A Framework for Socialisation of Work Practice for Improving Business Process Performance

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Abstract

Due to the competitiveness of today’s ever changing environment, many organisations pursue continuous improvement of their business processes. This is also essential for achieving the ability to quickly adapt business processes to changes and new requirements emerging in the business and regulatory environment. Organisation can undertake business process improvement in two alternative ways where improvement can be sought externally and can be solicited internally. Both alternatives imply a learning phase within the organisation so that organisations can develop insights, knowledge from past activities, and future actions. While many organisations often follow the externally sourced improvement by employing so-called best practice reference models, it is not uncommon for externally sourced process improvement to face rejection from employees in the organisation due to unfamiliarity and the lack of trust. On the other hand, there is evidence that internally driven process improvement may remove such barriers, as supported by the social theory of positive deviance. The concept of positive deviance is based on the observation that there are certain individuals within every group or organisation who have special practices or strategies that enable them to achieve better performance on certain problems. Positive deviance lets an employee to adopt new approaches from peers, who are in the same community or organisation. Using this concept, organisations can look into successful past practices of various activities internally and use those successful past practices as a baseline towards improving the business process performance. There are several challenges in the utilisation of positive deviance notions for business process improvement. These include finding best past practices that will become the source of improvement, identifying the most suitable past practices in a way that it fits employee’s level of experience, and understanding the complexity of the business process and its implications for process improvement. This thesis presents an integrated framework called Socialisation of Work Practice that systematically addresses the above challenges to achieve internally driven business process improvement. The framework consists of a series of analytical data driven methods, which can be used to extract and analyse the stored information from past practices, and elicit them into meaningful recommendations. The applicability of the framework is evaluated through the development of prototype system, namely PRIME system. PRIME has been successfully used to test the effectiveness and efficiency of the developed methods as well as provide a usable front-end to business process users.
Declaration by author

This thesis is composed of my original work, and contains no material previously published or written by another person except where due reference has been made in the text. I have clearly stated the contribution by others to jointly-authored works that I have included in my thesis.

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Contributions by others to the thesis

Professor Shazia Sadiq provided advice on conceptualisation and development of the framework, as well as reviewing and editing the publications and Thesis prior to submission.

Statement of parts of the thesis submitted to qualify for the award of another degree

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Process Improvement, Process Analysis, Process Complexity, Positive Deviance, Organisational Learning

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List of Abbreviations

BPM – Business Process Management
BPMS - Business Process Management System
CFC - Control Flow Complexity
EDL – Experience Driven Learning
MCDM – Multi-Criteria Decision-Making
PRIME – Process Improvement
SAW – Simple Additive Weighting
WP – Weighted Product
XES – eXtensible Event Stream
Chapter 1

Introduction

1.1 Research Background

Due to prevailing competitiveness in today’s business environment, process improvement continues to be named as the first priority for many organisations when implementing technology such as a business process management system (BPMS) (Sinur and Hill, 2010; Zellner, 2011). There are two main approaches to business process improvement, namely, process-driven improvement and people-driven improvement (Shtub and Karni, 2010). In the process-driven approach, organisations undertake business process redesign by replacing the current process with an arguably better process in order to achieve better performance. In the people-driven approach, human resources are the focus of improvement, and process improvement is expected to be an organic consequence of improvement on the human resources front. There is also another approach in process improvement namely product-driven improvement (Birk, 1998). In this approach, the focuses of improvement actions are on the quality factors of the product. The present study focuses on business process improvement driven through the human resources perspective.

Today, a sustainable edge in the competitive business environment can no longer be based on the implementation of technological breakthroughs such as those implemented in a BPMS. As the BPMS has become a mature product, most vendors will eventually deliver similar technologies (Sinur and Hill, 2010). The best practice process templates or so-called reference models (Rohloff, 2009; Schonenberg et al., 2008) delivered by the business solution vendors would no longer be the only solution to achieve process improvement even though it helps to create standard business processes that can be used in various organisations (Reinhartz-Berger et al., 2010). The issue is that every organisation is not the same even if they are working in a similar area; hence, the same solution cannot always be applied to a similar organisation. Furthermore, like the body’s immune defence system, individuals and organisations often resist
what is perceived as a “foreign matter” (Carter, 2003) even though the external template solutions can provide organisations with intellectual capital and competitive value. There is evidence that when the process improvement approach is driven externally, there is a significant likelihood of resistance due to misalignment with the organisational culture and norms (Pascale et al., 2010).

Many psychological and behavioural factors contribute to why people are reluctant to adopt something that is sourced externally (Zeitlin et al., 1990). Many studies on social relations show that people tend to interact with others like themselves (McPherson et al., 2001). Continuous interaction in the working environment within the organisation also creates similarities in work habits, not because of individual choice, but from social influences which further makes individuals’ behaviour more similar (Centola et al., 2007). Social homogeneity within a group of people increases the level of trust and leads to the imitation of habits within the group (Kleinbaum et al., 2013). People will only work with a new approach if they believe that the approach is trusted and achievable with the resources that are available. A major difficulty lies in the fact that the adoption of an externally sourced approach in improving the business process faces rejection due to unfamiliarity with the approach itself and the lack of trust. Hence, it can be observed that social factors greatly affect the implementation of new approaches in an organisation striving to improve its business process.

Substantial research has been conducted on the behaviours related to the adoption of new approaches within a group of similar people (Marsh et al., 2004). One such behaviour is positive deviance (Marsh et al., 2004). The concept of positive deviance is based on the observation that there are certain individuals within every group or organisation who have special practices or strategies that enable them to achieve better performance on certain problems (Carter, 2003) even though they have exactly the same resources as others. Positive deviance is not a typical behaviour, yet the actions of positive deviants can provide benefits beyond what others in similar circumstances can achieve. As it is behaviour exhibited by peers, positive deviance can generate greater motivation to achieve higher quality outcomes in social settings. The knowledge of these positive deviants (also referred to as internal experts) is important as organisations often face a dynamic environment in order to keep pace with the level of competitiveness. This forces the individuals who work within the environment to adopt a degree of improvisation in order to tailor their approach to individual process cases or instances. It is evident that when such diverse work practices incorporate the creativity and individualism of knowledge workers, they potentially contribute to the organisation’s competitive advantage even though they depart from the norms and procedures of the
organisation (Vadera et al., 2013). Although deviating from the norms could create harmful experiences (Lee and Allen, 2002), it also beneficial for the organisation and contributes to excellence and high performance within the organisation (Spreitzer and Sonenshein, 2004). The positive deviance concept focuses on these cases of excellence. In the organisational context, positive deviance could help organisations perform better without having to be dictated or directed by external sources of process improvement that do not always fit the business culture and work traditions. From the perspective of business process performance, the positive behaviours of employees are typically measured by the performance of the processes in which the individuals are involved. Various criteria define the norms (or expected performance) for a process.

Unfortunately, the experience of the internal experts as exhibited in their positive practices or strategies is often overlooked. Even though the practices of these experts constitute the corporate skill base, the failure to capitalise on these practices to build knowledge obscures the positive deviant behaviour. The absence of explicit articulation makes this capitalisation a very difficult task. Knowledge from experience is often regarded as tacit knowledge (Nonaka and Takeuchi, 1995). Contrary to explicit knowledge, which is in documented form and easily available, tacit knowledge is owned only by the individuals involved. Polanyi and Sen (1983) described tacit knowledge as knowledge that cannot be articulated or verbalised. The present study proposes that the value of tacit knowledge can only be realised if it can provide relevant and meaningful recommendations for others who are working in similar events. Some studies have suggested that the relevant practices of colleagues are “interesting”, in the positive sense of the word, and are regarded as a trustworthy source of knowledge (Stenmark, 2001). Thus, the present study proposes an approach called the socialisation of work practice.

The socialisation of work practice refers to the capture of the best work practice that has been experienced by the internal experts to allow current and future users to work at their full potential. This thesis develops novel methods to capitalise on the knowledge of internal experts and deliver the knowledge in the form of personalised recommendations, which will be used as the source of user performance and subsequently business process improvement. To effectively deliver the recommendations, they need to be matched to the user current profile. Some studies have suggested a learning process that aligns with the measurement of learners’ performance (Day and Payne, 1987) as well as being matched to a certain situation (Santos and Boticario, 2008) could achieve a better learning result which business process improvement could benefit from.
1.2 Research Objectives

The premise of this research is that the experiences and knowledge of employees can help achieve process improvements that are driven from within an organisation rather than externally. The research seeks to investigate and validate this premise.

This research aims to address the relevance, issues and problems in sharing and delivering the tacit knowledge, as defined by Polanyi (1967), that is embodied in the experiences and strategies of successful past business processes as sources of business process improvement. It conceptualises and formalises a method of capturing the tacit knowledge of experts, and subsequently delivering it into explicit, sharable and repeatable knowledge in the form of recommendations for users of the business process of the organisation. It also aims to personalise the recommendations to suit individual characteristics. To realise these aims, a software system is proposed to facilitate business process analysis and knowledge sharing. In summary, the research objectives are as follows:

- To investigate and understand the theories and methods relating to business process improvement, business process analysis, positive deviance, and organisational learning.
- To develop a framework for the socialisation of work practices that serves as the theoretical foundation of internally-driven business process improvement.
- To investigate the factors affecting the socialisation of work practices within organisations and develop an analytical method for identifying the most suitable work practices for individuals.
- To develop a comprehensive model for understanding business process complexity and its impact on the socialisation of work practice.
- To validate the framework and establish the practicality of the methods through the development of a system prototype and experiments to evaluate the developed methods.

1.3 Thesis Structure

This thesis consists of eight chapters. This introductory chapter began with a discussion of business process improvement through the socialisation of work practices, including a brief overview of the supporting theories within this domain. The context of the present study was outlined.

Chapter 2 reviews the literature related to business process management, business process analysis and learning within organisations. The chapter explores the current field of theory and
practice and identifies the open issues and challenges. It also highlights the gaps found in the literature and presents the background theories.

Chapter 3 presents the research framework including the conceptual framework that is the basis of the developed prototype with which the study of the socialisation of work practices for business process improvement is carried out. It also presents the architecture of the prototype system based on the framework.

Chapter 4 discusses experience-driven learning (EDL) and presents the concept of knowledge discovery from within an organisation. This chapter discusses the background theories on which learning from experience is based and presents the methods to capture the knowledge. It highlights how business process event logs can be a beneficial knowledge base that can drive process improvement.

Chapter 5 introduces the process improvement through personalised recommendation approach. The concept of learning from peers is discussed, including how it can help organisations improve business process performance effectively through learning that fits the performers.

Chapter 6 investigates business process complexity and how it affects the comprehension and performance of a business process. This chapter presents an approach, called the Integrated Framework for Business Process Complexity that provides a comprehensive view of complexity beyond the process model/structural view and includes variability and performance.

Chapter 7 presents the Process Improvement (PRIMe) system and shows how the system helps to capture the tacit knowledge and convey recommendations to improve the business process. The system is built as the evaluation mechanism for various methods developed for the framework for socialisation of work practice. To achieve this purpose, the system delivers detailed reports, graph visualisations, and personalised recommendations to the relevant users.

Chapter 8 concludes the thesis. A summary is presented and the primary contributions of the research are outlined. Recommendations for directions of future research are suggested.
Chapter 2

Literature Review

2.1 Introduction

This chapter presents a review of the literature on organisational learning and business process management in the context of improvements in business processes. The literature review is conducted with a focus on the capture and sharing of successful work practices in organisations that utilise a business process management system, and how they contribute to business process improvement.

Figure 2.1 presents an overview of the related topics on organisational learning and business process management systems. The review of the literature on organisational learning is presented in Section 2.2, including the topics of knowledge management, positive deviance and learning from experience. The review of the literature on business process management systems is presented in Section 2.3, with a focus on process analysis, business process improvement, business process variants and business process complexity.

Figure 2.1: Areas of study
2.2 Organisational Learning

Organisational learning is a process of acquiring new insights and knowledge in organisations that sense new insights and changes based on the information and knowledge they currently have (Argyris and Schön, 1999). The development of knowledge creation and the capability of knowledge sharing often form the basis of achieving competitiveness (Holsapple and Singh, 2001). These actions are the driving force behind the vision of organisations that are capable of thriving in a world of interdependence and change (Kofman and Senge, 1993). To promote knowledge creation and sharing, a conducive organisational culture should be established which has the paradigms that stimulate proactive behaviour (Nevis et al., 2000) and social interaction (Corbett et al., 1999).

Senge et al. (1999) identified five points that represent the study and practice of individuals and teams in organisations. These are: (1) personal mastery, (2) mental models, (3) shared vision, (4) team learning, and (5) systems thinking. Senge et al. argued that each individual who works in an organisation needs to align his/her personal vision with the organisation’s vision. In relation to mental models, people are asked to reflect upon and talk about their work. The shared vision establishes a focus on mutual purpose and a sharing of the vision of the future they seek. This vision is tied to the subsequent point, which is team learning. Team learning refers to how the individuals interact within the organisation. The last point, system thinking, refers to change that is initiated from feedback and leads to improvement or stability over time.

Organisational learning itself is a capacity (or process) within an organisation to preserve or improve performance based on experience (Dibella et al., 1996). This activity involves knowledge acquisition (the development or creation of skills, insights and relationships), knowledge sharing (the dissemination to others of what has been acquired by some), and knowledge utilisation (integration of the learning so that it is assimilated, broadly available, and can also be generalised to new situations) (Huber, 1991). The concept of organisational learning is widely researched and has been defined in a number of studies (Argyris and Schön, 1999; Boud et al., 1993; Senge et al., 1999).

In a social system environment in which learning takes place just as in an organisation, the learning process always starts from the individual (Wang and Ahmed, 2003). Organisational learning is also founded on the learning process of individuals in the organisation. Hence, the individual learning process in an organisation facilitates the understanding of organisational learning (Marquardt, 1996). As learning in an organisation starts from the individual, social theories that support interaction among individuals are also important. Monge and Contractor (2001) identified the theories that have been used to explain the networks of individuals within organisations.
an organisation such as homophily theories, contagion theories, and exchange and dependence theories. In homophily theory, individuals have choices based on similarity, and have their own group identity. Homophily has been found among age groups and occurs on many dimensions such as acquired characteristics (i.e., education and social class), personal attributes like beliefs and attitudes, and social behaviour (McPherson and Smith-Lovin, 1987). In the contagion theory, exposure to others leads to the social influence and imitation of others. This theory suggests that individuals adopt the attitudes or behaviours of others in the social network with whom they communicate (Scherer and Cho, 2003). In the exchange and dependence theory, individuals in an organisation exchange valued resources such as their knowledge with other individuals (Frooman, 1999). All of these theories point to the mechanisms by which individuals build their interactions, which in turn leads to the building of knowledge within an organisation.

The concept of organisational learning starts from the individual learning process within an organisation. Understanding the individual learning process is a good way to begin to understand organisational learning, but evaluating the individual learning process cannot capture the whole picture (Gratton et al., 1999). The organisational learning process helps to transfer knowledge and competence between generations of employees (Van Maanen and Schein, 1977) in a form of collective learning (Prahalad and Hamel, 2006). This highlights the necessity for organisations to manage and share the knowledge of individuals, especially experts who have successful practices, among the rest of the organisation’s stakeholders.

2.2.1 Knowledge Management

Organisational learning is the process of improving actions and activities within an organisation through better knowledge and understanding (Fiol and Lyles, 1985). This raises questions about the creation, acquisition and utilisation of the knowledge. Knowledge, whether stored in computer databases, human brain, or any other media, is the key in processing information (Kock, 2005). In organisations, knowledge is predominantly captured by means of individuals working in teams where the organisational knowledge is an assembly of the knowledge possessed by the individuals who work in the organisation (Kock, 2005). It is important to note that knowledge can be obtained from external sources or generated internally.

Nonaka and Takeuchi (1995) emphasised the importance of knowledge creation in organisations and the sharing of knowledge among the parties involved in an organisation. If the skills and experiences within an organisation are not shared within the organisation, it is common for the organisation to suffer from the “reinvent the wheel” syndrome (Davenport and
Prusak, 2000). In addition, if the knowledge is not accessible, even though it is abundantly available in the skills and experiences of employees, it will never become a valuable corporate asset and provide little benefit.

Knowledge is typically categorised as tacit or explicit (Polanyi, 1967). In contrast to explicit knowledge that is clearly formulated or defined without ambiguity or vagueness, tacit knowledge, as per Polanyi’s (1967) definition, inhabits the minds of people and is difficult to articulate. Tacit knowledge is largely unspoken even though it is abundant among people and is often difficult to describe and transfer (Bollinger and Smith, 2001). Due to the nature of tacit knowledge, many organisations do not know what they know and knowledge is largely underutilised (O’Dell and Grayson, 1998). Many organisations do not know that they actually have the necessary knowledge; this means there is a need to convert the tacit knowledge to an explicit form through the means of socialisation or externalisation (Nonaka and Takeuchi, 1995) in order to manage the organisational knowledge effectively. This process of capturing, managing and providing access to an organisation’s knowledge or an enterprise’s information asset is referred to as knowledge management (Gold et al., 2001).

Knowledge management is about enabling individuals or entire organisations to collectively create, share and implement knowledge that is embodied from insights and experiences in order to improve the performance and the outcome of their business objectives (Alavi and Leidner, 2001). Knowledge management is regarded as an increasingly important feature for organisations to achieve effectiveness, survivability and competitive strength (Mårtensson, 2000). Milton et al. (1999) defined knowledge management as the provision of strategies to get the right knowledge to the right people in the right setup. Van Beveren (2002) described knowledge management as a practice that has the goal to collect valuable information and transform it into the knowledge necessary to support decision-making and performance. In summary, knowledge management according to the definitions provided by these studies consists of activities that collect an organisation’s own experiences or the experiences of others to achieve the goal of the organisation. Knowledge management complements other organisational initiatives, such as business process re-engineering and total quality management (Pathirage et al., 2004), to gain insights into process improvement.

To socialise or externalise the tacit knowledge, the activities in knowledge management involve knowledge acquisition, creation, refinement, transfer, sharing and utilisation (King, 2009). In the context of the socialisation of work practices, there needs to be a methodology to develop the knowledge, a system that supports it, and sharing of the knowledge in such a way that it will motivate people to improve the quality of their activities. Such motivation can be
achieved when people see the knowledge as beneficial and trustworthy. When people trust the source of knowledge, it is easier for them to absorb and learn something from it (Savolainen, 2008). The challenge here is to determine how knowledge can be both beneficial and trusted. This in turn requires the identification of who has the authority to be the source of knowledge in an organisation. These questions are related to the concept of positive deviance, which is discussed in the next section.

2.2.2 Positive Deviance
Organisational learning introduces change management as the act of renewing an organisation’s path and structure, and continually adapting to the ever-changing needs in the environment (Moran and Brightman, 2000; Todnem By, 2005). Today, having good strategies for managing change is important as marketplace is often experiencing rapid changes. Many organisations use traditional approaches that allow external parties to determine the best practices that need to be performed by employees to make the improvement. This approach is known as the deficit-based approach, as it is based on the perspective of “Why can’t we do what someone else is doing?” (Tarantino, 2004). However, even though humans are social creatures, so that they may get cues and ideas of how to act and think from others, people are also born with ego and often choose their own path and judgement rather than what others want them to do (Marcia, 1966). This happens particularly when the cues and ideas come from outsiders whom they do not know very well, thus, there is a lack of trust and familiarity.

Sternin and Choo (2000) and Pascale et al. (2010) presented a different approach to organisational change management, namely, positive deviance. Positive deviance is a term used to define behaviours that depart from the norms of a group but exhibit certain positive characteristics (Spreitzer and Sonenshein, 2004). Positive deviance is an uncommon practice, yet it can lead to good outcomes when everyone else is facing similar challenges and similar limitations from the available resources.

Positive deviance is explained as uncommon (good) behaviour that is exhibited by peers. Peers are known to have greater influences in a community than others do. There is a large body of knowledge in psychology that supports this statement (Katz and Kahn, 1978). Cialdini (2001) in his article titled “Harnessing the Science of Persuasion” presented the six principles of persuasion. Those principles are: liking, reciprocity, social proof, consistency, authority, and scarcity. Table 2.1 provides a summary of these principles.
Table 2.1: Six principles of persuasion (Cialdini, 2001)

<table>
<thead>
<tr>
<th>Principle</th>
<th>Definition</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liking</td>
<td>People like those who like them</td>
<td>Uncover real similarities and offer genuine praise</td>
</tr>
<tr>
<td>Reciprocity</td>
<td>People repay in kind</td>
<td>Give what you want to receive</td>
</tr>
<tr>
<td>Social Proof</td>
<td>People follow the lead of similar others</td>
<td>Use peer power whenever it’s available</td>
</tr>
<tr>
<td>Consistency</td>
<td>People align with their clear commitments</td>
<td>Make their commitments active, public, and voluntary</td>
</tr>
<tr>
<td>Authority</td>
<td>People defer to experts</td>
<td>Expose your expertise; do not assume it’s self-evident</td>
</tr>
<tr>
<td>Scarcity</td>
<td>People want more of what they can have less of</td>
<td>Highlight unique benefits and exclusive information</td>
</tr>
</tbody>
</table>

The six principles of persuasion explain that people will follow the lead of ‘similar’ others. According to the six principles of persuasion, the persuasion that comes from peers can be extremely effective (Cialdini, 2001). The effectiveness is achieved since successful performers and other/prospective performers share a similar challenge and environment, as described by the positive deviance concept, wherein the positive deviant (the positive deviance exhibitor) and others share the same settings.

