INTRODUCING A RULE-BASED ARCHITECTURE FOR WORKFLOW SYSTEMS IN RETAIL SUPPLY CHAIN MANAGEMENT

Master’s (one year) thesis in Informatics (15 credits)

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Abstract

Problem: While global IT competition is becoming increasingly severe, various business organizations and companies, in order to maximize the profit and gain market competitiveness, are in urgent need of high-performance workflow systems to improve efficiency. However, the workflow systems that are currently used are embedded with fixed business rules that cannot be easily adjusted by users, resulting in the inability of users to make adjustments to the business rules, so as to satisfy changed requirements and deal with high cost of business management and low efficiency. Therefore, it is highly desirable for users of workflow systems, especially retail supply chain companies, to employ a new type of systems that can be easily adjusted by end users themselves when required.

Solution: The rule-based workflow system architecture for the management of retail supply chain business process is recommended. In such architecture, the business rules can be separated from the system logic and managed by users via a friendly interface. The rule-based workflow systems can greatly enhance the system efficiency and lower maintenance cost, as compared with the traditional workflow system or other similar information systems. And the efficiency of retail supply chain business process management can be greatly enhanced by employing rule-based workflow systems.

Methods: Two main research problems and four sub-research problems, which serve as the guidance to conduct related research work, have been identified. The research work has been divided into the theoretical part and the empirical part. In the theoretical part, the theory of rule base establishment and rule-based workflow system architecture are discussed. In the empirical part, data analysis as well as prototype design are conducted by employing both quantitative and qualitative methods of data collection. Attempts are also made to verify the theories suggested in the theoretical part by means of empirical research. Based on both theoretical and empirical research, attempts are made to find solutions to the research questions.
In general, this thesis aims at providing references for the future research related to rule-based workflow system management in retail supply chain management. The thesis also aims to provide references for the practical use of rule-based systems in the retail supply chain field with such issues as system development and maintenance, especially for the system of complex and changeable business processes. Most importantly, some solutions are offered to the challenges of retail supply chain management.

**Keywords:** Rule-based Workflow System, Retail Supply Chain Management, Business Rule, Business Process Management
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1 Introduction

1.1 Background

1.1.1 Background Information of Workflow and Workflow System

Workflow is a broad concept, which refers to a series of steps that involve decisions and rules to accomplish a certain task. An apparent example of workflow is the ordering of food at a restaurant by a customer. The customer first checks the menu, then orders the items he wants, the waiter takes down the order and forwards it to the chef. The chef checks whether the stock meets the requirement to make the dishes that the customer ordered. If so, he starts making them. Otherwise, he tells the waiter to change the order. When the dishes are done, they will be served to the customer.

‘Workflow’ stems from the fields of manufacture and office automation, with a series of procedures or tasks that need to be done step by step or documents that need to be passed from one place to another for review or approval. Workflow Management Coalition (1994) defined workflow as “the automation of a business process, in whole or part, during which documents, information or tasks are passed from one participant to another for action, according to a set of procedural rules.” Furthermore, Workflow Management Coalition defined a workflow management system as “a system that defines, creates and manages the execution of workflows through the use of software, running on one or more workflow engines, which is able to interpret the process definition, interact with workflow participants and, where required, invoke the use of IT tools and applications.” (Kappel et al. 1995, p. 11) discussed that workflow management systems (WFMS) had been introduced to design, execution and monitoring of business processes.

While market competition becomes increasingly severe, organizations or companies are seek to establish information systems to improve efficiency and lower the cost, so as to maximize the profit and gain market competitiveness. However, traditional information systems lack effective mechanism and design to handle complex business processes. (Royce, 2007) The management of business processes by using information systems is still conducted ‘manually’ instead of ‘automatically or semi-automatically’. (Casati and Shan, 2002) Under such circumstances, organizations and companies that strongly rely on good business process management start to introduce workflow management systems to manage their business processes.

1.1.2 Background Information of Business Process Management

Nowadays, much attention has been focused on the management methodology of supply chain management (SCM), which integrates business processes from suppliers to consumers and manages various tasks. (Kobayashi, Tamaki & Komoda, 2003, p.769)

Gartner defined BPM as follows: “business process management provides governance of a business's process environment to improve agility and operational performance. BPM is a structured approach employing methods, policies, metrics, management practices and
software tools to manage and continuously optimize an organization's activities and processes” (Flores and Sommaruga, 2009)

The IBM company defines the business process management as “to model, development and manage the business processes during their whole life-cycles, in order to attain the company’s goal.” Cardoso et.al (2004) argued that business process management could help organizations to fulfill their corporate visions and to improve their competitive positions.

1.1.3 Background Information of Retail Supply Chain Management

The International Center for Competitive Excellence defines supply chain management as “the integration of key business processes from end user through original suppliers that provides products, services and information that add value for customers and other stakeholders.” (Changchien and Shen, 2002) One of the important issues of supply chain management is how the company can utilize the supplier, IT technology and capability to improve the competitive advantage. (Farley, 1997) Retail supply chain management is an important branch of the supply chain management. The reason why Wal-Mart ranks the top among all the supermarkets in the world is because of its good mechanism of supply chain management. Retail supply chain management has the characteristics of a complicated business process, as well as complex and volatile business rules. It is extremely important for the retail supply chain companies to possess a well-designed dynamic workflow system for its business process management. Therefore, business process management is an important research field of retail supply chain management.

1.2 Problem Description

Due to the trend of globalization, the businesses of global companies tend to be more and more complicated. Thus, the trends of business rules are becoming increasingly complicated and dynamic. This is an especially significant issue for such organizations as retail supply chain companies. They are faced with volatile business rules that need to be updated every week or even every day. For example, there is one rule in the retail supply chain that is defined as “if the total volume of the products ordered by the customer is less than 10 cubic meters, the order will be rejected by the supplier and returned to the buyer”. But the next day, the rules could be changed to “if the total volume of the products ordered by the customer is less than 8 cubic meters, the order will be rejected by the supplier. Moreover, if the volume is between 8-10 cubic meters, the order will be accepted by the supplier but the customer will be charged extra 5% of the total payment”. Just as Chin and Kotak (2006) had stated “we have been witnessing an ever-increasing trend of organizations that having enormous quantities of volatile data.”

The current workflow system is characterized by its ‘in-agility’ to handle dynamic changes in retail supply chain business process, especially in business rules. The word ‘in-agility’ here refers to two kinds of interpretations.

Firstly, since the current system architecture forces programming codes of business rules to be embedded in the system programming codes, it is hard to maintain and update the workflow systems if business rules change frequently. (Liu et.al, 2005) It has been also stated by Royce (2007) that “traditional workflow systems do not provide the ‘agility’ to easily change the
system when the business requirements changed” and Liu et.al (2005) argues that “the agility of a company’s response to customer demand has been recognized as a critical success factor in meeting competition”. The maintenance of traditional workflow systems requires software development teams to change the source codes regularly. Obviously, that is not an easy job.

Secondly, system developers often do not clearly understand the complex business rules that are defined by business process teams. The reason could be that many business rules are implicit knowledge stored in people’s mind which cannot be easily transferred to explicit knowledge that can be depicted by the written documents and words. Another reason could be that business rules cannot be defined at the initial stage of programming.

Moreover, system development teams might conduct system development and maintenance tasks independently without cooperation with business process teams, business rule teams and system development teams. Such a situation results in the low efficiency of system development and maintenance.

1.3 Research Questions

The research questions are the guidance of the research work. Research questions help to define the area of research and clarify the contents of research work. The issue of designing research questions is discussed in section 2.1 ‘research approach’.

The author raises the following two main research questions and four sub questions. The sub questions are designed to analyze the main research questions step by step.

(1) **How can rule-based workflow system provide a solution to the ‘in-agility’ of retail supply chain management?**

1.1: What are the steps to establish a rule base?

1.2: What is the architecture of the rule-based workflow system and how it can provide a solution to in-agility?

(2) **How to apply rule-based workflow systems to retail supply chain management?**

2.1: How can the business team and the system development team work together to develop and maintain the rule-based workflow system more efficiently?

2.2: How can rule-based workflow system be applied to business process management, especially in the retail supply chain field?

As discussed in section 1.2, the main problem of current workflow systems is its in-agility, which has two features: embedded coding and lack of understanding of complex business rules. In order to describe the problem in a simply and proper way, the word ‘in-agility’ is used in research question 1 to refer to the two features. The sub research questions help to find solutions to main research questions. Therefore, the author, in the first place, seeks to find the solutions for each sub research questions. When it is done, the solution to main research questions can be generated.
1.4 Purpose and Expected Results

The purpose of this research work is firstly to make theoretical contributions to the field of Informatics, through finding out the solutions to the ‘in-agility’ of current retail supply chain management by introducing a rule-based architecture for workflow systems. Secondly, to provide references for practical communities, by finding out how to apply rule-based workflow systems to retail supply chain management.

Through the literature review, the author finds out that although rule-based systems are being studied by many other researchers and implemented in many fields, very few researchers have examined its application in retail supply chain management or business process management. The rule-based architecture for workflow systems and the ways to address the problems that exist in current retail supply chain business process management are rarely discussed. (See section 1.7) It shows that the ‘in-agility’ of current workflow systems has become an unsolved problem of retail supply chain management. Thus, the author decides to carry out this research work.

The expected results are firstly the data analysis and assessment of current situations and problems of business process management in retail supply chain companies through both theoretical and empirical researches. Secondly, how to establish a rule base and what kind of system architecture can make the system to be labeled as ‘agility’. Thirdly, a prototype design of a rule-based workflow system of one of the investigated retail supply chain companies is developed to illustrate how rule-based workflow systems can be developed and implemented in retail supply chain business process management. Fourthly, how different teams can work together to develop and maintain the rule-based workflow systems more efficiently.

1.5 Delimitations

The research field will only be focused on retail supply chain management field instead of covering all the fields of supply chain management. As (Agrawal and Smith, 2009) discussed that the retail industry had emerged as a fascinating choice for those researchers in the field of supply chain management.

What is worth mentioning is that, the author only focuses on the business process management aspect of retail supply chain management. The purpose is to limit the research scope to be focused on one area-business process management instead of all the areas of retail supply chain management such as material management, financial management, risk management, etc.

The author intends to make the contributions to the field of retail supply chain management for the following reasons:

Firstly, the retail supply chain management is an important and typical branch of the supply chain management. It provides a vast array of challenges for the researches. (Agrawal and Smith, 2009) For example, it contains complex and changeable business rules. It is extremely important for it to have a well-designed dynamic workflow system for its business process management.
Secondly, to satisfy and respond quickly to the business requirements, many retail supply chain companies are now focusing on supply chain management (SCM) system in order to strengthen their ability to compete. This has therefore been recognized as an important area for IT innovation and investment. (Liu et.al, 2005)

Thirdly, from the overall perspective, the retail supply chain contains the activities of several functional departments from different companies. Those companies could play different roles such as the buyer, the supplier, the central retail supply chain management company, the third-party logistics, etc. The workflow connects these companies by the business processes. From the individual perspective, each company in a retail supply chain can be regarded as a dependent node. Each node has some business processes which connect each other to be a workflow.

1.6 Target Groups

The target groups of the thesis can be divided into academic and practical group.

In the academic group, it provides the references for the researchers within informatics or interdisciplinary fields. More specifically, future researchers of informatics field can take it as references as how to implement the rule-based workflow systems in the field of retail supply chain management and how to develop the rule-based workflow system efficiently based on the rule-based architecture. Besides that, the researchers of business process management could take it as references as how to introduce the rule-based workflow systems to enhance the efficiency of management. Furthermore, it may provide guidance for the researchers of knowledge management as how to conduct anecdote circles in rule acquisition.

For the practical group, those retail supply chain companies that have volatile business rules and complex business processes can take the research work as references to develop the rule-based workflow system, in order to attain efficient and effective business process management. The different teams within the retail supply chain company can take the research work as reference for developing and maintaining the system more efficiently.

1.7 Summary of Previous Knowledge Contributions

During the literature research, the author mainly focuses on the area of workflow system (including workflow engine), rule-based workflow system (including rule engine, business rule base, and system architecture) and business process management (including business process modeling and reengineering) according to the research questions and research approach suggested by author. The summary of previous knowledge contributions is closely related to the research questions discussed in section 1.3.

The discussion of previous knowledge contributions related to challenges of retail supply chain business process management is in chapter 3. Since the research question 2 and sub question 2.1 and 2.2 are practical oriented questions, it is hard to find the related knowledge contributions.

About the previous knowledge contributions of research question 1 and two sub questions:
Research question 1: How can rule-based workflow system provide a solution to the in-agility within retail supply chain management?

1.1: What are the steps to establish a rule base?

1.2: What is the architecture of the rule-based workflow system and how it can provide a solution to in-agility?

Concerning the research question 1.1, there are several knowledge contributions are related to business rules and rule base.

Joosten and Joosten (2007) stated that a rule base can help the designer to store, manage and check business rules. They also designed and discussed the ADL (A Description Language), and a method CC (Calculating with Concepts) that allowed IT professionals to find and verify them.

Chin and Kotak (2006) mentioned that business rules were sometimes unclear, unspoken or even undocumented. But the written rules should be included into company’s business information systems.

Ferrer-Troyano (2004) discovered the approach called SCALLOP, through which the decision rules can be discovered and improving the simplicity and helpfulness for the end user.

Apte (1994) also discovered the machine learning algorism to discover the classification patterns for personalized filtering of free text and general document categorization.

Lijun, et al. (2007) suggested the workflow system to visualize the interface for defining the business rules and the rule engine can analyze the business rules, in order to adapt to the dynamic business rules. They discussed the system could provide the visible interface for the user and define the business rules in XML language. The inner workflow-supported supply chain management system was used to define and control the execution of business processes within the enterprise. Through the integrated interface, the whole supply chain system across several independent enterprises was implemented and the information exchange was fulfilled. The independent inner systems are connected by the integrated interface into a large, global, supply chain manage system to manage business processes across the independent enterprises.

Concerning the research question 1.2, there are couples of previous articles discussing the workflow system.

Müller, et al. (2004) stated that current workflow management systems still lack support for automatic and dynamic workflow adaptations. They further presented the concepts and implementation of AgentWork, which is a workflow management system supporting automated workflow adaptation in a comprehensive way. Furthermore, they suggested a rule-based approach, which is followed to specify exceptions and necessary workflow adaptations. The articles were mainly talking about how to provide sufficient flexibility to cope with unexpected failure events of the workflow management system.

Feng, Shuang and Xun (2004) discussed that although the workflow technology has been widely used, there are less definition for the workflow engine model. They proposed a
workflow engine architecture which including the workflow process definition model defined in XML language. They also discussed a structure based workflow engine controlling model and the algorithms for supporting complex business process workflow engine.

Concerning the research question 1.2, some of the authors were discussing about how to implement the rule-based workflow system in different fields by talking about the system architecture, design and implementation.

Liu, et.al. (2004) discussed that “an information system (IS) with an embedded workflow management component makes it suitable to implement cross-organization management”. In the paper, the co-authors discussed the system design and implementation for the large supply chain system which connects the independent inner enterprise systems within the supply chain. Thus, such system can manage the business processes across the independent enterprises.

According to Joosten and Joosten (2007), the rule-based architecture can help the business process designer to greatly decrease the design time and increase consistency and correctness of designs. They designed the ADL, which is a description language and a method called CC (Calculating with Concepts) that allows IT staff to find and verify them. They have also developed a tool that can manipulate business rules and generates specifications for database design.

Conery, et al. (2005) described data-centric software architecture for bioinformatics workflows and a rule-based workflow system. They suggested that the workflow system uses declarative specifications of data dependences between steps to automatically order the execution of those steps. They also stated that the rule-based approach supports an iterative design method for creating new workflows.

Chunfang and Qingping (2006) discussed the disadvantage of the current workflow model is hard to adapt to the dynamic business requirements by coding the business rules in the business processes. They proposed a rule-based workflow model – ‘BR-WFM’. It can record several critical time points and the workflow state in each point.

Poulymenopoulou, et al. (2003) stated that workflow technology promotes a component-oriented development whereby the process logic is separated from application logic. They presented an approach to capturing process logic requirements for healthcare workflow systems with a view to design a system that is easily adjustable to process changes and evolving organizational structures at a reasonable cost.

Knolmayer, et al. (2000) described a rule-based methodology for business processes and workflows modeling. They introduced an extended Event-Condition-Action (ECA) notation which is an approach for the refinement of business rules. They also proposed architecture of a rule-based repository which supports the modeling and refinement process.

Hongping (2009) introduced the ASP.NET programming based on workflow foundation. The author further suggested the high efficiency architecture for system design, to enhance the re-usability of the programming code, improve the readability of the software and largely reduce the software development time.
Chongying (2009) suggested the disadvantage of the traditional workflow system and proposed a workflow system with the rule engine. The author aims to enhance the system adaption and agility. Furthermore, the author used the Drools to design the system.

Müller, et.al (2004) focused on the workflow flexibility issue. They discussed that when facing the flexible business rules, the static business rules should be eliminated. The concept of rule engine should be introduced to improve system’s flexibility and facilitate the system maintenance.

Although the rule-based technology has been discussed by many other researchers and has been implemented in many fields, such as bioinformatics (Conery, et al., 2005), legal knowledge based systems (Stranieri et al., 2001), home settlement issues in divorce settlements (Pal and Campbell, 1997), or even basketball video categorization (Zhou et al., 2000) etc., fewer researchers were discussing the retail supply chain management or business process management field. They did not discuss how to establish rule base and how to address the problems currently encountered in the retail supply chain management field. What is more important, although some of the authors discussed that their system architectures allowed the system designer to modify workflows as and when the business requirements had been changed, they did not suggest the architecture how business process management staff who didn’t know about coding can modify the business rules via user interface.

According to the previous knowledge contributions, the author finds the motivation to fill the knowledge gaps and make the contributions to the field of business process management, especially in the retail supply chain industry. The author also determines to find the solutions to the research questions discussed in section 1.3, so as to accomplish the research work.

1.8 Background of Author

The author obtained the Bachelor Degree of Management Information System in 2008. His research interests are Workflow System, Information Systems and Knowledge Management. The author published the paper ‘Conducting Anecdote Circles in Organizations’ on the 3rd International Conference on Information Management, Innovation Management and Industrial Engineering in 2010. These backgrounds are useful to support the author to finish the research work.

1.9 Outline

In the first chapter, the author introduced the background information of workflow system and business process management. Then, the author talked about problem description. According to the problem description, the author put forward two main research questions and four sub research questions to conduct the research work. The purpose and expected results; Delimitations; Target group and summary of previous knowledge contributions are also discussed by author in the first chapter. The linkages between different parts in the thesis can be seen from the graph 1-1.
Diagram 1-1 Linkage between Different Parts in the Thesis
2 Research Method

In this chapter, the methods of research are depicted. More specifically, the scientific perspective, research approach, method of data collection, data analysis, and data evaluation and so on are described.

2.0 Scientific Perspective

Inspired by Hevner et al. (2004), the author’s research work is based on design-science perspective.

Hevner et al. (2004) defined the design science perspective as follows: “it creates and evaluates IT artifacts intended to solve identified organizational problems.” They also argue that “Such artifacts are represented in a structured form that may vary from software, formal logic, and rigorous mathematics to informal natural language descriptions.”

(Hevner et al., 2004) also argued that “design science research addresses important unsolved problems in unique or innovative ways or solved problems in more effective or efficient ways. It is inherently a problem solving process. It addresses research through the building and evaluation of artifacts designed to meet the identified business need. The goal of design science research is utility. An artifact may have utility because of some as yet undiscovered truth.”

The process of constructing and exercising innovative IT artifacts enables design-science researchers to understand the problem addressed by the artifact and the feasibility of their approach to its solution (Nunamaker et al., 1991).

Therefore, the fundamental questions for design science research are “what utility does the new artifact provide?” and “what demonstrates that utility?”. Evidence must be presented to address these two questions. That is the essence of design science. (Hevner et al., 2004) “Contribution arises from utility. If existing artifacts are adequate, then design-science research that creates a new artifact is unnecessary (it is irrelevant). If the new artifact does not map adequately to the real world (rigor), it cannot provide utility. If the artifact does not solve the problem, it has no utility. If utility is not demonstrated (evaluation), then there is no basis upon which to accept the claims that it provides any contribution.” (Hevner et al., 2004)

According to the theory of design science of (Hevner et al., 2004), the author attempts to create and evaluate the prototype design based on the suggested rule-based workflow system architecture in the research work. Moreover, the current problems and summaries of previous studies are discussed in the first chapter (See section 1.2 and 1.3). It shows that the ‘in-agility’ of current workflow systems has become an unsolved problem of retail supply chain management. Furthermore, the author attempts to conduct prototype design, and qualitative and quantitative research to find the evidences of utility for design science for the following purposes.

(1) To find out whether the existing artifacts in the retail supply companies are adequate.
(2) The prototype design will be based on the case of a real company, so as to map adequately the real world.

(3) The evaluation of prototype design is conducted to examine whether it accurately and effectively addresses the current problems of retail supply chain management.

