An Adaptive Framework for Improving the Effectiveness of Virtual Enterprises in the Supply Chain

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Declaration

I hereby declare that this thesis is composed by myself and that the work contained in it is my own, except where explicitly stated otherwise in the text, and that this work has not been submitted for any other degree or professional qualification except as specified. The thesis has been proof read and corrected with the assistance of my supervisor, Professor Alan Eardley.

The following publications have been produced from the research which has produced this thesis in collaboration with my supervisors and advisors.

Samdantsoodol, A., Cang, S., Yu, H., Tumur-Ochir, A. (2013). A structural equation model for predicting virtual enterprise and agile supply chain relation, ICAC'13, London, UK, pp.1-6, Sept. 2013, INSPEC Accession Number: 13898435ISBN

Samdantsoodol, A., Cang, S., Yu, H. (2012). Overview of virtual enterprises in supply chain management, ICAC'12, Loughborough, UK, pp.1-9, Sept. 2012, ISBN: 978-1-4673-1722-1

Samdantsoodol, A., Cang, S., Yu, H., Eardley, A., Buyantsogt, A. (2017). Predicting the relationships between virtual enterprises and agility in supply chains. *Expert Systems with Applications*,84, pp.58-7.

Abstract

This thesis describes a research project that develops an adaptive framework for improving the effectiveness of virtual enterprises in the supply chains in Mongolia. The research takes empirical and quantitative approach to study the phenomenon of virtual enterprises. Based on a literature review, the factors that influence organisations to join in virtual enterprises are studied by a higher-order factor analysis. As a result, agility is identified as one of the main benefits organisations can gain by joining a virtual enterprise temporarily and changes in business performance are conceived as the measures of effectiveness. Next, a taxonomy of enterprises is developed with five distinguishing clusters that achieve differing levels of agility and business performance. This study suggests that enterprises that are monitoring changes in their business environment take most advantage of agility and achieve the best levels of performance.

These findings then allow an adaptive framework based on common reference architectures to be developed as a main contribution of this study. The framework includes a breeding environment as a 'pool' of prepared enterprises with the ability to form temporary collaborations to react responsively, rapidly and effectively to the fast-changing opportunities. A structural equation model was used to examine the model fit with the supporting hypotheses, based on the observed data. Then, a powerful clustered expectation maximisation algorithm was applied to the analysis of the grouped enterprises.

Finally, a simulation-based case study was conducted to validate the developed framework. The results provide rich empirical evidence of the beneficial impact of virtual enterprises on agile supply chains. The research provides rich empirical evidence of the beneficial impact of virtual enterprises on agile supply chains. It also provides theoretical and managerial insights that can be used to strengthen the drivers, enablers and capabilities that enhance the effectiveness of virtual enterprises collaboration in agile supply chains that can be translated to a global context. These are major contributions the 'body of knowledge' in themselves, but the research also adds usefully to the study of applied research methodologies in the area.

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Abbreviations

AHP	Analytic Hierarchy Process
ANN	Artificial Neural Network
ANP	Analytic Network Process
ARCON	A Reference Model for Collaborative Networked Organizations
ARDIN	Reference Architecture for Integrated Development
ARIS	Architecture of Integrated Information Systems
ASC	Agile Supply Chain (definition in Section 3.1)
ASV	Average Shared Variance
AVE	Average Variance Extracted
BPM	Business Process Modelling
BM_VERAM	BM Virtual Enterprise Architecture and Reference Model
CFI	Comparative Index
CIM	Computer Integrated Manufacturing
CIMOSA	Computer Integrated Manufacturing Open System Architecture
CMI	Collaboration Management Infrastructure
CNO	Collaborative Networked Organizations (definition in Section 1.1.1.1)
DBMS	Database Management System
DBPMS	Distributed Business Process Management System
DEDS	Discrete-Event Dynamic System
DES	Discrete Event Simulation (definition in Section 7.3)
DSS	Decision Support System
e-Business	Electronic Business (definition in Section 2.4.1)
EDI	Electronic Data Interchange
EM	Expectation Maximization (definition in Section 5.1.1)
ESB	Enterprise Service Bus
GA	Genetic Algorithm
GDP	Gross Domestic Product
GERAM	Generalised Enterprise Reference Architecture and Methodology
GRAI/GIM	Graphs with Results Action Inter-related/Graphs Integrated Method
ICT	Information and Communication Technology
IFI	Incremental Fit Index

KMO	Kaiser-Meyer-Olkin measure
MAS	Multi-Agent System
MFALI	Ministry of Food, Agriculture and Light Industry
NFI	Normed Fit Index
NNFI	Tucker-Lewis Index or Non-Normed Fit Index
PERA	Purdue Enterprise Reference Architecture
R&D	Research and Development
RA	Reference Architecture (definition in Section 1.1.1.1)
RBV	Resource-based View (definition in Section 2.1)
RFID	Radio-Frequency IDentification
RMSEA	Root Mean Square Error of Approximation
SD	System Dynamics (definition in Section 7.1)
SEI	Sustainable enterprise interoperability
SEM	Structural Equation Model (definition in Section 4.2)
SME	Small and Medium Enterprise
SOA	Service-Oriented Architecture
SOP	Service Oriented Process
SC	Supply Chain
SCM	Supply Chain Management
SPMR	Standardised Root Mean Square Residual
STEP	Standard for the Exchange of Product model data
UML	Unified Modelling Language
VBE	Virtual Enterprise Breeding Environment (definition in Section 2.2)
VE	Virtual Enterprise (definition in Section 2.3.1)
VERAM	Virtual Enterprise Reference Architecture and Methodology
XML	eXtensible Markup Language

Notation List

Mathematical notation	Definition
χ^2	Chi square
Df	Degree of freedom
P	Significance level
$\boldsymbol{x_1, \dots, x_n}$	Set of observation, $x_i \in \mathbb{R}^d$
$\boldsymbol{n}$	Number of observations
$\boldsymbol{K}$	Number of clusters
$\boldsymbol{\omega}$	Weights of each Gaussian component
$\boldsymbol{\theta_k}$	The corresponding mixture component parametric
$\boldsymbol{p_k(x_i; \theta_k)}$	Component density
$\boldsymbol{f(x; \theta)}$	The mixture probability density function
$\boldsymbol{\log L(x, \theta)}$	Log-likelihood of probability density function
$\boldsymbol{\mu}$	Mean vector
$\boldsymbol{\Sigma}$	Covariance matrix
$\boldsymbol{\theta^t}$	Parameter estimates
$\boldsymbol{Q(\theta, \theta^{(t)})}$	Conditional expectation
$\boldsymbol{\phi_{ik}^{(t)}}$	Conditional density, (probabilities of which input belongs to which cluster)
$\boldsymbol{t}$	Count or number of iterations

CHAPTER 1: INTRODUCTION TO THE RESEARCH

1 Introduction

Collaborative behaviour and activities in supply chain management have gained considerable importance in recent decades as an essential pre-condition of staying competitive and enhancing performance, which in turn intensifies efforts for building enhanced value-based relationships through the supply chain network (Koçoğlu *et al*., 2011). While the external environment influences organisations, it is becoming more difficult and expensive for one company to handle all these issues and to adapt in a competitive context. The involvement in a collaborative network represents not only a survival factor but also provides competitive advantage in the face of turbulent market scenarios (Camarinha-Matos and Afsarmanesh, 2008). The emerging new collaborative and integrated business strategy is geared towards maximising the benefits of the relatively narrow windows of opportunity that are yielded by increasingly volatile global markets and by optimally sharing the demand and resources through forms of collaboration. In fact a large variety of collaborative networks have emerged recently as a result of the challenges faced by the business, social, and scientific worlds enabled by fast progress in the information and communication technologies (ICTs) (Camarinha-Matos and Afsarmanesh, 2008).

A virtual enterprise is seen as a new organisational paradigm, which is expected to serve as a vehicle for a seamless 'perfect' alignment of the enterprise with the market (Cruz-Cunha and Putnik, 2006). A virtual enterprise is a conglomeration of regular enterprises that collaborate on an *ad hoc* basis and gather data on markets and customer needs. It then combines this with the newest design methods and computer-integrated production processes and operates as an integrated network that includes suppliers, distributors, retailers and consumers (Aerts *et al*., 2002). A virtual enterprise is characterised in diverse ways, ranging from simple subcontracting networks to dynamic reconfigurable networks of independent enterprises sharing all resources, including knowledge, market and customers. It uses specific architectures, not only of software and data systems, but primarily the organisational architectures that reflect the enterprise's true virtual environment. This allows it to be permanently aligned with the highly demanding and dynamic global markets (Cruz-Cunha and Putnik, 2006).

By adopting the idea of a highly flexible organisation and by reforming themselves to cope with the requirements and opportunities of the business environment, enterprises have been able to obtain many benefits. These include; agility, complementary roles, operational dimensions, competitiveness, resource optimisation, and innovation (Camarinha-Matos and Afsarmanesh, 2003). Virtual enterprise formation facilitates the restructuring of the organisation to respond quickly to changing market needs (Gunasekaran, 1998). The virtual enterprise has therefore become an important business solution and agility is reckoned to be one of the most effective aspects of a virtual enterprise. Agility in supply chains refers to a firm's ability to achieve a high performance in operational activities together with 'channel partners' in adapting or responding to marketplace changes in a rapid manner (Braunscheidel and Suresh, 2009; Liu *et al*., 2013; DeGroote and Marx, 2013).

In the last two decades, virtual enterprise issues have received increasing attention from both academics and practitioners. However, it is rare to find studies in the literature that investigate and evaluate virtual enterprise effectiveness in depth. This research therefore attempts to identify the possibilities to improve effectiveness of virtual enterprise and to develop an adaptive framework that is easy to understand and to utilise.

1.1 Background and challenging issues

To determine the challenging issues in studies of virtual enterprise by reviewing the literature, this study assumes the virtual enterprise is a complex open system that has a set of interacting or interdependent components forming an integrated whole. This open system is delineated by its spatial and temporal boundaries of association, surrounded and influenced by its environment. This is shown by external changes as described by its structure and purpose in its functioning. summarises its interactions. The complex system has a purpose of taking actions to exploit business objectives effectively in short time periods by using input elements, under the pressure of external changes. The effectiveness of this complex system depends on inputs and its process, so studying the inputs and the process of achieving improved outputs is crucial to an understanding of the phenomenon of a virtual enterprise (see Figure 1.1).

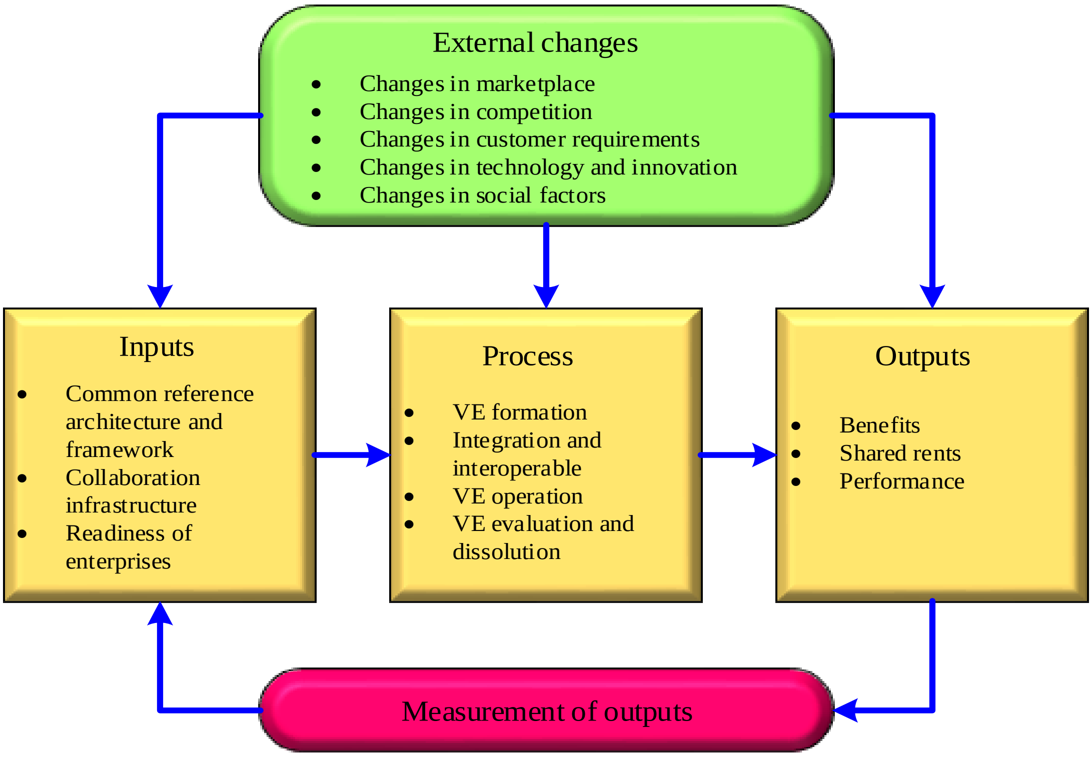

Figure 1-1: **The complex system of a virtual enterprise and its inputs and outputs**

1.1.1 Inputs of the system

The inputs involve elements that enter into the system and are operated upon to produce the outputs. As shown in Figure 1.1, the inputs into the virtual enterprise formation involve:

- The common reference architecture and framework that are developed as a high abstraction level solution and provide a basic description of the components of the system, the interrelationship of components and the organisational structure of the system;
- Collaboration infrastructures that are developed as a networking infrastructure to connect participants and enable enterprises to access the right information at the right time across different workspaces. The collaboration infrastructure adapts to the common reference architecture and framework;
- An enterprise's readiness to form a virtual enterprise is the main input that includes all the other inputs. As a main player, enterprises need to be ready to join in temporary associations by adapting to common reference architectures and transferring the right information at the right time by using collaboration infrastructures to receive benefits.

In the literature, researchers point out that there are barriers and challenges to form a virtual enterprise, such as the lack of a common reference model and its supporting tools (Putnik *et al.*, 2005), lack of information, lack of a common collaboration infrastructure and the reluctance of organisations to join in the collaborative process (Camarinha-Matos and Afsarmanesh, 2008).

1.1.1.1 Common reference architectures and frameworks for virtual enterprises

When modelling and forming complex systems like virtual enterprises, organisations need to adopt pre-determined forms of organisation and operations that allow them to obtain maximum benefits from their resources and activities and to improve their competitiveness. To accomplish the business mission and objectives, enterprise integration requires suitable business rules and organisational structures to enable them to provide products and services to its customers in conformance with agreed-upon criteria (ISO/TC184/SC5/WG1, 2000). The reference architecture is used for designing the preliminary essential features and characteristics of the system, architecture. In the Industrial Automation Systems - Requirements for Enterprise - Reference Architectures and Methodologies (ISO/TC184/SC5/WG1, 2000), an architecture is defined as 'a description (model) of the basic arrangement and connectivity of parts of a system (either a physical or a conceptual object or entity)'. Two types of reference architecture are identified that deal with enterprise integration: System architectures (sometimes referred to as 'Type 1' architectures) that deal with the design of a system, (e.g. the computer control system part of an overall enterprise integration system); Enterprise-reference projects (sometimes referred to as 'Type 2' architectures) that deal with the organisation of the development and implementation of a project such as an enterprise integration or other enterprise development programme.

According to the *Systems and software* engin*eering - Architecture description* (ISO/IEC/IEEE 42010:2011, 2011) the architecture of a system is defined as the 'fundamental concepts or properties of a system in its environment embodied in its elements, relationships, and in the principles of its design and evolution' and an architecture framework as the 'conventions, principles and practices for the description of architectures established within a specific domain of application and/or community of stakeholders'. Most reference architectures are developed at a high level of abstraction and provide a basic description of the components of the system, the interrelationship of the components and the organisational structure of system. Burkel (1991) views a reference architecture is a framework that guides the project of design and implementation of an integrated enterprise system using a structured methodology, the formalisation of operations and the support tools. A framework is needed for communicating the decisions, requirements, constraints, enablers and feedback among the stakeholders (Pulkkinen *et al.*, 2007). A framework is a meta-level model (a higher-level abstraction) through which a range of concepts, models, techniques, methodologies can either be clarified and/or integrated (Jayaratna, 1994). According to Camarinha-Matos and Afsarmanesh (2008), a framework is a ‘supporting structure that might include a number of (partial) models, collections of templates, procedures and methods, rules and tools (e.g. modelling languages)’ and an architecture is ‘an abstract description of a specific system.’

Several enterprise modelling frameworks have been produced that provide generalised reference architectures and methodologies to guide system analysis and design for whole life cycle of enterprise integration. A clear indication is provided by the reference modelling activities for virtual enterprises, a process that took over two decades to reach its maturity, as shown in Figure 1.2.

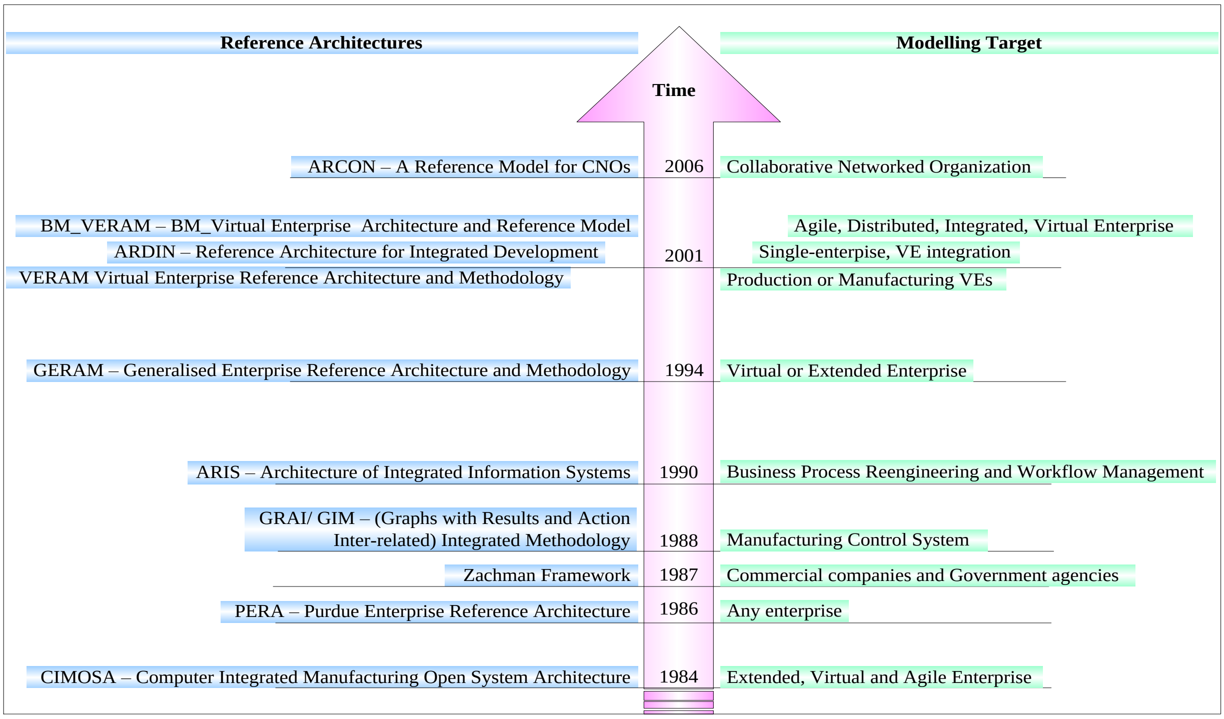

Figure 1-2: Reference architectures and modelling targets

The development of architectures for virtual enterprises could be divided into two phases. In the first phase, initiative architectures (mainly based on the system life cycle) are used to show what must be done to model, design and implement an integrated enterprise system. Among the most widely-used of these are CIMOSA (Computer Integrated Manufacturing Open System Architecture) (ESPRIT Consortium AMICE, 1993), PERA (Purdue Enterprise Reference Architecture) (Williams, 1994), the Zachman framework (Zachman, 1987), GRAI/GIM (Graphs with Results and Action Inter-related Integrated Methodology) (Chen and Doumeingts,

1996) and ARIS (Architecture of Integrated Information Systems) (Scheer, 2000). These are compared in detail in Appendix A and are described here briefly as follows:

- The CIMOSA architecture, developed by the European AMICE Consortium, originally aims to elaborate an open system architecture for Computer Integrated Manufacturing (CIM) and to define a set of concepts and rules to facilitate the building of future CIM systems;
- PERA is an enterprise reference architecture and methodology developed by Purdue Laboratory for Applied Industrial Control. It is characterised by its layered structure, which covers the full enterprise life cycle. The most significant contribution of PERA is that it is the first architecture that fully considers the human factor;
- The Zachman framework was invented by John Zachman[1]. It offers a simple and logical structure for classifying and organising the descriptive representations of an enterprise. It is not a methodology, in that it does not imply the use of any specific method or process for collecting, managing, or using the information that it describes. Rather, it is an ontology whereby a schema for organising architectural artefacts is used to take account of both the artefact targets (e.g. business owner or builder) and the issue (e.g. data or functionality) that is being addressed;
- GRAI/GIM is an architectural and methodological approach, originally called GRAI-IDEF0-Merise, now called GRAI Integrated Methodology, created in the GRAI laboratory of the University of Bordeaux in France. The objective of GRAI-GIM is to develop specifications for CIM systems. It designs an architecture including all the main constituent elements of CIM systems and the peripheral elements. Also, it serves to determine the specifications of all the constituent elements to select existing market elements and development elements. GRAI-GIM handles only the analysis and design phases from the manufacturing system life cycle;
- ARIS is an architecture proposed by Professor August-Wilhelm Scheer[2], which focuses on the analysis and requirements definition phase during the design of managerial information systems (IS), rather than on the execution of business processes.