In positive deviance, people who are departing from the norm can be considered to have greater authority than others since they exhibit successful outcomes and they become the experts in the field. To explain positive deviance theory further, the case in the following box illustrates the notion.
An external source of improvement that does not have a common organisational culture and affiliation often faces problems in transferring insights (Katz and Kahn, 1978). In the organisational context, positive deviance could help organisations to achieve improvement. By using positive deviance, an organisation is not dictated or directed by external sources, which do not always fit the business culture and work traditions. The remaining challenge is how to effectively capture the positive deviance. It is essential for an organisation to identify the measureable behaviours exhibited in the experience of employees that positively affect the organisation’s performance.

2.2.3 Learning from Experience

It is important to understand the role of experience in organisational learning, because experience is a fundamental notion of the work carried out in this study. Experience has the potential to enrich the knowledge sharing and knowledge transfer between learners, as a learning process is the process of knowledge transfer between tacit and explicit knowledge. Boud et al. (1993) argued that “experience is not just an observation, a passive undergoing of something, but an active engagement with the environment, of which the learner is an important part”. Each learner forms part of the milieu, enriching it with his or her personal contribution and creating an interaction, which becomes the individual learning experience as well as the

In the early 1990s, the international NGO Save the Children was assigned to reduce the widespread problem of childhood malnutrition in Vietnam. In the limited time available, the NGO had to produce a sustainable approach with little medical equipment and supplemental food which was only a temporal solution at best with no further sustainability. The NGO found that even within the poorest communities, there were a few individuals or families who were in good health. The NGO documented the methods that were used by these families, and encouraged the rest of the community to carry out the methods. The result was astonishing and successfully alleviated the childhood malnutrition problem. The approaches from the good families were within the community’s socio-cultural context and by definition, “culturally appropriate” (Marsh et al., 2004; Sternin and Choo, 2000). The positive deviance approach provides an alternative to the implementation of successful “models” which often fail when they are enabled in “unaccustomed soil” (Sternin and Choo, 2000).
shared learning experience. This continuing, complex and meaningful interaction is central to the understanding of experience.

The performance of organisations and individuals is often improved by doing repetitions of the same activity. Some studies have shown how repetition-based improvements exist in organisations (Yelle, 1979); these improvements are documented as knowledge gained from experience. Successful organisations are described as having the ability to learn and respond by adapting to change in technologies and practices (Stalk et al., 1992).

The socialisation of work practices uses the learning from experience approach as it emphasises the value of knowledge by incorporating successful peer learners’ experiences in a learning system, which can be harnessed by contemporaries through technology and improve the effectiveness of learning in a domain (Wan et al., 2009). The experiences of individuals in organisations constitute the corporate skill base and are valuable information resources for organisational learning and process improvement. The concept of “learning experiences” (Wan and Sadiq, 2012b) is based on the proposition that learners’ experiences can help improve the effectiveness of learning for the learners and their peers; through this process, the valuable information about the experts’ experience is harvested and shared with others in the organisation and can become one of the sources of business process improvement.

The notion of experience sharing itself is not new. It is commonly found in practice and has been widely researched (Pathirage et al., 2004). By capturing the experiential lessons of the enacted business process, the knowledge becomes accessible and sharable within an organisation and its members, especially those who have yet to experience the activities. The knowledge is then distributed via socialisation, education, training, imitation and personal or group movement (Levitt and March, 1988).

The knowledge of the members of an organisation can actually represent the corporate skill base and is considered a valuable information resource to utilise in the fundamental steps towards achieving competitiveness (Kock, 2005). However, this knowledge is often regarded as tacit knowledge (Nonaka and Takeuchi, 1995). In contrast to explicit knowledge that is written and can be described to others, tacit knowledge is usually not documented anywhere although it is known by the individuals involved. Polanyi and Sen (1983) defined tacit knowledge as knowledge that cannot be articulated or verbalised. This tacit knowledge is kept and recorded in the form of process logs, files and operating procedures where personal experience matters. Therefore, tacit knowledge is often learned through collaboration that requires the participation of people (Nonaka and Takeuchi, 1995).
One important question that remains is which experiences the employee should adopt. Evidently, people often choose the sources of improvement they are familiar with or the sources that exhibit similarity with what they are doing (Guy et al., 2009). A personalised adoption of experience shows that individuals may learn and absorb differently. It is also evident that personalised learning can create huge differences in the learning process (Martinez, 2002). With personalised learning, each learner has a learning path that must conform to the learning needs of the learner so that the learning process is delivered effectively. The challenges in effectively delivering personalised learning are to find the minimum proficiency as a standard for certain roles, to identify activities most critical to success, and to allow employees to self-assess against the given activities.

2.3 Business Process Management Systems

Business process management is a means to look at and control the business processes that are present in the organisation. It is incorporating the framework of organisational learning and knowledge management into a system and raising awareness that knowledge in the business process holds strategic importance as a resource for gaining competitive value (Armistead et al., 1999). Business process management is the concept of shepherding the business process through a multi-step approach. It involves supporting the business process using methods, techniques and software to design, enact, control and analyse operational processes involving humans, organisations, applications, documents and other sources of information (Aalst et al., 2003).

The business process is an ordered set of logically structured activities, linked by precedence relationships, which uses the resources of the organisation and expresses how the work is done within an organisation across time and place. Business process is often focused on repetitive process with strict workflows. It has a beginning, an end and clearly defined inputs and outputs, and is comprised of three main components: actions, decisions, and controls (Harrington, 1991; Shtub and Karni, 2010). Similarly dos Santos França (2014) have defined business process as a sequence of activities that aims at creating products or services, granting value to the customer, and is generally represented by a business process model.

As a concept, business process management has been interpreted as having several different meanings. In general, many authors put some or all of the management process functions into the business process management concept. The term “management process” itself embraces the five basic functions of managers: planning, organising, staffing, leading, and controlling (Dessler et al., 2004). The five basic functions that managers perform are in
line with the business process management functionality which includes the category of “management” functionality. Having a mature cross-functional approach, business process management is process-centred so that it becomes the way to understand, document, model, analyse, stimulate and execute the end-to-end business processes through the engagement of all the related resources (Shtub and Karni, 2010). This people-centred focus leads to the main concerns of business operations which are high leverage and added value (Zairi, 1997).

The difference between general management and business process management is that the latter has tasks other than the basic five management tasks. Business process management includes the management of the business process on all organisational levels. Involving management in the “business process” area is the consequence of the need to create and sustain improvements in the significant processes that depend heavily on large, complex, cross-functional business processes (Juran et al., 1999). When an organisation implements business process management, it generally addresses strategic business issues by making the business grow but operate in a cost-effective way both in the managerial approach and as an enabler for a technological solution or IT in the organisation.

In the research community, a BPMS is defined as a system that performs the functionality historically attributed to a workflow management system (Aalst et al., 2003). This view emphasises the capability of a BPMS in process enactment. Systems for business process management have grown to include the management of the performed business processes in organisations. Not only does the BPMS route documents as executed in a workflow management system, its scope has been extended to include the automatic allocation of work to qualified and authorised resources among both human and non-human actors (Reijers, 2006).

Hunt (1996) explained that business process management reaches beyond the process, and that the following four components should form the basis of effective business process management: process goal management, performance management, resource management, and process interface management.

The BPMS is useful to drive the business process in regard to both the management aspect and learning aspect. It benefits from the corporate culture as it contains the beliefs, expectations and values that are shared by the organisation’s members and that act to shape the behaviour of the people in the organisation (Wheelen and Hunger, 2009). Business process management has become popular in today’s competitive era with many organisations implementing a BPMS for managing, monitoring, controlling, analysing and optimising their business process (Aalst et al., 2003). A BPMS allows an organisation to design business process models, execute
process instances in accordance with the models, enable users/applications to access task lists and execute task operations (Yujie et al., 2004).

BPMS is meant to implement business strategies by modelling, developing, deploying and managing the business process so that organisations can have the benefit of innovation and optimisation. Quality in business process is fundamental to the organisation’s performance and competitiveness. Aalst et al. (2003) described the lifecycle of a BPMS including the phases that support the operational aspect of the business process, as shown in Figure 2.2.

![Business process management cycle](image)

Figure 2.2: Business process management cycle (Aalst et al., 2003)

As the phases work in a cycle, the overall business process can be improved by revamping various components of the cycle. The process to revamp the various components of the cycle lies in the diagnosis phase, where the organisation has the chance to analyse the previously executed processes with the goal of continuously improving the process and related practices (Biazzo, 2000).

2.3.1 Process Analysis

Business process analysis is a well-studied area. It is an essential part of business process management in terms of process diagnosis (Lu, 2008). The process analysis gets the information from all the stakeholders of a business process and the interaction between them, which can be collected from the current running process as in business process monitoring or business activity monitoring, or it could be extracted from the event logs or post-execution of the process as in business process mining (Aalst et al., 2007). It then chooses the proper information and provides feedback to the stakeholders. Various aspects of the business process are monitored, managed and optimised. It then reveals the information to be fetched in the design and/or execution phase, where the goals and priorities are reworked in real-time (on the fly) or it reuses the best information as a basis of knowledge for other potential users.
Process analysis research addresses the need to improve the quality of the business process. A focus on quality is required for the value creation and delivery that are vital to the organisation. The efficiency, cost, completeness and confidence level of the business process are the key to the definition of quality. The performance of an organisation can be measured through quantitative, measurable indicators. Hornix (2007) stated that performance indicators rely on time-related factors (e.g., throughput time of a process or service time of an activity), cost-related factors (e.g., process costs or material costs), or quality-related factors (e.g., error rates, visiting frequency). The indicators represent how interventions are to be done to boost the overall performance. These indicators also reflect the critical success factors of the organisation and help the organisation to define and measure progress towards its organisational goals.

Business process analysis is an essential prerequisite for smart interventions for organisational change and is needed to create gradual or incremental change (Biazzo, 2000). Developing better business process practices in the business process analysis area can be approached through different means (e.g., redesigning the business process, adopting an adaptive/flexible business process) (Lu, 2008) or learning from business process experience. These approaches will help an organisation continue the improvement process to match the quality demand.

A number of contributions have been made in the general area of business process analysis. For example, business process mining allows information to be extracted from transaction logs (Aalst et al., 2007). An audit trail of a BPMS is an example of how it can be used to find models which describe the process, organisation and products. An audit trail has information about the events (i.e., who executes the process, what time was taken, which activity and process instance). All the information can then be analysed in many areas as explained by (Bozkaya et al., 2009), such as to measure the performance of the process (Hornix, 2007), process discovery (Günther and Aalst, 2007), process conformance (Rozinat and Aalst, 2005), and social networks (Aalst et al., 2005).

Some research has proposed the process model as the output of process discovery (Aalst et al., 2004). From a workflow log, a process model is partly or fully developed. The process model can then be used later for specific purposes, such as discovering patterns of execution (Dubouloz and Toklu, 2005) and analysing variances in the process model (Tsai and Chen, 2009). Similarly, interaction patterns can also be learnt to cover the social networks that exist (Aalst et al., 2004).
Most research on business process analysis has focused on the structure of the business process. The business process itself involves not only the structural aspect, but also the human aspect that drives it. Hence, questions remain about how to analyse the human aspect of the business process.

### 2.3.2 Process Improvement

The basic goal of business process analysis, as stated above, is to increase the quality of current business processes. The process of increasing the quality is called business process improvement. Business process improvement is a systematic approach to help any organisation make significant improvements and to add value to the way the organisation does its business. The key aim of this approach is to continuously improve the process and related practices, and reduce unnecessary or not useful actions. Business process analysis has been identified as an essential prerequisite for gradual and incremental organisational change (Biazzo, 2000). In general, improving the business process will usually have the goals of reducing costs, improving productivity, improving competitiveness and reducing service or production time (Mansar et al., 2009). There is a large body of knowledge on business process assessment and improvement strategies.

Currently, there are two research approaches to understanding how business process improvements are implemented (Shtub and Karni, 2010):

1. **Business process redesign** – This approach focuses on how a business process can be improved. It includes how to ensure the process designer is qualified to improve the business process and how the improvement can be integrated into the enterprise process suite.

2. **Performer capability** – This approach focuses on how the process performer is qualified to carry out the process.

In business process redesign, changes to business process occur in the structure. It starts with the basic question about how things are done, followed by collecting the activities, decisions and events, and then arriving at the goal of understanding how the current work can be done better (Mansar and Reijers, 2005). Hammer and Champy (1988) explained the necessity of radical design to cut costs and increase quality by introducing the business process redesign that focuses on the analysis and design of workflows and activities within an organisation to achieve dramatic improvements with certain criteria (such as costs, time and quality).
However, although business process redesign is a popular tool, it has also proven to be a challenging tool for transforming organisations (Broadbent et al., 1999). Introducing a radical business process redesign into an organisation also introduces a new learning curve. Inexperienced performers may struggle to learn the new approach. Hence, another school of thought that sees improvement from the process performer perspective has started gaining momentum (Shtub and Karni, 2010).

Many vendors have responded to this situation by offering best practices to improve an organisation’s performance. However, as previously discussed in relation to positive deviance, many of these solutions are rejected because there is lack of trust from employees. Employees reject new practices that are disharmonious with the working environment. This scenario raises questions about how to make the employees accept the new approach to improve the process performance and how to gain their trust. It is the aim of the present study to answer these questions.

The socialisation of work practices is an improvement at the performer level, as it focuses on improving the business process by having the people who enact the business process follow the path of successful work practices performed by internal people who are experts in the domain.

With regard to the aspects of business process improvement, there are several business process improvement metrics discussed in literature. Below we present a brief discussion on some of them.

1. **Time** – The time needed to execute an instance of a business process. It comprises the service time which shows how long the process takes, the wait time which shows how long it waits after being synchronised with other activities before proceeding, and the queue time where nothing happens as resources required unavailable. Decreasing the time needed to complete an activity is clearly desirable in improving the business process (Mansar et al., 2006; Shtub and Karni, 2010).

2. **Quality** – Quality defines how well the activities are commenced from the viewpoint of the customer who receives the result of the process and the performer who executes the process. An improved business process will ideally also improve the quality of the service it delivers (Lockamy III and McCormack, 2004; Mansar et al., 2006).

3. **Cost** – The issue of cost is usually the primary and most noticeable indicator in business performance. Intuitively, reducing the cost is the expectation of business process improvement (Shtub and Karni, 2010).
4. **Flexibility** – In a dynamic environment, adaptation to something new and different is necessary for a successful organisation. Improving the business process means enhancing the ability to react to and meet the future demands (Mansar et al., 2006).

5. **Resource Utilisation** – Resource utilisation discusses the ratio of activity versus availability of resources in organisation. If the supply of work and resources remain constant, an improvement in business process leads to the reduction of utilisation (Reijers and Aalst, 2005).

Among above issues, three most important issues, which represent the criteria for assessing how issues in business process improvement should be addressed, will be discussed further in the study, *time, cost, and flexibility*.

**2.3.3 Process Variants**

As flexibility is a key criterion in improving the business process, a further understanding of the flexible business process is necessary. A typical BPMS follows rigid graph-based models. It does not allow flexibility, dynamism and adaptability to occur in the business process. This makes a typical BPMS fail to react to dynamic changes in the business process to match the demand that often changes and when exceptional circumstances arise. Some approaches have been proposed, such as those from Sadiq et al. (2005) and Reichert et al. (2003), to address the adaptation problem. However, the change implemented increases the overall complexity (Lu, 2008).

A flexible business process is an approach that allows variation and uncertainty. Flexibility is introduced as a kind of competence to efficiently respond to the changing environment. Process variants are introduced to address the need to have a flexible business process (Lu, 2008). Some studies have shown the existence of process variants (Lu and Sadiq, 2007) in the business process research area. Generally, as mentioned previously, a BPMS will produce records of process activities into log files. The log files record activities and their attributes (i.e., contributor, time stamp) which further can be used as sources for business process analysis. Contrary to a typical strict BPMS, a flexible business process produces more than one type of instance. In a typical BPMS, only one process model is generated, but a flexible business process can produce more than one type of process model. The schemas of the activities in the produced process models of the flexible business process are different to each other, but they perform similar activities. A structural similarity query is launched during the process mining activity to reveal the process variants. The algorithms presented by Lu (2008)
demonstrate the ability to precisely distinguish the complete and partial matches of process models.

Process variants are basically individually tailored process instances in the business process. Process variants are complex objects that contain various designs and exceptional properties. The particular design of a variant is reflective of a knowledge worker’s preferred work practice. An executed process variant represents the realisation of the process constraints, and provides valuable knowledge of the organisation at the operational level. Such resources can provide valuable insight into work practices, help externalise previously tacit knowledge, and provide valuable feedback on subsequent process design, improvement and evolution (Lu, 2008).

The process variant is closely related to the flexible business process (Lu, 2008). The flexibility of the business process allows the execution phase process to be executed on the basis of a loosely or partially specified model, where the full specification is made at runtime (Sadiq et al., 2005). Process variants are only available when a flexible business process is introduced into the organisation. As described previously, with their creativity and knowledge, the flexible business process will allow the users to specify their own approach and methodology within certain circumstances and with the stated goal of the process. For example, in the insurance industry, insurance claim processes can be done differently for VIP clients compared to regular clients, or for insurance policies above a certain amount and below a certain amount. An executed process variant provides valuable knowledge at the operational level. The knowledge will be a useful insight into the work practice, and provides feedback to subsequent users. Without process variants, no best practices would be revealed, as the whole business process strictly follows the design, and only a little or no tacit knowledge will be available.

Lu (2008) observed that a process variant contains information from at least three dimensions:

1. The structural dimension contains the process model on which the process instance is executed. For a given process variant, the instance-specific process model is adapted from the design time model during instance adaptation.

2. The behavioural dimension contains execution information such as the set of activities involved in the process execution (which may differ from the structural dimension due to choice constructs in the process models), the exact sequence of activity execution, the performers and their roles in executing these activities, the process-relevant data, and the execution duration of the process instance and constituent activities.
3. The contextual dimension contains descriptive information (annotations) from the process modeller about the reasoning behind the design of a particular process variant.

The log files generated by these process variants are valuable resources for business process analysis. As stated above, the tacit knowledge is to be externalised through some means such as process redesign or knowledge sharing which converts the log files into meaningful knowledge which is later shared among users, designers and developers. The process variants help the externalisation part. In application domains where significant amounts of variances are produced during business process execution, managing the resultant process variants and subsequently reusing the knowledge from the variants needs to be supported explicitly (Lu and Sadiq, 2006). However, with the existence of process variants, new challenges have emerged and presented questions that remain open. For example, which process variant has the most benefits for organisations? How will process variants affect business process performance?

2.3.4 Process Complexity

The service quality of the business process can be seen from its performance, not only whether it has satisfied the purpose, but also whether the process is delivered effectively. However, to deliver the business process effectively, new challenges often arise unexpectedly. It is often necessary for an organisation to introduce some degree of complexity in a business process due, for example, to the introduction of new regulations or organisational growth, as well as due to the introduction of elements in the business process that will lead to process improvement.

Complexity theory is known in many areas including economics, computer science and social science. Complexity theory is focused on the significant cognitive aspects that affect the acceptance and comprehension of a system. Even though complexity is often depicted as factor that will inhibit success, it has been found to motivate strategic development (Locke et al., 1981) and innovation in organisations (Damanpour, 1996). From the business process management perspective, business process complexity is known to have a connection with and direct impact on process performance (Cardoso et al., 2006). Numerous aspects of complexity have been studied in the area of business process management. Complexity is considered to be relevant to the business process model, and is expected to increase as the number of activities and/or their inter-relationships grows (Cardoso, 2008). At the beginning of the implementation of the business process, organisations can gain improvement by implementing a complex process. However, when the complexity is not properly understood, complexity in the business
process can increase, and once it reaches its tipping point, it can become detrimental and create a higher error probability rate in the performance of the business process (Cardoso et al., 2006). Figure 2.3 presents an inverted U-shape graph of the complexity curve that shows how complexity starts as a beneficial factor but ends up as a detrimental factor that lowers the individual’s overall performance (Flood and Carson, 1993).

![Figure 2.3: Impact of complexity on individuals’ performance (Flood and Carson, 1993)](image)

In the current state-of-the-art research in business process complexity, many researchers have focused on the structure of the business process as depicted in the research by Cardoso et al. (2006), Gruhn and Laue (2006) and Rolón et al. (2009). It is evident that complexity within a business process could manifest itself in a variety of ways. A business process is represented through a number of aspects. Business processes are characterised by the data and the data flow, the control flow within the business process, the assignment of individuals to the process activities, and applications that perform the process activities, as explained by Heinl et al. (1999). In a further breakdown of the business process, it is found that the activities that construct a business process are in fact characterised by a few dimensions: the structure, the skill and organisational requirements, and the person-process interactions (difficulty, familiarity and intrinsic interest) (Wood, 1986). From this situation it can be concluded that the dimension of process complexity is not only determined by the structure as seen in the business process model complexity, but also in other dimensions. How to define the integrated complexity framework remains an open question.
2.4 Summary
This chapter has provided a critical review of the related works on business process improvement and the implementation of business process management systems. The literature review focused on process improvement through two perspectives, namely, redesigning the business process, and improving performer capability. From the business process perspective, improvement is approached through process redesign which often comes from external vendors and is focused on the analysis and often radical redesign of workflows and activities. Even though business process redesign is a popular approach, it adds a steep learning curve for employees. Performers – especially the inexperienced ones – can struggle to adapt to the new design. In addition, externally-sourced process improvement has drawbacks such as the lack of trust and familiarity.

