–292