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[1] CEO Zachman International®, Inc. https://www.zachman.com/about-the-zachman-framework

[2] German Professor of Business Administration and Business Information at the Saarland University, and founder and director of IDS Scheer AG, a major IT service and software company. http://www.uni-saarland.de/en/lehrstuhl/prof-dr-peter-loos/team/prof-a-w-scheer.html

The second phase of the development of reference architectures came with more generalised and moderated structures to focus on more specific targets. This stage includes; GERAM (Generalised Enterprise Reference Architecture and Methodology) (IFIP-IFAC, 1999), VERAM (Virtual Enterprise Reference Architecture and Methodology) (Tølle *et al*., 2003), BM-VEARM (BM Virtual Enterprise Architecture and Reference Model) (Putnik, 2001), ARDIN (Reference Architecture for Integrated Development) (Chalmeta and Grangel, 2003) and ARCON (A Reference Model for Collaborative Networked Organizations) (Camarinha-Matos and Afsarmanesh, 2008). These are compared in in detail in Appendix B and are described here briefly as follows:

- GERAM is a RA as well as a methodology, and was developed by the IFIP-IFAP Task Force and adopted as an Appendix of ISO15701:2000 (ISO/TC184/SC5/WG1, 2000, p. 15, Bernus *et al*., 2015). By generalising the contributions of various existing and emerging enterprise architecture frameworks, GERAM aims to define a complete collection of tools, methods and models which are needed to build and to maintain the integrated enterprise. This applies either to a part of an enterprise, a single enterprise or a network of enterprises (virtual enterprises or extended enterprises). Thus, the scope of GERAM encompasses all knowledge describing the components needed for enterprise engineering and integration. GERAM gives a description of all the elements recommended in enterprise engineering and integration. It thereby sets the standard for the collection of tools and methods with which any enterprise would benefit from more successfully tackling initial integration design and the change processes which may occur during the enterprise's operational lifetime (ISO/TC184/SC5/WG1, 2000, p. 15);
- VERAM is a reference architecture and methodology created by the IMS GLOBEMEN (IMS 99004, 2000) project and based upon GERAM. It was the first industrial application of GERAM (Bernus *et al*., 2015). Its aim is to organise knowledge about the formation and operation of virtual enterprises and its contribution was to solve existing problems around global engineering and manufacturing. To save time and cost, VERAM is intended to formalise the main procedures, tools and methods that are used in common every time a virtual enterprise is developed and operated;
- BM_VEARM is an enterprise architecture reference model for use with concurrent engineering (Putnik (2001). In this hierarchical model, a broker is inserted into a process control system to ensure integrability, 'distributability', agility and 'virtuality'. This broker can provide higher flexibility for a concurrent engineering team during virtual enterprise

operation. It can minimise time losses and maximise the response to a client's demands. According to Putnik (2001), this model meets two basic principles; firstly, it satisfies the characteristics of a virtual enterprise, (i.e. the 'open' architecture of the system, its capacity for 'agility 'including re-configurability in real time and its operation within an abstract (i.e. virtual) environment and secondly, it has the capacity to execute processes concurrently; this is the principal concurrent engineering characteristic;

- ARDIN is a reference architecture developed by the IRIS Group, part of the University Jaume I of Castellón, Spain, as a result of the ARDIN project during 1994 (Chalmeta and Grangel, 2003). The existing complementary approaches were synthesised with new techniques, methods, models and templates in five dimensions. However, the objective of the project was to develop and validate a step forward in the state-of-the-art of the use of reference architectures for Enterprise Integration. Later the ARDIN architecture was extended to include virtual enterprise integration. For instance: Methodology for Enterprise Integration (the first dimension of the ARDIN architecture) has been extended firstly to describe the whole life cycle of a virtual enterprise and secondly to develop the appropriate virtual enterprise integration program. The second dimension (Reference Models) describes both the company's internal processes (e.g. purchases, production, storage, dealing, finances, etc.) and the external processes (e.g. relationships with suppliers, customers, transport companies, public administrations, etc.) that are essential to virtual enterprise integration. The Technological Infrastructure (the third dimension) is designed to automate the information traffic in the virtual enterprise for supporting the cross-organisational business process;
- ARCON is a modelling framework for Collaborative Networked Organizations (CNOs) developed during the ECOLEAD project, inspired by the modelling frameworks introduced earlier in the literature related to collaborations and network areas (Camarinha-Matos and Afsarmanesh, 2008). The framework considers both the internal and external aspects of CNOs to cover all the relevant perspectives of the collaborative network comprehensively and systematically. According to Camarinha-Matos and Afsarmanesh (2008) the vision behind the model is to develop a generic abstract representation, and is intended as an authoritative basis for understanding the entities and significant relationships among all the entities in the system.

Earlier work on enterprise modelling produced some well-known reference architectures and modelling frameworks that have been extended to cover networks of enterprises. Even so, the second phase of the development of architectures for enterprise integration focused more on the virtual enterprise characteristics of formalisation, process and technological integration based on existing architectures to propose harmonisation. However, these highly abstracted approaches were focused on collaboration and networking, integration, and inter-operation among autonomous entities with some temporary common interests. Apart from the notable approaches to virtual enterprise architectural modelling indicated above, studies have been conducted into applying different techniques and model-based reference architectures (see the literature review of the virtual enterprise in supply chains for more specific examples). The author argues that there are notable challenges in developing an adaptive and specialised framework. Although, some of these models underpin the representation of the virtual enterprise from different viewpoints at differing levels of granularity, generality and abstraction during different life-cycle phases. A full understanding of these architectures needs an extensive modelling effort. Also, the adaptive features of frameworks need to be considered to allow enterprises to respond creatively to the changing needs of the situation.

A framework needs an adaptive design to deliver a consistent experience regarding multiple enterprises. From beginning to end, a framework is designed to adapt continuously to the changing requirements of a project. A change in the understanding of the solution might prompt a change in the way the project is managed. Also, learning and discovery in the early cycles may lead to a change in the approach taken. Every part of it is variable, and it constantly adjusts to the characteristics of the virtual enterprise formation project. Depending on the involvement of the client and the project team, acting in an open and trusting partnership could be the basis for any approach to collaboration and integration for virtual enterprise formation.

1.1.1.2 Collaboration infrastructures for Virtual Enterprise

A large number of research and development projects sought to establish some technological foundations for the support of virtual enterprise (Camarinha-Matos and Afsarmanesh, 2003). Many of the reported virtual enterprise collaboration projects were launched in developed countries and some of them were completed successfully as shown in Figure 1.3. For the technical details and results of these examples of virtual enterprise projects see Appendix C. The projects mainly focused on enabling the integration of physical systems and on application integration for the virtual enterprise. Many of these development efforts were concentrated on the design and development of infrastructures and basic virtual enterprise support functionalities. However, only a few of the initiatives correspond to horizontal developments, aimed at establishing the base technology, tools and mechanisms. Most initiatives correspond to vertical developments, addressing the needs of specific sectors such as; cooperative design (collaborative engineering) in manufacturing, dynamic supply chain management in manufacturing and agribusiness, service federation in tourism, etc. (Camarinha-Matos and Afsarmanesh, 2003).

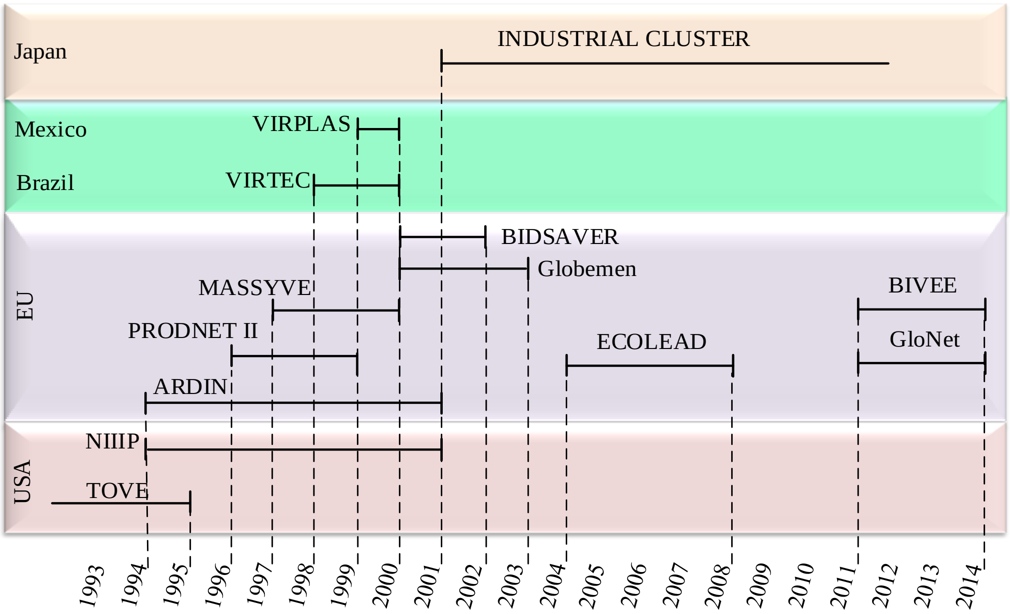

Figure 1-3: Projects for Virtual Enterprises

Although the conceptual advantages of virtual enterprises are well known, it has not been so easy to find practical applications of virtual enterprises, except for more stable, long-term networks. Some reference modelling approaches as shown previously in Figure 1.2 were used for some of the projects, but most of them used specific standards and work only with themselves, and all systems involved in the communication must be functioning concurrently. Common infrastructure and knowledge and information sharing are forcing every vertical development project to design and implement its own mini-infrastructure. This diverts valuable resources from the primary focus of the project, while generating an artefact that is limited as it applies only to that project. A gap exists in the study of common infrastructures that aim to enable the adaptation of enterprises to join in the virtual enterprises. To fill this gap, common shared infrastructures, such as web-based infrastructures, are studied to increase the benefits to virtual enterprises by integrating different information sources and allowing the filtering, combining and routing of information.

1.1.1.3 Readiness of enterprises

One of the primary features of successful virtual enterprise projects is player (i.e. participant) enterprises that are fully prepared (i.e. 'readiness') to join virtual networks. In collaborative networks, readiness for collaboration means the organisation's capability of leadership to support collaborative activities, to allocate or assign resources (e.g. money, staff, technology and information) across organisational boundaries, and to adopt a common ground for successful collaboration (e.g. common operating principles, common ontology, interoperable infrastructures, and co-operation agreements) (Romero *et al*., 2009). The lack of readiness of enterprises to join in the collaborative process affects the effectiveness of collaboration and destroys trust.

Romero *et al*. (2008; 2009) studied readiness for collaboration and produced an enhancement approach aiming at identifying critical evaluation elements for collaboration assessments to determine if a potential virtual (enterprise) breeding environment member has the necessary elements to collaborate and take part in a collaborative network such as a virtual breeding environment or a virtual enterprise. Even so, a gap exists in the literature on assessing and evaluating the readiness of enterprises for collaboration. Although the window of opportunity for virtual enterprise formation is short, the readiness of potential partners to take part in and support the rapid formation of a virtual enterprise needs to be studied. To assess the readiness of enterprises to join in a virtual enterprise, the enterprises' capabilities, ICT adoption, capacity for responding to external changes, and the ability to collaborate by sharing information, knowledge and resources are identified as more challenging factors.

From the systemic perspective, the inputs to a virtual enterprise system consist of the technological infrastructure, the co-ordination of process and information, and the players of participating enterprises. However, while the technological infrastructure and co-ordination issues are well studied and are becoming more mature, the enterprises' readiness issue needs more critical research. This study argues that there is a gap in the literature. To improve the effectiveness of virtual enterprises, the complex systems of affiliation of virtual enterprises, the causal factors of this affiliation, the consequences of the affiliation, and the players in this type of system need to be studied further.

1.1.2 Process and outputs of the system

The process of the system includes all the value-creating strategies and operations that participating enterprises adopt at every stage of virtual enterprise formation to achieve effectiveness and to accrue rents while receiving specific capabilities and profits. Based on the literature review, the challenging issues in virtual enterprise were investigated including; collaboration and integration, network organisation structure, partner selection, security, negotiation and risk management. When discussing the collaboration and integration of a virtual enterprise in a supply chain, the mode of organisation and co-operation needs to be considered and to be optimised. Some of the optimisation techniques are well established, using enterprise architectures and frameworks (Tamm *et al.*, 2011) and mathematical models, artificial intelligence and hierarchical process models. Although the integration of virtual enterprises at physical and application level and its system interoperability are well studied, research related to business integration and co-ordination of virtual enterprises is rarely found in the literature. The selection of the correct partners is becoming the main issue in the development of virtual enterprise applications. Researchers have made efforts to develop the right framework and methodology for the selection of proper partners by using; artificial neural network, analytic network process, analytic hierarchy process, multi-objective mathematical models and fuzzy sets, while dividing the problem into sub-levels using selected criteria. However, very few papers have focused on the negotiation, security and risk management of virtual enterprises in supply chains. Chapter 2 discusses these issues more specifically.

Effectiveness is an output of the complex system of a virtual enterprise and is one of the results obtained after running an entire process. The output of this system is determined by ‘rents’ or benefits that partners could receive from an interconnected alliance. From the resource-based perspective, enterprises can accrue relational rent when they collaborate by sharing knowledge and resources (Dyer and Singh, 1998; Lavie, 2006). Camarinha-Matos and Afsarmanesh (2003) and Gunasekaran *et al*. (2008) state that enterprises can obtain the agility to cope with and take advantage of changes, when temporary collaboration is conducted successfully. As a measure of the effectiveness of a virtual enterprise, the rents and agility capability may be assessed by measuring a change in business performance. Ngai *et al*. (2011) explore the impact of the relationship between supply chain competence and agility on firm performance. Yusuf *et al*. (2012) assess the levels of correlation of the dimension and attributes of agility with performance in the oil and gas supply chain (e.g. the interaction between turnover, net profit, market share, customer loyalty, relating to competitors’ performance) and competitive advantage. Also, Liu *et al*. (2013) and DeGroote and Marx (2013) empirically test the impact of agility on performance in complex situations with the influence of different factors. No evidence is found about how enterprises having different strategies have achieved differing levels of performance. Thus, this study investigates empirically the achievement of levels of agility in enterprises using different strategies to handle the factors that influence the effectiveness of virtual enterprises.

1.1.3 Features of the chosen case

The globalisation of supply chains offers comparative advantages to countries that have mastered innovative technologies and have succeeded in the adoption of new technology. In the future, faster technological progress is expected to revolutionise all the enterprises through the synergy of ICTs. There are opportunities for developing countries to accelerate their development using ICTs in the supply chain to fall into step with more developed countries. Therefore, business companies in Mongolia are selected as a targeted group for this empirical study.

According to the Global Competitiveness Report 2015-2016[4], Mongolia was ranked in 104th place out of 140 countries with a score of 3.81. Competitiveness is defined as the set of factors that determine the level of productivity of a country. The twelve pillars of competitiveness are ranked and scored according to key indicators and Mongolia is classified as moving from the factor-driven stage to the efficiency-driven stage of development. However, the market size is very small, the basic requirements including institutions, goods market efficiency, labour market efficiency and technological readiness are scored highly and innovation is scored very close to many emerging and developing Asian countries. Also, Citigroup (Business Insider, 2011) indicates that Mongolia is one of the 'Global Growth Generators' (i.e. countries with the most promising growth prospects for 2010–2050)[5]. These facts indicate that Mongolia is an 'open country' in the global economy, and a chance exists to enhance its competitiveness and to drive sustainable, inclusive growth.

Although the Mongolian economy is traditionally based on herding and agriculture, the development of extensive mineral deposits of copper, coal, molybdenum, tin, tungsten, and gold have recently emerged as a driver of industrial production and a cause of economic growth. According to the World Bank report (Shiilegmaa *et al.*, 2013), the Gross Domestic Product (GDP) of Mongolia was projected as shown in Table 1.1. Besides agriculture (21.3% of GDP)

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[4] Available at: http://reports.weforum.org/global-competitiveness-report-2015-2016/

[5] The Global Growth Generator (3G) Index was a weighted average of six growth drivers of (1) a measure of domestic saving/ investment, (2) a measure of demographic prospects, (3) a measure of health, (4) a measure of education, (5) a measure of the quality of institutions and policies, and (6) a measure of trade open-ness.

and mining (8.9% of GDP), the dominant industries in the composition of Mongolia’s GDP are transportation, wholesale and retail trade and service, and car and motorbike maintenance service activities[6]. Mining continues to rise as a major Mongolian industry, as is shown by the number of Chinese, Russian and Canadian firms that are starting mining businesses in Mongolia. Minerals now make up more than 80% of Mongolia's exports. However, Mongolia still sits on vast quantities of untapped mineral wealth and, driven by the mining boom, foreign investment in a number of mining projects is expected to transform the Mongolian economy in the coming years. These massive mining projects that are implemented with foreign investment open up the possibility of collaborating virtually and temporarily within government contracts, and many business sectors are booming as a result. As of June 2013, outstanding foreign direct investment stood at $1.5 billion (Shiilegmaa *et al.*, 2013) and projections indicate that foreign direct investment will continue to rise in the short term, having reached $2 billion in 2013, before dropping back considerably as a result of large-scale mining projects having completed their construction phases.

Table 1-1: GDP Growth Projections

	2013	2014	2015	2016	2017
East Asia	6.9	6.7	6.2	5.9	5.7
China	7.7	7.3	6.9	6.5	6.2
Mongolia	11.6	7.9	2.3	0.4	2.5

(Source: International Monetary Fund, Regional Economic Outlook, April 2016)

To create a business environment that can ensure efficient integration into the world economy, to enhance the intellectual property of domestic and national products and to improve competitiveness, a blueprint of Mongolian ICT development has been developed[7]. Based on activities taken as objectives of the blueprint, all the economically beneficial areas are already connected to the national backbone ICT network. This makes it possible for enterprises to penetrate international markets virtually.

[6] Mongolian Statistical Yearbook 2012, http://www.nso.mn/

[7] The White Paper on ICT Development of Mongolia, http://itpta.gov.mn/wp-content/uploads/2013/11/White%20paper%202013.pdf

As shown in the Business Register Database[8], there were 99,603 enterprises registered in Mongolia in 2013 and 54,922 enterprises (or 55.1%) were operating actively. Among all the active enterprises 84.4% had 1-9 employees, 6.9% of them had 10-19 employees, 5.4% of them had 20-49 employees and only 3.3% of them had more than 50 employees. The report concludes that establishments with few employees are dominant in the economy. In terms of their sector, 38% of enterprises belong to the wholesale and retail trade, the repair of motor vehicles and household goods, 11.4% of enterprises belong to real estate, renting and other business activities, 7.8% of enterprises belong to manufacturing, and rest of the enterprises belong to the remaining divisions.

This situation indicates that the possibility for Mongolian enterprises to co-ordinate with international enterprises and to affiliate temporarily and virtually needs to be studied. There is still a challenge in investigating the possibility of developing an adaptive and robust virtual enterprise framework for similar countries to enter international markets and enhance their competitiveness and business performance. The Mongolian cases have been chosen to study the possibilities of developing virtual enterprise's ability to provide better effectiveness in supply chains by investigating the drivers, providers, capabilities and effects.

1.2 Aims, objectives, and contribution

The aim of this project is therefore to research, develop and validate an adaptive virtual enterprise framework for enabling agility capability and increasing business performance in supply chains for networks of enterprises that are involved in export-oriented production and services through the co-creation of value and end-to-end collaboration with customers and local suppliers. The above aim will be achieved through the following objectives:

1. To examine the domain literature on virtual enterprises and supply chains to identify the issues, challenges, constraints, gaps, methodologies and opportunities to implement virtual enterprises for supply chain agility, theoretically and practically;

2. To examine the domain literature on frameworks and architectures especially related to collaborative networks to identify the challenging issues and limitations which must be overcome in the development of the proposed adaptive framework;

[8] Business Register Database . Available at: http://www.1212.mn/statHtml/statHtml.do

3. To analyse the research literature in two areas as suggested by Hart (2001); the concepts and theories related to the research and definitions and key studies of the theories, and the key questions and problems on the current situation to recognise the gaps and issues for further investigation;
4. To investigate the methodology literature to study the methodological problems and empirical gaps, and to select the appropriate research methods and techniques to design the data collection, analysis and validation phases of the research;
5. To investigate the possibilities for the achievement and improvement of virtual enterprise effectiveness. by analysing the causal drivers and providers of virtual enterprise effectiveness and forming and testing hypotheses on factors influencing the effectiveness of virtual enterprises by cluster analysis;
6. To develop an adaptive framework for improving the effectiveness of virtual enterprises by combining their common features and characteristics, while including modularisation and reusability and considering the business goals of time and cost reductions and profits and benefits increases;
7. To evaluate and validate the proposed framework, by conducting a simulation-based case study, discussing the suitability and analysing the effectiveness of the selected case study analysing the similarity of the historical data and the observed data from the simulation to give confidence that the simulation runs properly and correctly.

The original contributions of this research (which will make it of doctoral standard) include:

1. An aggregated research domain schema that bridges separate studies of virtual breeding environment, virtual enterprise and agile supply chains grounded on the resource-based view;
2. A novel complex conceptual model based on hypotheses tested on business companies in Mongolia;
3. A fresh numerical taxonomy of enterprises through comparative cluster analysis based on the relative importance attached to drivers and providers for virtual enterprise formation and agility;
4. A novel adaptive virtual enterprise framework based on enterprise capabilities and ICT adoption, that can enable supply chain agility and increases in business performance;
5. Original data collection and analysis for the primary study and the validation of the proposed framework;

6. An emerging market case study, set in Mongolia, to determine the possibilities of enterprises to join in temporary collaboration to penetrate global markets.

The research work has significant academic and practical contributions. Firstly, the original adaptive framework will form a useful addition to the body of knowledge in the domains of virtual enterprise, its breeding environment and benefits. Secondly, it gives the possibility for academic researchers to use the original case study for comparative analysis with subsequent research. Thirdly, virtual enterprise practitioners may adopt the recommended adaptive framework to improve the practice among virtual enterprises in their own country.

1.3 Statement of ethics

According to Saunders *et al*. (2009) research ethics relates to questions about how it should be formulated and to clarify the research topic, design the research and gain the access, collect data, process and store the data, analyse data and write up research findings in a moral and responsible way. Therefore, the research design follows the University's ethical principles and statements as follows:

- **Intellectual honesty:** A Harvard referencing model is adopted for citation of published sources. This model involves a short author-date reference, being inserted after the cited text within parentheses and the full reference to the source being listed at the end of the article and used sources are clearly listed in the reference section to track them easily;
- **Anonymity and confidentially:** Anonymity is adopted for the survey and action research, in a manner which that participants can be confident that their privacy and confidentially will be properly protected;
- **Self-determination:** Participants are treated as autonomous agents by informing them about the study and allowing them to voluntary choose to participate or not. The cover letter for questionnaire survey and action research, compromised the aims, objectives, confidential and related concepts, were sent to participants;
- **Purposeful collection of data:** Data is only relevant to the research collected and that data is not provided to third parties.