2.1 Research Approach

The research is mainly consisted of two parts - a theoretical part and an empirical part. As the topic of the thesis is practical-orientated, it is obviously that it is not sufficient to only cover the theoretical part. The empirical part that contains survey and practices is indispensable. Qualitative research method has been applied in both parts while the quantitative research method has been used in the empirical part. On one hand, the theoretical part guides the conducting of the empirical part. On the other hand, the empirical part uses different methods in order to validate the result of theoretical part. What is worth mentioning is that, the empirical part also helps the conducting the theoretical part. The reason is that the empirical research helps to find out the current problems of retail supply chain management which cannot be fully found out through theoretical research.

In the theoretical part of the research, the author has conducted the literature review. The relevant contents about workflow system, workflow engine, and rule engine in the literature have been found out and discussed as well as refined in the thesis. The purpose of literature study is trying to find out what other researchers have been done on the previous related knowledge contributions so as to take the essence and discard the dregs for the author’s own research.

More importantly, the theoretical research also helps to establish the research questions and to decide the research approaches accordingly. It also helps to find the way of data collection, data analysis and data evaluation. At the beginning of the research, the author found out that a few articles were concerning about the challenges and problems of retail supply chain business process management. (See section 1.7) Besides that, some of the previous studies have been found out and the author also discussed the problems of the traditional workflow system which has been implemented in the supply chain field. Thus, the main research question 1 came up in mind. Then, the author believed that the way to find the solutions to the main research question 1, some of the sub questions should also be put forward. Therefore, the author designed the research question 1.1 related to the establishment of rule base which is one of the most essential components of rule-based workflow system. And then the research question 1.2 came afterwards and both two sub questions were designed to find solutions to the main research question 1 step by step. The research question 1.2 came out subsequently to find out the proper system architecture of the rule-based system concerning the problems and challenges of current retail supply chain BPM. As discussed in section 1.7, almost no previous knowledge contributions have been considered about how to establish the rule base from the beginning to implementation, as well as very few of the knowledge contributions were concerning the rule-based workflow system architecture, in order to find the solution of current problems of retail supply chain management. As a result, the main research question 1 and sub question 1.1 and 1.2 came up.
The purpose of theoretical research is acquiring the theoretical base to develop the theory in order to find the solutions to the research questions as well as making contributions to the research field. Such as suggesting the steps to establish the rule base; proposing the new system architecture and so on. Besides that, the theoretical study can make the guidance for the empirical research. Such as conducting the empirical part by using the rule establishment theory and making the prototype based on the proposed architecture discussed in the theoretical part. In the theoretical part, the main research question 1 and sub question 1.1 and 1.2 have been partially addressed.

During the theoretical research, the problems of current business process management and workflow system within retail supply chain field have been found out. Obviously, the theoretical part of the research is not sufficient to address all the research questions and accomplish the research. The empirical research has also been conducted. The purpose of conducting empirical part is intending to verify the theories put forward by the author in the theoretical part and help to find the solutions to research questions. Therefore, the research question 2 which is related to the application of rule-based workflow system to retail supply chain management field comes up. With the help of empirical research, the challenges of current retail supply chain BPM in both theoretical and practical aspects have been found out. Then the sub question 2.1 and 2.2 related to empirical research came up to be motivated to find the solutions to research question 2.

The empirical part is conducted in order to validate the theories suggested in the theoretical part, as well as to find the solutions for comparatively practical-oriented research question 2. The empirical research part has been divided into three parts. In the first part, the qualitative and quantitative data collection and data analysis has been done. In the second part, the rule base has been established and business processes has been modeled according to the result of first empirical part. In the third part, the prototype has been designed based on the result of first and second part of empirical part.

In the first part of empirical research, both quantitative and qualitative data collection method has been implemented in the empirical part, which is through questionnaires and interviews correspondingly. The purpose of it is to understand the exact problems and situations of current information system used in business process management of retail supply chain company. The result of first empirical part creates the basis for further conduction of empirical research. Then in the second and third part, based on the system architecture and the steps of establishing the rule base discussed in the theoretical part, the establishment of rule base and the prototype design of a real case have been conducted in the empirical part. The empirical knowledge has been generated in the empirical part, which helps to validate and evaluate the theories put forward in the theoretical part as well as finding the solutions to research question 2.

In the empirical research, the author emphasizes on the conduction of prototype design according to the scientific perspective discussed in section 2.0. The role of prototype design in the research work is as follows:

1. It is an effective way to verify the ideas put forward in the theoretical part.
2. It is the powerful tool to find the solution to research question 2 and 3.
3. The informative knowledge that contributing to the field can be proved to be trustful as the result of prototype design.

The thesis writing was proceeding at the same time with theoretical and empirical researches. The referencing style for using is Harvard Referencing Style. Firstly the thesis comes the introduction part, which introduces the background information, problem description, research questions, purpose and expected results and so on. What is worth mentioning is that, the summary of previous knowledge contributions has been put in the first chapter.

In the second chapter “research method”, the scientific perspective and research approach have been discussed which are the guideline and pathway for the research. Then, the knowledge characteristics, research strategy, data collection, analysis and evaluation methods has been discussed in this chapter.

In the third chapter “Theoretical part”, the theoretical discussions have been depicted and most importantly, the author’s own theories have been also put forward based on the previous knowledge contributions.

In the fourth chapter “Empirical part”, the data collection and analysis of empirical research has been noted down. What is more, the process of rule base establishment, the business process modeling and re-engineering as well as the prototype design has been argued in this part.

In the “theory meets empirical data” chapter of the thesis, the emergence of different knowledge contributions has been discussed based on each research question. The process of how the theoretical data and empirical data were combined together to generate different forms of knowledge that referring to each research question has also been discussed.

Finally, the chapter “conclusion” of the thesis has been followed by the above parts to summary and evaluate the result. The implications and the future research have also been discussed in this part.

In the appendix chapter, snapshot pictures have been used to illustrate how the prototype works step by step. What is more, some important codes of thesis have been depicted in this chapter of the thesis.

The linkage between different parts in the thesis has been discussed in section 1.9.

The following diagram 2-1 illustrates the role of theoretical and empirical part.
2.2 Knowledge Characteristics

There could be different kinds of knowledge generated in the research work.

1. Explanatory Knowledge

The explanatory knowledge is the knowledge which describes what something is.

The explanatory knowledge generated in the research work is mainly coming from literature materials, such as scientific paper, journal and books, etc. Most of explanatory knowledge is
important concepts, definitions, knowledge and previous knowledge contributions which lay the essential grounds for author’s further research, and on the other hand, helping other researchers to have prerequisite knowledge for understanding the research work. In related to the main research question 1 and sub question 1.1 and 1.2, the explanatory knowledge of the understandings and description of workflow engine, rule engine, rule base, business rules and workflow system is the basis for the further knowledge generated in the theoretical part of the thesis, in order to further address these research questions. Moreover, without such explanatory knowledge, other researchers may not understand the concept of rule-based workflow system.

2. Empirical Knowledge

Three kinds of empirical knowledge has been defined which has been generated in the research work.

The first kind is the personal knowledge and experiences based on previous studies and knowledge contributions. In the thesis, for example, how to conduct anecdote circles to acquire business rule is the empirical knowledge that the author has acquired before.

The second one is the knowledge gains from the qualitative and quantitative research. This kind of knowledge is coming from the result of data collection and analysis. For example, the author did not have the personal knowledge or experience of the current situations and problems of retail supply chain management. Thus, the empirical knowledge generated through interviews and questionnaires are essential.

The third one is the knowledge gains from author’s own research experiences. For example, the research question 2 is related to the application of rule-based workflow system to retail supply chain BPM. Since such research questions cannot be addressed through above two kinds of empirical knowledge, the third kind of empirical knowledge has been suggested in designing the prototype.

3. Comprehensive Knowledge

There are also two kinds of comprehensive knowledge generated in the research work.

The first kind is formed through the theoretical research based on the explanatory knowledge. The main research question 1 as well as question 1.1 and 1.2 were addressed mostly through such kind of comprehensive knowledge. Through theoretical research based on the explanatory knowledge of workflow system, rule engine and rule base, as well as the previous knowledge contributions, the discussion of system architecture of rule-based workflow system and the steps of constructing the rule base belong to such comprehensive knowledge. In the thesis, such knowledge is named as comprehensive knowledge 1.

Another kind of comprehensive knowledge is based on both the first kind of comprehensive knowledge and the empirical knowledge. The research question 1.1 was addressed totally through such kind of knowledge. In the first kind of comprehensive knowledge, the theoretical steps to establish rule base has been discussed. In the empirical knowledge, the author has discussed the practical way to establish rule base and how to use it to maintain the business rules. In the thesis, such knowledge is named as comprehensive knowledge 2.
4. Informative

In the thesis, the informative knowledge can be regarded as normative knowledge which is put forward in order to making the contributions to the field of Informatics by providing references. It is formed based on the comprehensive knowledge discussed above. In the research work, the author aims to address the research question 1.1 through the comprehensive knowledge, while at the same time provides the informative knowledge. The informative knowledge provides the references for the researchers who are interested in the related field. The informative knowledge contributes to the related field to some extent, because such knowledge exclusively gained from research work has never or seldom been discussed by the previous researchers.

In the diagram 2-2, it shows the overall relationships of knowledge characteristics in the research work.

![Diagram 2-2 Knowledge Characteristics in the research work](image-url)


2.3 Research Strategy

As (Babbie, 1995) discussed the importance of explorative study which can generate new knowledge in the research area when the research subject is comparatively new and unexplored. What is more, the explorative study can develop method or test feasibility of future research.

The author decided to implement the explorative study during the research. The reasons are as follows:

1) The application of rule-based workflow system in retail supply chain business process management is a relatively new and studied by very few researchers.

2) The author is interested in exploring and creating the new knowledge of such research area and aims to make references of applying rule-based workflow system to business process management for the future research.

3) Through theoretical and empirical research, the author can test the feasibility of how different teams can work together more efficiently to develop and maintain the rule-based workflow system for future research of large retail supply chain system development.

What is worth mentioning is that, the author chooses prototype design as an important research strategy in the research work. According the definition given by Wikipedia, “prototype is an early sample or model built to test a concept or process or to act as a thing to be replicated or learned from.”

Firstly, the research work does not need a well-designed rule-based system and thus the prototype is perfect to illustrate the functions.

Secondly, the best way to test the feasibilities of the ideas that put forward in the theoretical part is through prototype design.

Thirdly, the research question 2 can hardly be addressed through the theoretical research. The prototype design can help to find solutions for research questions and make main contributions to the research work.

2.4 Data Collection

There are essentially two data collection methods which are qualitative and quantitative method.

The qualitative research method is through observation, interview or case study to analyze the information. As (Sale, 2002) states that they can be combined for the complementary purposes.

The quantitative method is through experiment or investigation to collect certain amount of data or information and conduct further analysis and validation. (Mertens, 1998) The questionnaire is one of the typical ways of the quantitative method.
Both the qualitative and quantitative method generates the second kind of empirical knowledge discussed in section 2.2 ‘Knowledge characteristics’. Such knowledge is the new knowledge that author gains from the empirical research, such as interview and questionnaire. But this kind of empirical knowledge is very important to the research, since it is the basis of other empirical knowledge.

2.4.1 Qualitative Method

The purpose of qualitative method is to understand the detailed business processes and the problems as well as the current situations of the retail supply chain business process management team of one or two multinational companies, in order for the further analysis and research. The author chooses in-depth interview as the qualitative method. Compared to the questionnaire, the in-depth interview can get more detailed and interesting answers for the proposed questions. More topics can be explored through interview and motivate the interviewees to contribute more answers. The disadvantage is that interview cannot reach most of the respondents and it needs be scheduled for arrangement. The interview questions have been well prepared before the interview. The specific conduction of qualitative research can be seen in Section 4.1 ‘Data Collection’. What is worth mentioning is that there is another method of qualitative method- observation. The author considered such method in the beginning, but he gave up such method after interviewing with the company’s staff. The reason is because the company did not let me to stay some time in their company to observe how they operate business process management and to find out the problems of it, in order to protect their commercial secrets.

2.4.2 Quantitative Method

The purpose of quantitative research method is to collect certain amount of data in order to make further analysis and conclusions of current situations of retail supply chain business process management. The author selects questionnaire as the quantitative method because the questionnaire can collect information from relatively large number of respondents. The disadvantage of it is that the respondents are practitioners who have no patience to answer lots of questions in depth or in detail. Especially the correspondents who are working in the retail supply chain companies are normally busy with their routine work. Thus the author has to limit the number of questions and only select Multiple-choice questions instead of short answers. The actual conduction of quantitative research can be seen in section 4.1 ‘Data Collection’.

2.4.3 Selection of Cases and Respondents

The criteria of selecting the cases for data collection should meet the requirements of the following rules in author’s view:

(1) The company should be focused on retail supply chain management which has been discussed in section 1.5. It is better to be the large multinational retail companies rather than the small company. Because the large companies can be representatives of the retail supply chain industry, which own the mainstream ideas, skills and methods by using the information systems.
(2) The company should have comparatively complex business processes and volatile business rule. This is essential according to the research requirements.

(3) The retail supply chain should have different parties involved that need to be coordinated and managed. The party should have at least consisted of supplier, buyer and logistics company.

The criteria of selecting the respondents for both qualitative and quantitative data collection within those selected cases are as follows:

(1) The respondents should have at least 1 year working experience and have enough patience.

(2) The first kind of respondents being interviewed should be the practitioner who is responsible for the retail supply chain business process management. Such kind of respondent should be very familiar with company’s business process management and business rules.

(3) The second kind of respondents should be the practitioner who is responsible for the development or maintenance of retail supply chain related information system. Such kind of respondent should be familiar with the company’s retail supply chain business process management related information system or workflow system.

In the research work, the author implements both qualitative and quantitative research methods. The combination of them is aiming for data collection, which is the basis for data analysis. Thus, the combination of them is both for data collection and analysis in the research. In order to understand the current situations and problems of business process management in retail supply chain companies. The qualitative method is essential because the in-depth interview can help to understand the specific business process and the problems of a specific company. It is important to the further data analysis. Obviously, if only focusing on qualitative method results in the gaining of limited number of samples for generalization, which draws an unconvincing conclusion of the current situations and problems. Thus the quantitative method is as the subsequence of qualitative method, which is also critical because it can help to know more situations from different people and companies that cannot be obtained from qualitative method.

What is more, the author has also collected the data for evaluation of the result of prototype design. The data can be the results of testing the prototype. They can be collected from the process of system simulations and the database for recording the system operation data. These collected data will be used for data evaluation of prototype design. See section 2.6.

2.5 Data Analysis

Backman (1998) described the data analysis phase as the most difficult and critical phase in qualitative studies. The author suggests that the data analysis is also a critical and important phase of the quantitative studies. Thus, the author carefully carries out the data analysis.
Through the **quantitative method**, the great amount of data has been collected.

Firstly, each questionnaire has been checked carefully and those invalid questionnaires which have not answered totally have to be discarded.

Secondly, the answer of each answer has been input in the computer for further analysis.

Thirdly, MS Excel has been used to draw the bar chart or pie chart depending on different questions to illustrate the results of each questionnaire question.

Fourthly, the author implemented both vertical and horizontal data analysis. The author conducted vertical data analysis for each question which could be obviously noticed from the different charts drawn in the previous step.

Fifthly, the horizontal data analysis has been conducted, which is the in-depth and comprehensive analysis of all the questionnaire questions. In other words, relationships and interconnections between the different questions have been found out.

Through **qualitative method**, the more specific data has been collected compared to quantitative method.

Firstly, the detailed and useful information from interviewed respondents have been retrieved. The specific business processes and the way of management has been analyzed and illustrated through the graphs. The analyzed business process has been used for further business process modeling and reengineering.

Secondly, the business rules of the company have been summarized from the interview. They have been depicted by the words and organized into different rule sets. This is one of the most important steps of the research. Based on such analyzed business rule, the rule base has been established and the prototype can be established.

Thirdly, through qualitative method such as interview, some more information can be found out by observing the interviewers’ non-verbal behaviors. For example, the interviewees may not directly express their opinions towards a certain questions, but the author can find out the answer through their facial expressions.

As a result, the useful data of detailed business processes and business rules of the interviewed company came up. More importantly, the data collected from the database that recorded down the states of system operation would be analyzed to be reliable for further evaluation. See section 2.6. The criteria can be seen as follows:

1. The data of order recorded in the database is accordance with the actual data. Such as the person who submits the order; the contents of the order; the submitted time.

2. The states of the workflow and the activities are recorded correctly and properly, according to the actual operational data.
The data analysis phase is the most critical and essential phase of empirical research. It is the solid basis for finding the solutions to sub research questions. It helps to further verify the theories put forward in the theoretical part as well as to develop the prototype.

2.6 Evaluation Method

The author conducts three kinds of evaluation and they are the data collection evaluation, data analysis evaluation and finally the evaluation of research result.

The author evaluates the data collected from quantitative method through the data validation check. The questionnaires have been checked one by one to see whether all the answers have been filled. If more than two questions in a single questionnaire have not been answered, the answer has been regarded as invalid.

Evaluation of data analysis is an important phase of research. After the data analysis, the empirical data has been made and the result will be evaluated and verified to be valid. Such work has been done through inviting the interviewees to double check the validity of the empirical data. Through such evaluation, the author intends to make sure the empirical data reflects what exactly the interviewees want to convey and the fact of situations. It is extremely important because the result of data analysis has been the base for further empirical research.

Guba and Lincoln (1994) suggested the ‘generalization’ as the criteria for evaluation of result. They also discussed two kinds of generalization that were the nomothetic generalization and naturalistic generalization. The author chooses ‘naturalistic generalization method’ which based on personal experience. Besides that, the author will also use ‘validity’ and ‘reliability’ as the criteria to evaluate the result. Through ‘validity’ check, cross-checking will be used by using empirical data generated in the empirical part to verify the theoretical data generated in the theoretical part.

As discussed in the section 2.1, the prototype design is an essential part of the research work. The evaluation standard of the prototype design is described as follow:

1. The data of business processes modeling and business rules coming from the qualitative data collection and further data analysis should be tested to be valid and can be used in the prototype design.

2. The prototype design should contain the interface for business team and roles of different parties within the retail supply chain. The rule can be modified by the central retail supply chain management team through user interface and the system should run smoothly. Such team can also monitor the status of each instance in the workflow.

3. At least 20 instances of different kinds of situations should be tested to run successfully from beginning to the end. Such as: changing the business rules once, twice or third times during system operation; Test different alternative choices for each possible decision for different users. The running states of each instance can be recorded in the system database for tracing.

4. The interviewees should test the prototype to decide its availability. They are also asked to evaluate whether the results of the research work to be feasible and constructive.
3 Theoretical Part

“Retailing comprises about 40% of the U.S. economy, and same situation has happened in many other countries. In recent years, the competitive nature of the retail supply chain field has increased dramatically. Retailers have to become more price competitive and utilize information technology to enhance the efficiency of supply chain management. However these requirements have increased the complexity of managing retail supply chain. Most retailers are struggling to maintain profitability.” (Agrawal and Smith, 2009)

Thus, the retail supply chain management is facing a variety of challenges.

(1) As discussed in section 1.2, the trends of business rules in retail supply chain companies are becoming increasingly complicated and dynamic, in order to compete with other companies in such competitiveness market. The current used information systems are ‘in-agility’ to handle dynamic changes in retail supply chain business process and especially the business rules. (Liu et.al, 2005) Traditional workflow systems do not provide the ‘agility’ to easily change the system when the business requirements changed. (Royce, 2007) It is because that IT architects often decide for the approaches that hard-coding the business rules or executing the business processes manually. (Casati and Shan, 2002). Casati and Shan also believe that such system architecture will increase the system operating costs; slow down response to the market change; decrease the efficiency and flexibility of retail supply chain management.

(2) Besides that, Chunfang and Qingping (2006) believed that the current information system of retail supply chain management was not eligible for business process management when the business processes changed. The system needs to be re-coding and re-testing in order to modify the business processes. It leads to high maintenance cost and more importantly, the cost of slow responses to the market requirement is un-measurable.

(3) Furthermore, Hongping (2009) argued that the retail supply chain business process management had the characteristics of increasingly complex business processes. Usually there are lots of parties within the retail supply chain, such as supplier, buyer, third party logistics, etc. How to coordinate and manage different parties within the supply chain properly is a big challenge for the retail supply chain management.

(4) As (Agrawal and Smith, 2009) talked about that the fierce competition within the retail supply chain management made every companies within such industry become price competitive. Thus, to maximize the profit means that the company should reduce the operational cost. (Casati and Shan, 2002) believe that many companies are managing the retail supply chain manually. Even those who are using the information system or workflow system is not managing the retail supply chain efficiently, which will increase the operational cost of system.

In the theoretical part, the author conducts the theoretical research including the literature review. Some important theories related to the rule-based workflow system have been discussed. Moreover, the author put forward the new theories based on previous knowledge contributions and those theories have been further validated and verified in the empirical part.
In this part, the author mainly focuses on addressing the main research question 1 “How can rule-based workflow system provide a solution to the in-agility within retail supply chain management?” In order to address it, the author will firstly find the solutions to the question 1.1 and 1.2 in this part.

3.1 Business rule

(Knolmayer, Endl & Pfahrer, 2000, p. 16) defined the business rules as “statements about guidelines and restrictions with respect to states and processes in an organization.” They also mentioned that “A lot of knowledge and many rules exist in an organization to prescribe and/or restrict the way in which the organizational goals are achieved.” Chin and Kotak (2006) defined the business rules as “statement that defines or constrains some aspects of the business which is intended to assert business structure or to control or influence the behavior of the business.”