The shortcomings of externally-sourced process improvement has opened up the opportunity to explore sources of improvement from within the organisation. Experience, skills and knowledge from internal sources can be exploited in many ways to facilitate business process improvement in an organisation. The research presented in the following chapters is focused on the internal, performer capability perspective.
Chapter 3
Framework of the Socialisation of Work Practices

3.1 Introduction
This chapter presents the framework for the socialisation of work practices that is proposed to enhance the performance of individuals within an organisation and result in business process improvement. The framework integrates the key techniques and concepts in the literature including the EDL method, personalised recommendation concept and business process complexity. The system architecture of the framework is implemented in a system prototype as an experimental test-bed.

3.2 Framework Overview
We first present the rationale for the framework design as briefly mentioned in the introduction. Shtub and Karni (2010) present two main forms of business process improvement to keep businesses competitive in an ever-changing environment: business process redesign and performer capability improvement.

Business process redesign achieves process improvement by redesigning the current business process according to criteria such as cutting costs and/or improving the quality of services. Unfortunately, a radical design in the process also creates challenging conditions that add new learning curves (Broadbent et al., 1999) due to unfamiliarity with the redesigned business process. The redesigned business process that is intended to achieve effectiveness or help the employees do the right things (Anand and Singh, 2011) can arguably lead to inexperienced employees struggling to enact the redesigned process (Schonenberg et al., 2008; Setiawan and Sadiq, 2010). A business process itself is characterised by its structure, organisational requirements, and person-to-process interactions (Wood, 1986). These characteristics indicate that the factors that affect the quality of the business process are not only the structure of the process, but also the person who executes the business process. Hence, it is observed that process improvement can be approached not only from the structural
perspective, but also from the perspective of the users who perform the business process activity.

The premise of the present study is that organisations can make use of the experiences and knowledge of employees to achieve process performance improvements that are driven internally from within the organisation rather than externally. The skills and knowledge of these experts becomes a valuable source of improvement to others. From this valuable knowledge, the focus is shifted to increasing user performance and productivity such that it will later manifest as improvement in the business process. However, there are challenges and issues in capturing and sharing the information which is gathered from the experiences and knowledge of these experts. Another challenge is how to effectively deliver the knowledge to employees who are diverse in numerous ways (Tenkasi and Boland Jr, 1996). This also makes it necessary to identify the factors that affect the learning process. To overcome these challenges, the present study develops a framework for business process improvement called the socialisation of work practices.

The first challenge that is addressed by the proposed framework is that the experiences and knowledge of employees are often not widely available in explicit forms. These skills and experiences are rarely documented. Hence, the proposed framework presents a method to capture the tacit knowledge and transform it into explicit knowledge, through the EDL module which is the basis of the framework. The EDL module has the capability to elicit the behaviour of the experts in an organisation from the business process logs which record the events and activities of the business process, and present it in a form that can be shared as the source of improvement for the relevant stakeholders such as other employees and management.

The next challenge to be addressed by the proposed framework is to deliver the valuable information, which will be used as the source of learning, in the most effective way. Studies have shown that individuals have different needs, and learning approaches should take into account these individual needs by tailoring the approach to the learners’ learning styles (Lu, 2004; Wan and Sadiq, 2012b). This creates a shift from traditional learning to personalised learning. In personalised learning, each individual in the organisation has a different learning path reflecting their diverse backgrounds and experiences. In the proposed framework, the knowledge from the EDL module is transformed into a personalised recommendation for each individual.

EDL is based on a number of aspects of process performance. Process performance, as an indicator of the success of a process improvement, often has a direct relationship with the process complexity (Setiawan and Sadiq, 2013). Thus, a comprehensive understanding of the
business process – and how complex it is – is also needed (Damanpour, 1996). Current studies on process complexity typically focus on a single aspect, namely, process structure. The proposed framework presents an integrated framework of business process complexity to address the issue.

Based on the three components of the proposed framework, namely, experience-driven learning, personalised recommendation and process complexity, a proof of concept system is developed, called the Process Improvement (PRIMe) system. PRIMe provides an experimental test-bed and working environment in which to test and analyse the results of the three components in the framework.

The functionality of the proposed framework is explained with respect to the continual improvement phase of the business process management lifecycle (Aalst et al., 2003). The business process management lifecycle, as illustrated in Figure 3.1, starts with process design, which is then followed by system configuration, then process enactment, and diagnosis. The proposed framework fits within the diagnosis stage of the business process management lifecycle. In the diagnosis stage, the activities and events of the business process are analysed in order to identify the problems and aspects that can help improve the business process. The proposed framework aims to identify the valuable experiences that can inspire others to also lift their performances to their full potential.

![Business process management lifecycle](image)

**Figure 3.1:** Business process management lifecycle (Aalst et al., 2003)

In the framework of the socialisation of work practices, as illustrated in Figure 3.2, the business process logs are pre-processed for further analysis. The business process log usually records information such as the event/activity name, time stamp, and identity of the person executing the event (Aalst et al., 2007). EDL is the first component introduced in the
framework. EDL evaluates and promotes activities that have been selected as the potential candidates to become the source of process improvement. The EDL module then puts the candidate activities into a pool of selected activities that also holds information about how those activities were enacted. This pool acts as the repository of the recommended work practices for performers.

Figure 3.2: Framework of the socialisation of work practices for business process improvement

The proposed framework aims to personalise the recommendation to suit the characteristics of the process performer. Unfortunately, there is only a little or no further information available from the process log with regard to the performers themselves. Hence, the proposed framework introduces the process of metadata enrichment of the process logs in order to further explain the characteristics of the person executing the event in the business process. This helps the recommendation tool to choose a subset of activities from the repository of the recommended work practices and deliver the most suitable recommendation that reflects the characteristics of the performer.
As process performance indicates the success of a business process (Aalst et al., 2007), it is necessary to understand all the aspects that may impact on the individuals who are performing the business process. Business process complexity is known to have a direct impact on and relationship with process performance (Cardoso et al., 2006). The proposed framework presents a complexity measurement to help the stakeholders (i.e., employees and management) to better understand the complexity of their business process and its impact on business process improvement.

Overall, the present study delivers three artefacts to improve process performer capability and facilitate business process improvement. The research is concerned with the design and construction of the artefacts, their use, and their evaluation in experimental settings. Design science (Hevner et al., 2004) is adopted as a guideline methodology for the research, as explained in the next section.

3.3 Research Methodology

Design science (Hevner et al., 2004) has been extensively used in information systems research in the past decade. Design means to “decide upon the look and functioning of an object” (Polanyi and Sen, 1983); hence, design science in information systems research is an activity that produces new and innovative artefacts as opposed to a naturally conceived object or artefact. Design science is known for its guidelines and criteria for the evaluation of the usefulness of an artefact, for connecting the relevance of research to the needs of real-world problems and for the rigor of the knowledge that shapes the research. In the information systems research, such artefacts are structurally formed as software, formal logic, or rigorous mathematics.

According to Hevner and Chatterjee (2010), it is necessary to both justify and evaluate a developed artefact. To effectively deliver the goal of the present study, the framework for the socialisation of work practices is developed with well-defined requirements and assumptions. This is necessary to ensure that the developed tool and artefacts are suitable and justifiable without limiting the scope which would prevent the tool or artefact from being implemented on a larger scale. To evaluate the developed artefacts, Hevner et al. (2004) has provided seven guidelines in conducting the research, and those are: Design as an Artefact, Problem Relevance, Research Contributions, Research Rigor, Design as a Search Process, Communication of Research, and Design Evaluation.

According to the first guideline, Design as an Artefact, a design-science research is expected to produce a viable artefact in the form of a construct, a model, a method, or an
instantiation. This first guideline is to make sure that the artefact is created to address an important organisational problem. In this research, artefacts will be developed in the form of a framework, methods, and an instantiation of the framework. Socialisation of work practice approach will provide a comprehensive framework that represents how the system works and how it produces recommendation of work practices to the stakeholders. The related methods will be developed based on the knowledge that can be elicited from the past practices exhibited from business process event log.

The second guideline of Design Science addresses the relevance of the research with a real world problem. This study focuses on improving the performance of process users in executing the business process. Some studies in the positive deviance area of research show that people can learn to improve their practice from their own community. Socialisation of work practice framework addresses the same real world problem, and aims to provide a desirable/alternative solution to provide change from within rather than sourcing externally.

The research contribution, together with the research rigour and design as a search process guidelines, relate to the design and assessment of the research leading to original and meaningful contributions of the research. This thesis is expected to produce novel strategies to provide an alternative approach to business process improvement. A combination of technology-based artefacts e.g. system conceptualisation, organisation-based artefact e.g. business process management, and people-based artefacts e.g. learning and training is necessary and significant to achieve a better business process performance. Improving performance in business process is not solely dependent on the business process itself, but also from other complex perspectives such as level of experience and socio-cultural environment within the organisation. This research utilises and proposes necessary augmentations to the event log of business process management systems with the focus to elicit and to capitalise the implicit knowledge about work practices and deliver it as a recommendation system to respective stakeholders.

A very important aspect to the success of the research is communication of the research, where it is necessary to be able to effectively present the results to all stakeholders in technology as well as management. The proposed framework will provide the capacity to extract information that can help managerial audiences in the decision making of how the business processes can be improved. We will also develop methods with the ability to provide personalised recommendation for learning and training for individuals performing the business process tailored to individual’s need. Accordingly, this research targets organisations that utilise a business process management suite and record the events and activities of the business
process in event logs. It also targets organisations that allow individual adaptations and allow different and/or flexible approaches when executing the business processes. Recently, Gregor and Hevner (2013) discussed the issue of the propagation of knowledge between individuals and artefacts. The design science research supports a clearer understanding of the project goals and the new contributions to be achieved (Gregor and Hevner, 2013).

The functionality of the artefact must be rigorously demonstrated via well-executed evaluation methods. In the Design Evaluation guideline, design science research presents five methods of evaluation: observational, analytical, experimental, testing, and descriptive evaluation. This research employs the experimental approach using the PRIMe system (see section 3.4) as the test-bed to process artificial and real process logs. The following sections present the design and development details of proposed methods within the framework.

3.3.1 Experience-Driven Learning

Many organisations undergo many forms of change initiatives to improve their performance. Among those initiatives are for example, restructuring the organisation, implementing ERP systems, undertaking audits, etc. However, any major change in the organisation is generally painful, as people are required to increase their focus and attention towards the requirement of change. It is not uncommon for any organisation that undergoes a change program to face resistance (Rock and Donde, 2008). The resistance comes from the pressure on people to have a better performance and to keep pace with change.

The support to this kind of change initiatives to improve the business process performance can be solicited both externally and internally. The external source of improvement is commonly sought from expert advice and successful practice reference models which are embedded in software solutions (Seethamraju and Marjanovic, 2009). Using external source of improvement seems the most logical approach as it is assumed that internal people within organisation are too busy to attain new skills and to teach others requires specific skill set. However, it is known that hiring external experts can be costly (Rock and Donde, 2008). In addition to that, while external expert advice and best practice reference models are widely implemented (Van Beveren, 2002), externally identified best practice strategies often face rejection due to unfamiliarity with the practices and the perception that they do not fit the organisational context (Carter, 2003; Dutton et al., 2005).

On the other hand the internal sources of improvement offer valuable and often overlooked information in the form of the experiences and knowledge of the individuals who perform various activities within the business process and who can be considered domain experts in
particular aspects of the overall operations. At the same time, it is evident that work practices at the operational level are often diverse (Lu and Sadiq, 2006), incorporating the creativity and individualism of knowledge workers and potentially contributing to the organisation’s competitive advantage. In general, the experience of individuals within an organisation is regarded as the skill and knowledge owned by the individuals based on their understanding of events within the business process as reflected in daily practices. The engagement of individuals with their environment builds the experience that involves perceptions, prior knowledge and influence from peers (Wan and Sadiq, 2012a). Constructed over time, this engagement is central to the understanding of the notion of experience. This notion of experience is central to the dissemination of the knowledge from internal sources. The knowledge becomes easily accessible by organisation’s stakeholders, especially for those who are about to experience the activities as discussed in Chapter 2 (Section 2.2.3). By its nature, internal knowledge is disseminated through socialisation and participation within an organisation; therefore, trust and credibility are needed to ensure that the knowledge will be absorbed easily (Savolainen, 2008).

Human beings are social creatures who rely heavily on the people around them to get cues on how to think and how to act. A large body of psychological research suggests that certain interactions lead people to comply and change (Cialdini, 2001). People follow the lead of similar others and the persuasion that comes from peers can be extremely effective. Testimonials from successful performers work best when the successful performer and the prospective performer share a similar work environment. In addition, people are known to defer to experts (Cialdini, 2001) who act as the authority. Hence, employing peer influence and authority within similar circumstances can increase the level of trust. This is the situation explained by Sternin and Choo (2000) as positive deviance. The example given in Chapter 2 (Section 2.2.2) about the methods utilised by the NGO, Save the Children, illustrated the concept of positive deviance. Positive deviance provides proven approaches in contrast to the enforcement of external “models” which often fail due to a lack of fit within the cultural and social contexts.

In the organisational context, positive deviance could help organisations perform better without having to be dictated to or directed by external sources of process improvement that do not always fit the business culture and work traditions. In order to capitalise positive deviance, it is essential for an organisation to identify the measureable behaviours that positively affect the performance of the organisation (through its business process). These behaviours can become the source of knowledge and recommendations for others in order to
achieve the expected improvement. The concept of learning from experience and the exploitation of positive deviance are explained in more detail in Chapter 4.

### 3.3.2 Personalised Recommendations

The question that arises for individuals considering the adoption of the positive deviants’ behaviours is, “Which behaviour shall I adopt?” This question arises because people often choose a recommended behaviour based on their familiarity or on the performer’s similarity with themselves (Guy et al., 2009). Another question that arises is, “How suitable is a recommended behaviour for a specific person?” Even though known to produce high quality outcomes, the good experience of one person does not necessarily mean that it is imitable by others. For example, an experiential lesson from a person with ten years’ experience might not suit those who have just started to work as a trainee. The lesson may not be entirely practical as an organisation’s employee base is bound to have a spectrum of experiences ranging from novice users to experts. The learning medium, such as a recommendation, that does not fit an individual situation may be counterproductive to the improvement (Lu, 2004).

The framework proposed in this study not only provides experiences as the source of valuable knowledge, but also provides a recommendation that is suitable to the specific needs of the individual. The key purpose of the personalised recommendation is to support users in improving their performance based on their potential and qualifications. It is clear that a personalised recommendation depends on the skills of users, their current context, and some prerequisites for understanding the delivered recommendation. This can be done by providing a recommendation that has an appropriate level of difficulty and content and is tailored to the individual’s circumstances (Wan and Sadiq, 2012b).

In order to deliver personalised recommendations, we propose that user profiles are added in the form of metadata to enrich the performer data from the event log. This profile is used to classify performers into three different levels based on the Bloom taxonomy, namely, the novice, advanced and expert (Anderson et al., 2000). The user profiling is helpful to determine whether a performance is aligned with the level of experience. It is assumed that people who have been working for years should have a higher performance level than those who have just worked in the organisation. Generally, more experience is reflected into a better performance (Vecchio, 1987), although this is not always the case.

With the help of the performance classification, performers are targeted with the personalised recommendation slightly above their current level. For example, for a novice performer, the most suitable recommendation would be the baseline of advance level, and for
advance user, the recommendation is to follow the best past practice. The concept is discussed in further detail in Chapter 5.

### 3.3.3 Process Complexity

Complexity is widely studied in many disciplines including computer science, economics and social science (Setiawan and Sadiq, 2013). While it does not necessarily determine how effective a system is, complexity is known to include significant cognitive aspects that contribute to the understandability and, consequently, the overall success of a system. Complexity is often represented as an obstruction to the achievement of difficult steps and goals, and as the cause of reduced understandability, but complexity can also serve as stimulus for strategic development (Locke et al., 1981). Complexity is also positively associated with innovation in organisations (Damanpour, 1996).

In the framework proposed in this study, employees learn the experiential lessons and draw the knowledge from experts of the organisation in order to improve their capabilities in performing the business process. However, as the experiences are coming from a complex ecosystem, there are complexity factors that may affect the learning process. It is also often necessary for organisations to introduce some degree of complexity into their business processes due, for example, to the introduction of new regulations or organisational growth, as well as due to the introduction of elements in the business process such as process redesign that will lead to process improvement. Hence, organisations that can successfully implement more complex processes could also expect to have better business process performance. The key challenge is the ability to strike the right balance between complexity and performance. Studying the dynamics of this balance is a key focus of the present study. This concept is discussed in more detail in Chapter 6.

### 3.4 Evaluation

Evaluation is an integral part of this research as per the guideline in design science research. The evaluation ensures that the artefacts developed in this research are not only useful to business process users but also provide a novel contribution to the information systems and business process management body of knowledge. Hevner et al. (2004) presented multiple methods for conducting evaluation and emphasised that the selection of evaluation methods must be matched appropriately with the designed artefact. The present study uses the experimental approach as the evaluation method. The research is evaluated with a developed simulation tool described above, namely, the PRIMe system (Figure 3.3). PRIMe uses artificial
data as a test-bed for the research as well as real-world data that act as the external validator to evaluate the usefulness of the proposed framework.

The PRIMe tool provides the proof of concept of the socialisation of work practices for business process improvement framework. PRIMe works as an instrument that delivers the captured knowledge to the relevant groups, namely, management and personnel (employees). The core components of the proposed architecture are the event log pre-process module, the process log’s metadata enrichment module, the analysis tool module, and the feedback and recommender module.

The PRIMe system works with the business process log in eXtensible Event Stream (XES) format as proposed by the IEEE task mining force. The XES has been proposed as the standard for business process logs for its simplicity, flexibility, extensibility and expressivity. The XES format maintains the general structure of an event log. A log of a process contains a set of traces that is a specific execution of process instances that holds a sequence of events. The logs are the main part of this research in the sense that they represent the main experiences of the individuals interacting with the business process. The logs capture the identity of the individuals who performed the activities, the amount of time spent, and other relevant data.

\[1\] http://www.xes-standard.org/
The PRIMe tool then converts the process log from XES format to a relational database format in the pre-processing module. This format enables the metadata enrichment module to enrich the process log with detailed information about the performer, for example, their years of experience. The analysis module involves several algorithms to generate the required outputs. Algorithms developed for the framework perform the data integration, data selection and data manipulation in this module. These algorithms are linked together in the analysis module. The analysis module comprehensively delivers the report that is needed by management and provides feedback and personalised recommendations for individuals performing the business process.

The recommendation and the feedback are an important part of this tool. A personalised recommendation is delivered to fit the appropriate learning path for the individuals based on their current performance. This will ensure that the recommendation suits the specific needs of the individual according to the individuals’ current performance. Further details of this work are discussed in Chapter 7.

Figure 3.3: Architecture of socialisation of work practices for business process improvement
3.5 Summary
This chapter presented the framework proposed in this study for business process improvement. The main goal of the research is to provide an auxiliary means and a novel approach to improving the business process performance through the socialisation of work practices framework. To reach this goal, the chapter discussed the various artefacts developed to support the framework based on the concepts of design science research by Hevner et al. (2004). The development of the artefacts involved a rigorous review of the literature and a synthesis of the available methods and techniques into a comprehensive framework that offers an effective business process improvement method. As a proof of concept, the PRIMe experimental-based tool was developed, and tests on both synthetic and real-world data were conducted. The next chapter presents an overview of experience-driven learning, including the demonstration of an approach to capturing the best experience of internal experts.
Chapter 4
Experience-Driven Learning

4.1 Introduction
The framework of socialisation of work practices stipulates that the experience of an expert employee should occupy a central place in organisational learning and considerations for improvements in business process performance. The acquisition of the knowledge to improve the business process performance can be sourced either externally or internally. However, sourcing of improvement internally can have low employee turnover, which in turn enables the knowledge and experience of the individual to be retained by the organisation (Oliver, 2008). The study conducted by Oliver (2008) also emphasises the use of internal source of knowledge rather than external source of knowledge in continuous improvement activities with the usage of external source of knowledge limited to either strategic or operational problem solving.

The grounding principle of the experience-driven learning presented in this chapter is the value of promoting the use of an organisation’s internal knowledge for improving process performance. A complementary theory from social sciences, namely, the theory of positive deviance (Berggren and Wray, 2002) provides the foundation for the research premise. Positive deviance is a term used to describe behaviours that depart from the norms of a group yet exhibit certain positive characteristics (Spreitzer and Sonenshein, 2004). The behaviours of positive deviants can provide benefits beyond what others in similar circumstances can achieve. As the positive deviance behaviour is exhibited by peers, it can generate greater motivation to achieve higher quality outcomes in social settings.

A traditional BPMS is not generally capable of selecting best practice precedents because all the instances in the traditional BPMS follow the same process model; thus, there is hardly any variance that can reflect individual or unique approaches. However, complementary work can be found within the business process management research community that has long recognised the need to facilitate flexible business activities (Aalst, 1999; Reichert et al., 2003; Sadiq et al., 2005). It is expected that, by implementing a flexible business process, an
organisation can rapidly adjust its business process to suit the changes in the environment and thereby capitalise on opportunities and/or save on costs. This situation creates business process variants (Lu and Sadiq, 2006), that is, the same process may have different approaches to achieve the same goals. Each variant has the same goal but by having different approaches (such as different time needed, different activity set and/or sequence and different cost), there is consequently a different level of perceived success. The creativity and individualism of the knowledge worker are embedded in the variants, but this knowledge is generally only tacitly available.