Staffordshire University guidelines and principles concerning research ethics [9]

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[9] Available at http://www.staffs.ac.uk/academic_depts/fbel/research/ethics/index.jsp.

1.4 Limitations of the research study

As in all research projects, there are some limitations to this study, which need to be recognised:

- The study has provided a preliminary framework consisting of six specific factors for understanding the influence of drivers and providers of virtual enterprise affiliation on business performance through supply chain agility. Further research could expand this framework;
- The research specifically focuses on the enterprises in the Mongolian case to study the possibilities of developing virtual enterprises to provide supply chain agility by investigating drivers, providers, capabilities and effects and to investigate readiness to join in virtual enterprises for agility in their supply chain. In future, the same study can be conducted in same case or different cases to build on this research;
- Research methods have some limitations by themselves. Therefore, the same research could be conducted in different ways using different methods and techniques and different results may be produced. Different data collection and analysis methods could also be used, but this would be a different project;
- Simulations produce the results of mathematical models that investigators postulate can capture the basic laws governing a physical system. However, when designing an abstract model of a real system and conducting experiments with this model for either understanding system behaviour or evaluating various strategies, some limitations need to be considered to eliminate bias. The limitations of the simulation are discussed more widely in section 6.3.4.

1.5 Structure

This thesis consists of seven chapters that are organised as shown in Figure 1.5. The contents of the chapters are as follows:

Chapter 1 demonstrates the motivations and challenging issues of the research work based on current situation. The research aims and objectives are identified and contribution towards the research are discussed briefly. The issues of ethics and limitations of research are included in this chapter. The motivation to conduct research ‘on the ground’ using Mongolian cases is explained.

Chapter 2 reviews the relevant knowledge of improving the effectiveness of virtual enterprise in supply chain. The resource-based view is adopted as a major theoretical background for understanding the relationship between formation and its benefits in supply chain collaboration. It explains how firms receive specific ‘rents’ or benefits from an interconnected alliance by applying tangible or intangible resources and creating value in supply chains. Based on resource-based view, the main research domains are aggregated and conventionalised with virtual breeding environment, virtual enterprise formation and its benefits and metrics.

Chapter 3 discusses the research methodology as a whole, evaluating the candidate research philosophies, approaches and methods (including those from the social sciences paradigm) and comparing their features in terms of their suitability for supporting the research. The components of the research design are justified for inclusion in the programme and the methodology is explained in diagrammatic form.

Chapter 4 introduces a novel conceptual model based on a literature review. This conceptual model hypothesises the relation between the influencing factors and the effectiveness of virtual enterprises and its measurement. One driver and three providers are found in the literature as an influencing factor on benefits of virtual enterprise. A structural questionnaire-based empirical survey is explained and developed hypotheses are tested by using a structural equation model. Rich empirical evidence is provided by this study in support of the research hypotheses, enriching the understanding of the relationship between virtual enterprises and agility and important findings are discussed.

Chapter 5 investigates the achievement of effectiveness through different enterprises’ clusters. Since the identification of the right partners from various enterprises in a supply chain brings the benefits of effective collaboration that deliver agility to the whole supply chain, the chapter shows that clustering initiatives have emerged to define a taxonomy of enterprises based on their implementation strategies. The previously-identified drivers and providers (see Chapter 3) are used as the underlying factors for clustering. A cluster analysis is described using the probabilistic clustering technique of expectation maximization (EM) algorithm, which is rarely found in the literature. Expectation maximisation was adopted to classify the dataset into an appropriate number of groups. Five distinguished clusters are identified and the achievement of agility and measuring indicators are compared by clusters. The results provide rich empirical evidence for the effectiveness for clusters regarding enterprises' characteristics.

Chapter 6 proposes the adaptive framework for improving the effectiveness of virtual enterprises in supply chains. As an enterprise integration tool, an adaptive framework is proposed with common dimensions that are adopted from previously developed architectures and the focused area of the framework is modelled more specifically and a description of basic concepts and goals for modelling are examined. In the scope of specific modelling, strategies to enterprises to improve their own capability to be selected as proper partners for a virtual enterprise are suggested. Furthermore, an implementation model is proposed and its platform and functions are discussed.

Chapter 7 illustrates a simulation-based case study used to validate the proposed framework. The environment for affiliating temporary alliances in Mongolian cases is introduced and joining enterprises in the virtual enterprise are analysed. A simulation model is proposed to analyse the product flow through the virtual enterprise and results are analysed by clusters. Real data obtained over a twelve month period from Mongolian meat companies linked together are used in a simulation. A simulation model is verified and validated and the functions and performance of the simulation are tested to give the confidence to readers for model's accuracy and credibility.

Chapter 8 concludes the research work and describes the implications for academics and practitioners. Future works are outlined for extending and enhancing the proposed adaptive framework and research on improvement of effectiveness of virtual enterprises in supply chains.

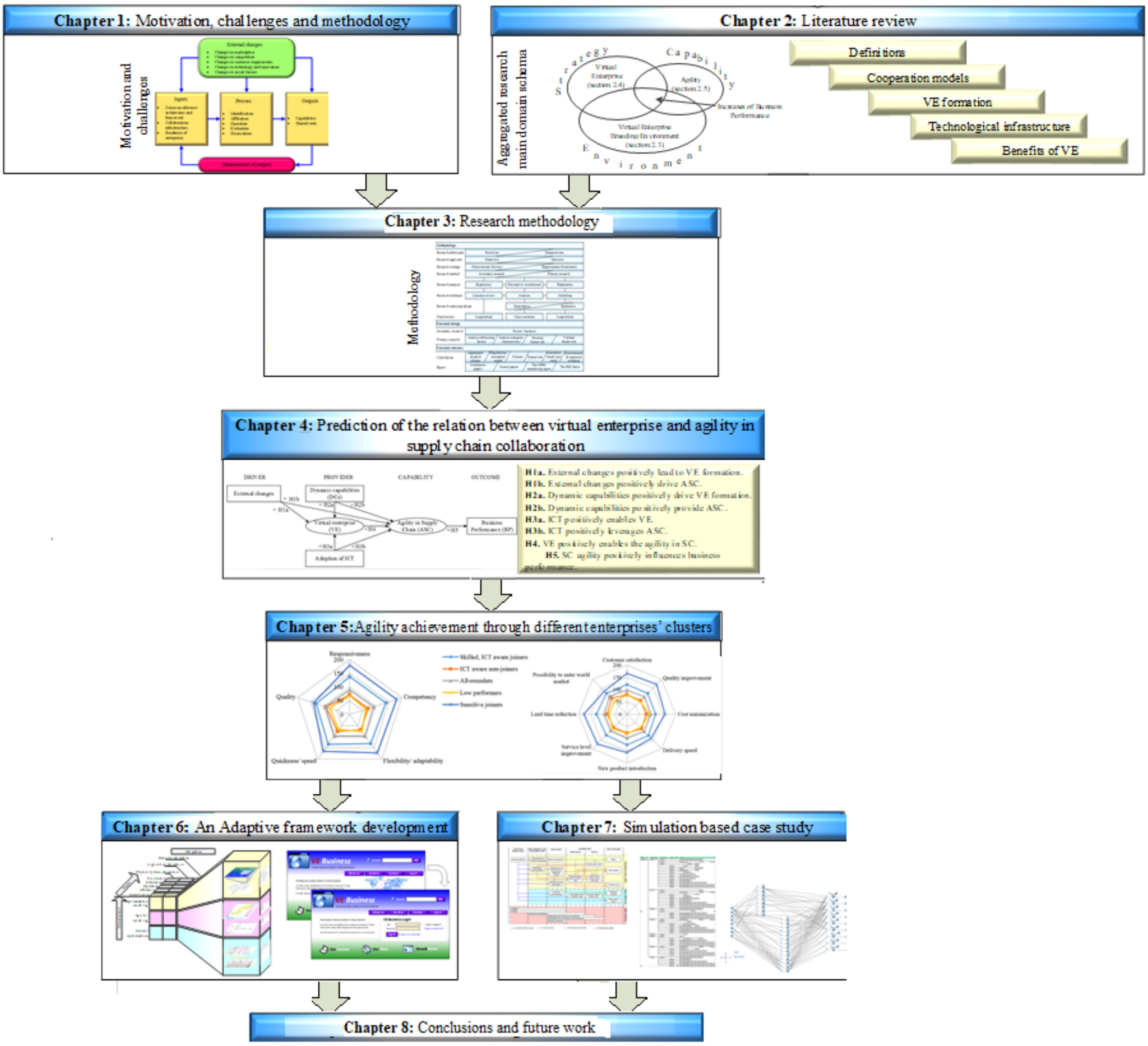


Figure 1-4: Structure of thesis

CHAPTER 2: LITERATURE REVIEW

2 Introduction

This chapter identifies the theoretical areas of the research work and introduces the relevant knowledge of the research based on relevant materials, and analysis and criticise them for synthesising previously unconnected ideas and issues. The aim is to provide a knowledge support to design an adaptive framework for improving the effectiveness of virtual enterprises in supply chains. With reference to the resource-based view (see Section 2) this chapter discusses the theoretical background and develops aggregated research main domain schema that based on reviewed theoretical issues of virtual breeding environment, virtual enterprises and supply chain agility. virtual breeding environment is considered in Section 2.2, as a main pool of enterprises that works like base collaboration for temporary alliance. To provide the knowledge and understanding to enable the design of an adaptive and robust virtual enterprise framework that is intended to effectiveness, the virtual enterprise concept is examined in Section 2.3, while agility is discussed as one of the main beneficial capability for virtual enterprises in Section 2.4.

The review includes a comparison of definitions of virtual enterprises, their lifecycles stages, co-operation models for virtual enterprises and their infrastructure, and an examination of the benefits to be gained from virtual enterprises for collaborating enterprises. Also, the overlapping domain areas are examined that are the main focus of the research; namely, the virtual enterprise formation (breeding) environment, the process of virtual enterprise formation, the effectiveness of virtual enterprise formation and its measurement.

2.1 Theoretical background

The resource-based view (Barney, 1991) is adopted as a major theoretical background for understanding the virtual enterprise, its breeding environment and effectiveness of virtual enterprise and possibilities to improve the effectiveness. To develop the competitive advantage for firms, resource-based view lies organisations competition and creation of value based strategy primarily in applying tangible or intangible resources that have four attributes of being valuable, rare, inimitable and non-substitutable (Barney, 1991). According to Barney (1991), firms have a competitive advantage when implementing a value creating strategy not simultaneously being implemented by any current or potential competitors. When other firms are unable to duplicate the benefits of the implementing strategy, the competitive advantage is sustained. Hence, the traditional resource-based view of Barney (1991) is based only focal firm, Lavie (2006) extends the resource-based view by integrating relational view and social network theories and identifies four specific rents that partners could receive from interconnected alliance. The four rents of the competitive advantage of a focal firm participating in an alliance/collaboration includes; internal rent, appropriated relational rent, inbound ‘spill over’ rent, and outbound ‘spill over’ rent. Internal rent derived from the firm's own resources extracted from the shared and unshared resources of its alliance partners. Dyer and Singh (1998) envisage firms receive relational rent as a supernormal profit that can only be created through the joint contributions of the collaborative partners by combining and exchanging the relation-specific assets, knowledge-sharing routines, complementary resources/ capabilities, and effective governance. Lavie (2006) determines the proportion of relational rents appropriated by the firm. Although firms accumulate inbound spill over rent derives from both the shared and unshared resources of its alliance partners through knowledge leakage, inter-firm learning, relative absorptive ability, and internalisation of the partner's practices, also loss of outbound spill over rent results from the transfer of benefits from the focal firm to the partner.

To win the rents (Lavie, 2006) and receive competitive advantages (Barney, 1991) in networking ground, modern competitive scenario pushes firms to explore new inter-firm organisational relationship models with two complementary directions: firstly, flexibility that is the organisational structures need to be more flexible allowing swift adaptation to change; and secondly, the intensive use of ICT to manage information and knowledge management to exploit innovation and collaborative relationships in a more efficient and effective way (Esposito and Evangelista, 2014). In recent environment co-ordination and co-operation between competitors and partners (rather than the optimisation of individual functions within a single organisation) would add to the competitive success of modern supply chains. Thus, the focus of supply chain management has shifted from the competitive advantage of individuals to the competitive advantage of the entire supply chain. Nowadays, organisational structure of the virtual enterprise has been indicated as a suitable dynamic co-ordination and co-operation model for addressing changing market conditions through flexibility, extensive ICT usage based on core competency of partners (Esposito and Evangelista, 2014). Compared with traditional alliances (Lavie, 2006) a virtual enterprise is a more dynamic and temporary structure that relies on multiperiod formulation rather than on a single phase of interaction to exploit fast changing business opportunities in the market. The main objective of a virtual enterprise is to allow several organisations to develop rapidly a common working environment and to manage a collection of resources provided by the participating organisations toward the attainment of some common goals (Gunasekaran *et al*., 2008).

Barney (1991) identifies resource heterogeneity and imperfect mobility as sources of competitive advantage for firms. The strategic resources controlled by a firm make its heterogeneous, and the condition of that strategic resources may not be perfectly duplicated establishes heterogeneity for long lasting (Barney, 1991). However Lavie (2006) believes the heterogeneity condition is tied to the conceptualisation of firms as independent entities, so the affiliation of alliances may contribute to resource homogeneity by facilitating asset flows among interconnected firms. This study argues that as a temporary alliance the formation of a virtual enterprise establishes network resource heterogeneity and suggests imperfect mobility. Such a value-creating strategy for forming virtual enterprises in turbulent environments could be an informal and autonomous strategy by itself and not be easily duplicated by other networked alliances simultaneously in a brief period. The network resources (Gulati, 1999) are external resources embedded in the firm's alliance network that provide strategic opportunities and affect its behaviour and value. They include all assets, capabilities, organisational processes, firm attributes, information, knowledge, etc. controlled by the formed virtual enterprise that enable the enterprises to conceive and implement strategies that improve their efficiency and effectiveness (Barney, 1991). For instance, closely knit, highly experienced management teams of virtual enterprises for a particular set of competitors are rare because they are socially complex and may be imperfectly imitable (Barney, 1991). Also, rationale virtual enterprise formation could enable simultaneous rent generation and appropriation at the network level to partners (Lavie, 2006).

Agility (Cruz-Cunha and Putnik, 2006) is considered in the present context of networked structure (resources providers) as a capability for rapid adaptability or fast reconfigure ability of the entities in co-operation to respond to market changes. As an ability to be tolerant of external changes, agility in a supply chain is perceived as the capability of being competitive in a global market and for an increased chance of long-term survival and profit potential (Gunasekaran and Yusuf, 2002). With regard to resources, capabilities are embedded in the dynamic interactions of multiple knowledge sources and are more firm-specific and less transferable (Yu *et al*., 2017). In this study, agility is perceived as an operational capability that is a valuable, rare, imperfectly imitable (Liu *et al*., 2013) and non-substitutable network resource enabled by a virtual and dynamic alliance structure. First, with responsive, flexible, and quick adaptive features, agility is conceived as a valuable resource for temporary alliance.

Recognizing the changes and responding rapidly and effectively to unanticipated opportunities and to proactively develop solutions for potential needs makes agility more valuable. Second, enabling agility by implementing a strategy of forming a virtual enterprise makes it rare network resource. It has not been so easy to find practical applications of virtual enterprise that enables agility to take place in a supply chain, because of several barriers and challenges (Putnik *et al*., 2005; Camarinha-Matos *et al*., 2009). Thus, it is difficult to achieve agility by adopting a strategy of forming a virtual enterprise with other networked firms in a brief period. Third, the formation of a virtual enterprise has its unique path through the creation and dissolution stages, so controlling members and their resources in a brief period is difficult. This characteristic makes agility achievement through a virtual enterprise formation strategy an imperfectly imitable networked resource. Finally, as a capability to exploit fast-changing business opportunities, agility is a non-substitutability network resource. Unanticipated changes in the economic structure of an industry may make what was, at one time, a source of sustained competitive advantages no longer valuable for a firm, and thus not a source of competitive advantage (Barney, 1991). Once a virtual enterprise formation strategy is adopted and achieved agility, it can no longer be a source of competitive advantage because other collaborative networks will try to duplicate the process to increase the efficiency and effectiveness of their own alliances.

In recent years, evidence has suggested that resources of alliance partners transferred *via* direct inter firm interactions have a considerable impact on firm performance (Lavie, 2006). According to Ngai *et al*. (2011) the resource-based view provides a robust framework for analysing the relationship between supply chain competence and firm performance, thus stating the proposition that agility is positively associated with firm performance. Liu *et al*. (2013) propose that IT capabilities (i.e., flexible IT infrastructure and IT assimilation) support the development of absorptive ability and supply chain agility, thereby influencing firm performance.

As a strategy to achieve agility, the virtual enterprise needs to be created based on a ‘virtual breeding environment’ (Camarinha-Matos and Afsarmanesh, 2003). This virtual breeding environment can be a network of enterprises within a supply chain that provides a basic level of trust through previous collaborations and enables the selection of partners for virtual enterprises from the wide ‘pool’ of available organisations. In this background, this thesis proposes an aggregated research main domain schema as shown in Figure 2.1. The benefits from collaboration, the success of a value-creating strategy based on previously conducted collaboration and efficiency and effectiveness of network resource that improved by successful strategy, may be measured by a change in business performance.

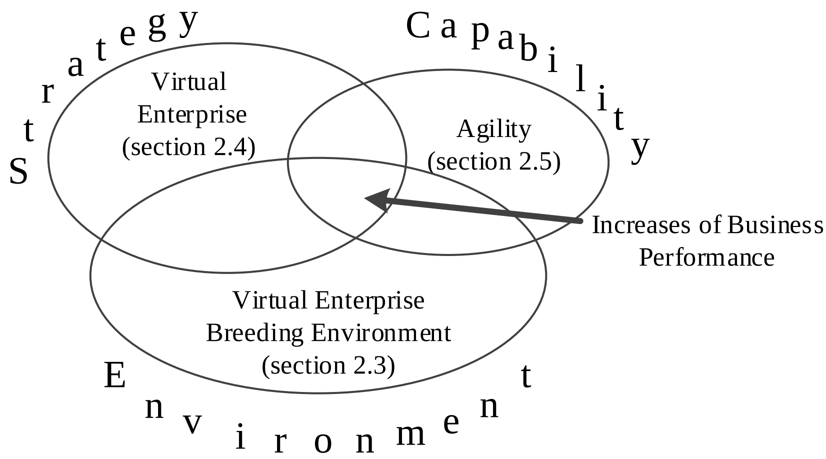


Figure 2-1: The proposed aggregated research main domain schema

The aggregated main research domain includes, firstly, the virtual breeding environment as a basic collaboration or partnering relationship, secondly, virtual enterprise formation as a strategy that is conducted based on collaboration and network resource heterogeneity and immobility, thirdly, agility as a capability and a rare, valuable, and imperfectly imitable network resource that is enabled and improved by proper strategy and provide effectiveness for virtual enterprise and finally, business performance that is a measure of output of strategy and achievement of network resource.

The resource-based view has proved to be an influential theoretical framework for understanding the achievements of firms holding a bundle of resources and capabilities. resource-based view has been adopted as a major theoretical background for understanding the influences of agility on business performance by the strategy chosen for joining in virtual enterprises. According to (Barney, 1991) the resource-based view suggests that firms possessing resources that are valuable, rare, inimitable and 'non-substitutable' can achieve sustainable competitive advantage by using them to implement strategies that are difficult for competitors to duplicate. Therefore, this study, by adopting the resource-based view, seeks to conceptually explain whether a strategy for joining in virtual enterprises to achieve agility in a market and an agility capability can contribute to an improved business performance for enterprises. This achievement depends the ability to create new resources, build upon existing capabilities, and make the capabilities more inimitable (Yu *et al*., 2017).

2.2 Virtual enterprise breeding environment

Trust-building in temporary collaborations is difficult for every partner, and the idea of using a cluster as the basis for the formation of a virtual enterprise has been identified in other research works such as the VIRPLAS or VIRTEC projects (see Appendix C). One of this kind of cluster identified by Camarinha-Matos and Afsarmanesh (2003), is virtual breeding environment that a pool of enterprises who have previous collaboration experience. virtual breeding environment is defines as: an association of organisations and their related supporting institutions, adhering to a base long-term co-operation agreement, and adoption of common operating principles and infrastructures, with the main goal of increasing both their chances and their preparedness towards collaboration in potential virtual enterprise . A main aim of the virtual breeding environment is focused on the transition from point-to-point connections among organisations to a network structure, to increase the chances of its member organisation's involvement in opportunities for collaboration (Afsarmanesh and Camarinha-Matos, 2005).

Since the 2000s, the concept of the virtual breeding environment has received attention from academics and practitioners. virtual breeding environments are mostly perceived as source networks or clusters that are long-term strategic alliances of organisations aimed at offering the necessary conditions (e.g. human, financial, social, infrastructural and organisational) to support the rapid and fluid configuration of a virtual enterprise (Romero *et al*., 2010). virtual breeding environments mainly focus on creating an adequate environment for the establishment of co-operation agreements, common operation principles, common interoperable infrastructures, common ontologies, and mutual trust among others, with the objective of preparing their members (organisations and support institutions) to be ready to collaborate in potential virtual enterprises that will be established when a collaboration (business) opportunity arises or is identified by a virtual breeding environment member acting as a broker (Camarinha-Matos and Afsarmanesh, 2008).

The resource-based view of the firm receives much attention in explaining collaboration in supply chains, partners in virtual breeding environment also able to receive benefits from their sharing resource. Lavie (2006) states that horizontal alliances among competitors that collaborate strategically are able to receive inbound spill over rent from shared or unshared firm resources. Dyer and Singh (1998) view collaborative partners as accruing the relational rent as a common benefit, and joint competitive advantage from a relational rent composes the collaborative advantage. The relational rents are created gradually, as a consequence of continuous collaboration (Lavie, 2006).