The business rule can be simply regarded as a set of conditions and the corresponding actions. It is normally defined in precise and simple sentences. The purpose of it is to describe, confine and control the structure, strategy and the operation of the company. (Chin and Kotak, 2006) Nowadays, the business rules are normally developed by the business group and the management team of the company. The system developers are responsible to realize them by coding, and they also need to update the codes afterwards if the rules are modified. Business rules are normally defined in several rule sets, and they are triggered when the conditions meet the requirements. Then one or several further actions will be implemented afterwards.

It is quite obvious that business rules are becoming increasingly complicated. When the managers define the business rules, the developer needs to understand the data and business processes first and later put them into codes that a computer can execute. Here is a simple example of the logic for withdraw the money from ATM.

“If the request value is greater than the available value in customer’s bank account, the request of withdrawing will be rejected”

It can be described as follows:

IF (RequestValue > AvailabeValue)

THEN Transaction = “rejected”

We can notice there are several problems of such logic. Firstly, if the customer has some extra credits for overdraft, then probably the transaction could be success. Secondly, if the bank account has a primary account which has sufficient money, the transaction could be accepted. Thirdly, if the customer has both the credit for overdraft and primary account, the transaction probably could be success. But the rules for taking customer’s credit or primary account as priority should be defined. We can imagine how complicated the coding will be just for such simple logic. (Scribner, 2007) discussed that what if the business rules themselves are complex spaghetti like in order to check every possible situations, the rules cannot be easily reused and the system is extremely difficult to maintain.
3.1.1 Why it is essential to manage the business rules

The business rule is one of the most important assets of the company. How quick the company responds to the change of the business rules decides the company’s strategic competition power. How company can operate to uncover tacit knowledge from individuals and convert it into explicit knowledge of the business rules is extremely important for effective attainment of organizational goals. (Li et.al, 2010)

It is described by Scriber (2007) that the “business rule management can avoid many ‘if’ and ‘while’ statements in coding. The business rule management changes the previously process-based way to manage the business logics. It uses structured business rules to express the business processes of the company and provides the effective tool to manage it.” The business rules are thus becoming the important intangible asset for the company which will bring several advantages to the company. Moreover, because the rules are important resources, the companies can replace them with different rules more easily than they can deploy a new set of assemblies. (Scribner, 2007)

3.2 Workflow Engine

Workflow management coalition (1994) discussed that the workflow engines are responsible for managing all, or part of the execution of individual process instances. They defined the workflow engine as “a software service or engine that provides the run time execution environment for a workflow instance. It may be set up as a centralized system with a single workflow engine responsible for managing all process execution or as a distributed system in which several engines cooperate, each managing part of the overall execution.” WMC (2004) further argued that “workflow engine can control the execution of a set of process, or sub-process, instances with a defined scope determined by the range of object types, and their attributes, which it can interpret within the process definition.”

Typically the workflow engine can help to handle the following functions discussed by Workflow management coalition (1994).

- Interpretation of the process definition
- Navigation between process activities, which may involve sequential or parallel operations, deadline scheduling, interpretation of workflow relevant data, etc.
- Control of process instances - creation, activation, suspension, termination, etc.
- Identification of work items for user attention and an interface to support user interactions
- Sign-on and sign-off of specific participants
- Maintenance of workflow control data and workflow relevant data, passing workflow relevant data to/from applications or users
- An interface to invoke external applications and link any workflow relevant data
- Supervisory actions for control, administration and audit purposes
Workflow management coalition (1994) also defined the workflow enactment service as “a software service that may consist of one or more workflow engines in order to create, manage and execute workflow instances. Applications may interface to this service via the workflow application programming interface (WAPI).”

The following is the workflow reference model established by WMC (1994).

The interactions between workflow engines in the workflow enactment services with external resources occur through five APIs. The interface around the workflow enactment service is designated WAPI - Workflow APIs and Interchange formats, which may be considered as a set of constructs by which the services of the workflow system may be accessed and which regulate the interactions between the workflow control software and other system components. (WMC, 1994)
From the above diagram, Liu et al. (2004) introduced that the workflow engine interpreted the process definition and controlled the instantiation of processes, activity scheduling and invoked the application tools. The workflow engine also manages the execution of workflow instances through various processes. From the diagram, it shows that the architecture of the workflow engine consists of several management modules and data models. The management modules consist of the workflow instance management module (WIMM), a model interpreter (MI), an event management module (EMM), an activity state management module (ASMM) and a data management module (DMM). The database stores three kinds of tables and they are the event table, the workflow process instance table and the activity table.

3.3 Rule Engine

Chin and Kotak (2006) discussed that the rule engine can be used when a large set of rapidly changing rules in ways that are too complex or cost-prohibitive to do manually. Usually the rule engine is used to centralize the rules and reduce the difficulty of system modeling. So far, there is no universal definition for the rule engine. Normally, the rule engine can be regarded as a component part of the software system which is embedded in the application program. (Friedman, 2005) The essence of it is to compare the object data submitted to rule engine with the business rules loaded in the rule engine, the corresponding business rules will then be activated. The further output actions will be implemented according to the activated rules which define the rules and corresponding actions. Since the rule engine is a component of the system, only the system developer can use and control it through Application Program Interfaces.

The interface of the rule engine consists of at least three fundamental APIs.

(1) API for loading and unloading business rule sets.

(2) API for data manipulation.
Five fundamental steps for software developer to use business rule engine is as follows.

(1) Create rule engine object.
(2) Load the business rule sets to the rule engine.
(3) Submit the object data to the rule engine which will be later handled by the business rule sets.
(4) Rule engine implementation and output the results.
(5) Recycle the processed data from the rule engine.

An open business rule engine can be ‘embedded’ in any place within the application program. The rule engine in different place can implement different rule sets, in order to process distinct object data. Furthermore, there is no limitation of the number of rule engines being used in one system.

Diagram 3-2 shows the architecture of rule engine. It is mainly consisted of four parts. Rule base, rule engine, rule engine APIs and the rules management environment. The rule engine works according to the following procedures: (Li, 2005)
(1) The initial data generated by the application, namely the fact is loaded in the working memory.

(2) The pattern matcher compares the rules (including the data) in the rules repository with the fact.

(3) If there exist the conflicts between the rules, then several rules are activated and the conflicted rules will be put in the conflict aggregation.

(4) To address the conflicts, the activated rules will be put in the agenda within the execution context sequentially.

(5) Execute the rules in the agenda. Step 2 to step 5 will be repeated until all of the rules in the agenda have been executed and completed.

(6) The rules management environment includes the rules editor, debug tools and user interface. Under such environment, the user can test, edit and update the rules though the friendly user interfaces.

When the rule engine starts execution, it will be executed in the order according to the priority of the rules in the rule set. Owning to the execution part of the rules may update the object data within the working memory, which could make some rules in the agenda invalid because of the rule update. These invalid rules should be eliminated from the agenda. On the other hand, the update of the object data may activate the rules in the rules repository that previously do not meet the execution requirement, and thus the new rules will be loaded in the agenda. Under such rules inference mechanism, the dynamic rules execution chain is generated.

### 3.3.1 Forward Chaining Algorithm

One important issue needs to be considered is how to balance the rules inference mechanism and the efficiency of rule set matching. One mainstream algorithm to address such issue is forward chaining algorithm.

Here is an example of forward chaining algorithm.

Rule 1 (P0)

If Total>$50,000 & Total <$100,000

Then Discount=8%

Rule 2 (P0)

If Total>=100,000

Then Discount=12%

Rule 3 (P0)
If Amount< $3,000,
Then rejected

Rule 4 (P0)
If Amount>= $3,000,
Then Total=Total + Amount

‘P’ in the bracket refers to execution priority. Since ‘P’ in all four rules in the rule set is ‘P0’, it means all four rules have the same execution priorities. Thus, the rules will be implemented one by one in sequences. Let us suggest that initial Amount for one order equals $40,000, Total amount of orders equals to $80,000, Discount equals to 5%.

Step 1, rule 1 is executed and since the Total is greater than $50,000 and less than $100,000, the Discount changes into 8%.

Step 2, then we find out that rule 2 is checked but not executed, since Total is not greater than $100,000.

Step 3, we still find out that rule 3 is sequentially be checked but also not executed, since Amount is greater than $3,000.

Step 4, at this step, Rule 4 is checked and we find out that the rule ‘Amount>= $3000’ is valid. Thus, Total equals $40,000 + $80,000 = $12,000.

Step 5, since the amount of Total is changed; any rule related to Total will be checked again and then rule 1 is checked again. The Total is $12,000 and we realize rule 1 is not validated and executed.

Step 6, rule 2 then be checked. This time, rule 2 is validated and executed. Discount becomes 12%. Since Amount has no any change, the execution of rule set is finished. Finally, Total equals to $12,000 and Discount equals to 12%.

As Scribner (2007) discussed that the essence of forward chaining is that rules are linked together closely, or chained, so that one rule’s decision affects how other rules are being evaluated. When there are more than one rule in the rule set to deal with, rule dependencies and how to handle forward chaining need to be concerned. Rules can be forward-chained as a result of three situations: implicit chaining, attributed chaining, or explicit chaining. Scribner (2007)

### 3.3.1.1 Rete Algorism

(Forgy, 1982) discussed that “The Rete Match Algorithm is an efficient method for comparing a large collection of patterns to a large collection of objects. It finds all the objects that match each pattern.” It is one of the most efficient forward chaining algorism. The core idea of it is to reduce the calculation significantly, through separating the matching item and construct the matching tree dynamically according to the content. The Rete Match Algorithm is to utilize the time redundancy and the rule structure similarity of the rule inference engine,
to enhance the inference efficiency through saving the process and the pattern sharing. (Forgy, 1982) It is noticeable that there could be several same modules of the business rules during the process of pattern matching, which results in a large number of repeated calculations during the rule matching. It will cause time redundancy and waste hardware resources. For example, there could be such rule sets.

Rule sets 1

Rule 1: if (X>Y) and (Y<Z), then A=10
Rule 2: if (X>Y) and (Y>Z), then A=28
Rule 3: if (X>Y) or (Y<Z), then A= 18
Rule 4: if (!((X>Y) and (Y>Z))), then A= 30

During the pattern matching, the expression ‘X>Y’ will be calculated four times which ‘Y>X’ will be calculated two times. While Rete algorism is implemented, the expression ‘X>Y’ is replaced by a1, ‘Y<Z’ by a2 and ‘Y>Z’ by a3. The above rules are modified into the following rules.

Rule 1: if a1 and a2, then A=10
Rule 2: if a1 and a3, then A=28
Rule 3: if a1 or a2, then A= 18
Rule 4: if (!a1 and a3), then A= 30

Only when X, Y or Z is updated, the a1, a2 and a3 are updated correspondingly. The merits are obvious that when calculating the same expression each time during pattern matching, the expression is regarded as one variable which will be only checked again and update if the related variable within the expression is updated. Therefore, the efficiency of the inference process is improved, the processing time is saved and the hardware resources can comparatively be fully utilized.

Overall, the Rete algorism is used to enhance the execution efficiency by sacrificing the space which stores all the related information created during pattern matching. During each pattern matching, a specific matching list is appended to store all the matching facts in the working memory. When one new fact is loaded in the working memory, all the matching rules are found and added in the matching list. Similarly, when a fact is deleted from the working memory, all the related matching patterns will accordingly be removed and the fact will be eliminated from the matching list.

3.3.1.2 WF Algorism

Windows Workflow Foundation (WF) which belongs to the .NET Framework 3.0 developed by Microsoft. (Cubo, et al., 2008) “WF ships with a rules engine, which accepts XML-encoded rules and applies those rules to methods and fields in the workflow. With WF, both imperative
(procedural) code and declarative rules can be combined to form a total solution.” (Scribner, 2007) There are three main attributes of WF algorism according to Scribner (2007).

RuleRead. This attribute tells the WF rules engine that the method reads workflow instance properties and fields but does not update their values.

RuleWrite. This attribute tells the WF rules engine that the workflow method updates the value of a potentially dependent field or property.

RuleInvoke. This attribute tells the WF rules engine that the method this attribute decorates calls one or more other methods that might also update potentially dependent fields or properties.

The WF algorism follows the following executed procedures. (Scribner, 2007)

(1) The list of active rules is derived.

(2) The highest priority rule (or set of rules) is found.

(3) The rule (or rules) is evaluated, and its then or else actions are executed as necessary.

(4) If a rule updates a workflow field or property used by a previous, higher-priority rule in the list, that previous rule is reevaluated and its actions are re-executed as necessary.

(5) The process continues until all rules in the rule set have been evaluated, or reevaluated, as required.

After comparing the three rule engine algorisms, the author decided to choose WF algorism in prototype design because it is accordant with the suggested architecture discussed in Section (3.6). It accepts XML-encoded rules and what is more, the procedural code and declarative rules can be combined, which makes it possible for the rule editing by the business rule personnel. Technically, the WF algorism is a kind of forward chaining algorithm.

3.4 Rule Base

Joosten and Joosten (2007) discussed that a rule base can help the designer to store, manage and check business rules. The rule base is one of the most essential components of rule-based workflow system. Although there are some literatures related to rule base, none of them are talking about the steps for establishment the rule base. In order to conduct the empirical part of the research, the rule base establishment is one of the most important steps. The author suggests the theories of the rule base establishment based on the previous studies of rule acquisition, analysis, defining, storage, implementation and maintenance. What is worth mentioning is that some of the contents (the rule acquisition and analysis steps) are based on the previous research conducted by the author. Such research has been published on the International conference.
Motivated by the research question 1.1 discussed in “section 1.3”, the following theories of how to establish the rule base has been brought forward by the author.

The diagram 3-3 illustrates the steps to establish rule base. It consists of six phases and two APIs.

Diagram 3-3 Steps to Establish Rule Base

The diagram 3-3 illustrates the steps to establish rule base. It consists of six phases and two APIs.
1. The first step is the data gathering phase of which the main task is to acquire business rules from different sources, which could be human or manuals. The data could be raw data without being organized and analyzed.

2. In the data analysis phase, business rules obtained from the first step will be processed to be well-organized and structured. Those data which is irrelevant or not useful will be eliminated.

3. In the data definition phase, the business rules described in the natural or semi-natural language will be defined by XML language or XAML language, etc.

4. The data storage phase is one of the core phases within rule base model. In this phase, the rule base is established and business rules are stored in database or rule file structurally. The establishment of rule base is the further step of data definition and the business rules defined in a specific language will be modified, in order to be adaptable and applicable for the end system.

5. In the data implementation phase, the rule engine interacts with the rule base through APIs to support the execution of the final system.

6. The last phase is rule maintenance through which the end user can modify the business rules through applications.

### 3.4.1 Rule Acquisition

Rule Acquisition is the first step to construct rule base through data gathering from the sources. The source could be both explicit knowledge and implicit knowledge. According to the author (Li et.al, 2010), “Explicit knowledge is formal knowledge that can be packaged as information and can be found in the documents of an organization. Tacit knowledge is personal knowledge embedded in individual experience and is shared and exchanged through direct, eye-to-eye contact. The explicit knowledge could be the business rules that are written in company’s operation manuals, documents, databases and so on. The implicit knowledge could be the business rules which are stored in employee’s minds, such as knowledge of business rules and experiences.”

One simple example of business rule of explicit knowledge is described as “If the amount of an order is less than US $3000 or the volume of an order is less than 10 cubic meters, the order will be rejected.” This kind of rule is easily to be acquired because it is obvious and easy to be gathered and taken down. However, the implicit knowledge of business rules is difficult to be acquired. As (Li et.al, 2010) stated, “The challenge of acquiring such knowledge is that most of them come from experience and opinions and are difficult to exploit”. One example of it is described as follow. Sometimes the supplier decides whether to accept the order or not is depending on manager’s knowledge and experience, though the total amount and volume of an order from the buyer meets the requirement. For example, the manager finds product A is profitable on the current market. He will probably utilize the resources of manufacturing products B to produce more products A. Thus, the supplier will reject the order of product B submitting by the buyer.
Nowadays, most of the business rules gathering to construct the rule base are coming from explicit knowledge in the documents or databases. The technology of acquiring business rules through machine learning is increasingly popular these years. The machine learning software can learn the implicit and potential relationships between the rule conditions in rule base and make inferences of possible new rules which are not recognized by the company. (Li et.al, 2010)

The author suggests a novel method for acquiring implicit business rules from employees in the organization, which is through conducting anecdote circles. The conduction of Anecdote Circles is an emerging technique in knowledge management field. There is no formal definition for it so far. (Callahan, 2004) defined the Anecdote Circle as “a group of people who share common experience”. In essence, conducting Anecdote Circles means eliciting stories from a certain group of people without commenting or giving judgment. Through these gathered anecdotes, further analysis can be done to obtain the explicit knowledge from them. Storytelling is a powerful tool for organizations to learn, make changes or even conducting evaluation. Organizations are full of stories and anyone inside them can be storytellers”. Telling the anecdote is one of the most nature and relaxing way to share experiences. Many of the leading business leaders regard anecdotes as vital in sharing the knowledge and understanding issues such as organizational learning. The author (Li et.al, 2010)

To acquire business rules of implicit knowledge through anecdote circles could be implemented in the sequence of following stages. In the preparation stage, the facilitator should focus on designing themes; selecting participants and crafting anecdote-elicit questions. When designing the theme, the facilitator should narrow the Anecdote Circle to very few themes. When selecting the participants, it is desirable to select those who have the same background and share same or similar experiences. It is also desirable to select a variety of participants of different genders and ages to construct a reasonable sample group. When crafting elicit questions, it is important to use the right words in the questions so as to help the guidelines of Anecdote Circles should be set up and announced in advance to avoid deviation from the theme. “Do not interrupt or comment on other’s anecdotes” and “Do not talk about irrelevant anecdotes” are two very important sampled guidelines. The facilitator should guide the participants to talk about anecdotes to each other. In the summary and analysis stage, useful explicit information and knowledge of business rules for the organization will be produced. The author (Li et.al, 2010)

3.4.2 Rule Analysis

The business rules acquired from the first phase needs further analysis, since there exist lots of ‘bad rules’ such as irrelevant rules, old rules, inaccurate rules, invalid rules, duplicated rules and so on. These business rules cannot be used to construct rule base directly before they are well analyzed and organized. During the procedure of rule analysis, those ‘bad rules’ are processed to be eliminated or modified in order to be defined in system recognizable language in the later phase.

Especially in conducting Anecdote circles, the summary and analysis of business rules are extremely important. During the implementation stage, anecdote circles can generate a large amount of stories told by employees, how to extract the useful business rules is on the number one of the priority list. For example, when the employee was asked the question “Which
mistake you have made impressed you mostly?” during anecdote circle, he could possibly talk such story – “I have been working in this retail supply chain company for many years to validate orders submitted by the buyer. When I entered the company, I have only been told that those orders of big amount should be handed to the supervisor or manager for further validation after I have validated it. But I have no idea to which extend the amount should be big until I made a big mistake one day. Before that day, the order which the total amount is less than US $80000 will be only validated by me without handing to the supervisor for further evaluation. But at that day, I made a big mistake of an order which total amount is US $60000 which causes lost for the supplier. Then my supervisor told me that the amount of order which exceeds US $5000 should be handed in to him for further check.” In the analysis phase, the business rules are further analyzed and in this case, it could be defined as “the order which amount exceeds US $5000 should be checked by retail supply chain officer and then be handed in to supply chain supervisor.”

3.4.3 Rule Language Definition

In rule language definition, the rule sets which are described in the natural language will be defined in the rule language, for the establishment of rule base. Nowadays, the rules are normally defined in XML and XAML language.

XML is the first language that makes documents both human-readable and computer-manipulable, a result of a tag set that is more powerful, flexible and extensible than HTML’s. Data independence, the separation of content and its presentation, is the essential characteristic of XML. Because an XML document describes data, it can conceivably be processed by any application. The absence of formatting instructions makes it easy to parse. This makes XML an ideal framework for rule definition and data exchange. It is text-based, so anybody can create an XML document with even the most primitive text processing tools. (Kwembe, et.al)

XAML stands for eXtensible Application Markup Language. It is Microsoft’s declarative language for defining application user interfaces. XAML provides an easily extensible and localizable syntax for defining user interfaces separated from application logic, similar to the object oriented technique for developing n-tier applications with the MVC (Model-View-Controller) architecture. (MacVittie, 2006)

XAML is an XML-based markup language and it shares many properties with other XML documents, such as case sensitivity and having to be well-formed. XAML has some specific syntax peculiarities designed for easing the declaration of specific types of elements. (MacVittie, 2006)

3.4.4 Rule Base Establishment

After the previous steps, the rules are defined in both natural language and the machine recognizable language, such as the XML and XAML language. Then, according to the different development tools or different rule engines, the rule defined in the rule language should be modified to be adaptable for the designed system. For example, if using Microsoft Workflow Foundation to develop the rule-based workflow system, the rule will be modified into a special XML language which is stored in a rule file. The optimized rule sets, which are
defined in the adaptable language, are stored in rule files or in the database. Thus, the rule base has been finally established.