The experience of the internal experts as exhibited in their positive practices or strategies, especially when working with variants, is often overlooked as the knowledge behind the experience is only tacitly available. Even though knowledge from these experts constitutes the corporate skill base and shows how the organisation works, the lack of externalisation from practices to knowledge makes the positive behaviour from these experts become obscured. Thus, having a flexible process is not always a solution to achieving the most efficient practice for the organisation. In fact, the more flexible the system, the more an inexperienced user may struggle to find the best approach to address a particular case. Individuals are required to have deep knowledge of the process they are working on if they are to be successful (Schonenberg et al., 2008). In such cases, the dissemination of best practices from reference models (Hutchinson and Huberman, 1993; Ramesh and Jarke, 2001; Schonenberg et al., 2008) becomes critically important. The absence of explicit articulation makes this a very difficult task, as knowledge from experience is often regarded as tacit knowledge (Nonaka and Takeuchi, 1995). In contrast to explicit knowledge, which is in documented form and easily available, tacit knowledge is owned only by the individuals involved. Polanyi and Sen (1983) described tacit knowledge as knowledge that cannot be articulated or verbalised. The present study proposes that the sharing of knowledge of best practices from peers or expert individuals within the organisation can also have a significant impact on the productivity and performance of individual (inexperienced) users (Setiawan et al., 2011), provided the users are able to use the knowledge to help them learn and acquire new perspectives, or by forming modified or new practices.

Despite the advantages of this approach, the identification and dissemination of such forms of knowledge is highly challenging. The challenge in this regard is the identification of the so-called best past practices of process variants from the potentially large number of instance executions. This identification is fundamentally dependent on the criteria that define the best. These criteria are generally extensive and relate to different aspects of the process. These could
include criteria such as cost (e.g., dollar value of a shipment process), time (e.g., time taken for an approval process), popularity (e.g., the frequency of execution of a particular sequence of field tests in a complaints response process), and so on.

This chapter investigates the utilisation of the experiences and knowledge of an employee who is expert in enacting the business process as the source of improvement in the current practices of others. An approach to capturing the best experience of internal experts is presented. The use of this approach as the foundation of, and the stimulus for, learning is demonstrated.

4.2 Discovering Insights from Work Practices through Business Process Analysis
Many organisations have implemented BPMS for managing, monitoring, controlling, analysing and optimising their business processes (Aalst et al., 2003). Business process management allows organisations to design business process models, execute process instances in accordance with the models, and enable users/applications to access task lists and execute task operations (Yujie et al., 2004). The system is meant to implement business strategies by modelling, developing, deploying and managing the business process so that the organisation can have the benefit of innovation and optimisation. The quality of the business process is fundamental to the organisation’s performance and competitiveness. Scheer (2005) depicted the business process management lifecycle, as shown in Figure 4.1, highlighting the phases that support the operation of the business process so that continuous improvement within the organisation is assured.

![Figure 4.1: Business process management lifecycle (Scheer, 2005)](image-url)
As the phases work in a cycle, the overall business process can be improved by revamping various components of the cycle. Business process analysis is the key means to this end. In business process analysis, the business processes are analysed and mapped (Biazzo, 2000) with the goal of continuously improving the process and related practices.

Business process analysis is a well-studied area. The process analysis gathers the information from all the stakeholders in a business process, including information about the interactions between them. This information can be collected from the currently running process (as in business process monitoring), or it could be extracted from the event logs or post-execution of the process (as in business process mining) (Aalst et al., 2007). The process then chooses the appropriate information and provides feedback to the stakeholders.

Business process analysis contends with the demand to create a better quality business process. Quality standards should be implemented in the value creation and delivery that are vital to the organisation. The efficiency, cost, completeness and confidence level of the business process are key to the definition of quality. Business process analysis is an essential prerequisite for smart interventions for organisational change and is needed to create incremental change (Biazzo, 2000).

A number of contributions have been made in the general area of business process analysis. For example, business process mining allows information to be extracted from transaction logs (Aalst et al., 2007). An audit trail of a BPMS is an example of how it can be used to find models which describe the process, organisation and products. An audit trail contains information about the events, such as who executed the process, what length of time was taken, and which activity or process instance was completed. The information can then be analysed in many dimensions, such as measuring the performance of the processes (Hornix, 2007), process discovery (Günther and Aalst, 2007), process conformance (Rozinat and Aalst, 2005), and social networks (Aalst et al., 2005). Some research has also provided the process model as the output of process discovery (Aalst et al., 2004). In process discovery, a process model is partially or fully developed from a workflow log. The model can be used later for specific purposes, such as discovering the patterns of execution (Dubouloz and Toklu, 2005) and analysing variances in the process model (Tsai and Chen, 2009). Similarly, interaction patterns can also be learnt to discover what social networks exist (Aalst et al., 2004).

At the same time, business processes are quite often characterised by variance. Variance itself in business process execution is the outcome of many situations. Lu and Sadiq (2007) gave examples including the disconnection between documented models and business
operations, different legal requirements, country-specific regulations, the active change and exception handling, flexible and ad-hoc requirements, and collaborative and/or knowledge-intensive work. Various work practices are demonstrated in the real world, and these practices incorporate the personal approaches and knowledge of workers that are of benefit to the organisation (Lu and Sadiq, 2006). Different users have different styles and apply different work practices to accomplish their goals. This especially happens when the organisation has flexible ways to complete activities. Variances come with consequences: some result in good processes, and some result in high costs such as when constructed by inexperienced users.

Examples of such variants can be found in many application domains such as healthcare, e-learning and insurance claims. Consider the insurance claim process in the healthcare industry as an example. During the insurance claim process, the same goal could be achieved in multiple ways. As customers vary (e.g., regular or VIP customer, with single or family type insurance, among many more criteria), the approaches and steps taken to complete the claim process will be executed differently. In addition, a claims officer will have different approaches to handling the claims within the constraints of the insurance policy. This situation leads to the creation of process variants. Each process instance may have a different execution record, even though it has the same goal (e.g., the handling of an insurance claim in minimum service time in which to complete the claim and successfully identify fraudulent claims). In the example of the insurance claim process, some clients might feel dissatisfied by the insurance company when it takes a long time to process the claim, but the insurance company also needs to scrutinise the claims carefully to identify fraudulent claims.

Lu and Sadiq (2007) presented a facility for the discovery of preferred variants through effective search and retrieval based on the notion of process similarity, wherein multiple aspects of the process variants are compared according to specific query requirements. The useful feature of their approach was the ability to provide a quantitative measure for the similarity between process variants. However, the problem is much more complex. The value of a process variant can only be realised if it provides relevant and meaningful insights for others who are working in a similar scenario. The insights come from the work practices that are discovered through business process analysis. The experience of work practices has the potential to enrich the knowledge sharing and knowledge transfer among employees who can learn the knowledge of the work practices. Boud et al. (1993) further argued that experience is not just an observation, a passive undergoing of something, but an active engagement with the environment, of which the learner is an important part. Each learner forms part of the milieu, enriching it with his or her personal contribution and creating an interaction, which becomes
the individual as well as the shared learning experience. This continuing, complex and meaningful interaction is central to the understanding of experience.

The insights for improving process performance come from the best work practices as they represent the optimal achievement that can be followed by others. The notion of the socialisation of work practices involves the selection of work practices which contain the tacit knowledge and can later be used as the source of learning. It is proposed that successful practices from experienced individuals can be used as the source of the learning established in a comprehensive learning ecosystem (Setiawan and Sadiq, 2010). This knowledge represents insights into successful practices within an organisation for improving business processes; being intrinsically driven, it is by definition aligned with the organisational culture and context.

Some research studies have been based on a rationale similar to the one presented in this study. For example, Schonenberg et al. (2008) developed a recommendation service as an add-on to a current process mining application. It predicts the next step to be performed in a case by looking into the execution log. Similarly, Thom et al. (2008) and Mahmod et al. (2008) proposed the reuse of activity patterns for subsequent process modelling. Others such as Pawlowski and Bick (2008) attempted to establish the association between business process management and organisational learning. The work in the present study is set apart from those works as the focus here is on user-specific learning.

The challenge, however, remains the creation and sharing of knowledge pertaining to internal expert behaviour. Knowledge creation and sharing (or reuse) is a widely studied topic. Dixon (2000) provided a guideline for successful knowledge management by offering knowledge on how to do something better, often called best practice. The best practice provides other individuals with a positive example of how works or activities should be performed.

4.3 Identification of Best Practice Instances

In the “learning from within” approach, a key aspect of the problem is the definition of the criteria that underpin the selection of the best process. This section first identifies and defines a set of criteria to characterise the process, and subsequently uses the criteria to efficiently analyse and rank the recommendation decision in a way that allows working communities to effectively utilise the results.

Methods for analysing and/or monitoring a given process against criteria such as time or cost are widely available in business process analysis tools. However, there can be a number of criteria that characterise the processes, and can in turn be used for process performance improvement. In general, business process improvement will be tied to goals, such as reducing
costs, improving productivity, improving competitiveness, and reducing service or production time (Mansar et al., 2009). There is a large body of knowledge on business process assessment and improvement strategies.

In the method proposed in this chapter, the analysis and ranking procedure commences once the process mining component has identified the various process models (variants) from the execution log. These are first grouped against behavioural similarity using the technique proposed by Lu and Sadiq (2008). The popularity of the various variants (models) is then determined by calculating the count of instances against each one. Process popularity forms a benefit attribute. A benefit attribute is an attribute that needs to be maximised e.g. a specific process variant might be providing a high performance and is widely used, hence there is a benefit in maximising the use of that process variant across the organisation. A benefit attribute offers an increasing monotonic utility where the greater the attribute value, the more preference the attribute is. On the other hand, there is a cost attribute as well. It offers a decreasing monotonic utility in contrary to the benefit attribute. In the proposed method, this is calculated as the weighted process based on the time utilised as the cost criterion. The work practice database captures this information. Finally, the cost and benefit attributes are combined through a multi-criteria decision-making (MCDM) approach to identify the best process instance found from the history of instances within the execution log. Some basic explanations are presented below, followed by some of the considered criteria in order to explain the analysis and ranking procedures:

**Process Model** – The process model is a specific process representation (for a set of process instances). The model is either explicitly designed by previous process designers in a flexible business process management system (Lu and Sadiq, 2008) or mined from the execution logs. All process models are referred to as variants, and have the same overall goal. The models may be grouped based on behavioural similarity, such as that considered in Aalst et al. (2006), Lu and Sadiq (2008) and van Dongen et al. (2008); that is, they belong to the same domain such as a customer response or an insurance claim process.

**Process Variance** – $P$ is a process model variance mined from the execution logs, where $P = \{P_1, P_2, P_3, \ldots, P_n\}$, $P_i$ represents the model for a process variant. The architecture restricts $P$ to process models with variances which have the same goal. All the process models are evaluated based on the behavioural dimension (Lu and Sadiq, 2008) as it contains the information on execution, such as the set of activities involved in the process execution, the
exact sequence of activity execution, the performers and their roles in executing the activities, the process-relevant data, and the duration of the process instance and constituent activity. From the reconstructed process model, a number of process instances that follows each process variance are captured by the execution log.

**Process Instance** – From each defined or reconstructed process variant model, there can be a number of process instances captured within the execution log, assumed to contain execution information such as the set of activity involved in the process execution, the sequence of activity execution, the resources utilised in executing the activities, the process-relevant data, and the duration of the process instance and constituent activities. To be selected as the candidate for the source of experience-driven learning, a process instance needs to be weighted. We will use the additive weight method (Hwang and Yoon, 1981) which will be discussed later in this section to weight the process instances.

The selected top-\(k\) of process instances will be chosen from the set of process instances, where \(k\) is the maximum number of selected process instances defined by the decision-maker. The system will then select the process instances with the least weights.

**Criteria-Specific Derived Data** – The criteria-specific derived data are a dataset retrieved from the process execution logs and containing the computed values against designated criteria (namely, process model popularity, cost and currency, as presented below) for each completed process instance recorded in the log. The detailed working of the calculations from the execution log is provided in Table 4.1.

**Process Model Popularity**

Let \(P_i (i = 1 \ldots m)\) denote the set of process model variants and \(A_j (j = 1 \ldots n)\) be the set of process instances. Let \(F(A_j, P_i)\) denote that "\(A_j\) has the same process structure (behaviour) as \(P_i\)”. Thus, the process popularity \(R\) for a given variant \(i\) is:

\[
R_i = |A_j| \text{ where } F(A_j, P_i), \text{that } A_j \text{ and } P_i \text{ are behaviourally similar}
\] (4.1)

The popularity of the process model shows how many times a particular process (variant) model has been selected by a user or used previously. A process matching on structural
similarity (Lu and Sadiq, 2008) with the business process model is used to identify the various (groups of) variant models discovered.

The best practice of the business process will show the best alternatives from the selected instances of the process model, based on the weighted instance and the popularity of the process model. As it works with more than one criterion, the MCDM approach is used to rank the alternatives collected by the system.

Cost

The efficiency (with respect to time) and cost (with respect to resources utilised) criteria are collectively calculated as cost.

Currency

The currency of an instance is indicated through its start time, with the assumption that the time an instance is initiated is essentially the time at which the initial decision on how to tackle the particular case is made. Other interpretations of currency can be used without impacting on the approach to analysis presented below. It is assumed that recent instances is more preferable than instances executed at earlier time. To calculate currency, we set a range of positive values between $u$ and $v$. $u$ represents the oldest recorded process instance and $v$ represents the most recent instance. The granularity of the currency, $g$, is determined to group process instances that were performed. For example, a granularity equal to 10 means that the dates recorded of the process instances are grouped into 10 groups. Each group will be assigned with a currency value:

$$C = u + \left( \frac{(d_r - d_j)}{(d_r - d_o)}/g \right) \times \frac{(v - u)}{g} \quad (4.2)$$

$d_r$ = date of the most recent recorded process instance
$d_j$ = date where process instance $j$ was executed
$d_o$ = date of the earliest recorded process instance
Multi-Criteria Decision-Making – To select the best process instance, we utilise MCDM. MCDM is the most well-known branch of decision making. It deals with decision problems under the presence of a number of decision criteria. Generally, all criteria that represent different dimensions of the alternatives in MCDM can be classified into two conflicting categories i.e. benefit and cost. Criteria that are to be maximised are the benefit criteria while the one that are to be minimised in the cost category criteria. A very ideal solution for an MCDM problem would be where all benefit criteria are maximised and all cost criteria are minimised. The multi-criteria decision-making model can be defined as follows:

Let $C = \{c_j \mid j = 1, \ldots, n\}$ be the criterion set and let $A = \{a_i \mid i = 1, \ldots, m\}$ be the selected set of process instances. An MCDM approach will evaluate $m$ alternatives, $A_i (i=1, 2, \ldots, m)$, which are instances of business process, against $C_j (j=1, 2, \ldots, n)$ where every attribute is independent of the other and later will be determined the optimal alternative $A^*$ with the highest degree of desirability. A decision matrix, $X (M \times N)$, is given as follows:

$$X = \begin{bmatrix}
    c_1 & c_2 & \cdots & c_n \\
C & \omega_1 & \omega_2 & \cdots & \omega_3 \\
Alt & a_1 & a_2 & \vdots & a_m \\
X & x_{11} & x_{21} & \cdots & x_{m1} \\
& x_{12} & x_{22} & \cdots & x_{m2} \\
& \vdots & \vdots & \ddots & \vdots \\
& x_{1n} & x_{2n} & \cdots & x_{mn}
\end{bmatrix} \quad (4.3)$$

It is also assumed that the decision maker has determined the importance factor or the weights of relative performance of the decision criteria (denoted as $\omega_j$, for $j = 1, 2, 3, \ldots, n$) to show the importance relative to each criterion. Usually, these weights of the criteria are normalised to add up to one. The importance factor is generally defined by domain experts and represents an absolute preference of the domain expert. However, it can also be objectively defined from the set itself using entropy-based criteria weighting.

Entropy-Based Criteria Weighting

The weighting concept is an important part of the MCDM method. Weight of the attribute determines the relative importance of the attributes or criteria within the given alternatives. This information reflects the preference of the decision-maker in making the judgement involving the criteria. A subjective weighting means the decision-maker or expert judges the
importance of each criterion based on their knowledge and experiences, and quite often on their intuition. While such judgement is important, the lack of objectivity in determining the preference can create problems when the organisation has employee (expert) turnover which might result in changing criteria preference as the new employees may have different preferences over the criteria. Thus, an objective preferential method is needed to cater for the situation. Hwang and Yoon (1981) highlighted a few techniques to develop an objective weight of criteria, including the eigenvector method, weighted least square method, and entropy method. The objective weight of criteria may express some qualitative objective characteristic which indicates that if one criterion is more significant and more useful than another, then the weight of the first criterion will be greater than that of the second one.

The execution log of business process can be considered to reside within a probability space of random events where the process instances are characterised by the criteria. The Shannon entropy of information theory (Shannon and Weaver, 1959) is able to quantify the expected value of the information of uncertain data such as found in the execution log of business processes. Hence, in the present study, the entropy method is chosen in order to obtain the objective weight of criteria. Moreover, when the data within the decision matrix are known (in this case, the decision matrix is the record of past process instances; i.e., the execution log), the entropy method is preferable than the other methods (Hwang and Yoon, 1981).

Entropy is an important concept and has been used in many fields. It is generalised in different applied fields, such as communication theory, mathematics, statistical thermodynamics, and economics. In the information theory context as described by Shannon and Weaver (1959), entropy is a measure of the amount of uncertainty in the outcome of a random experiment, which is represented by a discrete probability distribution, $p_j$. The expression of entropy ($H$) of the probability distribution $p_j$ with possible values of $j \{1, \ldots, r\}$, is thus defined as follows:

\[
H(p_1, p_2, \ldots, p_r) = -k \sum_{j=1}^{r} p_j \ln p_j, \quad \text{where} \quad k \text{ is a positive constant,}
\]

and

\[
\begin{align*}
\sum_{j=1}^{r} p_j &= 1 \\
p_j &\geq 0
\end{align*}
\]
By utilising the entropy method, a more objective weighting method is achieved to weight the criteria used in the multi-criteria analysis (Hwang and Yoon, 1981). This approach does not necessarily remove the importance of the judgment of an expert to weight the criteria. This can still be used by applying the a priori weight (preference) to the entropy-generated weight on the criteria given. The entropy concept is principally useful when there is divergence between sets of data. Figure 4.2 illustrates the concept of weight entropy.

Suppose there is an example of some probability of performance of certain criteria that are believed to have an impact on the overall performance of each process variant. In this example, there are four process variants \((A_1, A_2, A_3, \text{ and } A_4)\). Each variant (typically called an alternative) has its overall performance determined by five criteria. In the example in Figure 4.2, an arbitrary figure is provided to represent the probability of criterion \(n\) being performed among alternatives. Figure 4.2 presents that criteria \(C_1, C_2, C_3, \text{ and } C_4\) provide diversity during the execution of process variants. The diversity shown in the criteria is an indicator of how each criterion is affecting the performance of each variant differently. If the probability of a particular criterion has similar values among all the variants, then the criterion does not do much in the analysis. In the example in Figure 4.2, \(C_5\) has the exact same performance probability on all variants. This indicates that \(C_5\) that was thought to have an impact on the performance of each variant does not really contribute to the overall performance difference of each variant. Hence this criterion can be eliminated from the performance determination. From here, it can be seen that entropy is able to provide the required information about how the criteria are perceived by the evaluated variant.

### Figure 4.2: Example of probability of performance of criterion \(n\) on each alternative \(x\)

<table>
<thead>
<tr>
<th></th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>0.2299</td>
<td>0.2500</td>
<td>0.3333</td>
<td>0.2136</td>
<td>0.2500</td>
</tr>
<tr>
<td>A2</td>
<td>0.2874</td>
<td>0.2188</td>
<td>0.2593</td>
<td>0.2524</td>
<td>0.2500</td>
</tr>
<tr>
<td>A3</td>
<td>0.2069</td>
<td>0.1875</td>
<td>0.2222</td>
<td>0.2427</td>
<td>0.2500</td>
</tr>
<tr>
<td>A4</td>
<td>0.2759</td>
<td>0.3438</td>
<td>0.1852</td>
<td>0.2913</td>
<td>0.2500</td>
</tr>
</tbody>
</table>
The method introduced in Hwang and Yoon (1981) is used to obtain the objective weight $w$ with the possibility of assigning a prior knowledge from experts to obtain subjective weight $w'$. Let us consider a different example of a decision matrix $X$ of business processes that has four alternatives ($A$) and four criteria ($c$):

$$X = \begin{bmatrix}
    c_1 & c_2 & c_3 & c_4 \\
    A_1 & 2 & 200 & 9 & 11,000 \\
    A_2 & 2.5 & 175 & 7 & 13,000 \\
    A_3 & 1.8 & 150 & 5 & 12,500 \\
    A_4 & 2.4 & 275 & 5 & 15,000 \\
\end{bmatrix}$$

The degree of deviation of the outcomes of criteria $j$ from alternatives $i$, $p_{ij}$, is defined as:

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}}, \quad \forall i, j$$

Thus, we obtain the degree of deviation of each criterion from each alternative:

$$\begin{bmatrix}
    c_1 & c_2 & c_3 & c_4 \\
    A_1 & 0.2299 & 0.2500 & 0.3462 & 0.2136 \\
    A_2 & 0.2874 & 0.2188 & 0.2692 & 0.2524 \\
    A_3 & 0.2069 & 0.1875 & 0.1923 & 0.2427 \\
    A_4 & 0.2759 & 0.3438 & 0.1923 & 0.2913 \\
\end{bmatrix}$$

The entropy $H(j)$ of the set project outcomes of criterion $j$ is:

$$H(j) = -k \sum_{i=1}^{m} p_{ij} \ln p_{ij}; \quad j = 1, 2, 3, ..., n$$

where $k$ represents a constant:

$$k = \frac{1}{\ln m}$$

where $m$ is the number of alternatives. This constant will guarantee that $0 \leq H(j) \leq 1$. 
The degree of diversification $d_j$ of the information is provided by the outcomes of the attribute:

$$d_j = 1 - H(j)$$

(4.8)

The expected objective weight of the criteria is:

$$w_j = \frac{d_j}{\sum_{j=1}^{n} d_j}$$

(4.9)

From the above formulas, the entropy of each criterion, $H(j)$, the degree of diversification, $d_j$, and the objective weight of the criteria, $w_j$, are:

\[
\begin{array}{cccc}
  c_1 & c_2 & c_3 & c_4 \\
  H(j) & 0.9937 & 0.9810 & 0.9771 & 0.9956 \\
  d_j & 0.0063 & 0.0190 & 0.0229 & 0.0044 \\
  w_j & 0.1199 & 0.3611 & 0.4348 & 0.0843 \\
\end{array}
\]

The weight as indicated above in order of importance is ($w_3 = 0.4348$, $w_2 = 0.3611$, $w_1 = 0.1199$, $w_4 = 0.0843$).