According to Afsarmanesh and Camarinha-Matos (2005), the establishment of a virtual breeding environment has the following advantages:

- Agility in opportunity-based virtual enterprise creation for profiting from emerging collaboration (business) opportunities;
- An apparent larger size to compete with larger companies;
- Lobbying and marketing influence to expand geography coverage/presence to access global market opportunities;
- Better negotiating power in joint purchasing conditions;
- Access to a transparent, easy-to-use and affordable “plug-and-play” ICT-infrastructure as an enabler of interoperation among virtual breeding environment members;
- Provision of mechanisms, guidelines and supporting services to facilitate the virtual enterprise creation process;
- Proactive virtual breeding environment members profiling and competency management to assure the availability of competencies and resources for responding to collaboration (business) opportunities;
- Provision of supporting services like insurance, coaching, training, etc. through support institutions;
- Introduction of mechanisms to build trust among virtual breeding environment members;
- Provision of general guidelines for collaboration such as working and sharing principles.

Since, it has the benefits of establishment the base trust for their members to collaborate in virtual enterprise s by reducing the cost and time to find suitable partners for virtual enterprises configurations and by providing the assisting means (e.g. methods and tools) to reduce the set-up times during the virtual enterprise creation process, virtual breeding environment is taken the main environment to form virtual enterprises.

2.3 Virtual enterprises in supply chain management

Since the concept of the virtual enterprise emerged in late 1980s, researchers distinguish virtual enterprises from a mere collaborations and the integration of business entities in outsourcing, and see virtual enterprises as technology-driven dynamic alliances formed based on the sharing of ISs (Esposito and Evangelista, 2014). Initially, a virtual enterprise was defined as a virtual corporation (Davidow and Malone, 1993) and a virtual enterprise model was indicated as being suitable for addressing changing market conditions together with proper partners based on ICT. It has the following essential characteristics that distinguish virtual enterprise formation from traditional alliance:

- **'Virtuality'**; virtual enterprises are usually highly relying on ICT. Utilisation of ICT enables geographically dispersed enterprises to join in a virtual enterprise to keep their time and cost to achieve business goal. A virtual enterprise owns no inventoried resources, assets, plants, factories or warehouses itself, ICT support to coordinate members owned assets;
- **Dynamics**; a virtual enterprise is highly dynamic and its life cycles can be very short. The temporary structure can be formulated again with same or different partners, multi periodically, to exploit new coming business opportunities in the market;
- **Flexibility;** virtual enterprises have strategic objectives to maximise flexibility and adaptability to environmental changes;
- **Autonomy;** To design an effective enterprise collaboration, workflow and information flows need to be controlled by a well-defined knowledge management system. To respond fast changing environment and enable flexibility, an automatically negotiating and decision-making system is mostly adopted for a virtual enterprise. Most examples rely on a multi-agent system that interacts to solve problems which are beyond the individual abilities or knowledge and makes decision as quick and correct as possible in a virtual enterprise;
- **Heterogeneity and immobility**; virtual enterprises are affiliated based on resource and core competencies of different firms by sharing different information, knowledge, and skills to obtain competitive advantages in a short run. New market opportunities no longer exist profitable, thus forming a virtual enterprise could be defined as a heterogeneity and immobility organisational process.

2.3.1 Definition of virtual enterprise

Researchers in different fields give definitions of a virtual enterprise from different perspectives, making it difficult to find a satisfactory definition. The definitions given by the significant research are compared in Figure 2-1 by the following factors; the purpose in forming a virtual enterprise, the participants, the duration of collaboration, the structure, networking tools and shared resources.

Table 2-1: A sample of definitions of the term 'virtual enterprise'

Authors	Definitions	Comparison					
		VE Structure	Purpose	Participants	Duration	Networking tools	Sharing
Davidow and Malone (1993, Pp.6-8)	Virtual corporation refers to a number of independent vendors, customers, even competitors, composing a temporary network organisation through IT, to share the technology, cost and meet the purpose of the market demand.	Network organisation	Meet market demand	Independent vendors, customers, even competitors	Temporary	IT	Technology, cost and demand
Byrne et al. (1993)	The virtual corporation is a temporary network of independent companies-suppliers, customers, even erstwhile rivals-linked by IT to share skills, costs, and access to one another's markets. Evolving corporate model will be fluid and flexible-a group of collaborators that quickly unite to exploit a specific opportunity.	Fluid, flexible and quick network	Exploit a specific opportunity	Independent companies-suppliers, customers	Temporary	IT	Skills, costs, and access to one another's markets
Goldman (1994)	The VE is an opportunistic exploitation of existing resources distributed among traditional companies for responding to new market opportunities quickly, analogous to assembling a home audio system out of components from difference manufacturers.	Opportunistic exploitation	Responding to new market opportunities	Traditional companies	Brief	Analogous to assembling a home audio system	Components
Bolton (1996)	VE are temporary consortia or alliances of companies formed to exploit fast-changing opportunities. Members bring a wealth of experience and technology, also they share costs and skills to create the necessary infrastructure to support	Consortia or alliance	Exploit fast-changing opportunities	Companies	Temporary	Necessary infrastructure	Wealth of experience, technology, costs and skills
Camarinha-Matos and Afsarmanesh (1999,p.4)	A VE is a temporary alliance of enterprises that come together to share skills of core competencies and resources to better respond to business opportunities, and whose cooperation is supported by computer networks	Alliance	Better respond to business opportunities	Enterprises	Temporary	Computer networks	Skills of core competencies and resources
Goranson (1999, p.66)	VEs are opportunistic aggregations of smaller units that come together and act as though they were a larger, long-lived enterprise. The virtual here is meant to convey that many of the advantages of a large enterprise are synthesized by its members. In most interesting cases, this synthesis is temporary, built around a specific opportunity. When the opportunity fades, the VE vanishes into constituent parts to reassemble into other configurations.	Opportunistic and synchronised aggregation	Built around a specific opportunity	Smaller units	Temporary	-	-
Jagdev and Thoben (2001, P.448)	VE is a network of independent organisations that jointly form an entity committed to provide a product or service. Partners form temporary consortium to exploit a particular market opportunity while making extensive use of ICT for commination and sharing information. VE pools costs, skills, and core competencies.	Formed entity	Exploit a particular market opportunity	Independent organisations	Temporary	ICT	Information, costs, skills, and core competencies
Cruz-Cunha and Putnik (2006)	The concept of A/VE as "highly dynamic reconfigurable agile networks of independent enterprises sharing all resources, including knowledge, market, customers, etc., and using specific organizational architectures that introduce the enterprise's true virtual environments" introduces several new features that the "traditional" approach to the implementation and management cannot manage. Some of these features are: (1) the nature of inter-enterprise relations, in the context of sharing all resources, and (2) the dynamic reconfiguration of the enterprise, or new networked enterprise, organizational structure. [page viii]	Reconfigurable agile networks	-	Enterprises	Highly dynamic		All resources, including knowledge, market, customers, etc
Esposito and Evangelista (2014, p.149)	VE is a temporary, flexible, rapid, dynamic and reactive partnership among independent firms, based on extensive use of ICT that share costs, skills, and core competencies to exploit fast-changing market opportunities.	Partnership	Exploit fast-changing market opportunities	Independent firms	Temporary, flexible, rapid, dynamic and reactive	ICT	Costs, skills, and core competencies

These definitions show several shared viewpoints. Generally, the authors agree that a virtual enterprise has following essential characteristics:

- A virtual enterprise is an alliance or partnership and networked organisation that requires the necessary infrastructure for collaboration. This kind of alliance requires trust, commitment and a mutual interest among the partners to achieve their goals. The partners achieve their goals through the collaboration;
- A virtual enterprise is formed with purpose of exploiting fast changing opportunities and responding to it which are difficult for a single enterprise to achieve. It is the goal-oriented and commitment-based characteristics of a virtual enterprise;
- The participants involved in a virtual enterprise are independent legal entities either companies or enterprises of suppliers, customers, even competitors. Collaborating with legal entities build the institution-based trust;
- The partners 'network' with each other and collaborate temporarily and then disassociate after the business opportunity has passed. It is limitation of collaboration. This kind of alliance work together until they achieve the goal then disassociate or reorganised for another goal;
- The co-ordination and collaboration in virtual enterprise are directly based on ICT through building virtual environment. ICT adoption enables the companies to communicate and exchange information to save time and cost.
- The participants share freely information and technology, cost, demand, skills and core competency. This characteristic of a virtual enterprise gives possibilities to single enterprises to focus on their core competencies while outsourcing other needed resources. Similarly, these characteristics encourage partners receive cost-sharing advantages.

However, some similar terms have been found in the literature. Among others, the terms 'supply chain', 'collaborative network', 'virtual organisation', 'extended enterprise', 'virtual manufacturing' or 'electronic business', are commonly used. Although Camarinha-Matos *et al*. (2009) clearly clarify the concepts of collaborative network, supply chain, virtual organisation, extended enterprise and virtual manufacturing, this study shares the perspectives. A collaborative network is a network consisting of a variety of entities (e.g. organisations and people) that are largely autonomous, geographically distributed, and heterogeneous in terms of their operating environment, culture, social capital and goals, but that collaborate to better achieve common or compatible goals, thus jointly generating value, and whose interactions are supported by computer network. A collaborative network is a general concept that contains all other networks. A virtual enterprise could be any kind of network, and some organisational forms are conceptualised by their purpose, the role of the participants, the structure and characteristics and the rules of collaboration and co-operation. ‘Virtual enterprise’, ‘virtual organisation’ and ‘extended enterprise’ are all terms for opportunity-driven, goal-oriented collaborative networked organisations.

A supply chain is a physical network of organisations that are involved through upstream and downstream linkages in the different processes and activities that produce value in the form of products and services in the hands of the ultimate consumers (Christopher, 1992). A supply chain could be a product-line based long linkage that is not fully integrated, with the purpose of increasing income while decreasing time, cost and buffering for the term of the collaboration. Indeed, the supply chain between the collaborating enterprises has to be set up before they ‘switch’ to extended or virtual enterprise mode (Jagdev and Thoben, 2001).

The baseline for an extended enterprise is always two or more willing enterprises that have chosen to concentrate on their core-competencies and *wish* to extend their activities into other enterprises to increase their competitiveness by achieving cost-, time- or quality-related advantages regarding their respective offerings (Jagdev and Thoben, 2001). An extended enterprise represents a concept typically applied to an organisation in which a dominant enterprise ‘extends’ its boundaries to all or some of its suppliers (Camarinha-Matos *et al*., 2009). An extended enterprise can be viewed as a particular example of a virtual enterprise. Example of extended enterprises are: outsourcing, 3PL and 4PL collaboration.

A virtual organisation represents a concept similar to a virtual enterprise, comprising a set of (legally) independent organisations that share resources and skills to achieve their mission or goal, but that is not limited to an alliance of profit-orientated enterprises (Camarinha-Matos *et al*., 2009). Beside profit making companies, institutes and government agents could be included in a virtual organisation. A virtual enterprise is therefore a particular case of a virtual organisation. Xu *et al*. (2002) and Gunasekaran *et al*. (2008) view a virtual enterprise as different from virtual manufacturing, which is the use of IT and computer simulation to model real world manufacturing processes for the purpose of analysing and understanding them (Gunasekaran *et al*., 2008). In this view a virtual enterprise is a co-operation partner among enterprises, which is based on virtual manufacturing (Xu *et al*., 2002).

Electronic Business (e-Business) is the use of the Internet, along with other electronic means and technologies to conduct business-to-consumer, business-to-business, and business-to-government collaborations (Ghenniwa *et al*., 2005). E-Business includes buying items or developing new items with partners during the virtual enterprise's operational period. Therefore, it is a function of a virtual enterprise to link between the virtual enterprises or suppliers and customers. The electronic links create an opportunity for a much more responsive channel for end-user registration and feedback, service and after sales (Camarinha-Matos *et al*., 1998).

Based on these shared viewpoints of definitions and analysis of similar terms, the virtual enterprise concept used in this research is defined as:

> 'An ICT-based temporary and dynamic networked organisation made up of independent enterprises that are able to share information and technologies, costs, risk, skills and core competencies to exploit fast-changing market opportunities and to respond to them together to achieve competitive advantages'.

2.3.2 Virtual enterprise formation

A virtual enterprise is generally formed as follows: when an enterprise with a big project in hand is willing to invite other enterprises to complete the project for reasons such as limited capabilities or lack of resources, the initiating enterprise (called the 'principal enterprise', 'virtual enterprise coordinator' or 'broker') breaks down the project into a number of sub-projects and then invites other enterprises to tender the sub-projects in brief period. As a result, the co-operation between the principal enterprise and its selected number of partners form a virtual enterprise that has the purpose of completing the project on time, with a higher quality standard and lower cost.

To work out and achieve the objectives of a virtual enterprise, every stage of the lifecycle of a virtual enterprise needs to be planned, organised, optimised and controlled. A typical virtual enterprise has a lifecycle that consists of four major phases: creation, operation, evolution, and dissolution (Camarinha-Matos *et al*., 2009). The creation phase is the initial stage that influences all the following stages of a virtual enterprise's life cycle. The major required functionalities required in this phase are: network definition/parametrisation, negotiation, join/leave functionalities, definition of access rights, sharing level, partner selection, etc. (Camarinha-Matos *et al*., 1998). The selection of the proper partners for the formation of the virtual enterprise is a very important and critical activity that has attracted more research attention in dynamic conditions. Decisions on partner selection have a significant impact on responding rapidly and effectively to unanticipated opportunities and on proactively developing potential solutions. When a partnership has to be considered among more than two enterprises, these issues are exponentially more complex (Sarkis *et al*., 2007). Therefore, most researchers break the problem down into subsectors to evaluate multiple attributes (e.g. cost, risk and time) to reach multiple objectives in multiple time periods.

Mikhailov (2002) suggest a new 'fuzzy' programming method for the assessment of the uncertain weighting of partnership selection criteria and uncertain scores of alternative partners, in the basic framework of an analytical hierarchical processing. The proposed fuzzy ranking method uses interval pairwise comparison judgements rather than exact numerical values of the comparison ratios and transforms the initial prioritisation problem into a linear program. Ip *et al*. (2003) developed a rule-based genetic algorithm with embedded project scheduling to solve the risk-based partner selection problem for virtual enterprises.

Huang *et al*. (2004) propose a two-stage selection framework based on the distinction between hard and soft factors that affect the partner selection process. Stage one identifies potential partner candidates who can meet the criteria of timeliness, quality and price for the required products or services. Stage two focuses on the assessment of their co-operation potential. Zhao *et al*. (2005) propose a heuristic algorithm based on particle swarm optimisation simulated annealing to solve partner selection problems to minimise the risk of failure and processing time in VEs. This is the same as the objective to select the optimal combination of partner enterprises for all sub-projects to maximise the success of the project, including the probability of finishing the project by the due date.

Sarkis *et al*. (2007) introduce a conceptual model for partner selection and agility, as measured by performance of time, cost, robustness and scope, in virtual enterprises. The analytical network processing approach was proposed for decision making for partner selection based on the evaluation of multiple attributes according to the proposed factors. An agent-based multi-level quantitative framework with a control algorithm for partner selection in inter-organisational supply chains was introduced by Ilie-Zudor and Monostori (2009) to support the decision making process in effectively selecting an efficient and a compatible set of partners. The agent-based paradigm is helpful for automatically evaluating the proposed criteria. Different agent behaviours were introduced and modelled, including profit-oriented, safe and greedy behaviours. A 'what-if' simulation model was developed to evaluate the process and make it possible to analyse the effects of different agent behaviour.

Crispim and Pinho de Sousa (2009; 2010) propose an exploratory process to help the decision makers to obtain knowledge about the network. This can identify the criteria and the potential partners that best suit the needs of a project for each virtual enterprise. The processes they propose involves a multi-objective *tabu* search meta-heuristic and a fuzzy TOPSIS algorithm. Many kinds of mathematical models, including particle swarm optimisation, simulated annealing, analytical network processing, artificial neural network, fuzzy methods are used, and simulation modelling is sometimes tried for partner selection. Case studies and examples are often conducted for the validation and verification of proposed models and sensitivity analysis is employed to study uncertainty in the output of a mathematical model that is apportioned to various sources of uncertainty in its inputs.

Additionally, Davidrajuh (2003) introduced a new e-commerce tool for supporting the formation of a virtual enterprises. Its characteristics include; inviting potential collaborators, the formation of a virtual enterprise and some issues in the selection stage. A proposed methodology based on pull-and-push type material flow control uses a deterministic Petri Net model. The characteristics of a supporting tool have also been discussed with support for the following; collaborative 'inter-enterprise' planning efforts, improved pipeline visibility and demand visibility and easy realisation.

Process planning, design and scheduling for participants, and their activities in a virtual enterprise, are another issue that received much attention from researchers. Time, resource, cost and demand are perceived as the most serious restrictions for process planning. Rupp and Ristic (2000) introduced the X-CITTIC system as a part of ESPRIT project 20544, dealing with the design of planning, scheduling and control systems based on an approach that leaves as much responsibility and expertise for optimisation as possible to the local planning systems while a global coordinating entity ensures best performance and efficiency of the whole supply chain. A centralised fine planning system networks all the virtual enterprise units and produces rough due dates based on capacity models of the local manufacturing units. It then and optimises both local and global order flows through the virtual enterprise.

As an IntaPS project, the integration of process planning and production control is discussed by Denkena *et al*. (2003). The planning and scheduling process consists of the three main phases of negotiation, verification and re-negotiation between resource agents and order agents on the shop floor. Kovács and Paganelli (2003) presented web-based solutions as an architecture for planning, design and operation for virtual enterprises to manage large, expensive, multi-site, multi-company projects. To integrate as many available solutions as possible, a management solution for complex logistics flows for distributed enterprises and decision support systems (DSSs) is included in the architecture.

Makatsoris and Chang (2004) and Makatsoris *et al*. (2004) present a reference design architecture as a part of the X-CITTIC project, that is capable of performing demand-driven collaborative supply chain planning and fulfillment for distributed enterprises. The system integrates three components; order management, planning exchange and capacity handling. The authors Makatsoris and Chang (2004) and Makatsoris *et al*. (2004) conclude that a prototype planning, scheduling and control system is aimed at improving manufacturing performance in a microelectronics virtual enterprise by integrating the heterogeneous manufacturing systems and by bridging the gap between the higher planning levels and the lower shop floor control levels.

Fung *et al*. (2005) presented a virtual warehouse system relying on IT and knowledge to plan inventory efficiently. Three main components include; a simulation model for inventory planning, a production optimisation tool and a knowledge-based allocation support module, all executed within the system. An agent-based architecture of the virtual enterprise and a production planning model were introduced by Ouzizi *et al*. (2006) in which the partners of the virtual enterprise were modelled as agents with their own negotiation and planning processes and behavioural models. The planning and decision tools used a linear programming model. Additionally, Chokshi and McFarlane (2008) propose a distributed approach to reconfigurable control of the continuous process operation of a virtual enterprise, with the basic process element types; design, operation and implementation. The proposed approach distributes the functionality of process control into several reconfigurable process elements. These elements, while having a stand-alone capability for making their own control decisions, are also able to reconfigure themselves into alternative process schemes which evolve with the changing requirements. Two different process examples, including the identification of process elements in semi-continuous processes and the operation of process elements, were introduced to test the proposed architecture. Mathematical optimisation models for planning the required information and knowledge of demand, resources, costs, risks, and technology-sharing processes in a virtual enterprise help to predict the rational effectiveness and benefits. To co-ordinate a virtual enterprise with members performing different tasks and having different core competencies, a revenue sharing contract was modelled with optimal productive efforts, risk taken and incentive intensity by Chen and Chen (2006) and a two-period model was proposed including:

- Period 1, the allocation of total revenue to members;
- Period 2, the evaluation of all members' productive efforts.

The mathematical optimisation problem was discussed in terms of cost, the enterprises' productive efforts and the profit function.

Chen *et al*. (2008b) introduced a new approach to evaluating the core competencies of virtual enterprises. An evaluation index system was measured with three aspects; innovative strength, the effect of capital investment and corporate credibility. The numerical analysis was conducted for explaining the proposed model. Akanle and Zhang (2008) proposed and tested the multi-agent system based methodology for optimising supply chain configurations including virtual enterprises to cope with customer demand over a period of time. The problem had been divided into three levels:

- **1st level**, find the optimum resource combination for order at a certain time;
- **2nd level**, find the best allocation resource combination to the customers' order by using a simulation algorithm and genetic algorithm;
- **3rd level**, make a quality evaluation of the supply chain structure.

A globally optimal local inventory control policy for multi-stage supply chains is introduced in Hennet (2009) as a sequence of linear dynamic models with distributed delays. Multi-stage production often motivates the design of a supply chain as a virtual enterprise, gathering in an enterprise network the most effective companies for each production stage. The author emphasized that the collection of local inventory policies is equivalent to the global policy which minimises the long-term average cost of the whole supply chain. Hassan *et al*. (2009; 2010) propose an auction policy aimed at reducing the cost and time of negotiation and at forming a dynamic collaboration platform among cloud providers. As a fundamental of collaboration, the multi-objective optimisation model for partner selection uses individual information and past collaborative relationship information, which is seldom considered in other models.

Affiliation or dissociation decision models in collaborative networks of enterprises were introduced by Yoon and Nof (2011) with optimum demand and capacity sharing. The experimental results and analyses indicate that a single enterprise always prefers to affiliate with the collaborative network in terms of demand fulfillment rate and total profit. The collaborative network should, however, dissociate from a member enterprise when that enterprise's mean demand (or capacity) is less than a value that can be calculated relative to the mean demand (or capacity) of all the other collaborating enterprises.

To optimise the sharing of resources, costs and profits and to reduce cost and time, linear sharing rules were employed by Chen and Chen (2006) and genetic algorithm was used by Akanle and Zhang (2008) and by Hassan *et al*. (2009; 2010) and Yoon and Nof (2011). In this research, numerical analysis, examples, experiments and case studies were conducted to evaluate the proposed approaches. Additionally, some studies attempt to optimise the continuous and discrete problems found during virtual enterprise formation when based on simulation. Simulation-based optimisation research has been conducted in two ways; by constructing a simulation model to find the optimal solution and by using a simulation process for the optimisation of a real system.