3.4.5 Rule Maintenance

The rule base needs to be constantly maintained after establishment. The maintenance of rule base could be any operation of modification of rule set or rule condition within the rule base. However, when a single rule set or a rule condition is updated in the rule base through rule maintenance, the situation of data inconsistence or incompleteness could occur. (Chaoqin and Hao, 2001) described the several kinds of situations need to be checked after rule base updating, which are redundancy, contradiction, dependency, loop, incompleteness and so on.

Redundancy means that there exist redundant or extra rule conditions in the rule base. For example, the rule conditions have the same expressions and operations. The expressions and operations in two different rule sets are same. Contradiction refers to that two different rule conditions or rules sets have same conditions but different operations. Dependency happens when two different rule conditions or rule sets have same operations but one of them has more expressions than the other. Loop could be happened when the rule conditions are dependent to each other which form a loop that the execution of rules never ends, and thus the dead-loop occurs. Rule base is the core part of rule-based system and the accuracy and the efficiency of rule base affect the performance of the whole system, thus the rule base should be taken efforts to maintain.

3.5 Business Process Modeling and Reengineering

Business process modeling and reengineering are two important ways to build the workflow system and customize the business process, in order to improve the efficency of business process management.

According to (van der Aalst, 1998a), Petri nets were devised in 1962 by Carl Adam Petri, as a tool for modeling and analyzing processes. One of the strengths of this tool is the fact that it enables processes to be described graphically. Moreover, they have a strong mathematical basis. Unlike many other schematic techniques, they are entirely formalized. Thanks to this formal basis, it is often possible to make strong statements about the properties of the process being modeled. There are also several analysis techniques and tools available which can be applied to analyze a given Petri net.

A Petri net consists of places and transitions. A place is indicated by using a circle. A transition is shown as a rectangle. Places and transitions in a Petri net can be linked by means of a directed arc. There are two types of arcs: those which run from a place to a transition and those which run from a transition to a place. Arcs from a place to a place or a transition to a transition are not possible. Places can contain tokens. These are indicated using black dots. The structure of a Petri net is fixed; however, the distribution of its tokens among the places can change. (van der Aalst, 1998a)

A transition may only fire if it is enabled. This occurs when there is at least one token at each of its input places. The transitions are then, as it were, 'loaded': ready to fire. A transition may fire from the moment it is enabled. As it fires, one token is removed from each input place and one
token added to each output place. In other words, as it fires a transition consumes tokens from
the input place and produces tokens for the output place. Transitions are the active components
in a Petri net. By firing a transition, the process being modeled shifts from one state to another.
A transition therefore often represents an event, an operation, a transformation or transportation.
The places in a Petri net are passive, in the sense that they cannot change the network’s state.
Under the Petri net, it is possible for several cases to be in progress simultaneously. (van der
Aalst, 1998a)

In the research, the author decides to use Petri net modeling in process modeling discussed in
the empirical part. The reasons are as follows.

1) The process modelers suggested in the research are business process team staffs, who are
not technical personnel. As Lu and Sadiq (2007) suggested that “Graph-based languages have
the visual appeal of being intuitive and explicit, even for those who have little or no technical
background.”

(2) Petri net is the traditional modeling language for carrying out BPR (van der Aalst 1998a). A
Petri net model abstracts from organizational aspects, as it does not bother about who is going
to execute a specific task (van der Aalst & van Hee 1996). This makes it very suitable for BPR
when considering the author’s modeling approach. The author was not primarily interested in
persons involved in processes but the documents involved in those as a result. Thus, it was
nearby to “detach” persons from processes for proposing an appropriate to-be model based on
an as-is model that was not created with a focus on persons. As they regard the terms workflow
and BPR as synonymous in respect of Petri nets, the usability of the author’s workflow model
for a BPR can apparently be seen as ensured. Particularly, for modeling a workflow van der
Aalst (1998b) gave three crucial reasons, which applied in author’s modeling:

1. Despite their graphical nature, Petri nets own formal semantics, which has several
advantages:

a) A workflow modeled with Petri nets is unambiguous, because the meaning of each
construction is well-defined. For example, there are common workflow primitives, like an
AND-join, an OR-split, or an iteration.

b) Therefore, Petri nets are very suitable in respect of contracting. In case of a conflict between
contracting parties regarding the interpretation of a workflow, a Petri net model appended to a
contract can be analyzed to clarify that.

c) Petri nets are not dependent to any particular tool. Thus, the probability of a vendor lock-in is
diminished.

d) Dynamic properties of the workflow, e.g. the occurrence of a deadlock, and performance
measures, e.g. the waiting time for the execution of a process, can be revealed by formally
analyzing the Petri net model.

2. While many other modeling languages are event-based, the Petri net language is state-based.
It supports a better distinction between the enabling and the actual execution of a process.
Particularly, this is of importance when considering concurrency of processes, which thus can
be expressed more clearly.
3. Although it could be taken for granted, it has to be mentioned that there are not only formal semantics for Petri nets, but also well-established analysis techniques that employ those. Furthermore, these analysis techniques could be applied to refine a Petri net model stepwise – or eventually practicing BPR. Hence, the modeling could be begun with a low-threshold approach, namely an initial, relatively simple graphical representation, without abandoning later analysis possibilities.

Van der Aalst (2003) discussed that business process modeling was the first and the most important steps in business process management which tends to separate process logic from application logic. Sarker and Lee (2002) defined Business Process Reengineering (BPR) as “an organization's activities of redesigning and implementing broad cross-functional business processes with the aid of Information Technology (IT) enablers and/or organizational enablers in order to obtain significant performance improvements”. It may lead to the emergence of new processes or the total alteration of existing ones. Through business process reengineering, the business process can be customized and be improved to enhance efficiency of both staff’s routine work and the system.

According to the above theories, the author will use process modeling language Petri net to model the business processes during the empirical research. The business process reengineering will also be conducted afterwards to enhance the efficiency of prototype system.

3.6 Rule-based Workflow System Model

3.6.1 System Architecture

The theories of some important components of rule-based system have been discussed in previous parts in this chapter, such as rule base, workflow engine and rule engine, etc. Motivated by the research question 1.2 discussed in “section 1.3”, the following theory of rule-based workflow system architecture has been brought forward by the author.

Based on the WorkFlow management coalition’s theory of workflow reference model which was discussed in section 3.2(workflow engine) and other previous theories, the author suggests the architecture of rule-based workflow system (RBWS) (See diagram 3-4). In such architecture, the author especially adds the rule engine and the user interface for the ordinary business rule management team into the architecture design, in order to address the current problems for business process management in the retail supply chain management field. Besides that, in the RBWS architecture, the author suggests that the business processes are connected by several nodes which have different functions. The author has divided the nodes within the model into five types, which are state node, decision node, task node, split node and joint node.

(1) Task node

The task node decides which end user should be responsible for a certain kind of task, in other words ‘task assignments’. Besides that, the task node also handles the response from the end user. For example, the supplier will be asked to click the button to decide whether to confirm or reject the order. When the workflow execution of ‘submit order to supplier’ goes to a task
node in the retail supply chain management case, the task node will wait for the response from supplier and the authorized end users who can confirm or reject the order. When the end user clicks the button, the workflow could be transferred from one state node to another.

(2) State node

The state node shows a certain state of the system for the execution of workflow. ‘Initial state’ and ‘End state’ are two special state nodes. In the retail supply chain management case, the state such as ‘Supplier Check Order State’ or ‘Manager Check Order State’ is the state node that represents a certain state of workflow system. The state node is normally be used in state machine workflow system.

(3) Decision node

When the workflow instance goes to the decision node, the workflow engine will interact with the rule engine to make decision. For example, if the amount of order is less than $1000, the workflow will be executed according to the predefined business rule that the system state will be transitioned or the activity will be transferred.

(4) Split node

The function of split node is designed to separate an execution path into several sub-paths. The split node could be ‘or-split’ or ‘and-split’ node. All the activities in the split paths separating by ‘and-split’ node will be executed, while only the activities in one of the split paths which are split by the ‘or-split’ node will be executed.

(5) Joint node

The joint node combines one or more sub-paths together. Joint node could be ‘and-join’ or ‘or join’. ‘And join’ node triggers the further action until the activities in all of the joint paths have been done. ‘Or join’ node executes the activities until the activities in only one joint path have been done. Joint node commonly appears as the pair of the split node.

Diagram 3-4 System Architecture of s Rule-based Workflow System
The diagram illustrates the architecture of rule-based workflow system (RBWS). In the RBWS, there are four important components which are workflow engine, rule engine, user interface and database. Each component also contains several modules. Such system architecture is an ECA rule-based system. Goh et.al.(2001) stated that “Event-condition-action (ECA) rules have been advocated by database practitioners as a powerful mechanism to transform passive data repositories into active ones and the rules make the data repositories react to internal or external events and trigger a chain of activities that include notifying users and applications or performing database updates.” Liu et.al. (2004) also suggested that “An ECA rule-based system can support ad-hoc, adaptive, flexible, and dynamic workflows that are modifiable at run-time. This allows the system designer to modify workflows as and when the requirements change.”

In workflow engine, process management module takes charge of the life cycle of process instances execution. The engine will guide the business process to execute through predefined procedures or rules. When the decision nodes have been encountered, the process management module interacts with rule engine through rule engine API to decide the execution of the following activity or transferring to another state of the system. The actual execution of the activity is handled by activity management module. The external application API helps to present the operation data of the workflow engine on the user interface, in order to let user to monitor the execution of the workflows. The business process manage team can check the state of the order through user interface. The task management module is responsible for task management issues which include task assignment, etc. Since the duty and the position of the staff are changeable, the task assignment changes frequently correspondingly. The task management module interacts with rule engine each time to execute task management. The user interacts with workflow engine through web application API. The rule editor in the user interface interacts with the rule base in the rule engine, so as to add, delete, modify and search for the business rules.

In the RBWS architecture, the rule engine and workflow engine coordinate with each other to manage the working memory together. The workflow engine takes charge of the workflow instance running on the internal storage, according to current process execution condition. The rule engine provides the rule service for the workflow engine and it provides route rules and task rule service for the process instances.

From the diagram 3-4, it is obvious that the rule-based workflow system developed based on such system architecture will be ‘agile’ and ‘in-static’. The rule engine and rule base separates the business rules from the workflow engine and they are no longer needs to be hard-coding. What is more, the user can manage the rule base through user interface and the change of business rule will not affect the operation of the system. Thus it can be safely concluded that such architecture can answer the sub research question 1.2, but there exist one question that whether it is feasible in practice.

In all, the rule-based workflow system can be used to define, create, and manage the execution of workflows through the use of software running on one or more workflow engine, with the interaction with the rule engine. The workflow engines can interpret the process definition and interact with workflow participants. The rule engine owns the rule inference algorithm to support the operating of the workflow engine.
There could be one or more workflow instances have already started if the workflow model has made some modifications. Thus, it is important to consider the strategy for these workflow instances which could be in the different operation stages of the system. Joeris and Herzog (1998) suggested there kinds of dynamic modification strategies of workflow instances.

(1) The first strategy is namely ‘Restart’. Once the workflow processes are modified, all the related workflow instances will roll back to the previous states. After that, all the workflow instances are restarted and run according to the new processes or model. The rollback can make sure all the instances will follow the modified processes and make the modification strategy easy to operation. The disadvantage is that it will waste lots of system resources. Moreover, some of the workflow instances cannot be rolled back.

(2) The second strategy is ‘Proceed’. Under such strategy, the workflow instances that have been already running would continue to be executed. The new started instances will follow the new business processes or the new model. Such strategy is also easy to be implemented and it is suitable for those instances which have short life cycle. Since such strategy is not flexible, it is not suitable for workflow instances that have long life cycle.

(3) The third strategy is ‘Migration’. This strategy is much more complicated than the previous ones. All the running workflow instances based on the old model will be migrated to the new model according to some algorithms, and those instances will run according to the new model. Casati et.al (1998) further divided migration strategy into two types - eager and selection. The former one applies on all the workflow instances of the model. The latter one only applies on some instances of the model. The migration can be done by the system automatically, or done by the user manually according to some criteria. Compare to the previous two strategies, the ‘Migration’ strategy has the feature of high efficiency and more applicable.

In the rule-based workflow system which is especially designed for retail supply chain, the rule will be modified in the rule file and the dynamic modification strategy will be ‘proceed’ for the instances. Thus, the incoming workflow instances will follow the new rule and those which have already followed the old business rule would proceed running. But one situation happens that only very few instances will follow a new rule while the large majority of instances will still follow the original rules. It is not reasonable to modify the business rules in the rule base just in order to let these minor instances to follow the new rule. For example, most of the instances follow the rule that “the amount of order which is less than US $5000 will be rejected”, but in some very few cases that the buyer has a special agreement signed with retail supply chain management department that the “the amount of order which is over US$3000 could be accepted”.

The author suggests another kind of dynamic modification way in rule-based workflow system architecture, named as ‘Exception’. Under such strategy, those exceptional instances which follow the different business rule will be adapted to the new rule separately, compared to the normal instances. The system clones all the activities in the current workflow of those exceptional instances. Then, the value in the rule base will be retrieved and the rules will be
modified in the cloned workflow. Eventually, the coloned workflow with rule modification will be implemented back to the original workflow and thus the dynamic modification has been accomplished. However, the disadvantage of such case is that such strategy could be only adapted to the sequential workflow system instead of the state-machine workflow system, and the new rule needs to be input into the system manually.

3.7 Workflow Process Design

There are essentially two kinds of workflow process design which are sequential workflow, and state machine workflow. (Scribner, 2007)

The sequential workflow refers to the workflow which activities are executing autonomously one after another. (Scribner, 2007) The main feature of sequential workflow is that the workflow itself primarily controls the execution of the tasks almost without user interaction. If the workflow involves user interaction for approval or disapproval of some kinds of specific tasks, the sequential workflow is also appropriate. But the disadvantage of sequential workflow due to the workflow can only be executed in the sequence.

The state machine workflow divided the workflow into several states. The state machine workflow is most appropriate that if the workflow tasks need a lot of event triggering or user interaction. (Scribner, 2007) These events trigger the workflow to move forward from one state to another. Through the state machine workflow, one state can be transitioned to the other depending on the event triggering that executed by user. For example, the “GSA officer check order” is one state and it can be transitioned to another state, say the “supplier check state” by triggering the event- ‘accept order’. It has the initial state where the order starts while the finalization state where the order is completed.

The main difference between the sequential workflow and the state machine workflow lies on the former one can only be executed by predefined sequences and the flow cannot be returned back, while as the latter one can be executed from one state to another and thus the workflow can go both forward and backward. Another difference goes to that the sequential workflow usually be executed without user interaction which is totally contrast to the state machine workflow based on state transition. (Scribner, 2007)

In the research work, the author decides to implement the rule-based workflow which mainly consists of state-machine workflow with sequential workflow embedded inside. The business rule guides the workflow to transit from one state to another which can be modified by the author according to the system architecture discussed in section 3.6. Thus it combines the advantage of both sequential and state machine workflows.

3.8 Development Environments and Tools for Prototype Design

The development environment the author has selected for prototype design is Microsoft .Net. The development environment of .NET makes the system developer much easier to develop the web applications running on Internet Information Server (IIS). On the other hand, .NET architecture supports to develop stable and reliable windows applications. .NET development environment mainly consists of the following components: (Zeng, 2003)
(1) .NET framework. One important part of it is Common Language Runtime (CLR), which is used to execute and load applications. Through such framework, the developer can visualize the user interface; make the application be able to access database and communicating on the web.

(2) .NET development toolkits. It includes Visual Studio.net development environment (IDE), which is used to develop and test applications. .NET programming language such as visual c# facilitates to create the applications which use the class library and run under CLR.

(3) ASP.NET. A new class library instead of the Active Server Pages (ASP), to create dynamic web content and web server applications. ASP.NET utilizes the internet protocols and data format such as HTML, XML, Simple Object Access Protocol (SOAP).

In the empirical research part, the author decides to select Microsoft Workflow Foundation (WF) as the development platform for RWSBPM because it supports the behavioral descriptions of components/services using workflows. In addition, the .NET Framework is widely used in the companies, and makes the implementation of services easier thanks to its workflow-based graphical support and the automation of the code generation. Cubo, et al.(2008). The WF framework allows developers to create intra-application workflows, by hosting the runtime engine in a host process. Windows applications, console applications, Windows Services, web applications and web services can all act as hosts and facades for a workflow-enabled application. De Smet, et al. (2007)

![Diagram 3-4 Architecture of Workflow Foundation](image)

In the WF designing, a Workflow is running on the host application program. The workflow consists of several activities which can be customized by the developer through custom
activity library, which also includes some system pre-defined activities. In the workflow foundation component, there are three parts. Base Activity Library takes charge of external event communication, interaction with web service, event driven, etc. Runtime service includes persistent service and tracking service. The runtime engine is the core of the system which provides both workflow execution and workflow lifecycle management capabilities. Since some workflows need to suspend for some times, the tracking service can store the system running state into the database and retrieve it next time when the workflow runs again. The persistent service is used to store the states of the system into the database. The host process is responsible for providing a set of services to Windows Workflow Foundation. A wide variety of host processes are available on the Windows platform including console applications, web applications, web services applications, SharePoint Server, and NT Service applications. Effectively, any executable process can host the Windows Workflow Foundation runtime engine.

The database management tool the author has selected is Microsoft SQL Server. The reason is because it is the database management system highly compatible to .NET framework and it can support the distribution/server service with the feature of high extension and efficiency.

### 3.9 Summary of Theoretical Research Results

In this section, the major theoretical research results are summarized. They are discussed according to the research questions. In the theoretical research, many related theoretical findings have been derived from literature review. Based on those findings, the author also suggests some new ideas and theories.

Through the literature study, the author finds out that although rule-based systems are being studied by many other researchers and implemented in many fields, very few researchers have examined its application in retail supply chain management or business process management. The steps to establish rule base and the ways to address the problems that exist in retail supply chain business process management are rarely discussed. (See section 1.7) Such findings indicated at the beginning of the study have motivated the author to continue the study according to the chosen topic.

**Research question 1:** How can rule-based workflow system provide a solution to the ‘in-agility’ of retail supply chain management?

**Sub research question 1.1:** What are the steps to establish a rule base?

- The business rules are the statements about guidelines and restrictions with respect to states and processes in an organization. (Knolmayer, Endl & Pfahrer, 2000, p. 16) The business rule is one of the most important assets of a company. The speed of a company responds to the change of business rules determines the company’s strategic competition power. (Li et.al, 2010) It is essential to manage business rules in this way. (See section 3.1)

- Rule base can help the designer to store, manage and check business rules. (Joosten and Joosten 2007) It is one of the most essential components of rule-based workflow systems. The author has suggested six phases of rule base establishment (See section 3.4)
Rule acquisition is the first step to construct a rule base through data gathering from the sources. The source could be either explicit or implicit knowledge. The author recommends a novel method for acquiring implicit business rules from employees in an organization through conducting anecdote circles. (See section 3.4.1)

The business rules acquired from the first phase needs further analysis in the second step – rule analysis. Within this step, those ‘bad rules’ are processed and thus eliminated or modified in order to be defined in system recognizable language. (See section 3.4.2)

In the rule language definition phase, the rule sets described in the natural language are defined in rule language. Nowadays, the rules are normally defined in XML and XAML language. (Kwembe, et al) and (MacVittie, 2006) (See section 3.4.3)

In the rule language storage phase, the rules are defined in both natural and machine recognizable language. Then, the rules defined in the rule language should be modified to be adaptable to the designed end system. The optimized rule sets, which are defined in the adaptable language, are stored in rule files or in the database. (See section 3.4.4)

In the data implementation phase, the rule engine interacts with the rule base through APIs to support the execution of the system. (See section 3.4)

In the rule maintenance phase, the rule base is constantly maintained after its establishment. The maintenance of rule base can be any kind of modification of rule sets or rule conditions within the rule base. Several scenarios need to be examined after rule base update. (Chaoqin and Hao, 2001) (See section 3.4.5)

Sub research question 1.2: What is the architecture of the rule-based workflow system and how it can provide a solution to in-agility?

Workflow engines are responsible for managing all or part of the execution of individual process instances. (Workflow management coalition, 1994) Workflow engines are recommended to be built on the basis of the workflow reference model. (See section 3.2)

The rule engine is employed to refine the rules and reduce the difficulty of system modeling (Chin and Kotak 2006) and such engines are regarded as a component part of a software system that is embedded in the application program. (Friedman, 2005) The mechanism of how rule engine works has been discussed (See section 3.3)

Based on the workflow management coalition’s theory of workflow reference model that is discussed in section 3.2(workflow engine) and other previous theories, author has suggested the architecture of rule-based workflow system (RBWS). (See section 3.6)

In the RBWS architecture, the author suggests that business processes are connected by several nodes with different functions. The nodes are divided into five types within the model, i.e., the state node, the decision node, the task node, the split node and the joint node. The task node decides which end user should be responsible for a certain kind of task. The state node determines a certain state of the execution of workflow system. When a workflow instance goes to the decision node, the workflow engine interacts with the rule engine to determine the way to execute the system. The function of the split node
is designed to divide an execution path into several sub-paths. The joint node functions to combine one or more sub-paths. (See section 3.6.1)

In the RBWS architecture, there are four important components, i.e., the workflow engine, the rule engine, the user interface and the database. Each component also contains several modules.