A subjective weight $\omega_j$ as a prior judgment of experts can be incorporated in the entropy-obtained weight to factor the objectivity of the entropy-obtained weight with the subjectivity of experts; thus, the new weight $w_j'$ is:

$$w_j' = \frac{\omega_j w_j}{\sum_{j=1}^{n} \omega_j w_j}$$

(4.10)

If the experts (decision-makers) have the following a priori weight $\omega_j$ of:

$$\omega_j = (0.25, 0.25, 0.35, 0.15)$$

Then, the subjective weights are:

$$w' = (0.1051, 0.3167, 0.5338, 0.0443)$$
The weight obtained will be utilised in one of the most widely-used MCDM approaches in many research areas and applications, namely, simple additive weighting (SAW) (Yeh, 2002) which is also known as the “vector-maximum” problem (Zimmermann, 2001).

**Additive Weighting Method** – This concept is applied in the present research as it is able to represent the value of a process instance in a simple yet effective way to portray the performance of a business process. The aim is to obtain the weighted summation of the importance factor on each alternative (Fishburn, 1967) that is a selected instance of the process model. In many cases, SAW has shown acceptable results and it is widely applied because it is easy to understand and implement (Hwang and Yoon, 1981). In order to compare all the criteria, the decision matrix \( X \) is normalised into a comparable scale:

\[
    r_{op} = \begin{cases} 
    \frac{x_{op}}{\max x_{op}} & \text{if } p \text{ is a benefit attribute} \\
    \frac{\min x_{op}}{x_{op}} & \text{if } p \text{ is a cost attribute}
    \end{cases}
\]

(4.11)

where \( r_{op} \) is normalised rank of selected instance alternative \( A_o \) against attribute \( c_p \). Each selected instance will have a preferred value \( V_o \), where:

\[
    V_o = \sum_{0=1}^{n} \omega_p r_{op}
\]

(4.12)

\( \omega_p \) = the weight of criterion \( p \)

The preferred value \( V_o \) will indicate how the selected top-\( k \) instances are ranked. The higher the \( V_o \) value is, the higher its rank among others. It is noted that, for a given process instance, there is exactly one execution sequence resulting from the execution. In addition, having the same sequence does not guarantee that two process instances could complete the process at the same time, as each activity \( T \) of each instance might have different times spent, depending on how the workers performed the activities.
4.4 Experimental Evaluation

This section presents an experimental evaluation of the proposed methodology. The evaluation is based on a case study conducted at a building services consultancy.

4.4.1 Scenario Description and Experimental Setup

An example of a business process in use at a real business is presented in order to demonstrate the workings of the proposed approach. The business process used in the example is a bid tendering and completion process in a building services consultancy in Queensland, Australia. Queensland is currently experiencing economic benefits from the booming mining industry (Lewis, 2011). The surge in industry activity has brought a level of competitiveness not only in the mining industry, but also in non-traditional resource areas (Foster, 2012) which also affects non-mining industries, such as infrastructure industries including building services consultancies. This newly emerging situation has created a new level of competitiveness which, in turn, creates a demand for the highest possible level of performance (Luthans and Youssef, 2007). At the same time, the situation is characterised by a large number of new recruitments, which means that there is significant diversity in workers’ capacity and experience. As such, providing a means of process improvements based on existing best practice is highly warranted. Thus, the processes considered for the building services consultancy provide a fertile ground for conducting an experiment to evaluate the effectiveness of the proposed methodology.

A building services consultancy usually deals with organisations looking to build new buildings or developments (e.g., a property developer) or organisations looking to retrofit existing buildings with new electrical, air-conditioning and communication infrastructure (e.g., school buildings that need to be upgraded to cope with additional demand caused by increased enrolment and increased computer usage).

A bid represents a submission by the building services consultancy to an organisation looking for a contractor to undertake electrical and mechanical design work. This submission details what services will be rendered, and in what way. First, the opportunity to submit a bid must be identified. Management must approve this opportunity before continuing to the next stage. If this is successful, the bid document must be drafted and submitted to the company that requested the tenders. If the bid is successful, the work detailed in the bid must be completed. This work is then subjected to internal quality assurance mechanisms before it is released to the client. The final step in the process is to collect payment from the client. Figure 4.3 illustrates the bid tendering process.
In the bid tendering process, process variants might exist such as whether or not a design schema is needed (a schema is needed if similar works were never done before). The design schematics activities can also be broken down into sub-activities such as design general electrical schematics, design air-conditioning schematics, design fire protection relay circuit, and design acoustic schematics. The design schematics sub-activities are recorded separately from the main execution log. In the main execution log, all the design schematics are recorded as one aggregated design schematics activity. Parallel processes also exist while completing the process, namely, the “Client Invoice Generated” and “ISO Certification” processes.

Through a period of observation and engagement, general data were collected on the overall process involved in the bid tendering process in the case organisation, including the distributions of the throughput time of each activity. This initial dataset was used to generate a large execution log through a simulation tool. The simulation tool was built to imitate the real case scenario, where the initial data distribution showed some behaviours involved in how performers did the activities (e.g., some individuals completed a particular activity faster than some others; some activities were done in relatively the same amount of time spent). To test the scalability of the proposed system, an execution log of business processes was generated through the developed simulation tool; 10,000 process instances were generated. From those 10,000 process instances, 6,471 completed processes were collected, including variants that existed in completing the process. Only completed process instances were considered as the source of knowledge as they represented the information on how a process instance was done. There were five performers who performed the bid tendering process; they were represented as Performer A, B, C, D and E. The study was conducted in a small company of building consultancy where a performer can perform any activity.
4.4.2 Experimental Results

The record of the simulated execution log data of the business process is partially shown in Table 4.1. The instance number \( i \) is represented as \( A_i \). The cost criterion represents the time value for the process instance. The popularity indicates the number of instances from the same/similar process variant model. An additional attribute was used, namely, “currency”, which translates the date into a numeric value representing a range. This addition is required because an instance created today does not mean it is seven times better than a one-week-old instance, nor is it 365 times better than a one-year-old instance. Hence, the date range is divided into the oldest and the newest on (an arbitrarily chosen) one-tenth basis and with 5 given as the lowest value, continuing with 5.1, 5.2 and so on until it reaches 6 (based on 1/10 increment). We utilised formula 4.2 to calculate the currency. Clearly, the currency computation can easily be fine-tuned to suit the temporal properties of a given application; for example, to make the granularity larger or finer depending on how sensitive the time interval needs to be made.

In this study’s experiment, two general approaches to choosing the best process performance are considered, namely, the instance-based performance (which focuses on the process), and the activity-based performance.

Best Practice Instance Identification

In instance-based performance, the judgement is based on each process instance. The best process instance is selected to be recommended to and considered by (inexperienced) users. The selection and ranking are based on the overall criteria used in a process, namely, cost, popularity, and currency.

Table 4.1: Partial criteria-specific derived data of simulated execution data

<table>
<thead>
<tr>
<th>Process Instance</th>
<th>Currency</th>
<th>Cost</th>
<th>Popularity</th>
</tr>
</thead>
<tbody>
<tr>
<td>( A_1 )</td>
<td>5</td>
<td>17.1624</td>
<td>2273</td>
</tr>
<tr>
<td>( A_2 )</td>
<td>5</td>
<td>19.2015</td>
<td>297</td>
</tr>
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<td>( A_3 )</td>
<td>5</td>
<td>18.3989</td>
<td>989</td>
</tr>
<tr>
<td>( A_4 )</td>
<td>5</td>
<td>13.2293</td>
<td>2273</td>
</tr>
<tr>
<td>( A_6 )</td>
<td>5</td>
<td>15.4688</td>
<td>989</td>
</tr>
<tr>
<td>( A_7 )</td>
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</tr>
<tr>
<td>( A_9 )</td>
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<td>2273</td>
</tr>
<tr>
<td>Process Instance</td>
<td>Currency</td>
<td>Cost</td>
<td>Popularity</td>
</tr>
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<td>------------------</td>
<td>----------</td>
<td>--------</td>
<td>------------</td>
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<tr>
<td>A9988</td>
<td>5.9</td>
<td>17.1777</td>
<td>1480</td>
</tr>
</tbody>
</table>
Using Equations 4.5, 4.6, 4.7, 4.8 and 4.9 to calculate the objective weight of criteria based on entropy, the entropy of each criterion $H(j)$, the degree of diversification $d_j$, and the normalised weight $w_j$ are as shown in Table 4.2.

### Table 4.2: Entropy, degree of diversification and normalised weight of criterion

<table>
<thead>
<tr>
<th>Currency</th>
<th>Cost</th>
<th>Popularity</th>
</tr>
</thead>
<tbody>
<tr>
<td>$H(j)$</td>
<td>0.99979</td>
<td>0.99654</td>
</tr>
<tr>
<td>$d_j$</td>
<td>0.00021</td>
<td>0.00346</td>
</tr>
<tr>
<td>$w_j$</td>
<td>0.00634</td>
<td>0.10504</td>
</tr>
</tbody>
</table>

The results indicate that the popularity criterion has the greatest impact among other criteria, followed by cost, and the last one is currency. Thus, currency holds less significance for the overall process and the popularity criterion is the most important factor for an individual user in choosing the variant. This can be interpreted to indicate that people tend to “follow the crowd” in performing activities.

If the a priori knowledge is incorporated to define the weight set by the experts, $\omega_j$, with, for example, some arbitrary value of $\omega = (0.2, 0.6, 0.2)$, then the subjective weights in the order of currency, cost and popularity are $w' = (0.00524, 0.26041, 0.73435)$.

### Table 4.3: MCDM ranking on selected instances

<table>
<thead>
<tr>
<th>Instance</th>
<th>MCDM SAW score</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_{2387}$</td>
<td>0.73031</td>
</tr>
<tr>
<td>$A_{2388}$</td>
<td>0.86314</td>
</tr>
<tr>
<td>$A_{2389}$</td>
<td>0.27257</td>
</tr>
<tr>
<td>$A_{2390}$</td>
<td>0.92665</td>
</tr>
<tr>
<td>Instance</td>
<td>MCDM SAW score</td>
</tr>
<tr>
<td>----------</td>
<td>----------------</td>
</tr>
<tr>
<td>$A_{2391}$</td>
<td>0.88195</td>
</tr>
<tr>
<td>$A_{2392}$</td>
<td>0.47734</td>
</tr>
<tr>
<td>$A_{2393}$</td>
<td>0.86519</td>
</tr>
<tr>
<td>$A_{2394}$</td>
<td>0.22818</td>
</tr>
<tr>
<td>$A_{6176}$</td>
<td>0.72282</td>
</tr>
<tr>
<td>$A_{6177}$</td>
<td>0.86537</td>
</tr>
<tr>
<td>$A_{6178}$</td>
<td>0.10742</td>
</tr>
<tr>
<td>$A_{6179}$</td>
<td>0.85790</td>
</tr>
<tr>
<td>$A_{6180}$</td>
<td>0.19368</td>
</tr>
<tr>
<td>$A_{6181}$</td>
<td>0.87199</td>
</tr>
<tr>
<td>$A_{7939}$</td>
<td>0.71392</td>
</tr>
<tr>
<td>$A_{8261}$</td>
<td>0.36799</td>
</tr>
<tr>
<td>$A_{8262}$</td>
<td>0.25204</td>
</tr>
<tr>
<td>$A_{8263}$</td>
<td>0.85936</td>
</tr>
<tr>
<td>$A_{8264}$</td>
<td>0.18173</td>
</tr>
<tr>
<td>$A_{8265}$</td>
<td>0.85984</td>
</tr>
<tr>
<td>$A_{8267}$</td>
<td>0.86791</td>
</tr>
<tr>
<td>$A_{9572}$</td>
<td>0.32959</td>
</tr>
<tr>
<td>$A_{9755}$</td>
<td>0.95041</td>
</tr>
<tr>
<td>$A_{9756}$</td>
<td>0.44187</td>
</tr>
<tr>
<td>$A_{9757}$</td>
<td>0.88037</td>
</tr>
<tr>
<td>$A_{9758}$</td>
<td>0.10255</td>
</tr>
<tr>
<td>$A_{9760}$</td>
<td>0.16048</td>
</tr>
<tr>
<td>$A_{9761}$</td>
<td>0.61479</td>
</tr>
<tr>
<td>$A_{9939}$</td>
<td>0.68587</td>
</tr>
<tr>
<td>$A_{9953}$</td>
<td>0.93926</td>
</tr>
<tr>
<td>$A_{9954}$</td>
<td>0.84590</td>
</tr>
<tr>
<td>Instance</td>
<td>MCDM SAW score</td>
</tr>
<tr>
<td>----------</td>
<td>----------------</td>
</tr>
<tr>
<td>A9956</td>
<td>0.84458</td>
</tr>
<tr>
<td>A9957</td>
<td>0.85896</td>
</tr>
<tr>
<td>A9959</td>
<td>0.43290</td>
</tr>
<tr>
<td>A9960</td>
<td>0.84314</td>
</tr>
<tr>
<td>A9962</td>
<td>0.64236</td>
</tr>
<tr>
<td>A9963</td>
<td>0.62863</td>
</tr>
</tbody>
</table>

Using SAW implementation as shown by Table 4.3, A9755 is found to be the preferred alternative as it has the highest rank. The result of the ranking is then delivered as a recommendation for process performance improvement (Setiawan and Sadiq, 2011). This recommendation allows users to review how the (best) instance was handled; that is, the selected best practice, process instance A9755, will give users/individuals information and/or recommendations for best practice.

4.5 Summary
The motivation of this work is based on the premise that the experience of internal experts in an organisation is beneficial for the improvement of process performance, as is also evidenced by the notion of positive deviance. The aim of the proposed framework within the context of business process improvement and user productivity is to develop a means to shift the performance of users, as illustrated in Figure 4.4. By utilising the knowledge obtained from the best practice (or positive deviance) found within the organisation, individuals can benefit and improve their own performance.

Figure 4.4: Individuals’ current and expected future performance level
This chapter presented a set of methods to systematically and objectively extract and communicate the knowledge on behaviours of positive deviants. These include multi-criteria decision-making and entropy. Another important aspect of this approach is the criteria used in the analysis. So far, the study has used three criteria based on a review of the literature and the context of the considered scenario, namely, cost/efficiency, currency, and popularity. The additive weight method from multi-criteria decision making has been used to find the preferred process instance as best practice. Further, to objectively weight each criterion, an entropy-based weighting method is used. The entropy weight explains the average information quantity of the respective criterion. Although only three criteria have been used for this study, it does not limit the applicability of the method. The criteria can be extended further and the method is still valid. The next chapter discusses the personalised recommendation approach which provides a method to recommend learning that fits the performer.
5.1 Introduction
This chapter discusses a personalised recommendation approach to applying experience-driven learning for business process improvement. A classification of the importance of activities that significantly affect the business process is proposed. This classification helps business process performers (employees) to have a greater understanding when executing the business processes. A method to allocate a recommendation that matches the profile of the business process performer is also presented.

5.2 Background
The premise of the research is that the experience of internal experts in an organisation is beneficial for the improvement of business process performance. The experience is delivered in the form of recommendations that cover aspects such as: How was the overall performance of the employee? Which process instances are the best past practices?

However, after successfully identifying the best past practices based on certain criteria such as cost (e.g., dollar value of a shipment process), time (e.g., time taken for an approval process) and popularity (e.g., the frequency of execution of a particular sequence of field tests in a complaints response process), questions still remain. Firstly, a process may include a number of activities and not all of the activities have the same level of influence on the overall process performance. Identifying what activities in the process generate the greatest impact is a significant challenge as there is little knowledge on how to define the relative importance of activities. At the same time, this identification is critical to process users as it allows them to direct their focus and attention where it matters.

Secondly, it is realistic to assume that individual users will have different backgrounds and different levels of work capacity and potential. Proposing that certain users can achieve best practice may be counterproductive, and may demoralise some users. Studies have shown that
a recommendation based on the most relevant conditions and information for an individual user (learner) is preferred (Drachsler et al., 2008) and potentially more productive. This scenario is commonly found in many domains, including e-commerce applications (Santos and Boticario, 2008), e-learning environments (Tang and McCalla, 2005), and most commonly in sports environments where the level of the athlete’s training and skill determines which competition to aspire for. As an individual gains experience in the given domain, expectations of excellence can also be raised. Thus, recommendations should be delivered to users not only based on their preferences or on the highest level of achievement, but also based on the current performance of the users; these are referred to as personalised recommendations.

The personalised recommendation approach has been widely studied in many areas. In recent years, it has been advocated in e-commerce area for a business entity to have a one-to-one marketing (Peppers, 1993). A personalised recommendation greatly improves the nature of one-to-one marketing to treat each customer individually for a better serve. For this purpose, user profile needs to be created and maintained to match with the individual characteristic. Example in e-commerce is as shown by Amazon.com (Eirinaki and Vazirgiannis, 2003). Another area of personalised recommendation is available in the area of e-learning (Zaíane, 2002). Some studies have suggested that a learning process along with the measurement of learners’ performance (Day and Payne, 1987) and matched to certain situations (Santos and Boticario, 2008) could achieve better learning results. Business process improvement could also benefit from this approach.

In the system proposed in the present study, the recommendations extracted from the analysis of process executions therefore need to be sensitive to an individual user’s level of experience and capacity. How to determine this capacity and current level of performance is a significant challenge. The recommended best past practice may not be entirely practical because an organisation’s employee base is bound to have a spectrum of experiences, ranging from novice users to experts. A recommendation that does not fit an individual user’s current level of experience may be counterproductive.

5.3 Approach

The work presented in this chapter is a continuation of the work in Chapter 4 which proposed the identification of best practices through MCDM, particularly the SAW method (Chapter 4, Section 4.3). In this section, the work in Chapter 4 is integrated with additional approaches in order to enhance the identification and delivery of personalised recommendations.
The decision-makers’ confidence in choosing the most suitable MCDM method is increased by synthesising the SAW method with another well-known MCDM method, namely, the weighted product (WP). This purpose of this synthesis is to create a consensus between the MCDM methods. The WP method uses multiplication to connect attribute ratings, each of which is raised to the power of the corresponding attribute weight (Yoon and Hwang, 1995). This multiplication process has the same effect as the normalisation process for handling different measurement units. The logic of WP is to penalise alternatives with poor attribute values (Chen and Hwang, 1992).

The average rank as described by Hwang and Yoon (1981) is used to achieve the consensus. The average score computed from the two MCDM methods is then utilised to formulate a personalised recommendation based on best process instances. In the context of business process analysis, the alternatives are assumed to be process instances, and the criteria are characteristics which define the process instances’ behaviour. Ranked alternatives as described in previous work (Setiawan and Sadiq, 2010) are then used as the source of the “learning from within” approach. Once the best past practices have been identified, the relative importance of the activities is then identified, followed by construction of the user-specific recommendation.

### 5.3.1 Identification of the Importance of Activities within the Business Process

In any process, but especially in processes that are characterised by variance, it is typical to find a large diversity in the importance and complexity of the process activities. For example, in a financial institution, the cost of a customer registration activity might not vary, as this is a relatively simple activity, whereas for another activity such as an insurance claim assessment, the time and the cost may vary significantly depending on who undertakes it. Thus, the more intensive or complex the activity is, the more important it is in the performance of the overall instance. It is necessary to find a way to determine the importance of activities within the overall process instance. This is similar to the criteria weight problem discussed in Chapter 4 (Section 4.3); hence, the entropy concept is re-utilised to determine the relative importance of the process activities.
Given a matrix $Y$, with $m$ activities, and on each activity there are $n$ criteria; the activities are recorded in the execution log that states $p$ number of process instances:

$$Y = \begin{bmatrix}
\text{Act}_1 & \text{Act}_2 & \ldots & \text{Act}_m \\
\left[\begin{array}{cccc}
pid_1 & x_{111} & \ldots & x_{11n} \\
pid_2 & x_{121} & \ldots & x_{12n} \\
\vdots & \vdots & \ddots & \vdots \\
pid_p & x_{p11} & \ldots & x_{p1n}
\end{array}\right]
\end{bmatrix}$$

(5.1)

The degree of deviation in the outcomes of activity $j$ from criteria $k$, $p_{ijk}$, can be defined as:

$$p_{ijk} = \frac{x_{ijk}}{\sum_{i=1}^{p} x_{ijk}}, \quad \forall i, j, k$$

(5.2)

Each activity within the process instance has criteria that determine the performance of the respective activity. The entropy $H_m$ of the set project outcomes of activity $m$ is the average entropy of the criteria within the activity:

$$H_m = -\frac{c}{n} \sum_{j=1}^{n} \sum_{i=1}^{p} p_{ijk} \ln p_{ijk} \quad ; \quad k = 1, 2, 3, \ldots, n$$

(5.3)

where $c$ represents a constant number of criteria on each activity:

$$c = \frac{1}{\ln n}$$

(5.4)

which will guarantee that $0 \leq H_m \leq 1$.