Based on the SCR model, Tang *et al*. (2004) developed an enterprise simulator that provides a more fundamental understanding of the impact of e-Solutions across operational supply chains in terms of both standard operational and financial measures of performance. Tang *et al*. (2004) state that this enterprise simulator allows for a complete supply chain to be modelled across four key applications; control system design, virtual enterprise, cross-supply chain performance metrics and the supporting e-supply chain design methodology. An optimistic protocol-based parallel discrete event simulation algorithm is modified to enable the implementation of the virtual enterprise concept, integrating semi-autonomous models of production cells, factories, or units of a supply chain by Roy and Arunachalam (2004). Their parallel discrete event simulation algorithm maximises parallelism and maintains the causality relationships between system events in a virtual enterprise. Conservative and optimistic schemes are compared and the proof of correctness and performance of the algorithm are assessed.

Rolón and Martínez (2012) suggest an extended autonomic manufacturing execution system to allow ‘selfish behaviour’ and adaptive decision-making in distributed execution control and emergent scheduling. The agent learning is assumed continuously to optimise the processing routes based on the cost and reliability of alternative resource agents (i.e. servers). Two reinforcement learning algorithms are implemented to simulate the learning curves of client–server relationships in the manufacturing execution system. Simulation has been chosen as an analytical tool for virtual enterprise formation by imitating a real system and the operation of that system. The simulation helps to find an optimum solution using an iterative process algorithm. A case study and prototype are used to test the proposed models. An access control model for the security of virtual enterprises is another issue that receives attention from researchers. Some examples are given below:

Chen *et al*. (2008a; 2008b) introduced a role-based access control model for the security and management of a virtual enterprise. According to the general information storage and function distribution of a virtual enterprise, the relevant sets of the role-based access control model are classified into three specific sets; the role set, the operation set and the object set. The access rules of the enterprises in the virtual enterprise are based on this classification. An example of a virtual working team including suppliers, manufacturers and franchisees located in Guizhou, Guangdong and Shanghai was used for the validation of the proposed model. Xu *et al*. (2012) introduce a cross-realm Service-oriented Architecture (SOA) based on an authentication protocol that requires neither credential conversation nor establishment of any authentication path between the participating services in a business session. Multi-party business sessions are used with message routing, authority and network threats. The two core protocols are:

- Protocol 1, introduction of a new session partner;
- Protocol 2, authentication protocols between two existing partners.

All the protocol messages are written in eXtensible Markup Language (XML) documents and are transported by web service protocols. The correctness of the protocol is formally analysed and proven using a production-quality grid middleware system.

In solving security issues in virtual applications by applying systematic threat analysis methods to isolated systems at design time, Badr *et al*. (2011) propose a holistic approach that integrates security requirements in SOA-based business processes. In this system, agreements are processed by a dedicated matching module with respect to security requirements and preferences to select business services, and then compose their appropriate technical security services. Integration of a security policy is developed with protection level agreements. End-to-end security is improved by annotating service descriptions with security objectives used to generate convenient quality of protection (QoP) agreements between partners. The SemEUse architecture was constructed with a service layer and a semantic layer. A case study from the crisis management field explains the proposed integration of the security policy, implementing a collaborative process between different organisational units involved in emergency crisis management (e.g. fire and rescue services, the police and hospitals, etc.).

The operation phase is a key stage where the member enterprises execute the whole business process collaboratively as quick and correct as is possible. This phase requires functionalities such as; basic information exchange and sharing, order management, incomplete orders processing, distributed and dynamic planning and scheduling, distributed task management, and co-ordination (Camarinha-Matos *et al*., 1998). When minor changes in membership, roles, or daily operating principles are needed, an evolution phase could be conducted simultaneously with the operation phase.

To fulfill the goal of a virtual enterprise, the development of dynamic (multi-period) and flexible approaches is important because of the temporary nature of this type of collaboration (Crispin and de Sousa, 2010). Many kinds of models and frameworks have been proposed to integrate different components, (e.g. agents, software, activities and systems) to work together in the operation phase to fulfill the desired goals of the virtual enterprise. For virtual enterprises to achieve profitability in supply chains, some studies propose organising approaches or strategies to co-ordinate the managerial function between participants and to organise resource, information and functions.

For instance, Fischer *et al*. (2001) introduce a multi-agent co-ordination infrastructure that represents the application of a multi-agent system in the context of supply chain management in virtual enterprises. A framework for a supply web management system (i.e. the TeleTruck system) is proposed with nodes and co-ordination policies and mechanisms of intelligent autonomous software agents. A simulated trading algorithm was chosen to optimize task allocation by successively selling and buying tasks in several trading rounds and agent-based information sources were used for a software repository.

Klen *et al*. (2001) propose an analytic system for supply chain co-ordination in the virtual enterprise environment. A distributed business process management system (DBPMS) was developed within the scope of the ESPRIT project PRODNET-II, and its advanced co-ordination based functionalities were introduced. The proposed system provides a means for obtaining, analysing, making available and managing the information from and about a virtual enterprise, enabling the enterprises to make their logistics more efficiently using an integrated information-based supply chain management. DBPMS functionalities are comprised of four blocks; the virtual enterprise supervisor, decision support for logistics management, the configurator and inter-operation. The main modules of the DBPMS include monitoring, conflict detection, reactive decision-making, simulation alternative, virtual enterprise analyser, control, supervision clause configuration and integration and interoperation mechanism.

Zaidat *et al*. (2005) developed an engineering framework for organisation networks. They view extended enterprises, virtual enterprises and supply chains as examples of new organisation forms then term them collectively as ‘enterprise networks’. The Generic Organization Network Modeling Concept (GONMC) and its principles, methodologies and concepts with dynamic and structural model was introduced on which this the General Organization Network Reference Architecture (GONRA) was developed. The framework used three dimensions and two modelling views (i.e. dynamic and structural) for modelling the operational and organisational structure of the network and business. A small and medium enterprise (SME) network located in the Rhône-Alpe region of France was chosen for the application of the proposed framework. An agent-based supply chain-oriented platform, which was introduced by Chen *et al*. (2011) to support virtual enterprise management, was constructed with the technology of network, communication and control, to achieve dynamic organisation and management. The interior structure of a platform framework included the organisation structure of a virtual affair co-operation center and several member enterprises (e.g. supplier, manufacturer and franchiser).

Research focused on the co-ordination of entities or organisations in virtual enterprises suggests that correct co-ordination among independent entities will bring benefits including; support for decision making, agility, flexibility, robustness, scalable, and competitiveness as included in the CIMOSA, GERAM and VERAM architectures. From a holistic and systematic point of view the design, control and integration of a system is the one of the biggest challenges facing distributed enterprises in different environments with heterogeneous information systems. Some researchers have attempted to co-ordinate whole systems by proposing a seamless connection between different computing systems and software applications physically or functionally in operating the virtual enterprise (Badr *et al*., 2011).

For instance, Fürst and Schmidt (2001) propose an internet and XML-based electronic data interchange integration approach. First, the system architecture was developed, based on the advantages of using the Internet/intranet and XML. The Data-Extractor was used for the data transmission between the different systems of virtual enterprise to handle the requests from the users working with standard Web browsers. The system functionality was implemented using Unified Modeling Language (UML). Finally, based on the case of BMW Motors Steyr in Austria, a prototype was tested, which provided the motivation to connect different systems.

Internet-based e-Commerce techniques are applied with agent technology in a proposed approach (Turowski, 2002) for supporting distributed, logically integrated inter-company data exchange, procurement, and co-ordination of production in mass customisation. The approach provides automated inter-company communication using a typical example of an XML-based EDI messaging system. Different parallel negotiation tasks with manager/contractor contract nets are included.

Georgakopoulos *et al*. (2002) introduce Collaboration Management Infrastructure (CMI) as process-based service integration through the Service Oriented Process (SOP) model that permits modelling of e-Services and provides for e-Service integration to construct efficient multi-enterprise supply chains. The CMI system implements SOP and uses a semantic broker that has knowledge about the service capabilities and quality. Multi-enterprise processes in CMI are capable of on-the-fly choice of the service providers that are best suited to its objectives, although testing tools are not included.

With the aim of addressing business integration for virtual enterprises, Gou *et al*. (2003) developed a framework for virtual enterprise operation management. In this framework both the distributed business process model and the model of the virtual enterprise itself are established. The former provides the functional basis of the virtual enterprise operation, while the latter provides its structural basis. The two models are integrated through the loading from the distributed business process model to the virtual enterprise model. Through such model separation and integration, business process management for the virtual enterprises is enacted and business integration for the virtual enterprises is achieved.

An Internet-based object-oriented paradigm for collaboration management in virtual enterprises is described by Lin and Lin (2004). In this paradigm, the collaboration management mechanism was divided into three layers, including; the commitment layer, the role layer and the activity layer. The establishment of commitment, the co-ordination between roles, and the interaction and co-ordination between activities is achieved through the proposed architecture. This method describes contractual behaviours between virtual enterprise members, using statements in object-based timed temporal logic for describing constraint rules.

Cheng *et al*. (2004) developed holonic information co-ordination systems with failure recovery consideration. The functional architecture of the Internet-based holonic information co-ordination system consists of generic holons and a sequence diagram of communication holons as follows:

- The generic holons are first developed by adopting the technologies of the distributed object-oriented approach with a common object request broker architecture infrastructure;
- The communication holons are then developed with a set of basic holonic attributes, such as intelligence, autonomy, and co-operation, which are generated by inheriting properties from the generic holons. Communication holons are employed to establish the holonic information co-ordination system. A case study illustrates the use of a holonic supply chain

system with three holonic companies at the Institute of Manufacturing Engineering, National Cheng Kung University, Tainan, Taiwan, R.O.C. (Cheng et al., 2004).

Molina et al. (2005) demonstrate the results of the XCETER project with collaborative product development (from concept to prototype) of high-technology products. A virtual collaborative engineering environment is introduced and its development is described. The web-based application is described using a manufacturing-aided service, a surface mounting technology tool (i.e. SMTAdvisor) and the Supporting Plastic Engineering Development environment (i.e. SPEED). Practical experiments on collaborative product development were conducted between UC-Berkeley and Technólogico de Monterrey (Molina *et al*., 2005).

The business process-oriented heterogeneous systems integration platform was developed for networked enterprises integration by Li *et al*. (2010), aiming at solving the problems of system integration and cross-system interoperability. A business process-oriented platform architecture was developed based on SOA and business process modelling (BPM). The service access agent mechanism ensures; cross-domain identity authentication, service authorisation, and information transmission security, for reasons of system security. A graphic service process method models service orchestration and an enterprise service bus provides JAVA-based service orchestration. Two cases compromising a grain trade market company and the AAA call center illustrate the use of the platform in practice.

Using appropriate ICT, Internet and mobile technology to build up speedy, flexible, responsive, agile, adaptive and collaborative business processes is still a big challenge in virtual enterprise integration in supply chains. The successful formation of a virtual enterprise needs a complete information and communication framework to share information at the right time, at the right position and for the right product and services. The agent-based Business-centric Knowledge Oriented Architecture (BCKOA) provides intelligent enterprise integration (Ghenniwa *et al*., 2005). The BCKOA model has two layers; the distributed-computing layer and the integration service layer. The Coordinated Intelligent and Rational (CIR) agent architecture includes basic components (e.g. the problem solver, interactions, and communication). In this architecture agents have several roles including; user-interface, business specific services, market services, and integration services. A dynamic trading mechanism (the Vickrey auction) and supply chain integration for the e-marketplace are used. An abstract example of ABC Corp and XYZ Inc. validates the proposed architecture.

An agent-based approach for the co-ordination of decisions in a multi-site system is described by Monteiro *et al*. (2007). Each enterprise is defined as an autonomous node called a virtual enterprise node that performs simultaneously at the local and global levels. Exchanges between the virtual enterprise node ensure the autonomy of decisions, and guarantee the consistency of information and material flows. Agents can negotiate with each other to find a global solution. Two complementary virtual enterprise node agents are the Negotiator Agent for external interactions and the Planner Agent for planning internal decisions. Another two agents are the Tier Negotiator Agent, which works at the tier level only and the Supply Chain Mediator Agent, which works at the level of the enterprise network. Based on the activities modelled by Petri Nets, an agent architecture representation is developed and planning and negotiation processes are set up. The research is extended in Monteiro *et al*. (2010) to validate the proposed approach by simulation. The main purpose of the approach is searching for a global performance while controlling the architecture with local bilaterally negotiated co-decisions. The approach was tried on a problem in which enterprises are searching complementary resources (e.g. stocks, production capacities, components and/or transport capacities) to deal with unexpected orders differing from the planned forecast.

The design and implementation of a unique bid auction application for procurement automation within supply chains embedded in an extended or virtual enterprise was introduced in Jagdev *et al*. (2008). Semantic web services technology was used to provide automatic integration of distributed autonomous systems, with independently designed data and behaviour models. Three main activities were used as tools, including; a web service modeling ontology, a web services modeling language, and a web services execution environment. Several auction types were examined (e.g. English auction, Dutch auction etc.) and an auction/negotiation component architecture is developed, identifying the relationships between components.

An ontology-based knowledge representation approach is introduced in Wang *et al*. (2011) to provide a semantic interoperable environment to enable automatic negotiations in the virtual enterprise. Based on an ontology, the multi-agent system framework was introduced with specialised interfaces for the VE participant’s service level and a core ontology based on the multi-agent system platform. An ontology-based knowledge representation approach includes; ontology construction, ontology matching and integration. Ontology matching unit finds out semantic correspondences between separate ontologies by identifying semantic similarities, which are calculated based on the shortest path (L) and the greatest depth (H) between the hypernyms of two terms. Ontology-based multi-agent system bid negotiation is carried out with ontology-based correspondence retrieval, bid negotiation, and negotiation performance. The approach suggests multi-agent system-based negotiation processes *via* the Internet. The most important criteria in vendor evaluation are; cost, price, quality, delivery performance, time, capacity and service. Some approaches seek to develop standard models for data and information exchange to manage effectively the sharing of information in virtual enterprises.

Giachetti (1999) proposes the use of standard information models to support the product realisation process in virtual enterprises. The standard manufacturing systems information model is written in EXPRESS (a standard data modelling language for product data) and adheres to the modelling methodology Standard for the Exchange of Product model data (STEP) to enable the creation of a neutral information format for the easy exchange of information on manufacturing process capability.

Yao and Trappey (2000) define a standard data model for supporting the configuration management of Personal Computer (PC) design and redesign. The ISO product data representation and the exchange standard (ISO10303) Application Protocol 203 (AP203) were adopted to study and identify the required data types and interpret them into an ISO10007-based standard configuration management procedure. This enables a configuration management-related data to be exchanged using a common data model among heterogeneous product data management (PDM) systems of the supply chain partners for data sharing and virtual enterprise integration. For the implementation of prototype some function had been introduced including product definition and product structure for integration, configuration assembly analysis for control, and enables information exchange between partners.

Choi *et al*. (2003) introduced XML-based Integrated Process Management - Process Definition Language (IPM-PDL) for supporting the design, analysis, automation, and management of business process knowledge. The IPM-PDL is translated into a coloured Petri Net, enabling various analyses and simulations to check the validity of a new process and to estimate its performance. A prototype system called ProcessWare uses the language to enact a business process scenario adopted from the CrossFlow project. The relationship between AGFIL, an insurance company, and Lee Consulting Services was used for evaluating the prototype system (Choi *et al*., 2003). To integrate and manage the sharing and exchange of information, many of the concepts already described meta models are used, including the STEP production model, the EXPRESS language, ISO 10303 and ISO 10007 standards and XML.

Blomqvist *et al*. (2005) describe an approach to the configuration of an integrated network of SMEs based on a shared domain ontology. The approach focuses on the application-driven development of ontologies and shared views of semantic community portals. Two types of ontology are defined; a domain ontology describing knowledge of a certain domain and an application ontology describing the domain knowledge which is required to solve a task. The supply chain configuration is 'parameterised' by sector with specialisation as the input parameter, and time and cost as the output parameter. An ontology matching model includes three situations including; domain component refinement, task knowledge refinement, and domain and task knowledge refinement.

A scalable semantics-based resource registration mechanism called SATOR supports the dynamic integration of heterogeneous enterprise resources (Liu *et al*., 2005). The architecture of SATOR has registration patterns with the responsibility of maintaining the registered resources and their semantics. Two patterns are represented including newborn and reuse patterns. The registration process has three steps; (e.g. identifying the semantic relationships, defining the semantics and registering the instances). A real-world project based on a large-scale electronic manufacturing enterprise was used to validate SATOR, using the grid application platform AmGrid to enable resource registration and utilisation in an open environment.

The supply chain model ontology was developed by Tsou (2008) using the IDEF5-based ontology language and the Ontolingua editor. First, a basic supply chain model and an ontology based on the IDEF5 and Ontolingua ontologies are developed and compared. The Ontolingua model is an ontology of the virtual enterprise. Cai *et al*. (2010) describe an ontology-based prototype intelligent system called SWMRD (Semantic Web-based Manufacturing Resource Discovery) for distributed manufacturing collaboration across a ubiquitous virtual enterprise. The system infrastructure of SWMRS has four layers including; the resource layer, the ontology layer, the meta ontology layer and the user layer. SWMRD also has four interactive functional modules; the resource acquisition and annotation module, the ontology and meta-ontology modelling module, the ontology and meta-ontology repository, and the knowledge retrieval module. It employs an ontology-based multi-level knowledge retrieval model that is devised to extend the traditional information retrieval approaches based on keyword searches. It has the following integrated capabilities; graph search, semantic search, fuzzy search and automated reasoning to realise the intelligent discovery of manufacturing resources (e.g. to facilitate more flexible, meaningful, accurate and automated resource discovery). The ontology supports interoperating software agents, increasing communication and knowledge sharing between entities by limiting complexity and organizing information. It also facilitates flexibility, agility, accuracy and automation in the information flow. Some process supporting tools for virtual enterprises include; a quality information management system, an order promising system, a cost and performance measurement tool, broker and an automated production development system. These tools are used to enable a combination of; agility, flexibility, intelligence, competitiveness and effectiveness in a dynamic business network and to support quality management communication between participants of value chain. Most research in this category suggests the use of a web-based integration system for the implementation of tools:

For instance Tang and Lu (2002) describe the Internet/Extranet/Intranet-based Quality Information Management System (IEI-QIS) for the following tasks; to capture quality information from both internal and external parties, to facilitate the communication environment and to share quality information among enterprises, customers and suppliers. For the integration tasks, a browser/server and the three-layer system architecture of IEI-QIS (i.e. the access layer, the application layer and the supporting layer) are included. An information and knowledge models is proposed by Liu and Young (2004) to support global manufacturing co-ordination (GMC) decisions. The model consists of three sub-models; the manufacturing model, the order model and the product model. These are combined into an integrated model that captures the required information and knowledge to support GMC decisions. The experimental system and its functions were validated using information collected from the Aeolus Automotive Corporation in China.

Gunasekaran *et al*. (2005) describe a framework for measuring virtual enterprise costs and performance. The framework emphasises the measurement of costs and performance in the virtual enterprise and along the supply chain to enhance competitiveness in global markets. A performance-based costing (PBC) system proposed has 9 steps including; defining the objectives, developing the team, addressing organisational issues, identifying value creation areas and drivers, establishing value area cost pools, identifying secondary value drivers, and relating and implementing value areas and objects.

Molina *et al*. (2007) proposes the concept of the virtual enterprise broker as an innovative model to design and create build to order SCs. The virtual enterprise broker's strategy is described in terms of core processes and competencies. The virtual enterprise broker operational model and accompanying operational framework are intended to support the creation of dynamic supply chains using a build-to-order model. The specific case study of IECOS S.A de C.V, a brokerage company, was created at CIDYT (Centre of Design in Innovation and Technology) of Tecnologico de Monterrey, Mexico was used to demonstrate how the virtual enterprise broker strategy was implemented in various industrial scenarios related to supply maintenance tooling for the aerospace industry, standard parts for capital goods equipment and design and manufacturing of medical devices.

A reference framework following a proactive approach for product lifecycle management was introduced in Marchetta *et al*. (2011) to solve the issues of capturing, sharing and maintaining product information in virtual enterprise formation. The proposed framework consists of a business process model, a product information model, and an architecture of application based on intelligent agents. Co-ordination, collaboration and information exchanges are supported through interfaces exposed as services to provide proactive roles. Product information models to support product lifecycle management integration are represented in the form of UML class diagrams. The final stage of co-operation is the metamorphosis and dissolution phase. After a business goal is achieved, the virtual enterprise partners can either metamorphose into a new organisation (changing its form) with a new purpose based on the knowledge that they accumulated during the short lives of the virtual enterprise or dissolve and remain eligible to join other virtual enterprises. Hence, although virtual enterprise affiliation offers the overall collection of knowledge and information within a brief time, any liability and legal agreements after dissolution need to be considered as a part of a plan for joining a virtual enterprise to build up trust and reliability. Support for virtual enterprise dissolution is, so far, a subject almost absent from research projects. In the real case, most obligations during virtual enterprise operation and after dissolution are co-ordinated by agreements that enterprises mutually agree when they join in a virtual enterprise. Concepts related to virtual enterprise formation reach a certain level in academic research, but there are many barriers to implementing these theoretical aspects in practical applications. Therefore, research into how to implement robust virtual enterprise s in practical environments efficiently and how to sustain the competitive advantages of virtual enterprises in supply chains need to be considered. By understanding the main building blocks of virtual organisations and their management processes, it will be possible to formulate a strategy and design process for developing effective virtual enterprises.

2.3.3 The technological infrastructure

The technological infrastructure automates the information traffic in the virtual enterprise for supporting the cross-organisation business process (Chalmeta and Grangel, 2003). When infrastructures comprise components from different technologies and vendors, it is difficult to determine which component (or tool provider) is responsible when something goes wrong with such complex virtual enterprise systems (Camarinha-Matos and Afsarmanesh, 2003). Many efforts have been made to integrate systems for collaboration in virtual enterprises through the technological integration by the understanding of information flows by the different partners. These integration models have usually been implemented by means of a multi-agent system supporting information sharing and querying and web services to guarantee the interoperability of the software components. The Internet, intranets and extranets have been used for communication networks and web services, and SOAs have been discussed as a convenient architecture to reach the required interoperability level. When dealing with enterprise architecture, enterprise integration, and interoperability a certain number of standards and protocols have been considered.