In the workflow engine, process management module takes charge of the life cycle of process instances execution. The engine will guide the business process to execute through predefined procedures or rules. The actual execution of the activity is handled by the activity management module. The task management module is responsible for task management issues, including task assignment. The workflow engine takes charge of the workflow instance running on the internal storage. The rule engine provides rule service for the workflow engine and it provides route and task rule service to process instances. (See section 3.6.1)

- It is obvious that rule-based workflow systems based on RBWS architecture will be ‘agile’ and ‘in-static’. The rule engine and rule base separates the business rules logics from the workflow engine and business rules no longer need to be hard-coding. Users can manage the rule base independently via user interface and the change of business rules does not affect the operation of the system.

The theoretical results, based on literature review as well as author’s own knowledge, need to be verified through empirical research. The empirical research part is discussed in the next chapter.
4 Empirical Part

In the empirical research part, the author focuses on finding solutions to research question 2. Inspired by the steps to establish the rule base discussed in section 3.4 and the architecture of rule-based workflow discussed in section 3.6, the author also intends to conduct the empirical part based on the theories put forward in the theoretical part as well as verifying the feasibility of them. Furthermore, the theoretical research of current situations and problems are not sufficient and the practical situations of problems and challenges are being motivated to be known. The empirical part consists of three sub parts – data collection and analysis; establishment of rule base; prototype design.

4.1 Data Collection

4.1.1 Interview

4.1.1.1 Choice of Cases and Respondents

According to the criteria for the selection of cases and respondents in section 2.4.3, the cases that the author selects are as follows:

Two companies which were selected for interview are Carrefour Global Sourcing Asia Ltd. and Tesco International Sourcing Ltd.

According to Carrefour website, Carrefour Global Sourcing Asia (GSA) Ltd. is the sourcing and procedure relay for the Carrefour Group. Carrefour GSA manages sourcing and orders placed by all of the Carrefour Group’s countries. Carrefour GSA is acting as a global retail supply chain monitoring and management group.

Tesco International Sourcing (IS) Ltd is also a retail supply chain monitoring group which manages business processes. According to Tesco website, it is a British leading retailer and one of the top three retailers in the world, operating over 3,700 stores globally and employing over 440,000 people. Tesco operates in 13 countries outside the UK.

Carrefour and Tesco are two representative companies focused on retail supply chain management which rank top in the world. Both Carrefour GSA and Tesco IS are the retail supply chain management department which monitor and manage the business processes and business rules. With the volatile business rules and complex business processes, both of them belong to the retail supply chain company. Thus it is extremely suitable for conducting case researches on these two tycoons.

The respondents being interviewed are two staff from each company. One comes from the IT department who is responsible for development and maintenance of retail supply chain management related system. One comes from the business team who is responsible for retail business process and business rule management.

The respondents who are selected for conducting questionnaire are different from those being selected for interview. Firstly, the respondents come from 6 different companies in Shanghai.
Secondly, the size of the company can be large, medium and small. Thirdly, the respondents from IT department who are developing or maintaining the retail supply chain management related system and those from supply chain management team are both qualified.

### 4.1.1.2 Data Collection of Interview

The data collection of two companies is through on-site interview. The author arranged time with the interviewees of two companies before hand and conducted the interviews in the two companies correspondingly. The detailed business processes and rules of one of the interviewed companies need to be acquired. It is the basis for further empirical research, in order to find the solution to the research question 2. Furthermore, the prototype design has also been considered in designing the interview questions. The detailed business processes and business rules acquired in the interview will be found out and used in the prototype design.

The following questions are the main interview questions that author have been prepared for the interview, according to the above discussion.

1. What are your company’s supply chain business processes?
2. How do you manage those business processes?
3. What kind of information system are you using to manage business processes? Do you use workflow system?
4. Have you intended to manage business rules?
5. If the business rules change, how do you handle it?
6. What do you think are the problems of your current information system or workflow system?
7. What’s your opinion of using rule-based workflow system? What do you think are the advantages of using rule-based workflow system in your supply chain business process management?

During the interview, the supply chain officers and IT department staff from Carrefour GSA and Tesco IS were asked about the questions above. The interviewees were very kind and cooperative to answer the questions when they were notified that the interview was a critical part of the research work. The author noted down the interview answers while the interviewees were answering. Since the interviewees cannot answer some of the questions, they wrote down those questions and later asked from the related person in the company. Then, the author went to the company again to acquire the answers.

### 4.1.2 Questionnaire

Through the qualitative method, the author cannot get enough samples to the knowledge needs. The author also conducted the quantitative method, which is through questionnaire. The questionnaire is expected to be distributed in order to acquire answers from more
respondents. The author intends to investigate the current situations and problems of business process management in different retail supply chain companies.

The questionnaire can be seen in appendix 4. 9 multiple choices questions were designed in the questionnaire. The reason is because that the personnel is usually very busy in their daily work and do not have patience to answer more than ten questions (2 pages), or answer the questions in short answers.

The questionnaire has been distributed to the respondents who meet the requirements discussed in section 4.1.1.1.

80 copies of the questionnaire have been printed and sent out to 80 practitioners in six companies with the help of the author’s friends working in those companies. 52 valid paper-based questionnaires were returning back. Besides that, the author also distributed the questionnaire through email to his friends who further forward them to their friends who were in accordance with the criteria of respondents. 21 valid email-based questionnaires were returning back. Finally, 73 questionnaires including both paper-based and email-based questionnaires were checked to be valid that can be used for data analysis.

4.2 Data Analysis

In this part, the author analyzes the data gathered from both qualitative and quantitative research in order to understand the current situations and problems of business process management in retail supply chain management field.

4.2.1 Data Analysis of Interview

1. Tesco group has almost same global retail supply chain procedures as Carrefour group with only minor differences. They also believed that the other large retail supply chain companies should have similar retail supply management mode as them. It shows that the business processes of large global retail supply chain companies tend to be same.

2. Tesco IS plays almost same role as Carrefour GSA in retail supply chain monitoring and management. They are acting as the retail supply chain management team in the group which monitors and manages the executing of workflow processes of their companies. Since the retail supply chain is such a value-added chain that decides the profits and value-creating abilities of the company, Carrefour GSA and Tesco IS are two core departments within the companies to be responsible for the high efficiency of business processes.

3. Tesco IS and Carrefour GSA are not implementing workflow management system, though both of them are using the management information system. This is one of the most surprisingly findings obtained from the interviews. Before the commencing of interview, the author assumed both of the companies should have workflow systems for business processes management since they are such powerful companies. It makes me believe that the technologies used in the companies are normally ten years lagging behind the latest researches. The author suggests the reason should be stemmed from the cost and much unknown risks of shifting to the new system even though they understand the benefits and efficiency of the workflow system. Thus, most of the retail supply chain management work
within those two companies is still done manually through sending the email, making the telephone call and even on-site visit. The officers from both companies recognize the disadvantages of the current systems which make the work in much lower efficiency than utilizing the workflow system. They need to contact and manage the buyer, supplier, quality assurance company and also third-party logistics in a single order. From interview, the author also notices another problem of Carrefour GSA’s system that sometimes when officer exports the data from the system into the Microsoft excel file in order to send to buyer or supplier, some of the original data will be lost in the MS excel file.

4. Carrefour has the global central information database that once the data in the database needs to update, one operation will make the data consistent in the global system. However, Tesco has the separate databases in regions such as Asia and Europe. It means that when the data is updated in Europe system, the same date in the Asian system is not correspondingly updated which needs to be done manually. In other words, sometimes the data could be inconsistent in Tesco’s Asia and Europe systems, which causes lots of problems during normal operations. Referring database aspect, Carrefour is doing much better than Tesco and consequently Carrefour manages business processes comparatively more efficient.

5. Although both of the companies do not have the workflow systems, when the order is confirmed by the supplier, the buyer can at least know it from the Tesco system while as in the Carrefour system, the buyer cannot see it when the supplier confirms the order; it needs to be sent by the Carrefour GSA manually through email. From the system perspective, the Tesco’s system seems to be more efficient than the Carrefour GSA’s system. It is obvious that if both of the companies start using workflow system, much of the tasks that are done manually previously could be done through computer systems in a much more convenient and efficient way.

6. They both have lots of volatile and complicated business rules. If the business rules change, they need to inform the IT department and it takes some times for the business rule to be modified in the system. Occasionally it may take one week! For example, the shipping price could be changed every month because of the changes in the shipping fees. One week of updating the business rule in the system makes the Carrefour’s system in-flexible.

7. Both of the companies do not taking care of managing business rules, which remain normally written on paper or stored in people’s mind. It causes several problems. Firstly, many company’s business rules are written on paper which cannot be easily shared with employees. Secondly, lots of business rules are scattered everywhere in the documents that the employees or even the manager does not know how much business rules they own. Thirdly, some business rules are connecting to each other that one rule changes may lead to the change of the other rules. Fourthly, many of the business rules are still implicit knowledge which is based on employee’s experience or knowledge. If the employee leaves the company, the knowledge cannot be passed or transferred easily from that employee to the other.

8. The interviewees from IT department also complain that they are doing too much works including business rule design and system development and maintenance. Sometimes the business rules they are not quite understand because they are not familiar with some special concepts of supply chain management. Besides that, the frequent maintenance of the system takes them so much time and efforts.
9. Interviewees from IT department of both companies never heard about the rule-based workflow system. After they listened to the author’s explanation of it, they were in favor of such idea and argued it will bring lots of benefits. This is one of the amazing news which encourages most for the author to conduct the further research of rule-based workflow system.

4.2.2 Data Analysis of Business Processes

Through the interview, the author has acquired the data of the business processes of Carrefour GSA and Tesco IS. Since the business processes are mostly similar within both two companies as the author discussed in section 4.2.1, so he only discusses the business processes and business process re-engineering of Carrefour GSA in the following part of the empirical research.

During the interview, the author only obtained separated business processes. For example, buyer submits the order to Carrefour GSA; the supplier returns the order to Carrefour GSA; the supplier informs Carrefour GSA that product is ready. The author organized the information and drew the single business one by one. Later, the author combined all of the single business processes together in order to use Petri net to model business processes.

Graph 4-1 the Whole Business Processes of Carrefour Global Retail Supply Chain

According to the interview, the overview procedures of global retail supply chain of the Carrefour group can be described by Graph 4-1. The more detailed steps are described as follows.
(1) The supplier applies for Carrefour’s supplier. Carrefour GSA evaluates the supplier according to some certain standards and rules. Once the condition of supplier is qualified, the supplier will create the product catalogue including product prize, size, details and specifications in Carrefour’s system for the potential buyer which could be any Carrefour supermarket in the world to check. The price the supplier provides is FOB (Free On Board) price which is different from the whole counter price and the retailer price. FOB price includes the product price plus the transportation price from factory to the ship.

(2) The quality assurance (QA) company applies for Carrefour’s quality assurance company. Carrefour GSA evaluates the QA company according to some certain standards and rules to decide whether it is qualified to inspect the product quality for Carrefour or not.

(3) The third-party logistics company applies to Carrefour GSA. Carrefour GSA evaluates the third-party logistics company according to some certain standards and rules to decide whether to accept it for product transportation.

(4) The procedure of the retail supply chain starts when the buyer issues the pre-order after buying trip and products selection, and submits to Carrefour GSA. The buyer could be any Carrefour supermarket all over the world.

(5) After receiving the pre-order from the buyer, Carrefour GSA will check it according to some criteria and rules. If the pre-order is qualified, Carrefour GSA will submit it to the supplier. Otherwise, it will be returned to the buyer with the suggestions for modification.

(6) After receiving the order from Carrefour GSA, the supplier will check it according to some certain rules. If the order is qualified, the supplier will accept it and check the inventory to decide whether they have enough stock to deliver, or making the production order. Otherwise, the supplier will return the order to Carrefour GSA who will then send it back to the buyer.

(7) Before commencing the mass production, the supplier should send the product samples to the Carrefour GSA’s appointed laboratory base on the inspection company to do relevant testing. Then after the supplier finishes 100% mass production and at least 80% packed in shipping cartons ready for shipment. The supplier have to book the inspection date with Carrefour GSA’s appointed QA inspection company that will dispatch the inspectors to the factory to proceed the FRI (final random inspection) and conduct the official inspection report to the quality engineer from Carrefour GSA to do the final decision for the quality. If the inspection report is passed, Carrefour GSA will release the OK quality letter both to the supplier and the previous selected third-party logistics company to get further approval for the shipping documents and arrange shipment. Otherwise, the products will be pending or rejected and the supplier can choose to re-manufacture or cancel the order.

(8) After receiving the products, the buyer will make the payment to the supplier. The amount of payment and the discount depends on some certain rules.

4.2.3 Data Analysis of Questionnaire

Through the 73 valid questionnaires returned from the respondents who are the practitioners of retail supply chain business process management, the following are some of the results of data analysis according to applying the data analysis methodology discussed in section 2.5.
Graph 4-2 Chart of Respondent Distributions

From graph 4-2, we can witness that most of the respondents are coming from large-sized retail supply chain companies, with comparatively small number of respondents coming from small-sized companies.

Graph 4-3 Chart of Opinion of Business Rule Management

We can notice from graph 4-3 that more than 30 percent of people think their companies do not manage the business rule well. 42 percent of people keep the neutral opinion and only roughly about 20 percent of people satisfy with the business rule management.
Seen from the graph 4-4, it is easy to decide that the companies do not implement workflow system overwhelms the companies that are using it in the figures. What is worth mentioning is that, most of the companies which are currently using the workflow systems are small companies after further analysis of questionnaires. This is maybe the small-sized companies can implement the workflow system easier than the large-sized companies.

Graph 4-5 Chart of Information System Implementation

Compared to the workflow system implementation, most of the retail supply chain companies are implementing information system to some extent in business process management. A large majority number of companies are partially using the information systems and a small amount of companies are even not using the information systems. With the further observations, all of those companies that are not using information system come from the small-sized retail supply chain companies.
Graph 4-6 Chart of Volatile Business Rule

From graph 4-6, we can find out that almost 70 percent of companies believe that their companies have volatile business rules. It is not surprisingly of such result because we know today’s market competitions are tending to be increasingly fierce. Only around 10 percent of respondents think their companies do not have volatile business rules. With the further analysis of the questionnaire, all of those 10 percent respondents come from small-sized companies.

Graph 4-7 Chart of Opinions of Rule-Based Workflow System

We can witness from the chart that 52 percent of respondents totally agree with the idea of application of rule-based workflow system in retail supply chain business process management. 23 percent of respondents choose partially agree and 15 percent of respondents hold the neutral opinions, while 7 percent of respondents and 3 percent of respondents choose partially disagree and totally disagree correspondingly. The further analysis will uncover their reasons of choosing agree or disagree of rule-based workflow system.
Here comes the statistics of the reasons for those who agree with the applications of rule-based workflow system. Comparatively more people choose ‘Increase efficiency’ with about 35%, ‘Reduce Manual Tasks’ ranks second with roughly 26%. Then it comes the reason ‘Better to Handle Business Rule’ of 25% and less people selects ‘Reduce System Maintenance Cost’. What is worth mentioning is that, most of the respondents maybe are business people instead of IT people. There could be some deviations of the reason ‘Reduce System Maintenance Cost’ and it is not surprising that most of people are thinking of increasing efficiency and reducing manual tasks which are closely related to their tasks.

The graph 4-9 shows the percentage of respondents who holds neutral opinion or disagrees with the application of rule-based workflow system in question 7. Large majority of respondents selects the reason of ‘Too much risks’. They believe that the change of totally new system will bring high risks and could lead to failure. 20 percent of people think the company does not need it. 17 percent of person selects the safety reasons of the system and small number of respondents chooses the reason of ‘less communications between company and the supplier or buyer’.

Besides conducting the above vertical analysis, the author also did the horizontal analysis. The relationships between different answers of each question have also been observed. Through the horizontal data analysis, the author found out that: Most of the large-sized retail
supply chain companies have the volatile business rules, but have not carried out the strategies of business rule management. Contrary to that, some of the small-sized retail supply chain companies have good management of business rules, although they may or may not have volatile business rules. Most of the retail supply chain companies no matter in big or small size are using the information systems to some extent. The majority of them are partially using information system. Only some small retail supply chain companies are totally implementing workflow system in their business process management. Among those people disagree of rule-based workflow system, the people from small and medium-sized companies tend to believe that the company does not need it or it may cause less communications; while as those from large-sized company suggest the safety concerns and too much potential risks.

4.3 Establishment of Rule Base

In the theoretical part, the author has discussed several steps and methods to establish rule base which are rule acquisition, rule analysis, rule language definition, rule base establishment and rule maintenance. (See section 3.4) The author establishes the rule base to illustrate those ideas and discussions put forward in the theoretical part. Rule acquisition was through data collection of interview and the other processes will be implemented in the following parts.

4.3.1 Rule Analysis

There are mainly 8 rule sets of Carrefour GSA. They are also been marked on the Graph 4-1.

Rule set 1: Carrefour GSA validates the buyer’s order

Rule set 2: Supplier validates the order submitted by Carrefour GSA

Rule set 3: Carrefour GSA selects the supplier

Rule set 4: Carrefour GSA selects the third-party logistics

Rule set 5: Carrefour GSA selects the inspection company

Rule set 6: Inspection companies proceed the products testing and FRI (final random inspection).

Rule set 7: The buyer’s payment rule

Rule set 8: PO Amendment Rule

The detailed rule sets are as follows:

Rule set 1: Carrefour GSA validates the buyer’s order

If the total amount of order is less than 3,000 dollars, the order will be rejected and returned to the buyer with the suggestions for further modifications.
If the total amount of order is less than 50,000 and greater than 3000 dollars, the validation can be done by the ordinary retail supply chain officer in Carrefour GSA.

If the total amount of order is greater than 50,000 dollars and less than 100,000 dollars, the order should be validated by the supply chain supervisor after the validation of supply chain officer.

If the total amount of order is greater than 100,000 dollars, the order should be validated by the supply chain manager after the validation of supply chain officer.

If the total volume of the products in the order is less than 10 cubic meters, the order will be rejected and returned to the buyer. The buyer will be suggested to charge the extra fee for transportation, dead freight or increase the order quantity if they want to continue the order.

**Rule set 2: Supplier validates the order submitted by Carrefour GSA**

If the supplier is the Just in Time (JIT) company, it will check the inventory first to decide whether to accept the order or not.

If the amount of order is less than the product minimum order quantity (MOQ), then the order will be rejected.

If the cargo received date (CRD) is less than production lead time, the order will be rejected or air shipment will be considered with buyers’ freight charge.

**Rule set 3: Carrefour GSA selects the supplier**

The criteria for selection are divided into the following 4 main points.

- **Commercial**: Overview of the supplier's marketing capability to reach the Carrefour requirements
- **Production**: Overview of the production equipment and labor force of the factory.
- **Qualification**: Overview of the knowledge of the supplier about the regulations
- **Inspection**: Overview of the supplier capability to control its production.

The maximum score of each point is 10; the total score can be 40.

If the supplier obtains a score < 28, Carrefour will stop the collaboration with the supplier.

If the supplier obtains a score >= 28 and, Carrefour will conduct a full technical audit and social audit after commercial & quality validation.

**Rule set 4: Carrefour GSA selects the third-party logistics**

The criteria for selecting are as follows:
Quality: the freight forwarder should promise the quality of the material or goods that delivered into their warehouse remains unchanged before shipped out;

Quantity: the freight forwarder are able to achieve a number of economic activities and transport requirements from the transport truck loaded with as much as possible, etc.;

Time: the freight forwarder have to respect the principle of reasonable cost and timely delivery to achieve fast;

Location: the freight forwarder should choose a reasonable set of transportation and storage to avoid the two invalid transfers or excessive transportation;

Price: the price quoted by the freight forwarder should refer to the time requirements to ensure quality and meet the premise of minimizing logistics costs;

Customer Service: the freight forwarder should keep good communication with both Carrefour supply chain officers and suppliers and proceed under requirement and arrangement from Carrefour, such as shipping documents, shipping instruction, etc.

Above each checking points has 4 levels: A, B, C, D.

The best score is to get 6 “A”.

If the freight forwarder gets one or more “C” for above any checking points, it will fail and Carrefour won’t select it for business;

If the freight forwarder achieves 3 or more than 3 “B”, it will be validated and Carrefour will select it for business.

Rule set 5: Carrefour GSA selects the quality assurance company

The criteria for selecting are as follows:

The quality assurance company should keep good communication with suppliers for testing request, testing result, inspection request, inspection arrangement, inspection result etc. based on the requirements from Carrefour.

The quality assurance company must keep a proper distance from suppliers, not accept bribes from suppliers, strictly control and conduct accurate testing or inspection report.

The quality assurance company must also promptly confirm and send back samples to the supplier (less than 3 days after received the samples from the supplier), to avoid affecting the production and inspection arrangements.

The quality assurance company must update the inspection result to any related person and system in time (less than 2 days after OK quality released by quality engineer from Carrefour) for the next step going on.

The above each checking point must be respected by the quality assurance company.
If they violate two more times for per checking points per year, Carrefour will issue warning letter to them;

If they violate three more times for per checking points per year, Carrefour will dismiss the collaboration with them directly.

Moreover, Carrefour proceeds appraisal for the performance of the assurance company every year, the total score is 50.