Using Equations similar to Equations 4.8, 4.9 and 4.10, the degree of diversification, $d_m$, is obtained; the expected weight of the activity $m$ indicates the complexity of the activity, $w_m$; and if a priori knowledge is implemented, $w'_m$ is also obtained.

### 5.3.2 Constructing User Specific Recommendations

The best practice identified from the method explained above is going to form the basis of the recommendation and is the baseline of high achievement in process performance. It is achievable for some, but would be not achievable for some others, especially novice or inexperienced performers. The key idea is that individuals need to be supported to improve
their performance by receiving a recommendation that has the most suitable content and presents a learning path adapted to the individual’s current performance.

In the framework developed in the present study, a user profile gathered from the execution log is used to determine the individual’s current performance level. There are many different ways to conduct user profiling; the proposed approach essentially classifies individuals into three different levels, namely, novice, advanced and expert, based on the Bloom taxonomy (Bloom et al., 1956). A process instance is called an expert-level qualifier instance if it has the highest rank; for example, the lowest average rank score on the MCDM SAW synthesis approach. An advanced-level qualifier instance is defined if it is on the median rank (median best process) from the set of process instances, and a novice-level qualifier instance is defined if it falls behind the advanced instance. As there are three levels of performance, two best past practices are selected as the classifier of user performance to determine the level that is novice, advanced or expert, as illustrated in Figure 5.1.

![Number of process instances](image)

**Figure 5.1: Individual performance classifier**

The expert-level process instance is the ultimate level at which a business process instance should be performed by a user. It is useful for an organisation if all users are following the recommendation from the expert instance; however, for novice users, an expert-level process instance could be beyond their current capability. Thus, a “mid level”, namely, the advanced-level process instance, serves as a bridge between a realistic level of performance and the expert level.
An example of a future target is shown in Figure 5.2 which explains how in the future, after the user recommendation has been performed by the users for some time, the overall users’ performance levels can be improved, with more users shifting from the novice level to the advanced level (and eventually to the expert level). This is the main goal of the proposed approach, which is to eventually train all process users to perform at the highest level of efficiency by providing precedents of work practice that encourage achievable improvements, peer learning and healthy competition. The experiments reported in the next section demonstrate how the individuals’ performance classification is used to deliver the most suitable recommendation for best practice based on individuals’ current performance.

![Number of process instances](image)

Figure 5.2: Expected future users’ performance level

5.3.3 Metadata Enrichment

Each of business process users has certain characteristics. For example, it is known that employees with higher level of experience would perform better in their performance (Vecchio, 1987). The experience/maturity level is generally expressed with the understanding and familiarity of the activity. Relevant work experience and training can help employees to have a higher maturity level. Hence, in general, it is assumed that employee who has been in the company for a certain amount of time should have a higher maturity level which would then be reflected in the performance.
However, the situation can be problematic if an employee who has been working for long time in the organisation did not exhibit the performance as it should be e.g. an employee who has been working for more than 5 years but still exhibit the performance of someone who has just joined the organisation. From the literature, it is evidence that users’ experience should develop over time (Karapanos, 2013). Karapanos (2009) studies that there is an expectation that the longer the users interact with the system, the more capable the users are. However, in reality, some performers might fail to progress as expected.

As with the construction of user specific recommendation section, metadata enrichment helps conducting user profiling but has a purpose specifically to compare the experience/maturity level of performers and the level of performance. The metadata enrichment is an activity to add information of the year a business process user joined the organisation. From this information, the maturity level is calculated.

Maturity level is defined with the same name as in individual performance classifier, namely, novice, advanced, and expert. Performer who has the least experience as indicated by the year of joining is categorised as novice performer. For example we can set the maturity level as novice for people who joined the organisation for less than 3 years. In contrast, performer who has longer experience time is categorised as expert performer. Hence we can set maturity level as expert for those who have been working in the organisation for more than 8 years, and advanced for those in between. Thus a specific recommendation can be given to the user if the maturity level is not matched under the expected performance level e.g. an advanced level of user according to the maturity level, but measured as novice level of user according to the performance level.

5.4 Experimental Evaluation

This section presents an experimental evaluation of the proposed methodology. The evaluation is based on a case study conducted at a building services consultancy, as discussed in Chapter 4 (Section 4.4.1). The business process used in the example is a bid tendering and completion process. As illustrated in Figure 5.3, there is an opportunity for process variants to be executed in activities T4, T5, T6, T7, T8 and T9. A dotted rectangles indicate that activities can be executed arbitrarily within the boundary.
5.4.1 Identification of Best Past Practices

In this research, an execution log of business processes was generated through the developed simulation tool. From the 10,000 process instances generated, 6,471 completed process activities were collected including variants that may exist in completing the activity. Five performers were recorded as users who did all the activities in completing each process instance. The users were anonymously identified as Performers A-E. From those past process instances, all the processes were ranked using MCDM approaches, namely the SAW method and WP methods, and then synthesised as shown in Table 5.1.

Table 5.1: Synthesised MCDM rankings using SAW and WP methods

<table>
<thead>
<tr>
<th>Process ID</th>
<th>Rank on SAW</th>
<th>Rank on WP</th>
<th>Average Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>5272</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>4765</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>1802</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>3362</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>5390</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>9953</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>5601</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Process ID</td>
<td>Rank on SAW</td>
<td>Rank on WP</td>
<td>Average Rank</td>
</tr>
<tr>
<td>-----------</td>
<td>-------------</td>
<td>------------</td>
<td>--------------</td>
</tr>
<tr>
<td>1170</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>8504</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>5183</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>6477</td>
<td>11</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>512</td>
<td>12</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>4753</td>
<td>13</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>7181</td>
<td>549</td>
<td>547</td>
<td>548</td>
</tr>
<tr>
<td>626</td>
<td>550</td>
<td>554</td>
<td>552</td>
</tr>
<tr>
<td>4896</td>
<td>551</td>
<td>548</td>
<td>549.5</td>
</tr>
<tr>
<td>6006</td>
<td>552</td>
<td>551</td>
<td>551.5</td>
</tr>
<tr>
<td>3636</td>
<td>553</td>
<td>557</td>
<td>555</td>
</tr>
<tr>
<td>8030</td>
<td>554</td>
<td>552</td>
<td>553</td>
</tr>
<tr>
<td>4457</td>
<td>555</td>
<td>558</td>
<td>556.5</td>
</tr>
<tr>
<td>7258</td>
<td>556</td>
<td>553</td>
<td>554.5</td>
</tr>
<tr>
<td>1972</td>
<td>557</td>
<td>561</td>
<td>559</td>
</tr>
<tr>
<td>2451</td>
<td>558</td>
<td>564</td>
<td>561</td>
</tr>
<tr>
<td>9599</td>
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<td>556</td>
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</tr>
<tr>
<td>4214</td>
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<td>562.5</td>
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<td>5439</td>
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<td>561.5</td>
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<td>562</td>
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<td>558.5</td>
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<td>563</td>
<td>563</td>
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</tr>
<tr>
<td>3053</td>
<td>3226</td>
<td>3226</td>
<td>3226</td>
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<tr>
<td>3525</td>
<td>3227</td>
<td>3227</td>
<td>3227</td>
</tr>
<tr>
<td>1497</td>
<td>3228</td>
<td>3229</td>
<td>3228.5</td>
</tr>
<tr>
<td>7417</td>
<td>3229</td>
<td>3225</td>
<td>3227</td>
</tr>
<tr>
<td>790</td>
<td>3230</td>
<td>3235</td>
<td>3232.5</td>
</tr>
<tr>
<td>1984</td>
<td>3231</td>
<td>3232</td>
<td>3231.5</td>
</tr>
<tr>
<td>7019</td>
<td>3232</td>
<td>3230</td>
<td>3231</td>
</tr>
<tr>
<td>4493</td>
<td>3233</td>
<td>3233</td>
<td>3233</td>
</tr>
<tr>
<td>2212</td>
<td>3234</td>
<td>3238</td>
<td>3236</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 5.1 shows some processes were ranked differently according to the result of the MCDM query using the SAW and WP methods and some were on the same rank. For example, the rankings for process 5272 and process 4765 were the same using both the SAW and the WP method. Process 2451 was ranked 558 using the SAW method, but was ranked 564 using the WP method. These results show that the different MCDM methods give different results. Hence, synthesising both methods by creating an average ranking from the results of both the SAW method and the WP method is necessary.

5.4.2 Defining the Importance of an Activity

For the activity based-performance, using Equation 5.3, the importance of each activity can be identified using entropy-based method. The method is designed to identify which activities have the most influence relative to other activities. Thus, the selected activities have a significant impact on the overall performance of the business process. In the experiment, the entropy of each activity $H_m$, the degree of diversification $d_m$, and the normalised weight $w_m$ are as shown in Table 5.2.

Table 5.2: Entropy, degree of diversification, and normalised weight of activities

<table>
<thead>
<tr>
<th>Activity</th>
<th>$H$</th>
<th>$d$</th>
<th>$w$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potential project identified</td>
<td>0.993189186</td>
<td>0.006810814</td>
<td>0.06640735</td>
</tr>
<tr>
<td>Proposal submitted to management</td>
<td>0.99708213</td>
<td>0.00291787</td>
<td>0.028450058</td>
</tr>
<tr>
<td>Bid drafted</td>
<td>0.993546764</td>
<td>0.006453236</td>
<td>0.062920871</td>
</tr>
<tr>
<td>Bid submitted</td>
<td>0.993090915</td>
<td>0.006909085</td>
<td>0.067365522</td>
</tr>
<tr>
<td>Design fire protection relay circuit</td>
<td>0.992603666</td>
<td>0.007396334</td>
<td>0.072116335</td>
</tr>
<tr>
<td>Design general electrical schematics</td>
<td>0.979495427</td>
<td>0.020504573</td>
<td>0.199925365</td>
</tr>
<tr>
<td>Design acoustic schematics</td>
<td>0.986556025</td>
<td>0.013443975</td>
<td>0.13108254</td>
</tr>
<tr>
<td>Design air-conditioning schematics</td>
<td>0.982835053</td>
<td>0.017164947</td>
<td>0.167363071</td>
</tr>
<tr>
<td>Client invoice generated</td>
<td>0.996958868</td>
<td>0.003041132</td>
<td>0.029651891</td>
</tr>
<tr>
<td>Internal ISO9001 certification requested</td>
<td>0.993268438</td>
<td>0.006731562</td>
<td>0.065634626</td>
</tr>
<tr>
<td>Schematics issued</td>
<td>0.998063027</td>
<td>0.001936973</td>
<td>0.018886031</td>
</tr>
<tr>
<td>Payment received</td>
<td>0.990749361</td>
<td>0.009250639</td>
<td>0.09019634</td>
</tr>
</tbody>
</table>
It is observed that the importance of the activities as determined through the entropy-based method is aligned with findings in the literature (Setiawan et al., 2011). Another examples are found in the study conducted by Wang and Lee (2009), where entropy-based method is used in developing a fuzzy TOPSIS approach for a software outsourcing problem, and also from study by Ding and Liang (2005) that discusses the utilisation of entropy-based method in a fuzzy MCDM problem in the liner shipping industry. This gives further confidence that the method utilised in this study accurately pinpoints activities that have a greater impact on overall performance. It is also found that if the performance of each performer on some particular activity does not show much difference, then that particular activity is not complex and tends to have less impact on the process performance. On the contrary, if a particular activity creates much performance variance then it is considered to be a complex activity and will impact on the overall process performance. In this study, there were three activities that had the greatest impact on overall performance based on the significance of their weight compared to others. As shown in Table 5.2 above, these activities were “design general electrical schematics”, “design acoustic schematics” and “design air-conditioning schematics”. It is noted that these were activities that determined the variance and flexibility of the business process. This indicates that, in a business process that allows flexibility, employees who are working on the variant activities should pay more attention to the activities that will affect the overall performance of the business process.

5.4.3 User Specific Recommendation

To measure individuals’ performance (and classify users), the average time spent by each individual on each activity is summarised and aggregated. The throughput time criterion (as part of the cost criterion) is selected for the user profile as the throughput time is directly linked to the user’s performance, while other criteria (e.g., process popularity, one-time cost and currency) are independent of the user. The time aggregation of an individual’s average time spent on activities is the most relevant method for comparing the individual’s performance with the best process instance performance. It is noted that different criteria could be used for a different scenario without impacting on the overall methodology presented in this study.

Figure 5.4 shows an example of Performer B’s performance. It is noted that the overall performance (in terms of time to complete) of the best process instance is better than the average time taken by Performer B, except in the “design schematics” and “client invoice generation” activities (some activities have a higher throughput time, caused by the
contribution of some performers who did not perform very well on the activities). Even though Performer $B$ did not perform better than the best past practice, this performer surpassed the median best process (the advanced-level classifier).

For particular users who already surpass the recommended process on each activity, the task is to maintain their performance and/or enable them to become peer tutors to others who still underperform. For underperforming users, the task is to improve their current performance based on the best practice performance that is closest to them; for example, a performer with very low performance (novice level) receives a recommendation to achieve an advanced level.

![Graph showing the comparison of average throughput time for business process activities between the best process, median best process, and Performer $B$.](image)

**Figure 5.4:** Overall performance comparison of best process vs. Performer $B$

Based on the analysis of the results of the simulation, it is found that among five performers who worked in the company, Performer $E$ was the best performer (identified as an expert user), Performer $B$ was at an advanced level, and the rest were at novice level. A deeper investigation of the data reveals that one of the most influencing activities within the business process was the “design schematic” activity.

From the chart shown in Figure 5.5, in general, large gaps can be seen between the performers of the “design general electrical schematics” activity, and the “design air-conditioning schematics” activity. The gaps between the “design fire protection relay circuit” and the “design acoustic schematics” activities were quite small. This indicates that some users were having difficulties in completing the process instances involving some specific sub-
design schematic activities, even though they were able to perform well in other activities. For these novice-level users, highly demanding and complex activities such as “design general electric schematics” and “design air-conditioner schematics” should be avoided.

Figure 5.5: Design schematics sub-activity comparison of all performers

A recommendation is then given to the users at the novice level not to perform these difficult activities for now, as it will contribute to a worsening of the whole business process instance. The best past process instance is shared with the users to be used as the recommended process instance for learning. The recommendation includes some key information for the users, such as the throughput time to be spent to complete the process instance and which process variants may be suitable for the specific level of user.

5.5 Summary and Evaluation
The work carried out in this chapter is based on the premise that personalised recommendation is far better than a generic recommendation to improve business process performance. Realistically, individual users will have different levels of work capacity and potential and different experience levels. Personalised recommendation is delivered to help achieve a better learning results. This chapter presented the set of approaches to provide a personalised recommendation to business process users. By utilising personalised recommendation, it will
ensure that only an appropriate practice is communicated to users so what they learn from those in the past can be connected to possible future performance.

The evaluation conducted in this chapter was intended to provide a clear understanding of the working of the proposed approach as well as to present a preliminary evaluation of the developed methods. However, this work is not without limitations. The segregation between the novice, advanced and expert levels is based on the selection of a specific process instance which shows how a process instance was performed. As clarified in the discussion above, a process instance consists of many activities that were performed by multiple users. While the best past process instance overall is considered to be the best among others, it does not mean that each activity inside the corresponding process instance is the best among others. To overcome this limitation, an aggregate of the throughput time spent on activities by users is proposed to measure the users’ performance against the best past process instance and to classify which user belongs to which level. This ensures that users can receive the most suitable recommendation which is closest to their current level of performance.

The methods presented in this chapter incorporated a multiple criteria-based ranking procedure to identify the best practices from previous instances and provide a personalised recommendation based on the initial information about the individuals’ current level of experience. This procedure assists in the development of an effective experience-driven learning mechanism within an organisation. The next chapter presents an integrated framework of business process complexity, and discusses how complexity in the business process affects the business process performance.
6.1 Introduction
This chapter discusses the key challenge of how to strike the right balance between complexity and performance. To date, studies on the complexity in business processes have primarily focused on the structural aspect of complexity. However, given the subjective nature of complexity, it is important to expand the notion beyond the structural dimension in order to provide a more accurate understanding of process complexity. This chapter presents an integrated framework for business process complexity analysis that spans across the structural, variability and performance dimensions.

6.2 Complexity in Business Process
Complexity theory is widely studied in many disciplines including computer science, economics and social science. While it does not necessarily determine how effective a system is, complexity has significant cognitive aspects which contribute to the understandability and, consequently, the overall success of a system. Interestingly, complexity, which is intuitively viewed as an inhibitor of success, is also being used as the basis of innovation and development (Damanpour, 1996; Locke et al., 1981). Nevertheless, if complexity is left unchecked, systems can become over-complicated and organisational performance is affected.

Complexity is a challenging issue in many organisations. Even though it is widely acknowledged, many organisations treat complexity as an uncontrollable aspect. The business process flows often carry multiple kinds of complexity that affect the cognitive aspects of the process performer and contribute to the success of business process implementation. Complexity occurs in many organisations because of the growth of business process implementation, the different types of individuals who enact the business process, or external pressures such as changes in competition and regulations and challenges from the ever-changing environment.
Various aspects of complexity have been studied in the context of business process management. Complexity is considered inherent to the business process (model), and is expected to increase as the number of activities and/or their inter-relationships grow (Cardoso, 2008). Complex processes can create a detrimental effect as complexity introduces a higher rate of error probability in performing activities (Cardoso et al., 2006). Business process complexity has a direct relationship with business process performance. It is often necessary to introduce some degree of complexity in a business process due, for example, to the introduction of new regulations or organisational growth, as well as due to introduction of elements in the business process that will lead to process improvement. At the beginning, organisations can gain benefits from implementing a more complex process as it will lead to better business process performance. However, without properly understanding the complexity, the complexity in the business process system can proliferate, becoming a deterrent to success and affecting the efficiency of the business process. Recapping on the discussion in Chapter 2, Figure 2.3 presents a complexity curve, which is an inverted U-shaped graph showing that complexity starts as a beneficial aspect, but once it reaches its tipping point, it will degrade the individual’s performance (Flood and Carson, 1993).

![Complexity Curve](image)

**Figure 6.1: Impact of complexity on individuals’ performance (Flood and Carson, 1993)**

In recent decades, researchers have promoted many approaches to improve the business process through skill development, transformation capabilities, and business process management. Two notable concepts in the literature are business process improvement and business process redesign (Mansar and Reijers, 2005; Siha and Saad, 2008). Both concepts focus on the structure of the business process by redesigning the business process model, introducing improvement stages, process mapping and benchmarking. While those concepts provide a sound structural overview, according to Zellner (2011), both lack focus on the act of
improvement, as the approaches do not directly consider the process performers, that is, the people behind the processes. The premise of these concepts is that, as the process model is structurally improved, process performance improvement will be naturally achieved. However, true process improvement is often realised with the improvement in the performance of the process performers. Process redesign offers newly redesigned process models which often are alien to performers. This situation adds another level of complexity that has to be rectified by the process performers.

It is evident that complexity within a business process could manifest itself in a variety of ways. A business process itself is represented through a number of aspects. As explained by Heinl et al. (1999), business processes are characterised by the data flow, the control flow, the assignment of individuals to the process activities, and applications that perform the process activities. In a further breakdown of the business process, it is found that the activities which construct a business process are characterised by dimensions including: the structure, skill and organisational requirements; and the person-process interactions, difficulty, familiarity, and intrinsic interest (Wood, 1986). These dimensions contribute to the complexity of a business process. To understand complexity better, organisations should first recognise the existence of complexity on all dimensions of a process and its constituent activities, and then measure the complexity level. Only then will the impact of the complexity on the process performance be fully understood.

To our best knowledge, recent studies on business process complexity have dealt primarily with the structural dimensions of business processes (Cardoso, 2006; Mendling et al., 2007; Muketha et al., 2010). There is evidence that structural factors influence the ability to understand the business process (Mendling et al., 2007). An understandable structural dimension of business process i.e. process model, enhances the knowledge base about causal connections between process and its sub-processes (Modarres, 2006). It is also to be noted that the goal of the process model is to change the behaviour of the performer of business process to the desired process performance (Münch et al., 2012).

In the structural dimension, the common method to measure complexity is through the size of the process model, the flow within the process model, and the modularisation (Cardoso, 2006). In this structural dimension, some studies such as Cardoso et al. (2006), Rolón et al. (2009) and Gruhn and Laue (2006b) have encouraged the measurement of the business process to be conducted through the process model and adapted from the measurement of software complexity. As in software development, where complexity is measured through factors such as the size and number of control paths, business process complexity is measured by its number
of activities, the existence of handlers (such as event handlers, fault handlers and compensation handlers), and the number of sub-processes (Cardoso et al., 2006).

In addition, when there is variance in a process model (e.g., to support flexibility in the business process) (Lu and Sadiq, 2007), the study of structural complexity becomes more challenging as a large number of process variants may exist within the same process. The reasons for process flexibility are well studied (Reichert et al., 2003; Sadiq et al., 2005). The flexibility afforded to process performers is often a consequence of such reasons; however, with this flexibility comes a degree of uncertainty, which could lead to (perceived) complexity. According to Campbell (1988) and Schwab and Cummings (1976), complexity can be found where some specific characteristics such as the presence of multiple potential ways to achieve the goals (Lu and Sadiq, 2006) exist. Complexity also emerges with the existence of multiple desired outcomes (Campbell, 1988), and the existence of exception handling (Lohmann, 2008).