Agent-based modelling has become an increasingly attractive methodology in modelling complex systems such as virtual enterprise formation. An agent can be viewed as an encapsulated problem-solving entity that possesses the following properties (Wooldridge and Jennings, 1995).

- **Autonomy**; agents can perform most of their tasks autonomously and have independent control over their actions and internal states;
- **Proactivity**; agents can perform their tasks in a goal-directed manner;
- **Social ability**; agents can interact and coordinate with other agents and persons;
- **Responsiveness**; agents can react to unforeseen events and changes in the environment in time;
- **Adaptability**; agents can adapt to a continuously changing environment.

Agent-based systems promise to offer both problem solving services and flexibility needed for a virtual enterprise, and the agent nodes represent either enterprises or the decision-making unit. The loose coupled network system that is formed by a number of agents coming together to solve a problem referred as a multi-agent system. Currently, many development platforms for multi-agent system are being developed and most of them are based on Java. Some of these platforms, (e.g. FIPA OS, JADE, ZEUS) follow the Foundation for Intelligent Physical Agents (FIPA) specifications and several of them are open-source (Camarinha-Matos and Afsarmanesh, 2003). Under the multi-agent system paradigm, a virtual enterprise can be portrayed as a set of intelligent agents belonging to different virtual enterprise partners, each responsible for one or more activities and interacting with other agents to accomplish the planning, scheduling and transaction tasks. multi-agent system can support distributed collaborative problem solving by agent collections that dynamically organize themselves. multi-agent system acts as a co-ordination unit, which seems suitable in developing an automated distributed manufacturing process, has been used successfully in distributed systems in the internet. In the literature, three research cornerstones in multi-agent system in a virtual enterprise, have been found including; communication between agents, co-ordination of agents' actions and negotiation or decision making to solve conflicts between agents.

Since the 1980s, data integration has been assumed to be of importance as at the heart of integration were common distributed, interconnected databases (e.g. MRP or CAD/CAM systems) and data exchange formats (e.g. IGES, STEP, EDI, etc.) (Vernadat, 2007). Data integration involves combining data that resides in various sources and providing users with a unified view of these data. Data integration appears with increasing frequency as the volume and the need to share existing data explodes. It has become the focus of extensive theoretical work, and many problems remain unsolved. In management circles, people refer to data integration as 'Enterprise Information Integration'. Although the literature includes diverse infrastructure tools as are reviewed in Section 2.4.2 and a number of shared viewpoints are identified are shown in Table 2-2.

Table 2-2: Overview of technological infrastructure

Issues	Shared literature evidence
Internet-based network	Camarinha-Matos *et al*., 1998, Ulieru *et al*., 2000, Yao and Trappey, 2000, Fischer *et al*., 2001, Garita *et al*., 2001, Fürst and Schmidt, 2001, Klen *et al*., 2001, Jagdev and Thoben, 2001, Turowski, 2002, Tatsiopoulos *et al*., 2002, Sarkis and Sundarraj, 2002, Davidrajuh, 2003, Choi *et al*., 2003, Kovács and Paganelli, 2003, Lin and Lin, 2004, Makatsoris *et al*., 2004, Cheng *et al*., 2004, Ghenniwa *et al*., 2005, Molina *et al*., 2005, Folan *et al*., 2006, Molina *et al*., 2007, Jagdev *et al*., 2008, Grefen *et al*., 2009b, Grefen *et al*., 2009a, Ilie-Zudor and Monostori, 2009, Cai *et al*., 2010, Li *et al*., 2010, Rodríguez Monroy and Vilana Arto, 2010, Hassan *et al*., 2010
Agent- based co-ordination	Ulieru *et al*., 2000, Fischer *et al*., 2001, Turowski, 2002, Sarkis and Sundarraj, 2002, Nigro *et al*., 2003, Denkena *et al*., 2003, Gou *et al*., 2003, Makatsoris *et al*., 2004, Cheng *et al*., 2004, Ghenniwa *et al*., 2005, Molina *et al*., 2005, Ouzizi *et al*., 2006, Molina *et al*., 2007, Monteiro *et al*., 2007, Akanle and Zhang, 2008, Jagdev *et al*., 2008, Chokshi and McFarlane, 2008, Grefen *et al*., 2009b, Grefen *et al*., 2009a, Ilie-Zudor and Monostori, 2009, Cai *et al*., 2010, Li *et al*., 2010, Monteiro *et al*., 2010, Hassan *et al*., 2010, Wang *et al*., 2011, Badr *et al*., 2011, Marchetta *et al*., 2011, Rolón and Martínez, 2012
Data integration tools	Giachetti, 1999, Yao and Trappey, 2000, Choi *et al*., 2003, Liu and Young, 2004, Blomqvist *et al*., 2005, Tsou, 2008

2.3.4 Co-operation models for virtual enterprises

Although short-term co-operative ventures launched to exploit new business opportunities are difficult to form and expensive in the beginning, partners need a plan for formation structure where the co-operation is configured *a priori*. With respect to organisational structure, the literature offers no prevailing point of view. Kovács and Paganelli (2003) view the adoption of a centralised approach as one of the major obstacles to the exploitation of virtual enterprise models. They suggest that partnerships in virtual enterprise need to be planned with decentralised architectures accountability structures. With the new virtual enterprise system, each node remains in charge of its own data and local applications, without giving up control of internal operations and without changing the IS architecture.

Jagdev and Thoben (2001) viewed bilateral relationships as either hierarchical or non-hierarchical. While one party is clearly superior in the hierarchical structure and that party makes the rules of engagement, the two parties are equal in status in the non-hierarchical partnership. The relationship between a set of nodes in a virtual enterprise will mostly be non-hierarchical in nature. Martinez *et al*. (2001) assume that the network of virtual enterprises is implemented with a non-hierarchical structure in a collaborative environment to systematise concurrent engineering. Each company is self-organised, while the virtual enterprise common structure controls global communications and synchronisation between them. Grefen *et al*. (2009b) share this point and view the members of the network as being arranged in a peer-to-peer topology that requires fine-grained synchronisation between the participating autonomous parties in the virtual enterprise. This means that the organisations collaborate at the same level, as opposed to a client/server topology in which organisations are organised hierarchically. The authors note that one organisation in a network may act as a contact point for a client party (i.e. one party accepts orders) or that a network may have one member that synchronizes all the other members (i.e. it functions as a 'collaboration hub') but that this does not imply that there is a hierarchy among the members of the network.

Similarly, Esposito and Evangelista (2014) found two structural models for virtual enterprise s, including hierarchical and 'holarchical' in the literature. However, they assume a hybrid form that has some characteristics in common with the two models and shares the relationships among peers with the 'holarchical' model, and the presence of a co-ordinating firm with the hierarchical model as shown in Figure 2-2. The collaborative relationships are continuously formed and re-formed *via* hybrid models (Esposito and Evangelista, 2014).

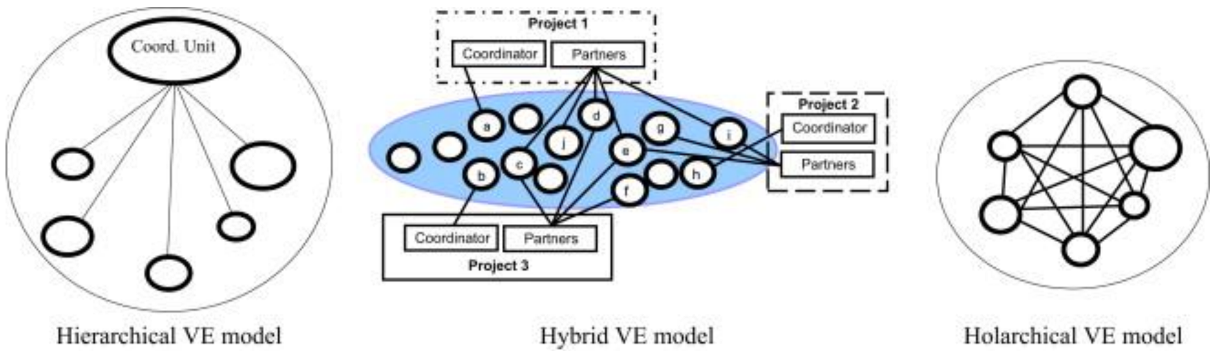


Figure 2-2: Taxonomy of virtual enterprise models
(Adapted from Esposito and Evangelista 2014)

2.3.5 The effectiveness of virtual enterprise formation

Many research publications focus on the potential success brought in by virtual enterprise. Successful completion of temporary collaboration brings many benefits. Benefits that is able to be received from virtual enterprise affiliation among right coordination with proper participants are summarised from the literatures and shown in Table 2-3: Benefits from the virtual enterprise formation. These shared benefits suggest that the virtual enterprise possesses several significant advantages over the conventional traditional enterprises. These advantages include:

- **Agility**; virtual enterprise is one of key enablers of agility and it is essential to develop virtual enterprise in a more productive way by reducing the time and cost as well as delivering goods/services in a competitive manner in global markets (Gunasekaran and Yusuf, 2002). This temporary collaboration increases the ability to recognize unpredictable changes and rapidly react and cope to it exploiting business opportunities in brief period with high quality and less investment. To implement agility, some capabilities have received attention from researchers that includes: responsiveness, speed, flexibility and competency (Zhang and Sharifi, 2007).
- **Increased efficiency and effectiveness**; the virtual enterprise is formed based on ICT networks that improve the operational effectiveness by speeding up and simplifying the exchange of information across the value chain. With the integrated virtual enterprise both the information and material flows will be simplified, streamlined and optimised reducing waste and lead times (Naylor *et al.*, 1999). Through more economical connections with partners, enterprises able to obtain greater opportunities to create revenue, more efficient operations, and growth of market while sharing costs and risks. The combination of specialisation and outsourcing not only makes the virtual enterprise more economically

efficient to the enterprises to avoid having additional capital commitments, such as new plants and infrastructure, that are not directly associated with their core business, it allows globally optimised performance.

Table 2-3: Benefits from the virtual enterprise formation

Benefits	Shared literature evidence
Agility	Klen *et al*., 2001, Nigro *et al*., 2003, Davidrajuh, 2003, Camarinha-Matos and Afsarmanesh, 2003, Cheng *et al*., 2004, Gunasekaran *et al*., 2005, Ouzizi *et al*., 2006, Zhang and Sharifi, 2007b, Gunasekaran *et al*., 2008, Jagdev *et al*., 2008, Grefen *et al*., 2009b, Cai *et al*., 2010, Li *et al*., 2010, Monteiro *et al*., 2010, Rolón and Martínez, 2012,
Flexibility	Camarinha-Matos *et al*., 1998, Fischer *et al*., 2001, Fürst and Schmidt, 2001, Turowski, 2002, Tatsiopoulos *et al*., 2002, Choi *et al*., 2003, Makatsoris *et al*., 2004, Liu and Young, 2004, Cheng *et al*., 2004, Gunasekaran *et al*., 2005, Blomqvist *et al*., 2005, Ghenniwa *et al*., 2005, Folan *et al*., 2006, Ouzizi *et al*., 2006, Molina *et al*., 2007, Zhang and Sharifi, 2007b, Monteiro *et al*., 2007, Akanle and Zhang, 2008, Gunasekaran *et al*., 2008, Jagdev *et al*., 2008, Grefen *et al*., 2009b, Grefen *et al*., 2009a, Ilie-Zudor and Monostori, 2009, Rodríguez Monroy and Vilana Arto, 2010, Wang *et al*., 2011, Váncza *et al*., 2011,
Speed	Giachetti, 1999, Yao and Trappey, 2000, Jagdev and Thoben, 2001, Zhang and Sharifi, 2007b, Wang *et al*., 2011, Váncza *et al*., 2011,
Responsiveness	Fischer *et al*., 2001, Turowski, 2002, Tatsiopoulos *et al*., 2002, Choi *et al*., 2003, Liu and Young, 2004, Blomqvist *et al*., 2005, Ghenniwa *et al*., 2005, Molina *et al*., 2007, Zhang and Sharifi, 2007b, Gunasekaran *et al*., 2008, Rolón and Martínez, 2012,
Competency	Zhang and Sharifi, 2007b, Gunasekaran *et al*., 2008,
Efficiency and effectiveness	Giachetti, 1999, Nigro *et al*., 2003, Rupp and Ristic, 2000,(Grefen *et al*., 2009b, Ilie-Zudor and Monostori, 2009,
Efficient share of cost, resource, and risk	Tatsiopoulos *et al*., 2002, Choi *et al*., 2003, Makatsoris *et al*., 2004, Cheng *et al*., 2004, Váncza *et al*., 2011,
Optimisation of global performance	Camarinha-Matos and Afsarmanesh, 2003, Gunasekaran *et al*., 2008, Monteiro *et al*., 2010,
Dynamic	Ulieru *et al*., 2000, Davidrajuh, 2003, Ghenniwa *et al*., 2005, Molina *et al*., 2007, Akanle and Zhang, 2008, Gunasekaran *et al*., 2008, Grefen *et al*., 2009b,
Adaptability	Davidrajuh, 2003, Cheng *et al*., 2004, Molina *et al*., 2007, Gunasekaran *et al*., 2008, Grefen *et al*., 2009b,
Competitiveness	Klen *et al*., 2001, Turowski, 2002, Denkena *et al*., 2003, Camarinha-Matos and Afsarmanesh, 2003, Gunasekaran *et al*., 2005,
Innovative	Camarinha-Matos and Afsarmanesh, 2003, Esposito and Evangelista, 2014

- **Enhance dynamism and adaptability**; when market requirements are changed, a new class of products or an improved version of the product should be turned out to meet the new market requirements. In this case, the principal enterprise may seek for a new combination of collaborating enterprises that are more suitable to manufacture the new class of products: thus the main aspect of virtual enterprise is dynamic logic of organisation and reorganisation of collaboration (Davidrajuh, 2003). Molina *et al*. (2007) viewed a virtual enterprise as a unique concept to achieve dynamic organisation. Because the use of modern and efficient ICT (information infrastructure) allows the formation and management of dynamic co-operation among different and also global partners. Grefen *et* *al*. (2009b) envisaged the shortened life cycle of products makes the virtual enterprise s need to have a dynamic or agile character: they are formed for new products and must be dismantled when products are abandoned again. To stay competitive in modern markets, the creation of dynamic virtual enterprises must be performed swiftly. virtual enterprises are characterised to maximise adaptability to environmental changes (Gunasekaran *et al*., 2008). When joining in a virtual enterprise, businesses can obtain adaptability ability to change something or oneself to fit to occurring changes and cope with unexpected disturbances in the environment. On the other word, enterprises benefit from the potential to adjust to changes in the selection environment.

- **Maintained competitive advantages**; from the resource perspective, dynamic and flexible alliance of virtual enterprise formation is not easy to duplicate, thus it may contribute network resource heterogeneity and sustain the competitive advantage. Besides, a virtual enterprise has innovative potential and create ideas and produce innovative products and services combining communication, electronic commerce and business process automation to provide effective and low-cost customer service worldwide. As a temporary alliance, virtual enterprise is perceived as an implementing strategy for enterprises that is not simultaneously being implemented by other potential competitors thus sustains the competitive advantages.

Since the literature indicates agility as a fundamental benefit of a virtual enterprise that support dynamism and adaptability and increase efficiency by reducing the time and cost to maintain competitive advantages, this research perceives agility as a main effectiveness of a virtual enterprise. However, Zhang and Sharifi (2007) identify enterprises that relied more on the lean strategy win on cost and those that relied more on the agile strategy win on speed, flexibility and their responsiveness to changes. The 'lean' and 'agile' paradigms can be combined within successfully-designed and operated 'total supply chains' and be accepted to be mutually supportive (Naylor *et al*., 1999).

Furthermore, it is necessary to study the relation between a virtual enterprise and its effectiveness in terms of agility, thus primary study is focused factors that have influences on agility achievements through the strategy of joining the virtual enterprise. Additionally, based on the results for identified factors, enterprises have better agility achievements are identified and utilised for framework development as a main goal of this study. Agility has been studied more deeply in next part.

2.4 Agility in supply chain management

The agility concept, introduced by the Iacocca Institute (Nagal and Dove, 1991), has received considerable focus from researchers in the last two decades. It has been defined as , 'the ability to thrive in an environment of continuous and often unanticipated change' (Sarkis, 2001) by the Advanced Research Programs Agency (ARPA) and the Agility Forum. However, several definitions are given from different points of view and at different levels, agility is usually viewed as an ability or strategy that requires specific capabilities in organisations that seek to attain it an organisational ability (Christopher, 2000; van Hoek *et al*., 2001; Gunasekaran and Yusuf, 2002). Thus Sharifi and Zhang (1999) identify four capabilities of agility; responsiveness, competency, flexibility, and quickness. Table 2-4: Highly cited definitions compared according to agility compares the most cited definitions by the agility capabilities, showing the common features. Quality is assumed to be another feature that qualifies the other four capabilities and therefore it is included in the examination of agility capability in this research. Yusuf *et al*. (1999) view quality as one of the competitive priorities and although it is now an 'order qualifier' rather than an 'order winner', it remains important in their view. Gunasekaran and Yusuf (2002) state that agility should be based on not only responsiveness and flexibility, but also on the cost and quality of goods and services that the customers are prepared to accept. Sherehiy *et al*. (2007) identify quality as a one of the key agility attributes for enterprises. Additionally, the issue of product and service quality is included in a study of competency capability by Sharifi and Zhang (1999). The issue of quality is not only related to product and services in a supply chain but also to information sharing, human resource management, innovation and design, performance and decision making.

Enterprises prioritise the agility capabilities that need to be developed to cope with and take advantage of changes (Zhang and Sharifi, 2007). Yusuf *et al*. (1999) distinguished three aspects of agility related to different levels of enterprise. Elemental agility refers to individual resources (people, machinery and management); micro-agility refers to the enterprise, and macro-agility to the inter-enterprise level. Finally, they suggested to achieve the higher level of agility the core competencies of prospective partners must be brought into joint venturing to maximise the gains of co-operation. However, as most definitions are concerned with enterprises, this study has considered agility that is achieved through networked collaboration. Cruz-Cunha and Putnik (2006) define agility, considered in the present context of networked structure (providers of resources) as a capability for fast adaptability or fast reconfigure ability of the entities in co-operation, to respond to market changes. Supply chain agility is defined as a firm's ability to effectively collaborate with channel partners to respond to market changes in a rapid manner (Swafford *et al*., 2006; Braunscheidel and Suresh, 2009).

Table 2-4: Highly cited definitions compared according to agility capabilities

Authors	Definitions	Features				
		Responsiveness	Competency	Flexibility	Quickness/ speed	Quality
Kidd (1994, p. 10)	Agility is a rapid and proactive adaptation of enterprise elements to unexpected and unpredicted changes.	√				
Goldman *et al*. (1995, p. 4)	Agility is a comprehensive response to the business challenges of profiting from rapidly changing, continually fragmenting global markets for high-quality, high-performance, customer-configured goods and services.	√	√			
Yusuf *et al.* (1999, p.37)	Agility is successful exploration of competitive bases (speed, flexibility, innovation proactivity, quality and profitability) through the integration of reconfigurable resources and best practices in a knowledge-rich environment to provide customer-driven products and services in a fast-changing market environment	√	√	√	√	√
Christopher (2000, p. 38)	Ability of an organization to respond rapidly to changes in demand, both in terms of volume and variety; a business-wide capability that embraces organizational structures, ISs, logistics processes, and mind-set.	√	√			
van Hoek *et al*. (2001, p.127)	Agility is all about customer responsiveness and market turbulence and requires specific capabilities, on top of those that can be achieved using 'lean thinking'.	√	√			
Gunasekaran and Yusuf (2002, 1362)	Agility in manufacturing is 'Capability of an organization, by proactively establishing virtual manufacturing with an efficient product development system, to meet the changing market requirements, maximize customer service level, and minimize the cost of goods; ability of a company to effect changes in its systems, structure and organization with an objective of being competitive in a global market and for an increased chance of long-term survival and profit potential.'	√	√	√		√
Zhang and Sharifi (2007, 352)	Agility is a manufacturing strategy that aims to provide manufacturing enterprises with competitive capabilities to prosper from dynamic and continuous changes in the business environment, reactively or proactively.	√		√		

Researchers conceptualise supply chain agility as having two features; firstly, the exploration and exploitation of market opportunities and secondly, the ability to deliver innovative products and services in a timely and cost-effective manner (Ngai *et al*., 2011). To explore market opportunities, tight collaboration with partners (Agarwal *et al.*, 2007; Braunscheidel and Suresh, 2009) and communication with customers (Christopher, 2000; Braunscheidel and Suresh, 2009) have been perceived basis of agile supply chains. To provide ability to be responsive, flexible and quick, the adoption of ICT (Liu *et al*., 2013; DeGroote and Marx, 2013) and ICT based integrated organisation structures (Ngai *et al*., 2011; Braunscheidel and Suresh, 2009) have received wide attention from academics and practitioner.

Rational operational strategies (Tseng and Lin, 2011; Liu *et al*., 2013; Braunscheidel and Suresh, 2009) enable agility and make it rare, valuable, inimitable and not substitutable. In recent turbulent markets, to improve their performance by being chosen as a collaborative partner by other successful business firms, enterprises need to enhance their competitive advantage factors and agility.

Many conceptual models for agility implementation have been proposed to assist managers (Tseng and Lin, 2011). Since, researchers view supply chain agility capabilities depend on the effects of drivers and providers, some research made attempts investigate relation between drivers, providers and capabilities to enhance agility level. For instance, Tseng and Lin (2011) suggest a new agility development method for dealing with the interface and alignment issues among the agility drivers, capabilities and providers using the QFD relationship matrix and fuzzy logic, Liu *et al*. (2013) study agility empirically in more complex environment by connecting with drivers, providers and outcomes of agility. Based on model proposed by Sharifi and Zhang (1999) this research shows that the following issues are likely to be key in agility study models:

- 'Drivers' lead a firm to embrace an agile strategy;
- 'Agility' is characterised by 'attributes or capabilities that would provide required strength for responding to changes';
- 'Providers' are the tools and strategies to enhance agility capabilities.