If the total score they obtain is <35, Carrefour will leave one year to observe if they are still suitable;

If the total score they obtain is >=35, Carrefour will keep the collaboration with them.

**Rule set 6: Inspection companies proceed the products testing and FRI (final random inspection)**

- The supplier must provide testing samples complied and built as per destination country standards and regulations. Mass production must be compliant with testing samples. The inspection company will do the product testing after receiving the requested samples from the supplier in terms of the requirements from Carrefour.

- The supplier must provide technical documentations. The qualification engineer will check and identify the required documents.

If a product is not in compliance with all relevant standards and regulations, Carrefour will not select it.

If a product is in compliance with all relevant standards and regulations, it will be selected by Carrefour, and the supplier can commence mass production once they received official purchase orders.

The inspection could start after the supplier finishes 100% mass production and at least 80% packed in shipping cartons ready for shipment.

If the supplier does not finish the required quantity, the inspection company should refuse to do the inspection directly;

If the inspection is done under above situation, Carrefour has to ask for re-inspection for it and all the additional inspection cost has to be absorbed by the supplier.

**Rule set 7: The buyer’s payment rule**

(Sub rule set1) Payment term

If the amount of payment is equal or greater than 10,000 US dollars, the buyer should pay by LC (letter of credit) when 90 days after shipment.

If the amount of payment is less than 10,000 US dollars, the buyer can pay by TT when 90 days after shipment.
(Sub rule set2) Penalties

Penalty on Final Random Inspection (FRI) is based on the FRI date indicated on the official order. If the supplier does not respect this date, penalty will be applied. In case the real inspection date exceeds by more than 5 days (vs. the required FRI date on the official order), 0.25% of the invoice value per day starting from the first day, will be deducted from the payment.

Penalty on late reception of cargo is also based on the cargo received date indicated in final confirmed official order. If the supplier does not respect this date, penalty will be applied. In case the cargo received date is delayed by more than 5 days (vs. required cargo received date), 0.25% of the invoice value per day from the first day, will be deducted from the payment.

Penalty on late documents: “The documents received date” specified on the FCR (Forwarders Certificate of Receipt) must not exceed the on-board date by more than 3 working days for all countries, otherwise a penalty of 300 USD, for the first day delayed plus 100 USD, per additional day will be deducted from the payment.

Penalty on carton volume (dimension): suppliers must ensure that the data provided are accurate. If the total carton volume (CBM) varies more than 7%, a penalty of 300 USD will apply. This amount will be deducted from the payment.

Suppliers must ship by air at their own cost if the goods are delayed for more than 15 days based on the required Expected Time of Delivery (ETD) mentioned on the final confirmed official order.

**Rule set 8: PO Amendment Rule**

If the ETD (Expected Time of Delivery) needs to be revised, the unit of the ETD change should be +/- 7 days;

If the Quantity (QTY) needs to be revised, the changed QTY should meet full carton loading;

If the European Article Numbering System (EAN) needs to be revised, the new EAN should not be same as other different products;

If the price, lading port, carton dimension, product description and so on that associated with the product change elements, the original product data base should be updated firstly instead of revising the information on the PO directly.

**4.3.2 Rule Language Definition and Rule Base Establishment**

The rule base consists of rules sets and the language is defined in XAML language to be compatible for the system development under Microsoft workflow foundation.

In the author’s prototype system design, the above rule set 1 is defined in XAML language and stores in the file ‘Workflow.rules’ which can be found in the appendix 3.
The above data analysis results of business processes and business rules have been checked to be valid and corrected by the interviewees and can be used for further workflow modeling and prototype design.

4.4 Workflow Modeling of Carrefour GSA

4.4.1 Modeling Approach

After an initial attempt of modeling the first core process of Carrefour GSA – a distinct misconception was revealed: Although, the author has tried to the very document-oriented nature of the modeling, he modeled with a focus on the people such as supplier, buyer, etc. in mind. This was recognizable in the Petri net model, because the author even tried to represent people through tokens by a 1:1 relation. Apparently, the people was subconsciously seen by the author as different between each other. Though, from an objectified modeling perspective, the supplier is nothing else than the buyer or Carrefour GSA – a resource.

The author’s second attempt was to explicitly focus on documents by considering the workflow of documents. In the Petri net, the author tried to represent documents (instead of people) through tokens, again by a 1:1 relation. Although the author identified much less difficulties than in the first attempt on the one hand, he found that this approach was too document-focused on the other hand. The cause for that was a strict interpretation of a token as a people or of an activity as a transformation of a document’s state respectively. This made the modeling of the entire process impossible, because there were some tasks or activities that could not be modeled with that understanding.

The author’s third attempt was a refinement of the second one. He determined to proceed with a document-oriented approach though he decided to pay an exclusive focus on documents and to allow deviations from that or simply exceptions where it was inevitable. This time the author changed from considering the transformation of a document’s state to considering the activity or task encompassed by a document. For example, the business process - the supplier manufactures the products. The author modeled such process as ‘supplier fills the manufacture order’. Thus, it addressed the issues created by previous two approaches and the modeling of an activity or task that involves a document was success.

4.4.2 Petri net modeling

The following diagram is Petri Net modeling of original business processes of Carrefour GSA. The circle represents place and the rectangular represents transition. They are connected to each other by arcs. The black dot in the place represents token. Once the transition fires, the token goes from one place to another which refers to that the state of the system is changing from one to another. One token is consumed in each input place after one firing while as one token will be generated in each output correspondingly.
The Petri net modeling the author used is using the Petri net graphical modeling tool PIPE.

Diagram 4-11 Interface of Petri Net Modeling Tool PIPE

By using PIPE2, the place and the transition can be modeled easily. Most importantly, the PIPE2 provides the animation mode. The user can use animation tool to fire the transition for simulation, the tokens will be consumed from the input place and generated in the output place correspondingly. When the business process goes to the decision mode, namely ‘or-split’ in the Petri net, the tokens can be fired randomly. In all, it is a good tool for Petri net modeling. The following diagram is the system-generated animation history of modeled Petri net for the simulations of firing.
4.5 Business Process Reengineering

Through Petri net modeling, the author has mainly concluded five problems of original business processes of Carrefour GSA.

(1) In the original business process seen from Petri net, the Carrefour GSA needs to be informed after the completeness of each business process. Some of the business processes are redundant and unnecessary. For example, if the supplier rejects the order, it will send back to Carrefour GSA first who will then send back to the buyer. Such process is redundant that supplier can definitely return the order to buyer directly. Similarly, after quality inspection, the QA inspection company does not need to send the notification letter back to GSA who will then send back to supplier again if the product is not qualified. The process is redundant and QA company can directly send the rejection letter back to the supplier as well as sending the notification letter to GSA.

(2) After receiving the order, the third-party logistics cannot reject and return the order back. It may cause some problems when third-party logistics cannot ship the goods and complete the order.

(3) When the order cancelled by the supplier, the buyer has received no notification of it. When the order is confirmed by the supplier, there is also no notification sent to the buyer. All these tasks of notifications should be done by the officer from Carrefour GSA manually.

(4) The buyer does not know the proceedings of the order submitting to the system. The buyer can only be informed in the way that Carrefour GSA contacts them by phone or email.

(5) Transferring forms such as the Microsoft Excel files by email is still an important way for Carrefour GSA to communicate with buyer, supplier, QA and third-party logistics during
retail supply chain management. Besides that, some of the business processes are still done manually. Those tasks could possibly be eliminated and replaced by the workflow system. For example, order can be returned to buyer automatically if the amount and volume of the order is less than the value defined in the rule set.

Diagram 4-13 Overview of Reengineered Business Processes
Diagram 4-14 Reengineered Business Process of Supplier Evaluation

Diagram 4-15 Reengineered Business Process of Carrefour GSA Evaluating Order
Diagram 4-16 Reengineered Business Process of Supplier

Diagram 4-17 Reengineered Business Process of QA

Diagram 4-18 Reengineered Business Process of Third-party Logistics
4.6 Prototype Design

Based on the suggested architecture discussed in the theoretical part and the reengineering workflow model as well as the rule sets of Carrefour GSA, the author has developed a prototype of rule-based workflow management system for retail supply chain process management (RWSBPM).

The prototype design acts as a critical role in the thesis. Firstly it can help to validate and evaluate the theories of rule-based workflow system discussed in the theoretical part in an obvious way. Besides that, through the prototype design, the empirical knowledge has been generated and thus the solution to the research question 2 and 2.1 as well as 2.2 can be accordingly found out. Apart from that, the informative knowledge can be proved to be trustful as a result of prototype design. It helps to contributes to the field and it is a main contribution to the author’s research work and thesis.

4.6.1 System Development Environment and tools

The development environment the author has selected is Microsoft .Net. The author selects Microsoft Workflow Foundation (WF) as the development platform for RWSBPM. The database management tool the author has selected is Microsoft SQL Server. The reasons have been discussed in section 3.8.

4.6.2 Internet Structure

The topology of RWSBPM system’s internet structure is star. There is one controlling center by using the centered management. The controlling center is managed by Carrefour GSA. Different users such as buyers, suppliers, third-party logistics and inspection company are connecting to the center through Internet in different locations. The advantage of star topology is ease to add new end users and increase the system security. Additionally, the connection priority can be controlled, the web condition can be monitored and have less connection delay. The ease of adding new end user is one of the most essential reasons for selection star topology, since every week there could be added several new end users.

![Diagram 4-20 Internet Structure of Prototype](Image)
4.6.3 System Structure

![Diagram 4-21 System Architecture of Prototype](image)

The RWSBPM is designed by Browser/Server (BS) architecture which has three layers structure. They are user layer, logical layer and physical layer.

(1) User layer has user interfaces through which the user can use web browser to interact with the system over APIs. The end user here can be separated into three types. The first one is the end users from the buyer, supplier, Carrefour GSA (officer, supervisor and manager), Quality Assurance and Third-party Logistics. The second type is system manager, who is responsible for workflow management including workflow runtime monitoring, user access management and so on. The third type is the system developer who can modify and update the business processes and coding.

(2) Logic layer is the core part of the system. It has both the workflow engine and the rule engine. The workflow engine provides the services for running, debugging and monitoring workflow instances. The rule engine interacts with the rule base to decide the proper execution rule for the workflow engine. Besides that, the web server and firewall are also included. The logic layer interacts with the physical layer and user layer through APIs.

(3) Physical layer is mainly consisted of database and rule base. Database stores the information of orders and the end users. What is worth mentioning is that the information of
the order instance is stored in the database for data persistency and data tracking service. The rule sets stored in the rule base is essentially the ‘*.rules’ file defined by XAML language.

The advantage of using B/S architecture is to simplify the client server by only installing the web browser with internet protocol software. The server is located in the center station which is managed by Carrefour GSA. It integrates all the development and maintenance works. If GSA wants to update the system, the clients do not need to update the software in their systems. Thus, it largely mitigates the cost and workload of system maintenance and upgrade as well as lowering the cost. The B/S architecture is extremely suitable for RWSBPM since there are a large number of buyers, suppliers, inspection companies and third-party logistics end users. It is impossible to maintain the system if implementing the C/S architecture.

4.6.4 Workflow Process Design

In the prototype design, the author decides to implement the rule-based workflow which mainly consists of state-machine workflow with sequential workflow embedded inside. See section 3.7 “workflow process design”.

The process design in WF can be done through xoml language or through WF workflow diagram which is one important feature of WF, or sometimes combining both of them. Usually the workflow developer uses the WF workflow diagram to design and update the workflow process. After handing in the software to the end user, the software developer does not need to take care of the further process modification. It can be done by the end user through modifying the xoml file which defines the workflow processes. Once the xoml file is updated, the workflow engine will reload the file and the business processes are thus automatically modified. Here are the examples of creating the workflow in both ways.

(1) Create the workflow through xoml language.

```xml
<SequentialWorkflowActivity x:Class="Workflow1" x:Name="Workflow1"
xmlns:x="http://schemas.microsoft.com/winfx/2006/xaml"
xmlns="http://schemas.microsoft.com/winfx/2006/xaml/workflow">
<IfElseActivity x:Name="ifElseActivity1"/>
<IfElseBranchActivity x:Name="ifElseBranchActivity1"/>
<IfElseBranchActivity x:Name="ifElseBranchActivity2">
<IfElseBranchActivity.Condition>
<CodeCondition Condition="OrderWorkflow" />
</IfElseBranchActivity.Condition>
<CodeActivity x:Name="codeActivity1" ExecuteCode="OrderWorkflow" />
</IfElseBranchActivity>
<IfElseBranchActivity x:Name="ifElseBranchActivity2">
```

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The workflow processes defined in prototype is using the visualized tool provided by WF.

Graph 4-22 Workflow Process Design through WF
Graph 4-23 State of officer check

Graph 4-24 Sequential Workflow Design for Officer Checking Order
4.6.5 System Service

The author has used four system services during prototype design. These system services were provided by MS Workflow Foundation during system execution.

The ‘Schedulerservice’ service is loaded automatically every time when the workflow start to schedule the execution of workflow.

The ‘CommitWorkBatch’ service is also loaded automatically for atomic transaction services.

The ‘SqlTrackingService’ service is mainly responsible for tracking the execution of workflow. Tracking service is one of the core functions of workflow system. Since the workflow will create different kinds of state changes during the execution, tracking service can record these states into the database and provides the interfaces for inquiries. The following states can be tracked by the tracking service.

The states of instances: Aborted; Changed; Completed; Created; Exception; Idle; Loaded; Persisted; Resumed; Started; Suspended; Terminated; Unloaded.

The states of activities: Canceling; Closed; Compensating; Executing; Faulting; Initialized.

The data of workflow instance cannot be stored in internal storage of the computer permanently that the system may crash or electronics could be power off. Thus it calls for a service that can store the workflow instances and all of its information into the physical database from the internal storage. The ‘SqlPersistanceService’ service can be loaded in workflow runtime and stores the workflow information from internal storage into physical database.
One major advantage of persistence service is that the real time data of workflow is stored in the internal storage and be transferred to physical database when it is free. Such mechanism greatly improves the efficiency of the system and most importantly, the safety of the data.

4.6.6 Rule Modification and Maintenance

The rule management function is an important part of the system. The rule management can be statics and also dynamic. The former one can be done by the ordinary business staff from Carrefour GSA while as the later one can be done with the combination of dynamic rule modification algorithms operated by the workflow engine and the rule engine.

Such situation could be happened that most of the companies follow a certain business rule with minor exceptions. For example, the amount of an order is under US$ 5000 or the volume is under 10 cubic meters will be rejected. Such rule is applicable to most of the companies. However, only very small amount of companies could be exception for some reasons, such as special agreements. Thus, the rule for them could be that: the amount of an order which is over US $3000 will be accepted. In such situation, it doesn’t need to change the business rule for the whole system, just in order to be applicable for a few companies. The dynamic modification could be used by special program designing which could change the rule of the workflow instance through running without interrupting most of the workflow cases. The realization of rule modification can be seen in appendix 1 and 2.

4.7 Summary of Empirical Research Results

In this section, the major empirical research results are summarized.

In the empirical research, the author has employed both quantitative and qualitative data collection methods through questionnaire and interviews correspondingly. Two companies that were selected for interviews are Carrefour Global Sourcing Asia Ltd. and Tesco International Sourcing Ltd. The respondents of questionnaire come from 6 different companies and 73 valid paper-based or email-based questionnaires were collected. The data acquired from quantitative and quantitative research methods have been analyzed. In addition to that, business process has been modeled in Petri net and business process re-engineering has also been done. The author also conducted the empirical research by establishing a rule base and developing the prototype to verify the theories put forward in the theoretical part and find the solutions for research question 2.

Through the empirical research of interviews, the author found that large retail supply chain companies such as Tesco and Carrefour, in a similar way, conducted business process management without employing workflow systems. Most of the management work was still done manually, although they did have many volatile and complicated business rules. The information systems were in-efficient and static when business requirements change. And these companies were in favor of the idea of rule-based workflow system. (See section 4.2.1)

Through the empirical research of questionnaire, the author found that a few practitioners were satisfied with business rule management and most of the retail supply companies currently using workflow systems were small companies. Most of the practitioners believed that their companies employed volatile business rules and were in favor of using rule-based
workflow systems. Among those respondents who disagreed with rule-based workflow systems, the practitioners from small and medium-sized companies tended to believe that their companies did not need it; while those from larger companies expressed security concerns over potential risks. (See section 4.2.3)

Through business process modeling by using Petri net, the author found that the people-oriented or document-oriented modeling approach were not appropriate. The author’s third attempt was a refinement of document-oriented modeling approach and it was a success. In such an approach, an exclusive focus was laid on documents and to allow deviations from that or simply exceptions where it was inevitable. The activity or task encompassed by a document has been considered instead of considering the transformation of a document’s state. (See section 4.4.1)

A rule base has been established in the way as suggested in the theoretical research part. The rule base consists of 8 rule sets. (See section 4.3)

Rule set 1: Carrefour GSA validates the buyer’s order
Rule set 2: Supplier validates the order submitted by Carrefour GSA
Rule set 3: Carrefour GSA selects the supplier
Rule set 4: Carrefour GSA selects the third-party logistics
Rule set 5: Carrefour GSA selects the inspection company
Rule set 6: Inspection companies proceed the products testing and FRI (final random inspection).
Rule set 7: The buyer’s payment rule
Rule set 8: PO Amendment Rule

Research Question 2: How to apply rule-based workflow systems to retail supply chain management?

Sub research question 2.1: How can the business team and the system development team work together to develop and maintain the rule-based workflow system more efficiently?

- In the first step, the business rules are acquired through both qualitative and quantitative methods by the business team. (See section 4.1)
- In the second step, the rule base is established by the business team according to the theories suggested in the theoretical part. (See section 3.4 and 4.6)
- In the third step, the business processes are analyzed, modeled and re-engineered by the business team. (See section 4.2.2, 4.4 and 4.5)
In the fourth step, the business process team designs the business processes in the visualized interface provided by MS WF Foundation graphically. (See section 4.6.4)

In the fifth step, the system development team does some coding. (See section 4.6.4)

Once system development is accomplished, the system development team only needs to do some routine system maintenance work. The business process team maintains the business processes. (See section 4.6.4) The business team can modify the business rules via user interfaces. (See section 4.6.6)

Sub research question 2.2: How can rule-based workflow system be applied to business process management, especially in the retail supply chain field?

A designed prototype verified the theory suggested in the theoretical part of rule-based workflow architecture and showed how a rule-based workflow system can be used in retail supply chain management. The business rules can be modified via user interface by users without interrupting the operation of the system. Different parties within the retail supply chain can be connected to the system and the central management group can monitor the execution and status of all the business processes. (See section 4.6)

The prototype design and the system simulation in the appendix (See the appendix 1 and 2) indicate that the rule–based workflow management system for retail supply chain management (RWSBPM) can be efficiently implemented.
5 Theory Meets Empirical Data

In this chapter, the author will discuss that the theory meets empirical data. The author will talk about the combination of theoretical data and empirical data in the previous part of thesis to discuss and illustrate the emergence of the different knowledge contributions. What is worth mentioning is that, the terminology of different knowledge such as explanatory knowledge, comprehensive knowledge 1, comprehensive knowledge 2, empirical knowledge and informative knowledge has been discussed in section 2.2 ‘knowledge characteristics’, the author will not explain those terminologies again in this chapter.

5.1 Emergence of Different Knowledge Contributions of Qualitative and Quantitative Data Collection and Analysis

Graph 5-1 Emergence of Different Knowledge Contributions of Qualitative and Quantitative Data Collection and Analysis
The above diagram shows the process of the emergence of different knowledge contributions by author.

Firstly, the author puts forward the explanatory knowledge of the concepts, definitions and background knowledge of business process management. It creates the basis for the further knowledge contributions. Then the comprehensive knowledge 1 of problem description and research method has been generated through literature study and author’s self-knowledge. The author discussed three main reasons for the problems of current information system and the research method of the whole research work. The comprehensive knowledge 1 guides the conduct of empirical research, especially the qualitative and quantitative research. Through the mix of quantitative method and qualitative data collection method in the empirical research, the author generated the empirical data - the result of empirical research based on the data collection, data analysis.

As shown in the diagram 5-1, the comprehensive knowledge 1 partially contributed to the emergence of comprehensive knowledge 2, while as the empirical knowledge mostly did. The comprehensive knowledge 2 is the answer of sub research question 2 which can be concluded as follows. It also created the basis for the emergence of informative knowledge that provided the references for other researchers. The detailed informative knowledge can be found in section 6.1.1.

What is worth mentioning is that, although the empirical knowledge was generated through both interview and questionnaire, the roles they had in generating empirical data for knowledge contribution were different. The empirical data generated from interview was in depth and detail, while it was depicted more general through questionnaire. According to such characteristics of two different methods, the author attempted to fully made use of different methods for acquiring distinct empirical data. For example, the author intended to gain more data about detailed business processes in depth opinions of retail supply chain management through interview. And the author tried to know how many retail supply chain companies were using workflow systems through questionnaire. Through the interview, the author can communicate and interact with the interviewees and much extended knowledge can be gained beyond the questions, while as the respondents of questionnaire only answer certain defined questions. It does not mean that one method is better than the other. They both played an important role in generating various kinds of empirical knowledge, which was equally essential for author’s research work.
5.2 Emergence of Different Knowledge Contributions of Research Question 1.1 and 1.2

Graph 5-2 Emergence of Different Knowledge Contributions of Research Question 1.1 and 1.2

Research question 1: How can rule-based workflow system provide a solution to the in-agility within retail supply chain management?
Research question 1.1: What are the steps to establish a rule base?