At the execution level, person-process interactions, skill level and the inherent nature of the activity will be some of the factors that contribute to the performance of a given activity and its (perceived) complexity. Previous studies also indicate the presence of performance-related dimensions, such as in Wood (1986) where skill, organisational requirements and person-process interactions were found to be significant factors in influencing process performance and consequently a key indicator of real or perceived complexity. For example, consider the buy-sell process in a stock exchange. A stockbroker basically works by buying and selling shares and other securities in a stock exchange. The process model of buying and selling stock is usually simple from a structural point of view. However, it carries a high level of expertise relating to market dynamics (Nagy and Obenberger, 1994), and this level of expertise influences the performance of different process activities.

As most recent studies on structural complexity focus only on its measurement (Gruhn and Laue, 2006a; Muketha et al., 2010; Rolón et al., 2009) and reduction (Gruhn and Laue, 2009), there is a gap in the integral understanding of complexity. As complexity is an inverted U-shaped graph, it does not always have to be reduced. On the contrary, some organisations may introduce complexity to improve their performance. In addition, complexity also emerges in the person-process interactions. As such, there is a need to consider the complexity analysis of business processes beyond the structural (or model understandability) level.
6.3 An Integrated Business Process Complexity Framework

This section introduces the integrated framework of business process complexity. The proposed framework consists of three dimensions for business process complexity, namely, structure, variance, and performance. The framework measures structural complexity through the size of the process models and the number of splits (such as AND, XOR and OR splits) using the control flow complexity (CFC) metric measurement as the basis, as introduced by Cardoso (2008). An AND split in the process model is a notation to indicate parallel flows that allow two activities to be executed in parallel after completing an activity. An XOR split is a notation to determine only one flow that satisfies the specified condition (True) among a number of flows that originate from the split. An OR split is a notation to determine that the subsequent activities can be any flow, and can be more than one activity that originates from the split.

The process variance is measured through variant distribution. With multiple ways of enacting the business process, individuals need to find the most suitable variant. As discussed above, this is a form of complexity that is encountered when process variance is found (Campbell, 1988). The process performance also reflects a person-process interaction that results from the nature of the activity (Payne, 1976). Process performance has been widely studied and includes measurements such as the time to complete and resource utilisation (Aalst, 1998).

The framework uses the following measures for complexity: non-uniform performances indicate that there is a degree of complexity which results in performance variation; on the other hand, uniform performances indicate that the process is either too complex (where most performers perform poorly) or too simple (where most performers excel). To illustrate the three dimensions of performance variance, process variance and structural complexity, a three-dimensional model is created as shown in Figure 6.2.
In line with the specific methods for measuring complexity for each of the dimensions – namely, CFC, process variance distribution, and performance variation – the three dimensions are represented on a 0 to 1 scale, where 0 indicates a high level of measurement and 1 indicates a low level of measurement. The methods to calculate these measures are described in the next section. First, eight axis points of the integrated framework for business process complexity analysis are defined as follows:

- **(HS, HV, HP)**. This is the highest point of complexity where all the identified dimensions are at a high level. The process model is characterised by high structural complexity in addition to having high variance, which means that there are a large number of different variants. Both elements will contribute to the overall understandability of the models. The
process model characteristics will in turn contribute to both perceived and actual complexity in performance at the time of execution.

- (HS, LV, HP). Process models that have little or no variance can conceivably become rather complex structurally. Arguably, this could be the result of building a large number of activities and choices into the process models, which then creates structurally complex process models (Cardoso, 2008), which in turn may negatively impact on performance as it increases the cognitive load and results in diminished level of understandability.

- (LS, LV, HP). A simple process from the structural point of view is not necessarily always simple to perform. This point is illustrated in a scenario where what looks simple is not always simple; for example, the buy-sell process in stock exchange trading. This type of process requires people with advanced knowledge to perform the activities successfully.

- (LS, HV, HP). This point is similar to (LS, LV, HP) except that it introduces flexibility in performing the business process. Having high process variance requires the selection of the optimum process activities according to the individuals who perform them (Campbell, 1988). The task to find the “best” variant to suit a particular instance adds a degree of complexity.

- (LS, LV, LP). The nature of this type of process is simple. Structurally, the business processes are simple, straightforward, less redundant and easy to understand. The absence of the process variants also amplifies the non-complex status of this process. Basically, this type of process should have a minimum requirement for high-level skills. It should be able to be performed by anyone within the organisation. However, the organisation’s management should be aware that too simple processes lack the stimuli which are the source of process improvement (Campbell, 1988). The consequence is that the organisation will be less competitive.

- (HS, LV, LP). There is evidence that structural factors influence the ability to understand and execute the business process (Mendling et al., 2007). Factors such as the individuals’ familiarity with the process, the span of attention and the availability of tools influence the reception and perception of complexity (Campbell, 1988). The question then arises as to the
reasons behind a more-or-less uniform performance. If all performers are under-performing, then it is likely that structural complexity is an issue that needs to be addressed. If, on the other hand, most performers are performing well, then the impact of structural complexity is of lesser importance.

- **(HS, HV, LP).** This point is similar to **(HS, LV, LP)** above, except that the process model is also characterised by high variance. Interestingly, if the low variance in performance is present because most performers are performing at a high level, then this can be viewed as an ideal situation in which people are able to perform well even though the processes are structurally complex and contain a high level of variability. An equally likely scenario is that most performers are performing at a low level.

- **(LS, HV, LP).** The variance level in this type of business process indicates that the business process model allows significant flexibility in performing the business processes. With low structural complexity, and a more or less uniform level of performance, the complexity can be largely attributed to difficulties in finding the best variant to suit a particular instance. It is noted, however, that uniformity in performance could be due to poor performance by all, in which case, addressing the complexity due to high variance may become a priority.

As personal factors undeniably influence the performance of individuals (Mendling et al., 2007), complexity is experienced differently by different performers. Although the structural complexity and subjective perception of complexity are related, there is no guarantee that both are identical (Campbell, 1988); even when the structural view seems simple, the process is not necessarily simple. The real test of complexity lies within the performance of the business processes. It is necessary to acknowledge that, among other factors, complexity could be a stimulus for better performance, as a sense of challenge is known to lift performance (Locke et al., 1981). Unfortunately, when excessive complexity is applied, the performance will decline to the sub-optimal level again: as Schroder et al. (1967) explained, when the performer cannot keep up with the demands of the task, the performance will diminish. Achieving the right balance is indeed a major challenge. The proposed integrated framework can be utilised to perform a meaningful and accurate analysis of complexity across the different dimensions and thereby assist organisations in investigating and finding the right balance between complexity.
and performance. The following sections describe the methods through which the individual dimensions of complexity can be measured.

### 6.4 Structural Complexity Measurement

The first axis that needs to be measured is the structural complexity of the business process. The proposed framework utilises the CFC metrics as introduced by Cardoso (2006). The metrics are commonly introduced during the development of processes to enhance quality and maintainability. Mathematically, the CFC is defined as:

\[
CFC = \sum CFC_{\text{XOR-split}(a)} + \sum CFC_{\text{OR-split}(a)} + \sum CFC_{\text{AND-split}(a)}
\]

\[
= \sum fan-out(a) + \sum 2^{fan-out(a)-1} + 1 \times m
\]

where \(a\) is an activity within business process \(k\), \(m\) is the number of splits, and \(fan-out\) indicates the number of branches.

Cardoso (2006) posited that the higher the value of the CFC, the more complex the process model. However, no threshold value has been defined to determine the level of complexity. Sánchez-González et al. (2011) introduced a threshold for CFC but their threshold measurements are very limited to their case studies and the threshold is based on the cognitive ability of the individual. Hence, the present study introduces a simple objective CFC threshold measurement for the structural complexity, measured by:

\[
CFC_{\text{Complexity level}} = \frac{|\text{split control}|}{CFC}
\]

where \(\text{split control}\) is a point within the workflow of the process model where a single thread of control splits into multiple branches. The above formula guarantees that \(0 < CFC_{\text{Complexity level}} \leq 1\). It is thereby defined that a process has low structural complexity if the \(CFC_{\text{Complexity level}} > 0.5\) and high otherwise. If the process is also characterised by variance (as discussed in the next section), then with \(m\) process variants, the \(CFC_{\text{Complexity level}}\) value will be:
\[ CFC\_Complexity\_level = \frac{\sum_{i=1}^{m} CFC\_Complexity\_level_i}{m} \]  

(6.3)

### 6.5 Variance Measurement

The next axis of the business process complexity framework relates to process variants. Process variants show alternatives through which a business process goal is to be achieved. Variants can include differences in activity sets and paths or a combination of both (Lu et al., 2009). In order to determine how many variants may exist for a given process scenario, it is often required to conduct a similarity analysis on the set of variants. There are a number of similarity functions proposed for process variants (Dijkman et al., 2009; van Dongen et al., 2008). Without loss of generality, the method used by Lu et al. (2009) and Mahmod et al. (2008) is utilised as an example to find the similar process variants. Once the similar processes are found, it is then possible to calculate the distribution of the process variants that are executed by the performers.

The variance measurement is defined as follows:

\[ pV = \max(\text{Process Variant distribution}) \]  

(6.4)

\[
\text{if } pV \geq 0.5 \text{ then } PV_{status} = \text{Low} \\
\text{if } pV < 0.5 \text{ then } PV_{status} = \text{High}
\]

where \( pV \) is a process variant distribution in the execution log of business processes.

For example, suppose that we have three types of process variants. Using similarity matching, the distribution of the process variants can be calculated. If, for example, the first variant is found in 95% of all executed process, then the executed business process is said to have a low variance as only one variant dominated the whole process. If the distribution of process variants is \((0.4, 0.3, \text{ and } 0.3)\), then we have a high variance situation. The highest value of variance distribution occurs when the process variants are in uniform distribution; for example, \( \max(0.4, 0.3, 0.3) = 0.4 \) which is \(< 0.5\), hence the \( PV_{status} \) is high.

### 6.6 Measurement of Variance in Performance

Performance is a somewhat subjective aspect of business process complexity and is influenced by a number of factors such as personal feelings, perception and opinions. Subjective or
perceived task complexity (Campbell, 1988) can be used as a validator for structural complexity measurements as introduced by Cardoso et al. (2006) and Gruhn and Laue (2009) to determine whether a process is perceived as complex or simple. Since subjective complexity is indeed a personal factor, it then becomes a qualitative value. Fortunately, this qualitative value is reflected in the performance of process activities by the performer. To quantify the subjective complexity, the present study measures the performers’ performance through the information extracted from the execution log\(^2\) of a business process.

Shannon’s entropy of information theory (Shannon and Weaver, 1959) is used as the method for obtaining the important information about the relevant people-task activities. The performer’s interaction with the process forms an uncertain value that indicates that various people work differently in executing the business process. Shannon’s entropy of information theory is able to quantify the expected value of the information in uncertain data such as found in the execution log of a business process.

Entropy is an important concept that has been used in many fields such as communication theory, mathematics, statistical thermodynamics and economics. In the information theory context, as described by Shannon and Weaver (1959), entropy is a measure of the amount of uncertainty in the outcome of a random experiment, which is represented by a discrete probability distribution, \(p_j\). The expression of entropy \((H)\) of the probability distribution \(p_j\), of \(r\) instances is thus defined as follows:

\[
H(p_1, p_2, \ldots, p_r) = -k \sum_{j=1}^{r} p_j \ln p_j, \quad k \text{ is a positive constant}
\]

where

\[
\begin{aligned}
\sum_{j=1}^{r} p_j &= 1 \\
p_j &\geq 0
\end{aligned}
\]

The entropy concept is principally useful when there is divergence between sets of data. In business process execution where there are performers of variable skills and experience levels, the probability of individuals performing differently to each other is high. A complex process is likely to produce different levels of performance, thus creating divergent records in

\(^2\)The IEEE Task Force on Process Mining proposed a standardised format of the execution log, namely the eXtensible Event Stream (Verbeek et al., 2011). The present study utilises this standard.
the execution log. On the contrary, simple processes will produce similar values in all records. The implementation of Shannon’s entropy of information theory can easily determine the performance variation within the execution logs.

In any process, but especially in processes that are characterised by variance, it is typical to find a large diversity in the complexity of the process. For example, in a financial institution, a customer registration process’s cost might not vary as this is a relatively simple process; whereas, for another process such as insurance claim processing, the time and the cost may vary significantly depending on who undertakes it. Thus, the more intensive or complex the process, the more impact it has on the performance of the overall instance. It should be recalled that complexity is a useful concept to move the performance from sub-optimal to optimal and that the performance will fall back to sub-optimal again when it exceeds the capability of the performer (see Figure 2.3 above).

To measure the complexity of an activity based on how it is perceived by individuals, the concept of defining the objective weight through entropy in MCDM (Hwang and Yoon, 1981) is borrowed. Weight determines the relative importance of the attributes or criteria within the given alternatives. A criterion does not function much when all the alternatives have similar outcomes. A similar situation arises in determining complexity as the result of people-task interactions. When every individual performs a process in a similar way, there is less information that can be learnt. This basically tells us that a uniform performance means a uniform perception of complexity. On the other hand, when there are contrasts within sets of data inside the log file, it shows that people are performing it differently; some people might perform well because of skill or experience. Thus, there can be degrees of subjective complexity between individuals involved.

To calculate the entropy in a given matrix $Y$ of a business process with $m$ executed process instances $p$, and $x$ as the performance score of process instances, the approach used in previous work (Setiawan and Sadiq, 2011) is used to calculate the performance score of the business process. The performance score is calculated based on the additive weight method (Hwang and Yoon, 1981) on the basis of the cost and time attributes:

$$Y = \begin{bmatrix}
  p_1 & x_1 \\
  p_2 & x_2 \\
  \vdots & \vdots \\
  p_m & x_m
\end{bmatrix}$$  \hspace{1cm} (6.6)
\[ H(\text{performance}) = -k \sum_{j=1}^{m} p_j \log_2 p_j \]

where \( k = \frac{1}{\log_2 m} \)

The above formula guarantees a value of \( 0 < H(\text{performance}) \leq 1 \). A diverse performance, as indicated by the smaller value of \( H(\text{performance}) \), indicating that the process has a substantial level of complexity as the performance between different people varies significantly. On the other hand, a uniform performance of the business activity where \( H(\text{performance}) \cong 1 \) indicates two possible interpretations: either the process is too simple or it is too complicated. When entropy is high \( (H \cong 1) \), one of the performance scores is investigated to determine whether the process is too simple or too hard.

6.7 Example Analysis

This section presents an example that provides the requisite datasets needed to analyse the complexity of a given process through measurement of the three axes of complexity, namely, the structure, variance and performance. The example is based on the building services consultancy case study (Setiawan and Sadiq, 2011; Setiawan et al., 2011), as also used in Chapters 4 and 5. To obtain the required data, the execution data of the bid tendering business process are collected. This log provides the data for the overall process execution and the distributions of the throughput time of each activity.

The process that is used as an example follows the lifecycle of a “bid”. A bid represents a submission by the building services consultancy to an organisation for electrical and mechanical design work. This submission details what services will be rendered, and in what way. The bid tendering process, as depicted in Figure 6.3, starts with identifying the opportunity to submit a bid. This opportunity must first be approved by management. If this is successful, the bid document is drafted and submitted to the company that requested the tenders. If the bid is successful, the work detailed in the bid must be completed. This work is then subjected to internal quality assurance mechanisms before it is released to the client. The final step in the process is to collect payment from the client.
The bid tendering process allows the existence of process variants for the T4, T5, T6, and T7 activities, and then the T8 and T9 activities; for example, whether the design schema is needed or not. Two sample variants are described in Figure 6.4(a) and (b). Both variants have the same outcome, that is, to deliver the detailed work of the consultancy. In the example, based on the data distribution finding, it is found that the first variant holds 75% cases ($pV \geq 0.5$); hence, the variant measurement indicates a low process variance in the case study business process.

The CFC from Figure 6.4(a) is then calculated using Equation 6.2, and if is found that the CFC is 11. The $CFC_{Complexity_{level-a}}$ is $\frac{5}{11} = 0.4545$. The CFC of Figure 6.4(b) is equal to 9,
and the $CFC_{Complexity_{level-b}}$ is $5/9 = 0.5556$. Using Equation 6.3, it is found that the $CFC_{Complexity_{level}}$ is 0.5051; hence, the process is a simple business process.

Table 6.1: Values of CFC metrics from Figure 6.4(a) and (b)

<table>
<thead>
<tr>
<th>CFC Metric Figure 6.4 (a)</th>
<th>Value</th>
<th>CFC Metric Figure 6.4(b)</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFCXOR-split(afterT2)</td>
<td>2</td>
<td>CFCXOR-split(afterT2)</td>
<td>2</td>
</tr>
<tr>
<td>CFCXOR-split(afterT3)</td>
<td>2</td>
<td>CFCXOR-split(afterT3)</td>
<td>3</td>
</tr>
<tr>
<td>CFCXOR-split(afterT4)</td>
<td>3</td>
<td>CFCXOR-split(beforeT8T9)</td>
<td>2</td>
</tr>
<tr>
<td>CFCXOR-split(beforeT4T5)</td>
<td>3</td>
<td>CFCAND-split(beforeT4T5)</td>
<td>1</td>
</tr>
<tr>
<td>CFCAND-split(beforeT8T9)</td>
<td>1</td>
<td>CFCAND-split(beforeT6T7)</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td></td>
<td>9</td>
</tr>
</tbody>
</table>

The last step to be performed is to measure the process performance measurement using the entropy concept. The performance score of the executed process is presented and then the entropy is measured. Each process instance performed has a performance score as prescribed in Table 6.2. The calculation of the performance score is based on Setiawan and Sadiq (2011), and is computed using the SAW method (Hwang and Yoon, 1981) on the basis of time and cost attributes.

Table 6.2: Entropy of performance

<table>
<thead>
<tr>
<th>Process Instance</th>
<th>Performance Score</th>
<th>$p_j \cdot \log_2 p_j$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$p_1$</td>
<td>20</td>
<td>0.196677</td>
</tr>
<tr>
<td>$p_2$</td>
<td>20</td>
<td>0.196677</td>
</tr>
<tr>
<td>$p_3$</td>
<td>100</td>
<td>0.478616</td>
</tr>
<tr>
<td>$p_4$</td>
<td>20</td>
<td>0.196677</td>
</tr>
<tr>
<td>$p_5$</td>
<td>100</td>
<td>0.478616</td>
</tr>
<tr>
<td>$p_6$</td>
<td>50</td>
<td>0.348004</td>
</tr>
<tr>
<td>$p_7$</td>
<td>70</td>
<td>0.413336</td>
</tr>
<tr>
<td>$p_8$</td>
<td>20</td>
<td>0.196677</td>
</tr>
<tr>
<td>$p_9$</td>
<td>40</td>
<td>0.306397</td>
</tr>
<tr>
<td>$p_{10}$</td>
<td>20</td>
<td>0.196677</td>
</tr>
</tbody>
</table>

$H(\text{performance}) = -k \sum_{j=1}^{m} p_j \log_2 p_j = 0.905604$

The entropy of the performance indicates that there is a substantial complexity measured from the variability found in terms of the business performance distribution. Hence, for this particular business process, the integrated complexity framework indicates that the business
process is at the \((LS, LV, HP)\) point. This type of complexity explains that even though the business process is not characterised by structural complexity, and there is low variability, there is a significant variation among the different performers. This description of the complexity was aligned with the organisational settings within the building services consultancy firm, where there were several experienced members as well as a large number of trainees and apprentices. An understanding of the complexity thus allows the management to direct resources and priorities accordingly in order to improve the overall process performance. That is, rather than focusing on process redesign or removing variance/flexibility, the focus should be on better training and induction mechanisms. Hence, the complexity of business process is not always to be seen as something that needs to be reduced. In cases where the reduction of complexity is necessary, for example where there is high structural complexity, it can be reduced using the approach proposed by Gruhn and Laue (2009).

6.8 Summary

This chapter presented an approach for business process complexity analysis that uses an expanded notion of complexity, well beyond the current understanding that limits process complexity to the process model structure. The development of the proposed integrated framework considered factors additional to the process model structure, the variability of the process, as well as the execution performance measures. Concrete measures were proposed for computing the complexity value of the structure, process and performance dimensions. The evaluation of the framework found that the framework is able to provide a more meaningful and accurate reading of the process complexity.

The proposed framework helps to consider the notion of complexity from both positive and negative aspects, since the reduction of complexity (e.g., simplification of process models) is not always the right approach as evidenced in the case study in this chapter. Embracing complexity and striking the right balance between complexity and performance is the key feature of the proposed framework.

At the same time, it is also acknowledged that there may be further aspects of business process complexity beyond the three dimensions considered above. For example, Steinmann (1976) identified the number of information sources (i.e., cues) that need to be processed by the process performer as another source of complexity. The amount and nature of the data that the performers need can also be an indicator. It is also noted that within a dynamic and flexible environment such as the dynamic case management platform, ad-hoc activities are introduced (Le Clair and Miers, 2011). The ad-hoc and dynamic activities could potentially add to the
complexity within the business process. In future work, business process complexity analysis could employ these aspects. Further empirical studies could also be conducted to evaluate the meaningfulness and value of the complexity analysis provided by the integrated framework in terms of process change and improvement strategies.

The next chapter presents an evaluation of the proposed socialisation of work practices framework for business process improvement. The evaluation uses a simulation tool, namely, the PRIME system, which is developed to provide proof of concept of the framework by analysing the performance of performers from event log data.
Chapter 7
PRIME Process Improvement Tool

7.1 Introduction
The experimental approach is used as the evaluation method in this study. A prototype system, namely, the Process Improvement (PRIME) system, is developed for the evaluation. PRIME is a web-based system that uses synthetic data as a test-bed for the research as well as real-world data that acts as the external validator to evaluate the usefulness of the proposed framework. PRIME is developed to provide proof of concept of the socialisation of work practice for business process improvement framework by analysing the performance of process performers from an event log.