To conceptualise agility and to measure agility capability, researchers suggest many models and references. For instance, Agarwal *et al*. (2007) model agility and proposed assessing features, and Yauch (2011) attempts to establish audit metrics of supply chain agility by measuring the changes in some elements that can enable agility. Many researchers perceive that it is possible to measure capabilities by performance outcomes (Tseng and Lin, 2011; Yauch, 2011). The outcome of strategy is measured by its effect on business performance in this study. The effect is conceived as a change in business performance (Cao and Dowlatshahi, 2005; Swafford *et al*., 2008; Ngai *et al*., 2011; Liu *et al*., 2013).

2.5 Summary

This chapter has described a topic-related literature review and has introduced the background knowledge related to virtual enterprise, and its fundamental condition to affiliate together for purpose to exploit fast changing opportunities in the market and benefits from the short-term collaboration. By applying the resource-based view as a theoretical basis, the main research domains of virtual breeding environment, virtual enterprises, and agile supply chains are aggregated and schemed to ground theoretical concepts. Researchers viewed virtual breeding environment is very supportive cluster for virtual enterprise formation by enabling proper partners, common technological infrastructure and data integration, etc. By forming virtual enterprises based on virtual breeding environment, enterprises can accrue four kinds of rents and achieve competitive advantages. The formation of a virtual enterprise is defined as strategy that produce rare, valuable and inimitable capability.

Then, main concept of virtual enterprise is reviewed and this study followed definition is determined. Also, the virtual enterprise formation lifecycle stages and related literatures are reviewed to investigate gaps. Additionally, the 'state-of-the-art' of technological infrastructure, co-operation model and benefits of being in a virtual enterprise are considered to support knowledge of virtual enterprise and find possibilities to improve the effectiveness of virtual enterprise. The chapter concludes by discussing agility capability as a main benefit from the virtual enterprise and finds the need still exists to investigate either of how agility capability achieved through virtual enterprises and influencing factors on that and or how to support agility as an effectiveness of the virtual enterprise.

CHAPTER 3: RESEARCH METHODOLOGY

3 Introduction

A research methodology is a way of solving a research problem systematically (Kothari, 2011). The choice of methodology is most important for identifying the correct solution to a particular research problem, understanding and formulating guiding principles that govern a particular procedure and developing and testing new theories that contribute to the advancement of practice and professional development. The research methodology discussed here is systematically based on the research 'onion' proposed by Saunders *et al*. (2009). As indicated in Figure 3-1, in this approach the possible research philosophies, strategies, approaches, purposes, techniques and time horizon are determined respectively and discussed, to allow a selection process to be carried out.

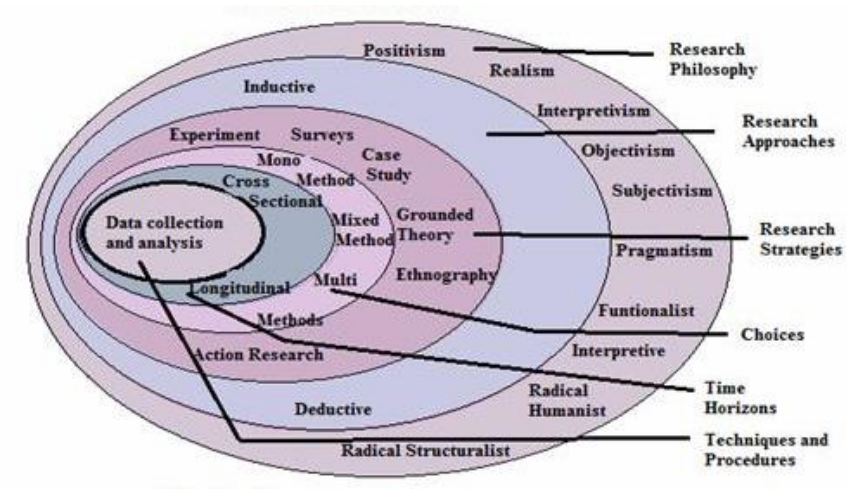


Figure 3-1: Research onion
(Based on Saunders *et al* 2009, p.108)

This layered model in effect offers an ontology, or exhaustive list of research terms with the more 'higher' or more abstract levels towards the outside (Saunders *et al.*, 2009). While the 'onion' suggests possible choices at each level it does not, however, offer assistance or guidance in the selection of philosophy, methods and techniques. In addition, the alternatives are offered without reference to the research background or context, which can make a choice difficult.

This research in effect follows a philosophy of pragmatism, in that existing underpinning theories are less important than analysing the 'real' data arising from a detailed analysis of actual data. This approach is combined with a 'mixed method' of positivism and interpretivism, as quantitative as well as qualitative data is gathered in the primary research phase, athough the statistical nature of the analysis and validation phases emphasises the quanitiative/positivist mode. A positivist approach is taken when measuring business performance in the supply chain and the overlap of the three domains (see Section 2.1) is studied to increase the effectiveness of virtual enterprises using a detailed statistical analysis (see Section 4.2). The interpretivist view would embrace the ways in which choices are made about supply chain management and human decision-making behaviour in composing virtual enterprises, which may not always be rational or trustworthy. In Saunder's model (Saunders *et al.*, 2009) the possible 'research strategies' include surveys, case studies and experiments, all of which are suitable for assessing such subjective aspects. Research of this nature therefore often places a social and psychology emphasis on the research through the use of a case study to reflect a realistic socio-technical situation. Case study research can be decomposed into exploratory, descriptive and explanatory categories (Yin, 2009) even though the main approach to the research may be quantitative, which implies the use of descriptive or correlational analysis.

The possibility of using mixed methods research (Cresswell and Clarke, 2011) to combine the qualitative and quantitative approaches by combining two different paradigms. This would be opposed to a choice of multi-method research which would not lend itself to this type of research because the methods are used simultaneously and not sequentially. Mixed method research often combines the exploratory, descriptive and explanatory modes of research, as follows:

- **Exploratory research** is typically used during the data gathering stages of secondary and primary research. The secondary research can be used to review the existing sources of literature in each of the domains (i.e. virtual breeding environments, virtual enterprises, and agile supply chains). This allows the researcher to define the research problem more clearly and to formulate more specific research questions or hypotheses (which can be developed from them). It also helps to select the best research design and data collection methods and techniques. The present type of research lends itself to placing greater emphasis on the exploratory mode of research (e.g. for developing a framework of the relationship of virtual enterprises in the supply chain, which can be used to test the validity of the hypotheses developed from the research questions. The potential for the present type of research is in conducting experiments and using quantitative data obtained from questionnaire forms. This creates the potential for using confirmatory research to validate the major research deliverable by experiments using simulation modelling methods;

- **Descriptive Research** typically uses comparative and correlative methods to establish the existence of relationships between the variables in a structured equation modeling exercise (Kumar 2014);
- **Explanatory Research:** Explanatory research seeks to investigate changes in behaviour rather than to simply identify the causes of behaviour (Maxwell and Mittipalli, 2008), which can be done through a simulation experiment to investigate the behaviour of the model so that the decision-making process and outcomes may be validated.

The timing of the research may also lend itself to the cross-sectional type of study, in which data is collected within a defined period or to a longitudinal type, which studies a phenomenon over time. In terms of experiments (Saunders *et al*. 2009) a simulation model can be used to validate the research deliverables and to collect both qualitative and quantitative data which can be analysed (e.g. by using a multi-stage structured equation modeling technique (Hoyle, 1995).

This discussion demonstrates that the choice of approach, methods and techniques is subjectively dependant on the researcher's perception of the research. The epistemology and the ontology of both may be different. Therefore, in general, it is necessary for the researcher to thoroughly describe his or her perceived paradigm in the definition of the research and to justify the choice of research methodology by referring to this definition. Hence, it may be said that theoretical paradigms do not exist in isolation, but only in relation to the essential nature of the research. The process by which the comparison is carried out (i.e. feature analysis) is shown to be a useful and effective way of revealing this fact. In this sense the choice of research methodology cannot be said to be scientific, as the projects both deal with human perception, judgement and behaviour.

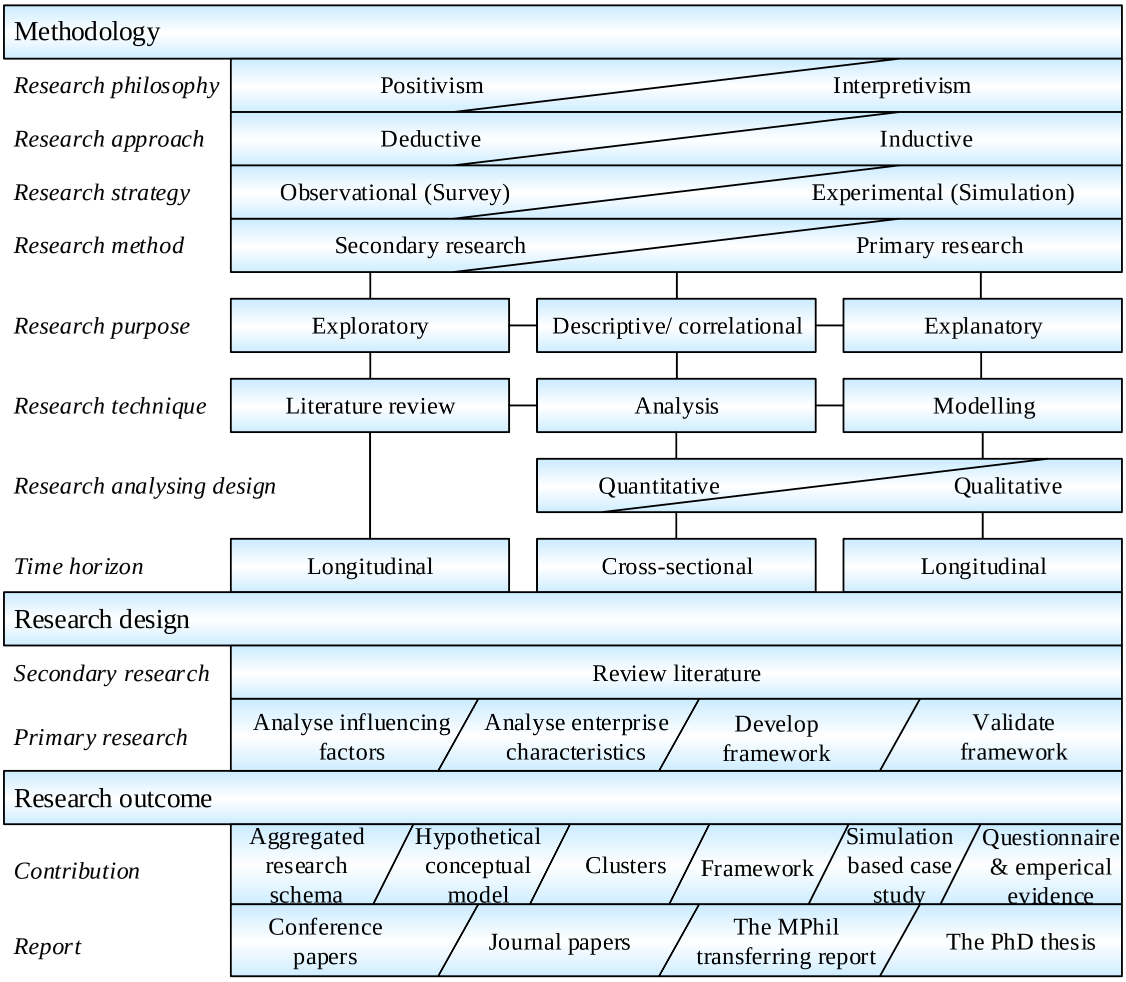


Figure 3-2: Research methodology

3.1 Research philosophy, approach, strategy and methods

It is often not possible to say that a single research philosophy, approach and strategy will suit a whole piece of research better than any other. Thus several research philosophies, approaches, strategies and methods have been adopted to fulfill the research aims. Saunders *et al*. (2009) sees 'research philosophy' as an over-arching term related to the development of knowledge and the nature of that knowledge. Research philosophies differ on the goals of the research and the approach to achieve these goals. To form a practical research strategy or 'plan of action designed to achieve a research goal', the research philosophies are narrowed down to approaches, strategies and methods. For a more systematic investigation, research methods should be approached. This research started with a secondary study investigating the key issues, challenges, gaps and motivation in the theoretical and practical literatures related to research topic. Secondary data was collected from existing sources such as journal publications, databases and Internet records and, based on this secondary study, primary research is conducted using systematic quantitative research techniques.

In the initial stage of the primary research, a positivist philosophy was adopted to develop the conceptual hypothetical model and to test the chosen hypotheses by collecting empirical data using the questionnaire-based survey to investigate possibilities for improving the effectiveness of virtual enterprises and the researcher's ability to target a group of enterprises that may lead to the development of a theory. The main characteristics of positivism are considered to reveal evidence of formal propositions, quantifiable measures of variables, hypothesis testing, deducing the inferences concerning the phenomena from the representative sample to a stated population (Orlikowski and Baroudi, 1991). Deductive positivism is often discussed as the predominant research approach (Spens and Kovács, 2006). The deductive approach starts on a strong theoretical footing, its aim being to test theoretical knowledge that has been developed prior to empirical research (Spens and Kovács, 2006). The deductive approach is therefore adopted for this research, coupled with positivism as a top-down method of developing hypotheses, producing a research framework and designing a research strategy to test the hypothesis. At this stage, an observational strategy is taken to test a theory by gathering empirical facts. According to Kothari (2011), structured observation is considered appropriate in descriptive studies, whereas in an exploratory study the observational procedure is most likely to be relatively unstructured. A structured observation is characterised by a careful definition of the units to be observed, the style of recording the observed information, standardised conditions of observation and the selection of pertinent data of observation. But when observation is to take place without these characteristics to be thought of in advance, the same is termed as unstructured observation.

After the framework is developed based on observational research with the purpose of designing and implementing a more effective way for virtual enterprises to achieve agility, an interpretive study is conducted to increase the understanding of the critical organisational issues related to the adaptation of virtual enterprises for supply chain agility through accessing the meaning that participants assign to it. Interpretive philosophy represents the critical thinking about positivist philosophy. Orlikowski and Baroudi (1991) state that interpretive studies are evidence of a nondeterministic perspective where the intent of the research was to increase understanding of the phenomenon within cultural and contextual situations; where the phenomenon of interest was examined in its natural setting and from the perspective of the participants; and where researchers did not impose their outsiders' *a priori* understanding of the situation. Interpretivism is adopted with an inductive approach that is conducted as a bottom-up method. In the inductive process the argument moves from a specific empirical case or a collection of observations to a general law (i.e. from facts to theory) following the pattern of case – result – rule (Spens and Kovács, 2006). To validate and explain the proposed framework, an experimental strategy is taken to collect data and to simulate a real case to develop a sound theory because of the data analysis. An experiment is the selection of samples of individuals from known populations and measurement on a small number of variables and control of other variables (Saunders *et al*., 2009). To validate the proposed framework, a simulation is conducted as an experiment to isolate the factors and to change the influences and then to observe the effects and compare the outcomes.

3.1.1 Research purpose and technique

Three types of research techniques are adopted, being respectively; a literature review for exploratory research, a questionnaire-based survey for descriptive (correlational) study and simulation based experiment for explanatory study. An exploratory study is carried out to explore an area where little is known or to investigate the possibilities of undertaking a particular research study. Saunders *et al*. (2009) define a critical literature review as, 'Detailed and justified analysis and commentary of the merits and faults of the literature within a chosen area, which demonstrates familiarity with what is already known about in research topic.' In this study, the literature review attempts to integrate what others have done and said, to criticise previous scholarly work, to build bridges between related topic areas and to identify the central issues in a field, or all these. A topic-related literature review aims to investigate the related theoretical ground and domains widely, to investigate possibilities to solve those issues, to determine causal factors on the issues, to find relationships between factors, to identify the impact of those factors on enterprises, evaluate and improve the effect of factors on performance of enterprises and explain the output in natural situation. A methodology-related literature review examines the literature for relevant and suitable research approaches, methods and techniques which are then chosen to meet the research objectives.

Descriptive research attempts to describe a situation, problem and phenomenon systematically, to provide information on a community or to describe attributes that contribute to an issue. Both comparative and correlational methods are utilised for descriptive studies to discover or to establish the existence of a relationship, association or interdependence between two or more aspects of a situation. An analysis technique is applied as a way of inspecting, cleaning, transforming, and modelling data with the goal of discovering useful information, suggesting conclusions, and supporting decision making. Reliability and validity tests are conducted to measure consistency and accuracy of statistics of analysing variables. This may be an extension of, or a forerunner to, a piece of exploratory research or, more often, a piece of explanatory research (Saunders *et al*., 2009).

Finally, the results of exploratory and descriptive studies are explained. Explanatory research attempts to clarify why and how there is a relationship between aspects of a situation or phenomenon. Modelling and simulation techniques and case study are adopted in the explanatory research phase to do experiments to investigate the behaviour of the model or changes in relation under certain conditions, to explain nature of certain relationship and help to indicate how to moderate the output of model.

3.1.2 Method of analysis

Both qualitative and quantitative research analyses are used in this study. The quantitative research focuses on the quantification of the collection and analysis of data (Bryman and Bell, 2007) and that entails a deductive approach to the relationship between theory and research, in which the accent is placed on the testing of theories; has incorporated the practices and norms of positivism in particular. By contrast, the qualitative research strategy emphasises values rather than quantification in the collection and analysis of data and predominantly emphasises an inductive approach to the relationship between theory and research, in which the emphasis is placed on the generation of theories (Bryman and Bell, 2007). Quantitative data in this research was collected by using a questionnaire and was tested quantitatively and evaluated by using a qualitative strategy. Also, qualitative and quantitative data is collected from a simulation model (in the validation phase) that is analysed qualitatively.

3.1.3 Time horizon

Saunders *et al*. (2009) envisage research relating to two specific time horizons, namely cross-sectional and longitudinal research. Cross-sectional study involves data collected from population, at one specific point in time. Longitudinal research involves repeated observations of the same variables over longer periods of time. The literature review and explanatory research have been conducted in this research on literature relating to particular periods during the PhD study and the observed changes relating to the same issues or variables. Rather, the survey was conducted as a cross-sectional study that involves data collected at a defined time.

3.1.4 Research design

Based on using the previously-explained research philosophy etc., the researching process was determined as a series of steps or phases. The literature was reviewed throughout the whole research period to include the earlier and more recently published researchers' contribution and findings. Based on the literature review, the primary research was designed with four stages to achieve the research objectives. Empirical data was collected through a questionnaire-based survey to test the hypotheses and to cluster enterprises; the data can be now used by other researchers.

The first stage was to identify the main factors that may influence improvements to the effectiveness of virtual enterprise. A new, hypothetical conceptual model was developed that demonstrates the complex relationships between virtual enterprises and agile supply chains in terms of the relationship drivers, providers, capabilities and effects for joining in a virtual enterprise to provide effectiveness. In the second stage, enterprise characteristics were investigated and the main strategic groups were identified that have an ability to achieve greater agility and business performance when forming the virtual enterprise. Because the effectiveness of the whole integrated system depends on the individual units, the strategies for improving an organisation's ability to form a virtual enterprise were discussed by the participating groups. The framework was then developed and its design and implementation are discussed and finally, simulation is conducted to validate how individual enterprises ability cause in improvement of the effectiveness of virtual enterprises in supply chains.

3.1.5 Research outcomes

During the research, a literature review was carried out, a hypothetical model has been proposed, a major survey was conducted in Mongolia, the design of a virtual enterprise framework for achieving agility in the supply chain was produced and a simulation model was developed. In addition, two conference papers and a journal paper have been produced and published and the MPhil to PhD transfer report of 23,000 words and the PhD thesis of 80,000 words were completed within the determined period.

3.1.6 Summary

In this chapter the competing research philosophies, approaches and methods are examined in relation to their application to the present research. Their advantages and disadvantages are discussed and a programme for the research is designed based on the definition of the research in Chapter 1 informed by the literature review in Chapter 2.

CHAPTER 4: PREDICTION OF THE RELATIONSHIP BETWEEN VIRTUAL ENTERPRISE AND EFFECTIVENESS

4 Introduction

This chapter discusses the first stage of the primary study that was conducted with the aim of predicting the relation between virtual enterprises and their effectiveness in complex markets. As discussed in Section 2.4, agility is considered to be the main source of effectiveness that an enterprise can receive from its temporary collaboration to respond better to business opportunities. Aerts *et al*. (2002) believe that to cope with the temporary lack of a particular type of capability a virtual enterprise should include several members with similar capabilities (i.e. redundancy) to help to achieve agility. Agility capabilities show how well the collaboration is defined and how the processes provide business and technological integration between enterprises within the supply chain (van Hoek *et al*., 2001). Christopher (2000) points out that to be truly agile, a supply chain must possess a number of distinct characteristics including; being market sensitive, operating virtually and being network-based and process-integrated.

This thesis argues that while some studies investigate only the relationship between a virtual enterprise and ICT and the effects on business performance (Cao and Dowlatshahi, 2005) others explore only the empirical evidence of the drivers, providers and capabilities of agility e.g. Ngai *et al*. (2011) and Liu *et al*. (2013). There is a consequent lack of evidence empirically proving how a strategy of joining in virtual enterprise affiliation influences agile supply chain and business performance. This chapter aims to identify and analyse the relationship between the drivers, providers, capability and outcomes of competing strategy using a virtual enterprise to achieve agility in the supply chain, and to provide practitioners and researchers with critical insights into the relationship between the factors. With reference to the resource-based view, the chapter develops a novel conceptual model of factors for the relationship between virtual enterprise and agile supply chains. The hypotheses about the relationship between factors are investigated through a literature review and are tested by a higher-order factor analysis.

4.1 Conceptual models and hypotheses

To analyse the aggregated research schema shown previously (see Figure 2-1) empirically, a novel complex conceptual model is proposed as shown in Figure 4-1.