Research question 1.2: What is the architecture of the rule-based workflow system and how it can provide a solution to in-agility?

As discussed in section 1.3 that the sub research questions help to motivate to find solutions to main research questions. Therefore, the author, in the first place, seeks to find the solutions for each sub research questions. When it is done, the solution to main research questions can be generated.

Through the literature study, the explanatory knowledge of business rules, the rule engine, rule base, workflow engine has been emerged in the theoretical part. The Explanatory knowledge is the fundamental knowledge which is essential for the further knowledge contributions. Through literature study, self reflection towards the previous research and combined with the comprehensive knowledge 1 of problem description, the comprehensive knowledge 1 which is the answer of research question 1.2 in theory has been generated. In the comprehensive knowledge 1, the author discussed a new system architecture of rule-based workflow system based on the previous knowledge contributions of workflow engine, rule engine and system model. It is designed to solve the problems and challenges found in the retail supply chain business process management. What is more, the mechanism for modifying the business rules in both static and dynamic ways has also been discussed.

Obviously, the theoretical part of the research is not sufficient to answer the research question 1.1 and 1.2. The theory needs to be verified by the empirical research. Thus, the author conducted the empirical research based on the comprehensive knowledge 1. The author generated the empirical knowledge (how to establish the rule base) based on the comprehensive knowledge 1 of sub research question 1.1 and also the empirical knowledge (What are the business rules of Carrefour GSA). Then the author developed the system prototype based on comprehensive knowledge 1 (the system architecture of rule-based workflow system) of sub research question 1.2; the empirical knowledge (the business process modeling and business process reengineering of Carrefour GSA) and the empirical knowledge (The establishment of a rule base). The emergence of empirical knowledge verified the comprehensive knowledge 1 which is the answer of sub research question 1.1 and 1.2 in theory. The comprehensive knowledge 2 is generated based on empirical knowledge and comprehensive knowledge 1, which leads to the answer of sub research question 1.1 and 1.2. The comprehensive knowledge 2 also creates the basis for informative knowledge which can be taken reference for other researchers. The informative knowledge can be the rule-based workflow system architecture and the steps as well as methods to establish rule base suggested by author are viable in both theory and practice. The detailed informative knowledge can be found in section 6.1.2.
5.3 Emergence of Different Knowledge Contributions of Sub Research Question 2.1 and 2.2

Graph 5-3 Emergence of Different Knowledge Contributions of Sub Research Question 2.1 and 2.2

Research question 2: How to apply rule-based workflow systems to retail supply chain management?

2.1: How can the business team and the system development team work together to develop and maintain the rule-based workflow system more efficiently?

2.2: How can rule-based workflow system be applied to business process management, especially in the retail supply chain field?

The comprehensive knowledge 1 of problem description and research methodology, and the empirical knowledge of self experience of prototype design guided the author’s prototype design of rule-based workflow system. The prototype design was also based on corresponding empirical knowledge and comprehensive knowledge shown in graph 5-3. During the process design, the empirical knowledge has been emerged. The emergence of comprehensive
knowledge 2, which is the answer of sub research question 2.1 and 2.2, is based on comprehensive knowledge 2 together with empirical knowledge. It also creates basis for informative knowledge, which can be taken reference by other researchers.

5.4 Rationale of Using Rule-based Workflow System in Retail Supply Chain Management

According to the theoretical and empirical research and the emergence of different knowledge, the author concludes the rationale of using rule-based workflow system in retail supply chain management company or retail supply chain management field.

The retail supply chain company normally has volatile business rules and complex business processes. The rule-based workflow system can help the retail supply chain company to make strategic decisions and quick response to the changes. The following three points illustrates the rationale of using rule-based workflow system in retail SCM.

(1) The business rules are no longer static and they are stored in a central database, namely rule base. In other words, the business rules are not hard-coding in the system. The business team can add, modify, delete, search and even test business rules. This is extremely important for the retail SCM with dynamic business rules.

The retail supply chain management has the feature of changeable market condition and customer diversity which causes the frequent changes in the business rules and strategies. If each time the system developer needs to modify the programming codes when they change, the system maintenance would be difficult and costly. Thus, the business rules have been abstracted from the programming codes. The business rule is then acting like a link between the business team and the system developer team. The developer team does not need to fully understand the business rules. On the other hand, the business team can help to conduct requirement analysis, system design, implementation and maintenance.

(2) The business rules will become logic. Each business rule will consist of two parts: condition and implementation. The condition part has the conditions for rules and the implementation part defines the further actions for data procession. Thus, the rules are becoming logic. The business rules are non-procedure-oriented and described in non-technical words instead of programming language which can be easily understood by the business team.

(3) The business rules can be accumulated, modified and shared by the employees, so as to help to implement the knowledge management of the business actions. The business team can have the edition management of the rules and set up the validation date.

(4) When the system is updated, the business rules do not need to be modified, and vice versa. The system stability is guaranteed and the maintenance becomes efficient. The efficiency of the system and the staff’s work has been greatly improved and the cost of system development and maintenance has been largely reduced. The profit can be thus maximized for the retail supply chain companies.
6 Conclusions

In this chapter, the author will track backwards and discuss explicitly the process of research, the emergence of different knowledge and how to address the research questions.

In the introduction part, the author discussed the background of the research and introduced the problem description. Then according to the problem description, the author put forward two main research questions and four sub research questions as well as the purpose and expected results. The author also discussed the delimitations that the research work will focus on the application of rule-based workflow system to retail supply chain business process management. Summary of previous knowledge contributions has also been discussed.

In the research method part, the author introduced the research approach which should be the theoretical part followed by the empirical part. The research perspective the author chose was design science. Five different kinds of important knowledge have been introduced which will be emerged in the research work through both theoretical and empirical research. The research methods have also been discussed which will be the combination of both quantitative and qualitative research method, together with the data analysis and evaluation.

In the theoretical part, the business rule, workflow engine, rule engine, business process modeling and business process reengineering have been discussed. Most importantly, the author also put forward the theory of “system architecture of rule-based workflow system and the steps to establish a rule base” relying on the previous theories and knowledge contributions. The dynamic modification strategy and workflow process design method has also been discussed.

In the empirical part, the author aimed to verify the theory discussed in the previous parts on one hand, on the other hand the author also intended to find answers of current situations and challenges through empirical researches which could not be accomplished through theoretical researches. The author implemented the both interview and questionnaire for data collection and then finished the data analysis. The author also conducted business process reengineering and established a rule base according to the results of data analysis and the theories bring forward in the theoretical part. Eventually, the author developed a prototype of rule-based workflow management system for retail supply chain process management (RWSBPM).

In the theory meets empirical data part, the author discussed the emergence of different knowledge contributions for each sub research question. The process of how the theoretical data and empirical data were combined together to generate different forms of knowledge has been clearly discussed.

6.1 Summary of the Results

The author will track backwards to discuss how each research question has been answered and to summarize the result.
6.1.1 Result of Survey on Current Situations and Problems

Through literature study and self knowledge, the author found out the current situations, challenges and problems of retail supply chain business process management.

Then, through the mix of quantitative and qualitative data collection method conducted in the empirical research part, the author analyzed and summarized the results based on the data collection and data analysis. As a result, more practical oriented challenges and problems have been discovered.

The result found in the theoretical research can be concluded as follows:

(1) The trends of business rules in retail supply chain companies are becoming increasingly complicated and dynamic and the current used information systems are ‘in-agile’ to handle dynamic changes in retail supply chain business process and especially the business rules, when the business requirements changed. It is because that IT architects often choose hard-coding as main approach to develop the business rules or executing the business processes manually. Such system architecture will increase the system operating costs; slow down response to the market change; decrease the efficiency and flexibility of retail supply chain management.

(2) Besides that, the current information system of retail supply chain management was not suitable for business process management when the business processes changed. The system needs to be re-coding and re-testing to modify the business processes. It leads to high maintenance cost and more importantly, the cost of slow responses to the market requirement is un-measurable.

(3) Usually there are lots of parties within the retail supply chain, such as supplier, buyer, third party logistics, etc. How to coordinate and manage different parties within the retail supply chain properly is a big challenge for the retail supply chain management.’

The results found in the qualitative empirical research can be concluded as follows:

1. Tesco group has almost same global retail supply chain procedures as Carrefour group with only minor differences. It shows that the business processes of large global retail supply chain companies tend to be the same.

2. Tesco IS and Carrefour GSA are not implementing workflow management system, though both of them are using the management information system. The author suggests the reason should be stemmed from the cost and much unknown risks of shifting to the new system even though they understand the benefits and efficiency of the workflow system. Thus, most of the retail supply chain processes within those two companies are still done manually through sending the email, making the telephone call and even on-site visit. The officers from both companies recognize the disadvantages of the current systems which make the work in much lower efficiency than utilizing the workflow system. They need concurrently contact and trace the buyer, supplier, quality assurance company and also third-party logistics in a single order.
3. Carrefour and Tesco have lots of volatile and complicated business rules. But one week of updating the business rule in the system makes the Carrefour’s system in-flexible.

4. The retail supply chain companies do not take care of managing business rules, which remain normally written on paper or stored in people’s minds. It causes several problems. Firstly, many company’s business rules are written on paper which cannot be easily shared with other employees. Secondly, lots of business rules are scattered everywhere in the documents that the employees or even the manager does not know how much business rules they are. Thirdly, some business rules are connecting to each that one rule changes may lead to the change of the other rules. Fourthly, many of the business rules are still explicit knowledge which is based on employee’s experience or knowledge. If the employee leaves the company, the knowledge cannot be passed or transferred easily from that employee to the other employees.

5. System development teams might conduct system development and maintenance tasks independently without cooperation with business process teams, business rule teams and system development teams. Such a situation results in the low efficiency of system development and maintenance.

The results found in the quantitative empirical research can be concluded as follows:

1. Most of the large-sized retail supply chain companies have the volatile business rules, but have not carried out the strategies of managing business rules and they don’t manage them well. They do not realize that the business rule is one of the most significant intangible assets of the company which leads to strategic competition power. The business rules may be lost when the employees left the companies. Contrary to that, some of the small-sized retail supply chain companies have good management of business rules, although they may or may not have volatile business rules.

2. Most of the retail supply chain companies no matter in big or small size are using the information systems to some extent. The majority of them are partially using information system. Only some small retail supply chain companies are totally implementing workflow system in their business process management. Among those people disagree of rule-based workflow system, the people from small and medium-sized companies tend to believe that the company does not need it or it may cause less communications; while as those from large company suggest the safety concerns and may have too much potential risks.

3. Most of the respondents in the retail supply chain companies are in favor of rule-based workflow system by believing that it can increase efficiency. To reduce manual tasks, better to handle business rule and reduce system maintenance cost are the other reasons suggested by the retail supply chain companies to implement rule-based workflow system. Still there are small amount of respondents does not support the idea of rule-based workflow system. The reasons which are ranking from top to bottom are too much risks of changing current systems, safety reasons of system, less communications and the company does not need it.
6.1.2 Result of Solutions to Research Question 1

According to the challenges of retail supply chain management found through both theoretical and empirical research (see section 6.1.1), and by combining the literature study and self-reflection, the author put forward the architecture of rule-based workflow system based on the previous theories and knowledge contributions. As the rule base is an important component of rule-based workflow system, the author also discussed the steps to establish a rule base.

Through the rule base establishment and prototype design in empirical research based on the theories brought forward by the author, the theory was proved to be practical and the sub research question 1.1 “What are the steps to establish a rule base?” and 1.2 “What is the architecture of the rule-based workflow system and how it can provide a solution to in-agility?” has thus been addressed. As a result, the solutions to research question 1 have been found out and proved to be practical.

**Results of solutions to research question 1.1 are as follows:**

The rule base can be established through six critical steps. See section 3.4.

1. The first step is the data gathering phase of which the main task is to acquire business rules from different sources which could be human or manuals. The data could be raw data without being organized and analyzed.

2. In the data analysis phase, business rules obtained from the first step will be processed to be well-organized and structured. Those data which is irrelevant or not useful will be eliminated.

3. In the data definition phase, the business rules described in the natural or semi-natural language will be defined by XML language or XAML language, etc.

4. The data storage phase is one of the core phases within rule-based model. In this phase, the rule base is established and business rules are stored in database or in rule file structurally. The establishment of rule base is the further step of data definition and the business rules defined in a specific language will be modified, in order to be adaptable and applicable for the end system.

5. In the data implementation phase, the rule engine interacts with the rule base through APIs to support the execution of the final system.

6. The last phase is rule maintenance through which the end user can modify the business rules via user interface.

**Results of solutions to research question 1.2 are as follows:**

The architecture of rule-based workflow system (RBWS) has been discussed in 3.5.1.

In the RBWS architecture, there are four important components which are workflow engine, rule engine, user interface and database. Each component also contains several modules. In
workflow engine, process management module takes charge of the life cycle of process instances execution. The engine will guide the business process to execute through predefined procedures or rules. The rule engine and workflow engine coordinate with each other to manage the working memory together. The rule engine and rule base separates the business rules from the workflow engine and they are no longer needs to be hard-coding. The user can also manage the rule base through user interface and the change of business rules will not affect the operation of the system. The function of split node is to separate an execution path into several sub-paths.

In the RBWS architecture, the author suggests that the business processes are connected by several nodes which have different functions. The author has divided the nodes within the model into five types, which are the state node, the decision node, the task node, the split node and the joint node.

(1) Task node

The task node decides which end user should be responsible for a certain kind of task, in other words ‘task assignments’. Besides that, the task node also handles the response from the end user.

(2) State node

The state node shows a certain state of the system for the execution of workflow.

(3) Decision node

When the workflow instance goes to the decision node, the workflow engine will interact with the rule engine to make decisions.

(4) Split node

The function of split node is to separate an execution path into several sub-paths.

(5) Joint node

The joint node combines one or more sub-paths together.

The dynamic modification strategy of the model has also been discussed. In the rule-based workflow system which is especially designed for retail supply chain management, the business rule will be modified in the rule file and the dynamic modification strategy will be ‘proceed’ for the instances. Thus, the incoming workflow instances will follow the new rule and those which have already followed the old business rule would proceed running. The author also suggests the ‘Exception’ dynamic modification strategy. Under such strategy, those exceptional instances which follow the different business rule will be adapted to the new rule separately and independently, compared to the normal instances.
6.1.3 Result of Solutions to Research Question 2

In the empirical part, the author illustrated the way of how to address the sub research question 2.1” How can the business team and the system development team work together to develop and maintain the rule-based workflow system more efficiently?” and 2.2” How can rule-based workflow system be applied to business process management, especially in the retail supply chain field?” through prototype design. The empirical research was based on the theories discussed in the theoretical part.

In order to find solutions to those questions, the author developed the prototype of rule–based workflow management system for retail supply chain management (RWSBPM). See the prototype design and system simulation in the appendix 1 and 2. The development of prototype was according to the theory suggested in the theoretical part which successfully separated the business rule from the system coding by putting in a rule file. In the prototype, the business rules can be modified through user interface by the retail supply chain management team without interrupting the system operation. The successful of prototype design proves the related theories of rule-based system architecture put forward in theoretical part to be valid and feasible.

Results of solutions to research question 2.1 are as follows:

1. The business rule team should gather both the implicit and explicit business rules through different methods. The idea of anecdote circles which is put forward by the author can be used. Then the rule sets should be established and the rule base should be created according to the steps to establish the rule base in theoretical part of the thesis. See section 3.4.

2. The business process team should summarize the business processes of the company and may use Petri net to model it. Furthermore, the business process team also needs to find out the redundant and the unreasonable business processes through modeling and conducting business process reengineering. Moreover, the business process team can design the business processes in the visualized interface provided by MS WF Foundation without knowing the knowledge of coding.

3. The system development team needs to do some basic coding according to the architecture of rule-based workflow system (RBWS), by using WF foundation and also design the APIs for managing the rule base and the business processes. The rule base is designed by the business rule team and the business process can be made by the business process team.

4. Once the system has been accomplished, the system development team does not need to care about the maintenance of the business processes and business rules. The business process designer can either modify the business processes through the visualized interface provided by WF Foundation or they can realize it through modifying the ‘xoml’ file which defines the workflow processes. (See section 4.6.4) The business team can modify the business rules via user interfaces.
5. Thus, each team is doing their competent tasks which can make the system development and maintenance more efficiently, and most importantly the system developer does not need to undertake so much works as previous.

**Results of solutions to research question 2.2 are as follows:**

The prototype design and the system simulation in the appendix (See the appendix 1 and 2) shows that the rule–based workflow management system for retail supply chain management (RWSBPM) can be efficiently implemented. Each party in the retail supply chain, such as the buyer, supply chain management staff, supplier, third party logistics and quality assurance company can manage the business process through such system. The central management team- supply chain management team can monitor and manage the whole business processes, and they can also modify the business rules at any time. Each party within the supply chain can check and complete the task that they are supposed to deal with. Such system can meet the requirements of retail supply chain management.

**6.2 Evaluation of the Results**

The purpose of this research work is firstly to make theoretical contributions to the field of Informatics, through finding out the solutions to the ‘in-agility’ of current retail supply chain management by introducing a rule-based architecture for workflow systems. Secondly, to provide references for practical communities, by finding out how to apply rule-based workflow systems to retail supply chain management. Since the architecture of rule-based workflow system has been discussed in the theoretical part; how to apply rule-based workflow systems to retail supply chain management has been found out. Thus, the purpose and the expected result of the research have been achieved. All the research questions have been addressed.

As discussed in section 2.5, the author will use generalizability, validity and reliability as the criteria to evaluate the result.

The result of research 1 has been validated by the interviewees who are the practitioners of the field. Besides that, since the author successfully constructs the prototype of the rule-based workflow system based on the theories put forward in the theoretical part, the result of research 1.1 and 1.2 discussed in the theoretical part as well as the result of sub research question 2.1 and 2.2 has been proved to be valid and reliable.

The generalization means that the result of the research is usable of other cases besides the one discussed in the research. In the research, the author focuses on the generalization of the result and the usability for the target group discussed in section 1.6.

(1) The case of Carrefour’s business process management for the empirical study has been discussed to be almost same as Tesco and can be the example in the retail supply chain industry. Thus, the rule base establishment, the prototype design and the way the author discussed that how different teams can cooperate with each other to efficiently develop and maintain the rule-based system can be regarded as universal way in retail supply chain management.
(2) The theory suggested by the author put forward through literature study and the empirical research also has been cross-checked the theory.

(3) The interviewees are professional practitioners who are familiar with the industry situations, thus their recognitions can be regarded as generalization.

However, the author wants to point out that both theoretical and empirical data were conducted not in a large scale. Whether the result and achievements of author’s work can be applicable and generalized in a large scale, say the architecture of the system can be implemented in a large retail supply chain company, needs to be carefully considered in the future research.

As the criteria of evaluating the prototype have been discussed in the section 2.6, the result of prototype design has also been evaluated.

1. The data of business processes modeling and business rules coming from the qualitative data collection and further data analysis were proved to be valid and can be used in the prototype design. The result can be generalized in the retail supply chain companies, since the business processes and business rules can be changed flexibly to meet the management requirements of each company.

2. The interface designed for business team can be seen in appendix 1.1. The rule can be modified by the central retail supply chain management team through user interface (see appendix 1.1.1) and the system can run smoothly. The central retail supply chain management team (in this case is the Carrefour GSA) can monitor the status of each instance. See appendix 2 – diagram 10.

3. More than 20 instances of different kinds of situations have been tested to run successfully from beginning to the end. It verified the availability of the prototype design. See appendix 2. The running states of each instance can be recorded stable in the system database for tracing.

4. The interviewees have been invited to test the prototype design and proved its availability. They also evaluated the way that the author suggested “How can the business team and the system development team work together to develop and maintain the rule-based workflow system more efficiently” to be feasible and constructive. They suggested the business rule can be designed in the way of ontology under such system architecture in the future research. Furthermore, they also suggested that more friendly and understandable interface can be developed in the future instead of using the interface of WF Foundation, especially for business process team who can design and modify the business processes through user interface.

6.3 Main Contributions

In this section, the author discusses the main contributions that have been made in the research work.
6.3.1 Theoretical Contributions

The author makes the following theoretical contributions in the research work to fill the knowledge gap.

1. The discussion of “The steps to establish a rule base” (see section 3.4) fills the gap of previous knowledge contributions which have not discussed the mechanisms of establishing the rule base in logical ways and systematically. It can provide the references for other researches related to business rule management of how to establish the rule base step by step.

2. “Conducting Anecdote Circles in business rule acquisition stage” (see section 3.4.1) has not been put forward by any other researcher according to author’s research. It is a novel and effective way of acquiring the tacit knowledge of business rules from staff. It provides reference for the researchers related to business rule acquisition methods.

3. “Architecture of rule-based workflow system (RBWS)” (see section 3.6) fills the gap for the rule-based workflow architecture especially designed for retail supply chain management. It provides the references for the researchers who are interested in architecture or system design in the field of retail supply chain management.

6.3.2 Empirical Contributions

The author has made the following empirical contributions to the retail supply chain management.