The goal of the PRIME tool is to operate as an instrument that delivers the knowledge captured from best past practices to the relevant groups, namely, management and personnel (employees). The tool allows an organisation’s stakeholders (management and personnel) to analyse the information, read the report and receive recommendations related to their current performance. The tool is available online at: https://prime.andrisetiawan.com

7.2 Conceptual Approach
The concept behind the PRIME tool is that it will aid in the synthesis of best past practices in the business process performed by positive deviants via the analysis of event logs and the creation of reports and recommendations for learning purposes. The event logs of an organisation’s business process contain instances of the business process being performed. The PRIME system generates reports and recommendations based on supplied event logs, sets of metadata from business process performers, and sets of parameters in the process complexity component.
7.3 PRIMe Tool Implementation

The core modules of the PRIMe tool are the event log processing module, analysis processing module and feedback-recommender module. Figure 7.1 illustrates the flowchart of the system. PRIMe starts the process in the event log processing module where the event log, which is in XES format, is processed. To analyse the event log, it first needs to be transformed into a relational database. Once an event log has been transformed into a relational database, the process performer profiles are enriched based on the year in which the performer joined the organisation. After the process performer profile has been added, the tool analyses and generates reports and recommendations to be used by the business process performers.

![PRIME FLOWCHART](image)

Figure 7.1: PRIMe flowchart

The PRIMe tool facilitates the following processes:

- Import the event log in XES format into the analysis tool
- Remove event log from the system
- Specify metadata of business process performers
- Specify parameters of business process complexity
- Generate a graphical representation of overall performance of a business process recorded in an event log
- Generate a report of the overall business process
- Generate a report on a specific process performer
- Generate personalised recommendations to process performers.
For the purposes of this study, an event log that is publicly available from 3TU.Datacentrum is utilised (http://data.3tu.nl/repository/uuid:da6aafef-5a86-4769-acf3-04e8ae5ab4fe). The file is an event log consisting of a synthetic event log of a Review Paper business process, which was created by the Eindhoven University of Technology. This event log has 236,360 events (activities), from 10,000 recorded process instances.

7.3.1 PRIME Environment Set-Up
In this study, PRIME is installed in a server that runs Apache Web Server with the support of hypertext preprocessor (PHP) language for the scripting language. For the relational database management, the server runs MariaDB. MariaDB is a fork of MySQL and is chosen as the relational database management system as it is known to have better performance. The details of the server are shown in Figure 7.2. The following sections explain the implementation of each module in the PRIME system in detail, namely, the event log processing module (Section 7.3.2), analysis processing module (Section 7.3.3) and feedback-recommender module (Section 7.3.4).

7.3.2 Implementation of the Event Log Processing Module
The first module of the tool is the event log processing module which presents a login page (Figure 7.3). There are two types of users who are able to log in to the system: users with administrative access (hereafter referred to as “admin users”), and general users. Admin users have the ability to manage the event log, perform analysis, manage process performers’ profiles, manage event logs and read the overall reports and recommendations. General users have a different level of access which only enables them to maintain their own profile and read...
their own reports and recommendations based on their previous activities recorded in the event log.

![PRIME LOGIN](Image)

Figure 7.3: PRIME login page

After a successful login, the admin user is redirected from the login page to a page that explains the PRIME system and how it works (Figure 7.4).

![PRIME FLOWCHART](Image)

Figure 7.4: Admin welcome page of PRIME
One of the important components of the event log processing module is the event log upload page. Only admin users are able to upload the event log to the designated folder. The event log will be stored in the folder named “XES” under the PRIME tool installation folder. The tool gives admin users the option to upload the event log in XES format (Figure 7.5). An admin user who has direct access to the PRIME installation folder can also upload the event log file directly to the “XES” folder using a tool such as a file transfer protocol or secure copy protocol client application. In the present study, all the XES files are kept in the “thesis\prime\XES” folder.

Figure 7.5: XES upload page

After the event log file has been uploaded, a list of event log files is presented in the subsequent page of the PRIME system (Figure 7.6). In this study, a large.xes event log file was uploaded to the XES folder of PRIME. PRIME system assumes that the event log contains only one business process.

Figure 7.6: List of event log files
To analyse the business process, the admin user needs to select the event log. The selected event log will be parsed and converted by PRIME system from XES file type that is in XML format to a relational database which is managed by MariaDB and will store it in the PRIME database.

In order to be able to perform the analysis task, the event log needs to be enriched. The admin user needs to first enrich the performers’ metadata with the year the employee joined the organisation. This information is needed in order to set the parameters of working experience expectation. In general, a person who has been working in the organisation for a longer time than others is assumed to have better experience and knowledge than the people who joined later. PRIME system tasks is to check whether the number of years a person has been joining the organisation is reflected in his or her performance score. In this study, 11 performers were found in the processed event log (large.xes), as shown in Figure 7.7.

![List of performers](image)

**Figure 7.7: List of performers**

### 7.3.3 Implementation of the Analysis Processing Module

#### 7.3.3.1 Admin User Implementation

After a complete analysis has been done, the PRIME system moves to the analysis processing module which brings the admin user to the analysis page of the event log. There are four tabs shown on this page, namely, “event log information”, “performance chart”, “best process” and
“average performance”. Each tab contains specific information about the event log being analysed.

In the first tab of the analysis page (Figure 7.8), *Event Log Information*, the user is presented with information about the name of the event log being processed, the number of events being analysed, and the number of performers who performed the business process. This information helps the admin user to sense how big the event log is.

Based on the information in this study’s example, the event log records 11 business performers who performed 10,000 process instances of a business process. In the second tab, *Performance Chart*, the admin user is presented with a performance chart (Figure 7.9).
In the second tab, the admin user can see the overall performance of all the recorded business process instances of the analysed business process. The chart itself is presented in bar graph form, from which the admin user can identify how well the business process instances were performed across performers. The chart shows the performance score against the process instance. The performance score has already been calculated by the PRIMe system using the approach presented in Chapter 4. The relatively uniform result in the performance chart shown above in Figure 7.9 indicates that most of the process instances were performed in a similar way with some minor exceptions.

In the third tab, Best Process, as shown in Figure 7.10, the admin user is presented with the process IDs of the best process instances from the event log. The PRIMe system has already allocated the process IDs based on the methods presented in Chapter 4 and Chapter 5. The best past performance is used as the source of knowledge for business process improvement.
In the fourth tab of the analysis tab, *Average Performance*, as shown in Figure 7.11, the admin user is presented with information about how the process instances were performed on average. The average process performance acts as a classifier to distinguish the process performance of individuals. There are two pieces of information presented here to the admin user, namely, the activity name, and the average processing time of each activity.

**Figure 7.11: Average performance**
Each event’s average value will be used in the future to cluster the process performers. The process performers are clustered into novice, advanced and expert performers as explained in Chapter 5. This classification is useful for delivering the individualised recommendations to each performer. When a performer logs in to PRIMe as a general user, he/she will receive the recommendation according to his/her own current process performance. A further explanation of this procedure is provided in the section on the feedback-recommender for general users.

7.3.4 Implementation of Feedback-Recommender

7.3.4.1 Feedback-Recommender for Admin Users

An admin user is presented with the recommended process page as shown in Figure 7.12. This page presents a summary of how the activities should take place in order to achieve the best process performance. The admin user is presented with information on the name of the activity and how the activity should be performed. The recommended performance is the best performance found from the recorded event log, but does not necessarily fit all process performers; for example, the best past practice might not be suitable for novice performers. A further refinement is necessary in order to generate the personalised recommendation.
7.3.4.2 Business Process Complexity Recommender

The business process complexity analysis tool is mainly useful for managers who want to understand more about the business process complexity. This tool will provide users with the report/recommendation according to complexity as measured by the tool. As discussed in Chapter 6, Section 6.2, even though complexity is often seen as a negative factor, process complexity can become a success factor if it is managed properly.

In order to analyse the complexity of the business process, the admin user needs to fill in some parameters obtained from the business process model (Figure 7.13). The method of obtaining the parameters was set out in Chapter 6. To obtain the process model from the event log, admin users can refer to the organisation’s documentation on its process model, or they can trace the event log to obtain the process model using the process mining (ProM) tool. The parameters that need to be filled in are the number of splits (where an activity is branched into two or more paths) and the CFC score. The other complexity aspects, namely, the performance and variance, are taken from the analysis of the event log.
The output of the complexity analysis is a report for users with administrative access, such as managers, providing information on three criteria of business process complexity, namely, the structural complexity, the performance complexity, and the process variance complexity. An example of the complexity report is presented in Figure 7.14. An interpretation of the complexity analysis is given based on integrated complexity measurement as discussed in Chapter 6. This recommendation is useful for process owner, process designer, and those who are involved as decision maker. The recommendation provides the degree of the complexity, and how to treat the complexity accordingly.
7.3.4.3 Feedback-Recommender for General Users

After a successful login, general users are directed to the welcome page which explains the PRIMe system (Figure 7.15). General users are given a menu with two items, namely, “profile” and “performance analysis”.

The performance analysis option presents the general user with three kinds of information in three different tabs: “performance analysis”, “performance chart” and “recommendation”. In the performance analysis tab, as shown in Figure 7.16, the general user is presented with his/her own statistics on performance of the business process. The statistics present information on how the activities were performed. The general user is also presented with comparisons that show the average performance for the same activity and the best performance of the same activity from the same event log. This will help the general user to understand how good his/her
performance was, especially when compared with others. Figure 7.16 shows how the activities of the business process were executed. Each activities were scored

![Process Improvement Enabler](image)

**Figure 7.16: Performance analysis**

General users also have the option to evaluate their performance in a form of a comparison chart. As shown in Figure 7.17, a performance chart provides the general users with an easy method to compare their profile with others. The chart provides an overview of the performance without the need to check the details of the performance. The chart provides information on activities and the performance scores.
Figure 7.17: Performance chart of two different process performers
The last tab of the performance analysis provides a personalised recommendation that suggests the aim that needs to be achieved by the process performer. Different personalised recommendations are pre-set by the PRIMe system and delivered to the process performer according to his/her current performance. Figure 7.18 shows two different recommendations for two different process performers. In the first one, the performance score was better than average, and it was recommended that the process performer should aim to achieve the best performance. The best performance is a reasonable target that can be achieved by this person. In the second one, the performance score was below average. The best past practice might not be suitable for this person. Hence, the PRIMe system provides a different recommendation and suggests that the person aims to improve his/her performance to the average level, which is considerably easier to achieve.

Figure 7.18: Recommendations for two different process performers

7.4 Management Implementation

7.4.1 Admin User Management Menu
An admin user has privileged access to manage the event log and manage the process performer list. There are five items on the admin user management menu (Figure 7.19), namely, “analyse other event log”, “re-analyse event log”, “delete analysis (+ event log)”, “process performer” and “edit your profile.”
To analyse other event logs, admin users need to click on “analyse other event log” which will forward the admin user to the XES upload page as shown above in Figure 7.5. Admin users can also re-analyse the event log when necessary (e.g., if the event log file has just been replaced directly from the XES folder). The “delete analysis” option can be used to delete the analysis results of the event log that is currently being analysed and also delete the respective event log. A confirmation page will prompt the admin user to confirm the delete action (Figure 7.20).
The management menu allows the admin user to manage the process performers’ profiles (Figure 7.21) and his/her own profile. To edit a process performer’s profile, the admin user needs to click on the edit icon in the action column. After the edit page is loaded, the admin user fills in the form to change any of the details in the profile of the process performer (Figure 7.22) or their own profile (Figure 7.23).

**Process Improvement Enabler**

![Image of PRiMe interface showing management menu and a table of user management of event log](image)

Figure 7.21: Edit process performers’ profiles

**Process Improvement Enabler**

![Image of PRiMe interface showing user profile editing form](image)

Figure 7.22: Edit page of process performer’s profile
### 7.4.2 General User Management Implementation

Just like the admin user menu as shown in Figure 7.23, a general user is also allowed to edit his/her own profile. The profile menu item provides general users with the ability to edit their own profile, as shown in Figure 7.24.

![General User Profile Editor](image)

**Figure 7.24: General user profile editor**
7.5 Prototype System Scalability

For the analysis of the PRIME tool scalability, we shall examine the time consumed to analyse the event log. Table 7.1 presents the time needed to process the event log file that is in XES format and then to convert it to relational database.

Table 7.1: PRIME tool Time Usage to Store Event Log to Database

<table>
<thead>
<tr>
<th>fileName</th>
<th>File Size</th>
<th>Number of Instances</th>
<th>Time to Store to Database (in seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>eventA.XES</td>
<td>10.3 Mbytes</td>
<td>100</td>
<td>5</td>
</tr>
<tr>
<td>eventB.XES</td>
<td>69.3 Mbytes</td>
<td>10000</td>
<td>20</td>
</tr>
<tr>
<td>eventC.XES</td>
<td>74.1 Mbytes</td>
<td>13087</td>
<td>22</td>
</tr>
</tbody>
</table>

From the data presented by Table 7.1, it can be seen that the process to convert the XES into relational database and then store it to the database system was relatively fast. Using interpolating polynomial from presented data above, the processing time from converting XES to database is following the chart in Figure 7.25. The complexity for this process is $O(n^2)$.

![Figure 7.25: Time to Store to Database](image)
Table 7.2 presents the time needed to analyse an event log. There are factors that may affect the speed of the analysis e.g. number of instances, number of performers, and number of activities in a business process.

Table 7.2: PRIME tool Time Usage to Analyse an Event Log

<table>
<thead>
<tr>
<th>fileName</th>
<th>Number of Instances</th>
<th>Number of Performers</th>
<th>Number of Activities</th>
<th>Time to perform Analysis (in seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>eventA.XES</td>
<td>100</td>
<td>1</td>
<td>68</td>
<td>9</td>
</tr>
<tr>
<td>eventB.XES</td>
<td>10000</td>
<td>11</td>
<td>14</td>
<td>30</td>
</tr>
<tr>
<td>eventC.XES</td>
<td>13087</td>
<td>69</td>
<td>24</td>
<td>33</td>
</tr>
</tbody>
</table>

From this data, it can be interpreted trivially that the higher the number of instances and number of performers, the longer it takes to complete the calculation. However, at the number of activities factor, the interpretation is not as easy as the two other two as it portrayed as an inverted parabolic chart (Figure 7.26). Thus, it can be assumed that number of instances does not really affect the performance unlike the two other factors, the number of instances and the number of performers.

Figure 7.26: Time to perform analysis on the factor of “number of activities”
However, the number of instances factor is shown to affect the time in performing the analysis as depicted in Figure 7.27. The similar situation also applies in the time to perform the analysis on the factor of number of performers (See Figure 7.28).

![Figure 7.27: Time to perform analysis on the factor of “number of instances”](image1)

![Figure 7.28: Time to perform analysis on the factor of “number of performers”](image2)

From the charts above, we can conclude that the complexity of the analysis process, the main feature of PRIME system is $O(\log N)$. 
7.6 Summary and Conclusions

The PRIMe system has been successfully used as the test-bed experiment for the methods and approaches presented in Chapters 3, 4, 5 and 6. In summary, PRIMe has been implemented as a prototype system that is able to acquire knowledge from the analysed event logs and deliver the knowledge accordingly. PRIMe generates reports and recommendations for both managers and personnel.

The reports and recommendations that are generated for managers (users with administrative access privileges) will help managers to gain a general overview as well as insights into the performance of the business process instances executed by the employees as the business process performers. For general users, PRIMe provides the means to evaluate their own performance, and provides them with the most suitable recommendation for business process improvement. PRIMe system also performs well with the complexity of the analysis function i.e. the core feature of the system is measured as \( O(\log N) \).
Chapter 8

Conclusion and Recommendations for Future Work

8.1 Conclusion

Business process performance plays a crucial role in the competitiveness of an organisation. Although technological advancements such as those implemented in business process management systems can improve the performance of a business process, the competitive edge is difficult to sustain as most organisations eventually adopt similar technologies. Most current business process improvement methods place an emphasis on redesigning the business process, which involves the analysis and radical redesign of the process model and activities. However, not every organisation is the same, even if in the same industry sector. Hence, the same or similar process improvement solutions from a vendor cannot always deliver the same level of success. Furthermore, even though process redesign is a pervasive tool, the approach is proven to add a steep learning curve for employees, especially the inexperienced employees who struggle to catch up with the new design. In addition, externally sourced process improvement has its own drawbacks such as the lack of trust and familiarity.

An alternative, and often overlooked, approach that can work as the solution for improving process performance is a solution from within the organisation. The organisation can identify experts who perform the business processes with knowledge that constitutes the corporate skills base and shows how the organisation works at its best. This is aligned with the positive deviance social theory. In positive deviance, the successful behaviour is identified and promoted based on the observation that, in any community, there are people whose uncommon behaviours enable them to find better solutions to a problem than their peers or colleagues. Exploiting the knowledge from positive deviants in an organisation has unique advantages. Some studies have suggested that the knowledge of practices carried out by colleagues within an organisation is regarded as more trustworthy than the knowledge offered by external sources.
However, the lack of explicit articulation obscures this internal knowledge from others. Therefore, the primary research objective of this thesis was to develop a framework and consistent methods to capture the best work practice experience from internal experts and deliver them as recommendations to allow both current and future performers to work at their full potential. To capitalise on the knowledge of experts, a framework called the socialisation of work practices framework was developed (Chapter 3). The framework and its methods were then used (Chapters 4-6) as the conceptual underpinning for the design of a system prototype, called PRIMe (Chapter 7).

The socialisation of work practices framework is based on organisational learning theories which explain the concept of acquiring new insights and knowledge from the information and knowledge that an organisation currently possesses. To gain the new insights, the socialisation of work practices framework uses an extended notion of the business process event log that records the events and activities of a business process. The socialisation of work practices framework is intended to become an enabler of business process improvement by facilitating the spread of best practices throughout the organization and hence the word “socialisation”. The interaction among business process users is indeed out of the scope of the thesis. However, where appropriate, the enabling nature of the framework has been clarified. The next section summarises the contributions made through the framework and its methods.

8.1.1 Summary of Socialisation of Work Practices Framework

The socialisation of work practices framework consists of three main modules: experience-driven learning, personalised recommendation, and complexity measurement. The experience-driven learning module (Chapter 4) is the first and main part of the framework in which the event log in an eXtensible Event Stream format is analysed. In this module, the framework successfully captures the best past practices from activities recorded in the business process event log. In order to capture the best past practices, a set of methods which systematically and objectively capture the knowledge from internal experts is defined. MCDM methods are applied to select the best past practices, and the entropy of information theory is used to objectively weight the importance of the practices based on the three relevant criteria found in the literature, namely, popularity, cost/efficiency, and currency. Due to the generality of the presented methods, the three criteria do not limit the applicability of the methods. The presented methods can be used by other researchers who can extend the criteria further and the methods will still be valid.
The personalised recommendation module (Chapter 5) is designed to cater to different types of users. Recommendations are delivered and classified based on the user’s performance in executing a certain type of process instance. The recommendation provided by the PRIME system prototype is the one closest to the user’s current level of performance and is therefore the most achievable. A personalised recommendation not only promotes appropriate learning paths for an employee, but also provides a means for the employee to self-reflect.

The complexity measurement module (Chapter 6) analyses the business process complexity beyond most current understandings of business process complexity which limit the business process complexity concept to the process model complexity point of view. The present study expands the understanding of business process complexity in a more meaningful way, with process complexity seen from three perspectives: structural complexity, complexity caused by process variance, and variance in process performance. Further, the complexity measurement module considers the notion of complexity from both the positive and negative aspects. When business process complexity is seen as a negative aspect, steps are taken to reduce the complexity; however, this was proven to not always be the right approach (Chapter 6).

Finally, this study successfully developed a system prototype, named PRIME, based on the socialisation of work practices framework. As an experimental test-bed, PRIME provides insightful knowledge to business process users in the form of a report and a personalised recommendation. The prototype successfully adopts novel strategies to provide an alternative approach to business process improvement.

8.2 Limitations and Recommendations for Future Work

The methods proposed in this study for improving the performance of business process users are not without limitations. The positive deviance concept, which is the basis of this research, requires people within an organisation to interact with the positive deviants who provide them with knowledge on the best practices or strategies. Although the socialisation of work practices framework is able to provide business process users with relevant knowledge and information, it is postulated that a higher level of communication and engagement is required among business process users and positive deviants. Thus, it is recommended that future research should focus on the interaction between business process users and positive deviants in order to improve the learning process. Such interactions can be done in a form of various engagement programs to create networks of trust and strong professional relationships among co-workers. The interaction between general business process users and positive deviants, in turn, can boost
a positive workplace atmosphere, which enhances employees’ positive perception of their workplaces. Future research can also investigate additional criteria and factors that influence the performance of business process users e.g. failure to meet schedule and failure to deliver required quantity of outcome, capacity utilisation, etc.

The personalised recommendation method adapts a basic approach to classifying and filtering the most suitable recommendation. However, with the diversity that exists in most organisations due to factors such as the different backgrounds and interests of employees, future research could introduce a more advanced technique so that the recommendation includes a consideration of those diversity factors. This would increase the personalisation capabilities and effectively pinpoint the most suitable recommendation for each employee.

Finally, the PRIME tool was developed as a Web-based tool to allow easy accessibility for users. The framework and the presented methods can also be developed as a plug-in for general business process management tools. The plug-in can be developed as a module that adds specific function e.g. reporting and recommendation function in the business process management tools. Such plug-in development was beyond the scope of this thesis. The development of the socialisation of work practices framework as a plug-in for business process management tools would further increase its usefulness to the business process and organisational learning communities as it adds more functionality to what is already being delivered by the general purpose tools.
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