1. The empirical research of finding the solutions to research question 2.1 has not been conducted and studied by other previous researchers. Therefore, the result (see section 6.1.3) is valuable and it provides references for how staff from business process team, business rule management team, system development team, database development team in the retail supply chain company can perfectly allocate their own tasks correspondingly and undertake tasks independently more efficiently during system development and maintenance. Moreover, it also provides references for the practical use of rule-based systems in the retail supply chain field with such issues as system development and maintenance, especially for the system of complex and changeable business processes.

2. The empirical research of finding the solutions to research question 2.2 has not been conducted before. Thus, the results of it (see section 6.1.3) is valuable and provides the references for those companies in the retail supply chain industry, which focuses on business process management and own complex business processes and volatile business rules, to manage their business processes and business rules.

6.3.3 Contributions to Retail Supply Chain Field

As discussed in the thesis, the retail supply chain business process management is faced by a couple of challenges. (See section 6.1.1)

What is worth mentioning is that, according to these challenges occurring in the retail supply chain field, the author conducted the research and come up with the solutions to them in both
theoretical and empirical way. This is one of the most significant contributions that the author has been made. Both academic and practical communities can take the results as the references. (See section 6.1, 6.3.1 and 6.3.2) The implications for the field will be discussed in next section.

6.4 Conclusions and Implications for the Retail Supply Chain Management

From the achievements of research work, three major advantages for retail supply chain management can be concluded.

1. The establishment of the rule base and stores it in the rule file makes the business rules separated from system programming codes. The end user can modify the rule base at any time via the user interfaces without interrupting system developer and it is even unnecessary to update the programming codes. Thus, the retail supply chain company can handle the volatile and complex business rules, which makes the system agile, dynamic and efficient. Thus the retail supply chain company can gain the competitiveness by quickly response to the market and eventually earn more profits.

2. The teams from different departments in the company can undertake their tasks independently through coordinating with each other to speed up the system development and build a more efficient system. The business rule team can be dedicated to establishing the rule sets. The business process team can focus on business process designing through workflow foundation. The database designer will be only focusing on database design and the development of codes for connecting the system and the database. The system developer can do much less coding of the system. Finally the system can be connected to the database and the rule base through system interfaces. Thus, different team can use their specialty to undertake their tasks and the situation that the system developer does not clearly understand the business rules and business processes will not be happened any more. Much duplicated works were diminished and the cost of the company will also be largely reduced.

3. The efficiency of business process management could be largely improved. Many tasks which are currently done manually would be handled automatically by the system. Therefore, the retail supply chain company can manage more orders at the same time which will increase the profits for both the retail supply chain company and the companies involved in the retail supply chain, such as the supplier, the third-party logistics, etc. While at the same time, the costs such as the labor cost and the system maintenance cost would be tremendously reduced. Moreover, the business process management will lead to fewer manual errors due to the confirmation through the system instead of the telephone or email. Through implementing the rule-based workflow system, the retail supply chain company will maximize their profits which are essentially the goal of the company.

4. Different parties (such as buyer, supplier, third party logistics and so on) within the retail supply chain can be managed by the retail supply chain company through the rule-based workflow system efficiently. They can cooperate with each other more efficiently through such system. It creates the basis for the formation of strategic alliance.
Rule-based workflow system can largely increase the system efficiency and lower the maintenance cost compared to the traditional workflow system or information system to enhance the market competitiveness. The retail supply chain management can be better implemented and documented. More importantly, the retail supply chain company can thus focus on the business rules which are the intangible but critical resources of the company.

6.5 Future Research

There are also some disadvantages of the research work which needs further researches to be conducted. Future research can be focus on the following aspects:

1. In the prototype, the business rules are defined in the ‘.rules’ file in XAML language. A better structure of the rule base needs to be considered for higher reliability and efficiency.

2. In the research work, both quantitative and qualitative research methods only covers the retail supply chain companies located in China, even though many of them are multinational companies. The factor of location and culture may somehow affect the result of the research. Future research can be done through the retail supply chain companies in the different countries which could be more reasonable. Whether the rule-based workflow system can be applicable in worldwide or can be implemented in large retail supply chain companies deserves further researches.

3. The disadvantage of star topology which is used in the prototype, lies on the information exchange of the entire system should be controlled and managed through the center station. If the center station happens to be overloaded or the malfunction of the hardware will lead to the crash of the entire system. So it requires the center station to build a strong, high reliable and high efficient computer systems and databases. The future research can be focused on the more reasonable topology for rule-based workflow system.

4. The author only developed the prototype of the system without considering many issues, such as the internet security, system security, user level grant, system upgrading, increase of the data in the database and multiple user accesses, etc. They need to be considered and improved in future research.

5. The researches of dynamic rule modifications could be further extended. For example, more situations could be considered such as ‘roll back’ or ‘restart’ strategies if the business rules change when the system is running.

6. The manufacture system of supplier and the logistics system of the third-party logistics have not been integrated into the prototype design. In the future research, those systems and even ERP system can be integrated to make the users from buyer to third-party logistics to be an alliance and bring more advantages and competitiveness to all these companies.
References


Kwembe, T. Chen, J. and Kwembe, A.I., Cooperative competing technologies enhancing the publishing industry: the xml revolution.


Appendix

Appendix 1 Prototype Design Interface

1.1 Rule Management Module

1.1.1 Static Rule Modification

Diagram 1 Interface for rule modification

In the rule management interface, the user can modify the rules through the following interface. The validation of input data will be validated automatically.

Diagram 2 User Interface for Rule Modification

The user can modify the rules by the rule editor. What is worth mentioning is that even the employee from the business department can modify the business rules at any time.
without knowing how to do the system coding. From the diagram, the condition 1 of the ruleset 1 “this.TotalAmount <3000” is changed into “this.TotalAmount>2900”. We can further notice the changes in the ‘workflow.rules’ file.

Previous codes

\[
\text{<ns0:CodeBinaryOperatorExpression Operator="LessThan"}
\]

has been changed into

\[
\text{<ns0:CodeBinaryOperatorExpression Operator="GreaterThan"}
\]

And previous codes

\[
\text{<ns1:Int32 xmlns:ns1="clr-namepace:System:Assembly=mscorlib, Version=2.0.0.0, Culture=neutral, PublicKeyToken=b77a5c561934e089">3000</ns1:Int32>}
\]

has been changed into

\[
\text{<ns1:Int32 xmlns:ns1="clr-namepace:System:Assembly=mscorlib, Version=2.0.0.0, Culture=neutral, PublicKeyToken=b77a5c561934e089">2900</ns1:Int32>}
\]

Thus, the business rules have been easily modified in the prototype.

1.1.2 Dynamic Rule Modification

In the prototype design, the author attempted to change the business rules for some exceptional orders without affecting most of the instances. The business rule will be replaced by the value the user input in the textbox1. Some of the programming codes are illustrated as follows:

The aggregation of the activities in the workflow can be obtained through method ‘GetWorkflowDefinition()’, and also locates to the root of the workflow.

\[
\text{WorkflowChanges wfchange = new WorkflowChanges(wfInstance.GetWorkflowDefinition());}
\]

Then, the method ‘TransientWorkflow()’ clones all the activities in the current workflow. Afterwards, the property of the cloned ‘IfElse’ activity is modified. After that, the modified property is applied back to the workflow instance and the cloned activity is stored in the object typed ‘CompositeActivity’.

\[
\text{CompositeActivity comactivity = wfchange.TransientWorkflow;}
\]

Through class ‘RuleDefinitions’ which is under the namespace ‘System.WorkflowActivities’, the user can operate the rules file. ‘GetValue’ method can retrieve value from the rule file.

\[
\text{RuleDefinitions ruleDefinitions =}
\]
Next step is to get the rule content from condition 1.

The following codes is to modify the rules by changing the rule condition without changing the rule file.

```csharp
(condition1.Expression as CodeBinaryOperatorExpression).Right = new CodePrimitiveExpression(Convert.ToInt32(this.textBox1.Text));
```

Eventually, the modified rules are applied back to the workflow instances.

```csharp
wfInstance.ApplyWorkflowChanges(wfchange);
wfInstance.Start();
```

Codes for dynamic modification:

```csharp
public partial class Form1 : Form
{

    public Form1()
    {
        InitializeComponent();
        wfRuntime = new WorkflowRuntime();
        wfRuntime.StartRuntime();
    }

    private void button1_Click(object sender, EventArgs e)
    {
        Dictionary<string, object> parameters = new Dictionary<string, object>();
        Type wftype = typeof(Workflow1);
        wfInstance = wfRuntime.CreateWorkflow(wftype, parameters);
        WorkflowChanges wfchange = new WorkflowChanges(wfInstance.GetWorkflowDefinition());
        CompositeActivity comactivity = wfchange.TransientWorkflow;
        RuleDefinitions ruleDefinitions =
        ```
(RuleDefinitions)=comactivity.GetValue(RuleDefinitions.RuleDefinitionsProperty);

RuleConditionCollection conditions = ruleDefinitions.Conditions;

RuleExpressionCondition condition1 =
(RuleExpressionCondition)conditions["condition1"];

(condition1.Expression as CodeBinaryOperatorExpression).Right = new
CodePrimitiveExpression(Convert.ToInt32(this.textbox1.Text));

wfInstance.ApplyWorkflowChanges(wfchange);

wfInstance.Start();

} } Appendix 2 System Simulations

Diagram 3 Buyer Submits order

The buyer can submit the order by inputing the value of amount, volume and detail, and press submit button.
Diagram 4 Buyer Checks Order Status

Then the buyer can check the status of the order which is now in the state of ‘OfficerCheckState’, through interface of ‘my submitted order’.

Diagram 5 Carrefour GSA’s Officer Checks Ongoing Task

Then in the officer interface, the Carrefour GSA officer can notice there is one coming order which is needed to be handled. The officer can do it through checking interface ‘Ongoing Task’.

Diagram 6 Carrefour GSA’s Officer Validates the Order

The Officer can further check the details of the order submitted by the buyer. Moreover, the officer needs to give suggestions and decide to accept the order or send the order back to buyer.
If the supply chain officer accepts the order, the Carrefour supervisor or manager which depends on the total amount of the order, should give suggestions and decides to accept or send the order back. In such interface, the supervisor can see the suggestions of supply chain officer.

Diagram 7 Carrefour Supervisor Validates the Order

Diagram 8 Supplier Validates the Order
The order now goes to the state of supplier state. In such interface, the supply can see the suggestions of supply chain officer and supervisor from Carrefour GSA. By the same rule, the order will further goes to quality assurance company and third-party logistics for further check.

Current User: Carrefour SH Log in
My Submitted Order

<table>
<thead>
<tr>
<th>Submitter</th>
<th>Amount</th>
<th>Volume</th>
<th>Date</th>
<th>Current State</th>
<th>State</th>
<th>Operate</th>
</tr>
</thead>
<tbody>
<tr>
<td>CarrefourSH91000</td>
<td>25</td>
<td></td>
<td>2011-2-8 22:41:10</td>
<td>SupervisorCheckState</td>
<td>Running</td>
<td>Check</td>
</tr>
<tr>
<td>CarrefourSH89000</td>
<td>21</td>
<td></td>
<td>2011-2-8 22:37:17</td>
<td>TLCheckState</td>
<td>Running</td>
<td>Check</td>
</tr>
<tr>
<td>CarrefourSH210000</td>
<td>15</td>
<td></td>
<td>2011-2-8 22:41:31</td>
<td>OfficerCheckState</td>
<td>Running</td>
<td>Check</td>
</tr>
<tr>
<td>CarrefourSH80000</td>
<td>12</td>
<td></td>
<td>2011-2-8 11:03:40</td>
<td></td>
<td>Completed</td>
<td>Check</td>
</tr>
<tr>
<td>CarrefourSH120000</td>
<td>16</td>
<td></td>
<td>2011-2-8 22:36:36</td>
<td>ManagerCheckState</td>
<td>Running</td>
<td>Check</td>
</tr>
<tr>
<td>CarrefourSH6000</td>
<td>11</td>
<td></td>
<td>2011-2-8 22:35:54</td>
<td>QACheckState</td>
<td>Running</td>
<td>Check</td>
</tr>
</tbody>
</table>

Diagram 9 Buyer Checks Order Status

The buy can check all the statuses of submitted order.

<table>
<thead>
<tr>
<th>Submitter</th>
<th>Amount</th>
<th>Volume</th>
<th>Date</th>
<th>Current State</th>
<th>State</th>
<th>Operate</th>
</tr>
</thead>
<tbody>
<tr>
<td>carrefourSH80000</td>
<td>18</td>
<td></td>
<td>2011-2-11 1:23:14</td>
<td></td>
<td>Completed</td>
<td>Check</td>
</tr>
<tr>
<td>carrefourSH90000</td>
<td>19</td>
<td></td>
<td>2011-2-11 11:01:18</td>
<td>SupplierCheckState</td>
<td>Running</td>
<td>Check</td>
</tr>
<tr>
<td>carrefourBJ 50001</td>
<td>23</td>
<td></td>
<td>2011-2-11 1:24:11</td>
<td>SupplierCheckState</td>
<td>Running</td>
<td>Check</td>
</tr>
<tr>
<td>carrefourBJ 21222</td>
<td>16</td>
<td></td>
<td>2011-2-11 1:31:16</td>
<td>TLCheckState</td>
<td>Running</td>
<td>Check</td>
</tr>
<tr>
<td>carrefourBJ 13090</td>
<td>17</td>
<td></td>
<td>2011-2-11 11:02:27</td>
<td>QACheckState</td>
<td>Running</td>
<td>Check</td>
</tr>
<tr>
<td>carrefourBJ 1200</td>
<td>15</td>
<td></td>
<td>2011-2-11 1:27:35</td>
<td></td>
<td>Completed</td>
<td>Check</td>
</tr>
<tr>
<td>carrefourSH120000</td>
<td>12</td>
<td></td>
<td>2011-2-11 1:16:30</td>
<td>SupplierCheckState</td>
<td>Running</td>
<td>Check</td>
</tr>
<tr>
<td>carrefourBJ 89000</td>
<td>12.5</td>
<td></td>
<td>2011-2-11 11:02:12</td>
<td>OfficerCheckState</td>
<td>Running</td>
<td>Check</td>
</tr>
<tr>
<td>carrefourSH80000</td>
<td>18</td>
<td></td>
<td>2011-2-11 11:01:06</td>
<td>SupplierCheckState</td>
<td>Running</td>
<td>Check</td>
</tr>
<tr>
<td>carrefourSH40000</td>
<td>11</td>
<td></td>
<td>2011-2-11 11:01:39</td>
<td>BuyerState</td>
<td>Running</td>
<td>Check</td>
</tr>
</tbody>
</table>

Diagram 10 Carrefour GSA Checks All Order Status

The Carrefour GSA officer, supervisor or manager can check all the statuses of submitted order from all the buyers to monitor and manage the business processes.
Database Activity

The Activity database stores the information of activity transfering for the workflow instances.
The ActivityInstance database stores all the information of activity instances.

![Diagram 13 tbl_Order]

The tbl_Order database stores all the information of orders.

**Appendix 3 Rule base**

The condition one can be defined as follows:

If \( \text{this}.\text{ExpenseDataProperty.Amount} \leq 3000 \) \( || \) \( \text{this}.\text{ExpenseDataProperty.Vol} \leq 10 \)

The following codes are designed for condition one of rule set one through XAML language in the rule file.

```xml
<RuleDefinitions xmlns="http://schemas.microsoft.com/winfx/2006/xaml/workflow">
  <RuleDefinitions.Conditions>
    <RuleExpressionCondition Name="condition1">
      <RuleExpressionCondition.Expression>
        <ns0:CodeBinaryOperatorExpression Operator="BooleanOr" xmlns:ns0="clr-namespace:System.CodeDom;Assembly=System, Version=2.0.0.0, Culture=neutral, PublicKeyToken=b77a5c561934e089">
          <ns0:CodeBinaryOperatorExpression.Left>
            <ns0:CodeBinaryOperatorExpression Operator="LessThanOrEqual">
              <ns0:CodeBinaryOperatorExpression.Left>
                <ns0:CodePropertyReferenceExpression PropertyName="Amount" />
              </ns0:CodeBinaryOperatorExpression.Left>
              <ns0:CodePropertyReferenceExpression TargetObject />
            </ns0:CodeBinaryOperatorExpression>
          </ns0:CodeBinaryOperatorExpression>
        </ns0:CodeBinaryOperatorExpression/>
      </RuleExpressionCondition.Expression>
    </RuleExpressionCondition>
  </RuleDefinitions.Conditions>
</RuleDefinitions>
```
<ns0:CodeThisReferenceExpression />
</ns0:CodePropertyReferenceExpression. TargetObject>
</ns0:CodePropertyReferenceExpression>
</ns0:CodePropertyReferenceExpression. TargetObject>
</ns0:CodePropertyReferenceExpression>
</ns0:CodeBinaryOperatorExpression. Left>
<ns0:CodeBinaryOperatorExpression. Right>
<ns0:CodePrimitiveExpression>
<ns0:CodePrimitiveExpression. Value>
<ns1:Int32 xmlns:ns1="clr-namespace:System;Assembly=mscorlib, Version=2.0.0.0, Culture=neutral, PublicKeyToken=b77a5c561934e089" xmlns:ns0="/ns0:3000"
</ns0:CodeBinaryOperatorExpression. Right>
</ns0:CodeBinaryOperatorExpression. Left>
</ns0:CodeBinaryOperatorExpression>
<ns0:CodeBinaryOperatorExpression. Right>
<ns0:CodeBinaryOperatorExpression Operator="LessThanOrEqual"
<ns0:CodeBinaryOperatorExpression. Left>
<ns0:CodePropertyReferenceExpression PropertyName="Vol"/>
<ns0:CodePropertyReferenceExpression. TargetObject>
<ns0:CodePropertyReferenceExpression PropertyName="ExpenseDataProperty">
<ns0:CodePropertyReferenceExpression. TargetObject>
<ns0:CodeThisReferenceExpression />
</ns0:CodePropertyReferenceExpression. TargetObject>
</ns0:CodePropertyReferenceExpression>
</ns0:CodePropertyReferenceExpression. TargetObject>
</ns0:CodePropertyReferenceExpression>
112
This questionnaire is one important part of my Master’s Thesis ‘The study of Rule-based Workflow System on Business Process Management’ of University of Boras. It contains the questions about your opinions of workflow systems and supply chain management. The questionnaire is anonymous. Please fill in the questionnaire and send back to me through Email address ‘oscarlisheng@gmail.com’. Thank you for your time and cooperation!

1. What is the size of your supply chain company? *

   - [ ] 1-100 people
   - [ ] 100-500 people
   - [ ] 500-1000 people
   - [ ] 1000-5000 people
   - [ ] more than 5000 people

2. How many years have you been working in the company *

   - [ ] 1-3 years
   - [ ] 3-6 years
   - [ ] 6-10 years
   - [ ] 10-20 years
   - [ ] More than 20 years

3. How does your company manage business rules? *

   - [ ] very good
4. Is your company currently using workflow system? *

- Yes
- No

5. To what extent your company is using information system during business process management? *

- Not using
- Partially using
- Mostly using
- Totally using

6. Do you think there are many volatile business rules in your company’s business process management? *

- Yes
- Partially yes
- Neutral
7. Do you in favor of the idea of rule-based workflow system that end user can modify the business rules through external user interface without changing system coding? *

- Partially no
- No

- Totally agree
- Partially agree
- Neutral
- Partially disagree
- Totally disagree

8. Those who answer ‘Totally agree and Partially agree’ in question 7, please answer this question. What is your reason of choosing ‘agree’? Select only one answer you mostly agree.

- Increase efficiency
- Reduce system maintenance cost
- Better to handle business rule
- Reduce manual tasks

9. Those who answer ‘Neutral, Partially disagree and Totally disagree’ in question 7, please answer this question. What is your reason of not choosing ‘agree’? Select only one answer you mostly agree.
Too much risks of changing current systems

Less communications

Safety reasons of changing rules

Company does not need it
University of Borås is a modern university in the city center. We give courses in business administration and informatics, library and information science, fashion and textiles, behavioral sciences and teacher education, engineering and health sciences.

In the School of Business and IT (HIT), we have focused on the students' future needs. Therefore we have created programs in which employability is a key word. Subject integration and contextualization are other important concepts. The department has a closeness, both between students and teachers as well as between industry and education.

Our courses in business administration give students the opportunity to learn more about different businesses and governments and how governance and organization of these activities take place. They may also learn about society development and organizations' adaptation to the outside world. They have the opportunity to improve their ability to analyze, develop and control activities, whether they want to engage in auditing, management or marketing.

Among our IT courses, there's always something for those who want to design the future of IT-based communications, analyze the needs and demands on organizations' information to design their content structures, integrating IT and business development, developing their ability to analyze and design business processes or focus on programming and development of good use of IT in enterprises and organizations.

The research in the school is well recognized and oriented towards professionalism as well as design and development. The overall research profile is Business-IT-Services which combine knowledge and skills in informatics as well as in business administration. The research is profession-oriented, which is reflected in the research, in many cases conducted on action research-based grounds, with businesses and government organizations at local, national and international arenas. The research design and professional orientation is manifested also in InnovationLab, which is the department's and university's unit for research-supporting system development.