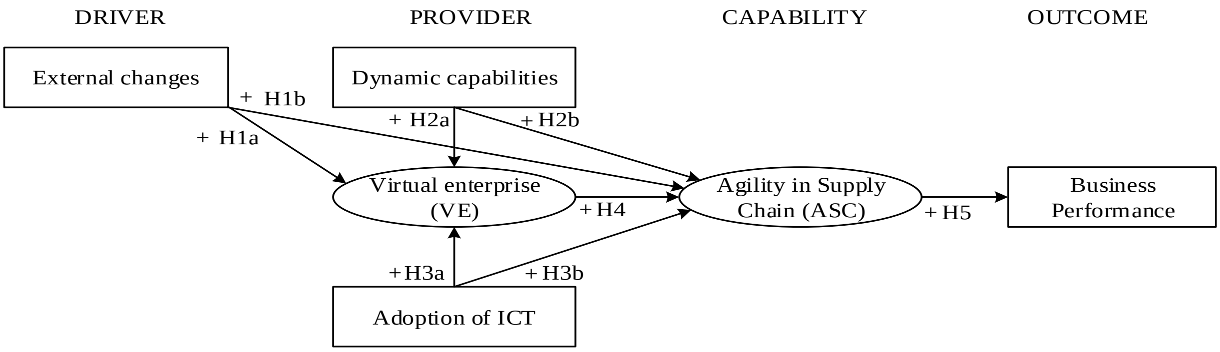


Figure 4-1: Model of the relationship between virtual enterprise and an agile supply chain.

(Hypotheses H1a, H1b, H2a, H2b, H3a, H3b, H4 and H5 are presented and explained below).

This conceptual model aims to investigate the following:

- How drivers and providers cause enterprises to join in virtual enterprises and achieve agility directly and indirectly;
- How virtual enterprise formation impacts on an agile supply chain based on a record of previous partnering collaboration;
- How agility is achieved through strategies joining in virtual enterprises affects business performance.

However, the identification of drivers and providers that enable enterprises to acquire the relevant capabilities and abilities to become agile has so far resulted in very ambiguous answers. From the literature, this research found one driver and three providers, then hypothesised their effects on achievement of agility capability for organisations in supply chains. The drivers lead to practical tools that are providers to provide capability with better outcomes (Samdantsoodol *et al*.,2017).

4.1.1 Drivers

Drivers lead a company to embrace a suitable strategy to maintain competitive advantage. Yusuf *et al*. (2004) cite the unprecedented pressures of competition from foreign products, new product introduction by competitors, reducing product life cycles, unanticipated customer shifts, and advances in manufacturing and information technology on companies push companies to improve their operational efficiency for enhanced competitiveness and overall business performance. Researchers define such as an environment as a set of external contextual elements that represent a source of opportunities and threats (Vázquez-Bustelo *et al*., 2007). Agility drivers represent the characteristics of the external business environment in reference to the turbulence and unpredictability of the changes that affect it (Sherehiy *et al*., 2007).

In the context of a firm's strategy, drivers are the essential driving forces for the firm to rethink its strategy (Zhang and Sharifi, 2007). The agility drivers would force a company to revise the company's current strategy, to accept the need to become agile and to adopt an agility strategy to maintain competitive advantage. This changing context drives organisational changes and leads organisations to collaborate temporarily through joining in a virtual enterprise (Katzy *et al.*, 2004). The aim would be to turn those changes into business opportunities with the potential partners or to adapt to changes themselves. The virtual enterprise model is indicated as eminently suitable for addressing changing market conditions (Esposito and Evangelista, 2014) while firms that collaborate strategically internalise the resources of their alliance partners to cope with turbulence and uncertainty in the business environment. Camarinha-Matos *et al*. (2009) classify a virtual enterprise as an opportunity-driven collaborative network. In this context, to exploit fast-changing opportunities (Byrne *et al*., 1993; Bolton, 1996) and to accrue inbound spill over rent that is associated with strategic collaboration (Lavie, 2006), the ideal type of virtual enterprise s is implemented as a certain short term project with potential members.

However, little research addresses how external changes affect the choice of virtual enterprise strategy to achieve agility, and to drive agility in the supply chain. External driving forces can have a negative effect on a business if they are not appropriately dealt with, and enterprises often cannot affect their environment but need to adapt to it. For a business to succeed and to gain a competitive edge, the enterprises involved must assess the external driving forces and know what changes are occurring and what changes might emerge in the future. Therefore, external change is chosen as one factor affecting both virtual enterprise and supply chain agility and their relationship for the proposed conceptual model. The following hypotheses are therefore proposed in this context:

H1a. External changes positively lead to virtual enterprise formation.

H1b. External changes positively drive agility in the supply chain.

4.1.2 Providers

Providers are enabling increasingly more sophisticated ways for a company to improve its capability to respond to changes or to be 'agile'. Tseng and Lin (2011) hold that achieving agility requires responsiveness in strategies, technologies, personnel, business processes and facilities. Agility providers should exhibit agile characteristics as well as make them available to others and to determine the agility capabilities of themselves or potential partners. A number of studies have been conducted that were intended to identify a set of agility providers from which organisation leaders can select items appropriate to their own strategies. Vázquez-Bustelo *et al*. (2007) believe that human resources, technologies, practices relating to internal organisation and external relations, to product development and to knowledge management and learning are providers of agility. Yusuf *et al*. (1999) propose a set of thirty-two agility-providers grouped into four dimensions:

- Core competency management;
- Virtual enterprise;
- Capability for reconfiguration;
- Knowledge-driven enterprises.

It is highly probable that there is no single set of agility providers reflecting all aspects (Tseng and Lin, 2011). Based on these models, the following providers have been selected in this study. It includes dynamic capabilities, degree of ICT adoption and the ability to join in virtual enterprises.

Teece *et al*. (1997) define dynamic capabilities as the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments. Dynamically renewing the distinctive abilities of competency, and to make network resources heterogeneous, inimitable and rare. Dynamic capabilities reflect an organisation's ability to achieve innovative forms of competitive advantage given the current path dependencies and market positions (Leonard-Barton, 1992). Although Binder and Clegg (2007) view core competencies and outsourcing as the main drivers of a virtual enterprise and Cao and Dowlatshahi (2005) consider core competence to be one of the aligning items of a virtual enterprise to achieve improved business performance, this study envisages the core competence as part of a dynamic pattern. A virtual enterprise should therefore be formed based on the dynamic capabilities that renew competences to respond to changes by exploiting existing internal and external capabilities.

Kidd (1994) views agility as being achieved through the integration of the internal capacities of human resources and ICTs. Sharifi and Zhang (1999) state that agility providers can be derived from four areas of organisation, technology, people, and innovation and the providers need to be fully integrated with the support of information systems/technology. Gunasekaran and Yusuf (2002) envisage that agility must be supported by flexible people, processes and technologies to effect changes in a firm’s systems, structure and organisation with an objective of being competitive. This thesis assumes that the firm's abilities and technologies are a fundamental condition that enterprises need to help them to be able to respond quickly and effectively to the dynamic and unpredictable changes in the business environment. Unfortunately, there is little evidence from investigations into the impact of dynamic capabilities on the virtual enterprise and its ability to achieve agility through its virtual enterprise strategy in the research domain. To fill this gap in the research, the followings are also hypothesised:

H2a. Dynamic capabilities positively drive virtual enterprise formation.

H2b. Dynamic capabilities positively provide agility in the supply chain.

ICT infrastructures play the intermediary role as a provider of inter-operational abilities between organisations and the support services provided and involved in the virtual enterprise (Camarinha-Matos *et al*., 2009). It is the basic provider of safe and co-ordinated interactions among the virtual enterprise members. The fast development of ICT is therefore another empowering factor for a virtual enterprise to enable processing large amount of data and save time. ICT is also regarded as a major provider and facilitator of agility. Top management should actively engage in a strategic ICT plan for supply chain agility and for measuring its effect on supply chain performance (Ngai *et al*., 2011). Liu *et al*. (2013) propose a model for examining how relevant ICT capabilities (e.g. flexible IT infrastructure and IT assimilation) can affect a firm's performance through absorptive capacity and supply chain agility and empirically validate the hypotheses. DeGroote and Marx (2013) conducted an empirical survey that investigates the impact of IT on supply chain agility measured by the virtual enterprise's ability to sense and to respond to market changes, and the impact of the agile supply chain on the firm's performance.

Many researchers e.g. Cao and Dowlatshahi (2005), Camarinha-Matos *et al*. (2009), Koçoğlu *et al*. (2011) and Esposito and Evangelista (2014) agree that ICT and a strategy based on ICT (e.g. virtual enterprise affiliation) are a key to an effective and efficient supply chain by; speeding up the information flow, shortening the response time to customer needs, providing enhanced coordination and collaboration and sharing the risks as well as the benefits.

Although some research has been conducted into the effects of ICT on virtual enterprises (Cao and Dowlatshahi, 2005) and agility in the supply chain (Swafford *et al*., 2008; DeGroote and Marx, 2013; Liu *et al*., 2013), it is argued in this thesis that there are still insufficient studies of the influences of ICT on the relationship between virtual enterprise strategy and agility capability. Therefore, the next hypotheses are posited:

H3a. ICT positively enables virtual enterprise formation.

H3b. ICT has a positive impact on agility in the supply chain.

Van Hoek *et al*. (2001) identify virtual integration relating to optimising information flow as one of five dimensions which reflect the more general aspects of an agile supply chain. Kidd (1994) holds that agility is achieved through the integration of enterprises, known as a virtual corporation, based on its core competences, with highly skilled and knowledgeable employees, advanced technologies and intelligent decision-making systems. Agility means using market knowledge and a virtual corporation to exploit profitable opportunities in a volatile marketplace (Naylor *et al*., 1999). However, empirical studies of how the virtual enterprise enables the agility that affects business performance are rare in the literature. Therefore, the following hypothesis is offered to investigate the virtual enterprise impact on agility in a complex system with other factors affecting and influencing business performance:

H4. Virtual enterprise positively enables agility in the supply chain.

4.1.3 Capabilities

Supply chain agility is referred to as a type of operational capability (Liu *et al*., 2013) that reflects a high-level routine or a collection of routines that are used to respond to market changes. The dynamic capability that is determined to be a provider in this study is distinguished from operational capability and is regarded as a higher-level concept that is used to adapt operational routines and capabilities to develop new value-creating strategies (Liu *et al*., 2013). In this study, agility is viewed as a capability that partner enterprises can receive from the successful formation of virtual enterprises for exploiting fast changing opportunities in the market and sustaining competitive advantage. Furthermore, supply chain agility affects a number of significant enterprise business performance variables (Yusuf *et al*., 2012; Roberts and Grover, 2012). However, Ngai *et al*. (2011), Liu *et al*. (2013) and DeGroote and Marx (2013) tested relation between agility and business performance, no evidence is found on how business performance has been impacted by a strategy of joining in virtual enterprise for providing agility in the supply chain. Therefore, we offer the following hypothesis:

H5. Supply chain agility positively influences business performance.

4.2 Analysis technique

To analyse multiple variables simultaneously, multivariate analysis had been selected, especially the structural equation model (SEM) as a proper method for this study. The structural equation model has the following advantages:

- The structural equation model is powerful technique that can estimate for a series of separate multiple regression equations simultaneously. structural equation model surpasses traditional regression models by including multiple independent and dependent variables to test associated hypotheses about relationships among observed and latent variables (Carvalho and Felix O. Chima, 2014);
- This method can conduct analysis together in the same time that performed separately. For instance, there are many following analyses included in the structural equation model: causal modelling or path analysis; confirmatory factor analysis; second order factor analysis; covariance structure models; and correlation structure models. structural equation model also enables statistical analysts to handle difficult data including; time series with auto-correlated error, non-normal data and even incomplete data (Alavifar *et al.*, 2012);
- It enables researchers in measurement of direct and indirect effects and performing test models with multiple dependent and independent variables.

Recently, the structural equation model is increasingly seen as a useful quantitative technique for specifying, estimating, and testing hypothesised models describing relationships among a set of meaningful variables (Hair *et al*., 2010). Therefore, to find the causal relationship among the determining factors shown previously (see Figure 4-1) simultaneously in this study, the structural equation model technique was applied to test the hypotheses proposed in the conceptual model and to indicate the direct and indirect relationships between the proposed factors.

Since the structural equation model is commonly used for the study of virtual enterprise and agility, some empirical studies are compared in Table 4-1 by factors, the used fit indices and the software. However high-order factor analysis is rarely found in the literatures. Cronbach's alpha value, composite reliability, convergent and discriminant validity tests were executed for all the empirical studies.

Table 4-1: Papers that adopted the structural equation model

Authors	Factors	Fit indices[a]	Software
Cao and Dowlatshahi (2005)	Two 1st orders and one 2nd order factor	χ^2/df, SRMR, RMSEA, GFI, AGFI, CFI	LISREL
Swafford *et al*. (2008)	Four 1st order factors	χ^2, RMSEA, SRMR, CFI, GFI	COMPUSTAT
Braunscheidel and Suresh (2009)	Five 2nd order, one 1st order factors	χ^2	PLS-Graph 03.00
Liu *et al*. (2013)	Five 1st order factors	χ^2, df, RMSEA, CFI, IFI, NFI, NNFI	LISREL
DeGroote and Marx (2013)	Three 1st order factor	χ^2/df, CFI, RMSEA	Mplus

NB: See abbreviation from Figure 4-2

As shown in Figure 4-2, this research uses a methodology with three steps (Hair *et al*., 2010) as follows; firstly to identify underlying constructs, exploratory factor analysis eliminates variables with weak or negative correlations and then to measure the model fit, confirmatory factor analysis is conducted to specify how latent variables depend upon or are indicated by the observed variables and finally to test the hypotheses, the path analysis is performed for the developed structural model.

4.3 Empirical study

The proposed hypothetical conceptual model is shown in Figure 4-2 was tested by the empirical study based on the questionnaire. The survey was targeted at business companies who are responsible for planning, coordinating, control, realising and monitoring all internal and network-wide material and product flows, with the necessary information flow, in industrial and trading sectors along the complete value-added chain for conforming to customer requirements in Ulaanbaatar (the Mongolian capital). From the members' list of the Mongolian Logistics Association, companies have a direct export and import with companies abroad for last three years[10] were selected as a target group.

Since it is difficult to find physically integrated companies, enterprises with active web pages both in English and Mongolian were selected to narrow down the target group. Internet and web services have emerged as a serious technology to provide the middleware platform to support effectively the operations of a virtual enterprise (Rezgui, 2007) that enable alliances to be agile with quick response with which it can respond to changing market requirements (Gunasekaran and Yusuf, 2002). These criteria indicate companies that are interested in collaborating with potential partners.

[10] Data collected from statistics of Mongolian Customs on the web page of http://www.customs.gov.mn

Measurement model

Exploratory factor analysis (EFA) is conducted for factors reduction

- Principal component analysis with varimax rotation is used for factor extraction
- For modification, variables with not strong or negative correlations are eliminated then extract into suitable number of factors, again
- Reliability is indicated with Cronbach's alpha coefficient
- Statistical package SPSS® (version 20.0 for Windows) is used

Confirmatory factor analysis (CFA) is conducted to test model fit

- Maximum likelihood method is used for calculation of covariance matrix
- Fit indices calculated to measure model fit with as set of observation
  - Absolute fit indices measure how well the model is specified by the observed data.
    χ^2: df (chi square per degree of freedom) ratios on the order of 3:1
    the standardised root mean square residual (SRMR) < 0.09
    the root mean square error of approximation (RMSEA) < 0.08
  - Incremental fit indices measure how well the estimated model fits relative to some alternative baseline model.
    the incremental fit index (IFI) > 0.9
    the normed fit index (NFI) > 0.9
    the Tucker-Lewis index, also known as the non-normed fit index (NNFI) > 0.9
    the comparative index (CFI) > 0.9
- For modification of measurement model an additional causal relationship is established.
- Reliability (composite reliability) and validity (average variance extracted and average shared squared variance) tests were executed to measure consistency and accuracy of measurement models
- The SPSS® AMOS software (version 20.0 for Windows) is used

Structural model

- Standardised regression coefficient (path coefficient) measures the power of effect from causal variable to an endogenous variable. In statistical significance testing the p-value is used.
- T-value is used for checking the significance level of estimation for the structural model
- The squared multiple correlation (R^2) for the regression equation indicates the proportion of variance in the dependent variable that is accounted for by the set of independent variables in the multiple regression equation

Figure 4-2: Schema for structural equation modelling

Hard and soft copies of questionnaires were conveniently distributed to randomly selected companies. Participants were treated as autonomous agents by informing them about the study and allowing them to voluntarily choose to participate or not. The cover letter for survey explains the purpose of the research, provides concept definitions and the confidential guarantee of participation. Five draft questionnaires with the cover letters were submitted to a focus group of two academics and three practitioners, to check the readability and possible ambiguity of the questionnaire and four of them replied. The interviews were conducted with respondents and minor changes were made such as rewording some questions, removing several unnecessary items and simplifying the language.

In the first round 400 questionnaires were distributed and 179 responses were received. In the second round, another 100 were distributed and 54 were returned. Out of 233 responses, 205 were usable. The other 28 unusable responses did not contain sufficient data for further analysis. Although this response rate (41%) is not unusual it is recognised that 205 responses cannot cover the total business firms in the whole market. The non-response bias (Armstrong and Overton, 1977) was tested by comparing the chi-squares of overall assessments of key factors of the responses from the single-mailing respondents, and the respondents of hard copy of questionnaire. No significant differences were found between these two groups and the result indicated there is not significant non-response bias exist in this study.

4.3.1 Instrument development

The questionnaire consists of three sections. Section 1 contains basic questions of profile information of participating enterprises. Table 4-2 shows the demographic information of the sample. In addition, the position of respondents is defined to give confidence that participants have the capability and experience to answer the questions. Section 2 provides questions related to drivers, providers and capabilities which cause on relationship between virtual enterprise and agility in the supply chain. Section 3 covers questions related to the success of agility in the supply chain. Questions were ranked with a five-point Likert scale (i.e. very low rate to very high rate) to reduce skewing of the statistical problem in section 2 and 3.

4.3.1.1 Instruments among drivers, providers and capabilities

Section 2 covers five sets of questions related to factors that are designed into the hypothetical model, including external changes, dynamic capabilities, adoption of ICT, ability to join in virtual enterprise, and agility in the supply chain. The factors involve specific constructs which contain number of items relating to drivers, providers and capabilities.

Part I includes the questions related to the factor of external changes. This factor consists of five constructs determined by Tseng and Lin (2011):

1. Market volatility caused by growth in the market niche, increasing the introduction of new products and affecting product life cycles;
2. Intense competition caused by rapidly changing markets, pressure from increasing costs, international competitiveness, and a short development time for new products;
3. Changes in customer requirements caused by demands for customisation, increased expectations on quality and a quicker delivery time;
4. Accelerating technological changes caused by the introduction of new and efficient production facilities and system integration;
5. Changes in social factors caused by environmental protection, workforce/workplace expectations and legal pressure.

Table 4-2: Profile of respondents

Type of industry/ company profile	Frequency	Percentage
Total	205	100.0
Type of industry[a]		
Transport & Freight Forwarder	37	18.05
Mining & Quarrying	29	14.15
Construction & Materials	23	11.22
Wholesale & Retail trade	20	9.76
Other services	17	8.29
Hotels & Restaurants	15	7.32
Information & Communication	13	6.34
Tourism	5	2.44
Oils & Gas	2	0.98
Manufacturing/ Processing:		
Food products & Beverages	13	6.34
Apparel & Textile	10	4.88
Wood & Wooden products	6	2.93
Publishing, Printing & Reproduction of recorded media	6	2.93
Parmaceuticals, Medical products & Biotechnology	5	2.44
Paper & Paper products	4	1.95
Number of employees[b]		
1-9	48	23.41
10-19	49	23.90
20-49	33	16.10
50-199	31	15.12
over 200	44	21.46
Company annual turnover (tugrik-Mongolian currency) [b]		
Less than 250 million	72	35.12
Less than 1 billion	61	29.76
Less than 1.5 billion	19	9.27
More than 1.5 billion	53	25.85
Designation of respondents		
CEO, Director	78	38.05
Manager	117	57.07
Others (Master, Planner, Leader)	10	4.88

[a] Type of industry was defined based on Mongolian Statistical Yearbook 2010
[b] Classification of enterprises regarding to the Mongolian Law on SMEs

Part II provides questions related to the dynamic capabilities involved. Barney (1991) identifies resources that may enable firms to conceive of and implement value-creating strategies, and divides them into three categories (physical capital resources, human capital resources, and organisational capital resources). This thesis adopts these three categories and extends them with two more capabilities to assess enterprises' adjustments for virtual enterprise characteristics. Thus, the dynamic capabilities factor includes five constructs:

- Human related competency as a pool of experience, knowledge, intelligence and insight of individual managers and workers (Leonard-Barton, 1992);
- Information quality determined by real-time information availability, accuracy, completeness and frequency of updating contributes to enterprise operations and decision-making (DeGroote and Marx, 2013);

- Technology competency (Leonard-Barton, 1992) referring to the ability to deploy and expand the full implications of the core competencies, to develop and design new products and processes and to upgrade knowledge and transform it into designs and instructions for the creation of desired outcomes;
- System integration (Eisenhardt and Martin, 2000), which supports the integration of knowledge and technology to define the enterprise strategy;
- Firm strategy (Eisenhardt and Martin, 2000) which is a development map of a firm's core competency to create a close relationship between actions and preferred outcomes.

Part III of the questionnaire covers the adoption of ICT. Four key issues of ICT adoption enabling the virtual enterprise and agility in the supply chain are addressed:

- Information systems (Liu *et al*., 2013) that integrate members to enable them to co-operate easily;
- The efficient utilisation of ICT (DeGroote and Marx, 2013) to manage and share large amounts of information across the SC and to coordinate intra- and inter-organisational processes;
- Smart technology that enables smart enterprises and keep time and information accuracy (Ngai *et al*., 2011);
- Decision support systems to aid in the design and development of an effective enterprise collaboration and knowledge management flow (Esposito and Evangelista, 2014).

Part IV aims to reveal the respondents' ability to join in virtual enterprise and to work together for a brief period. Questions cover six specific ability constructs:

- The ability to share business opportunity (Byrne *et al*., 1993) to accrue relational and spill-over rent based on trust;
- The ability to affiliate or organize the virtual enterprise (Bolton, 1996) to establish heterogeneous and immobile network resource;
- The ability to share risk (Camarinha-Matos *et al*., 2009) to reduce the barriers and increase the trust to enterprises who willing to join in virtual enterprise;
- Information and knowledge sharing ability (Cruz-Cunha and Putnik, 2006) to discover possibilities to exploit business opportunities and implementation of virtual enterprise project;
- Time and cost reduction abilities (Davidow and Malone, 1993) to receive benefits from temporary affiliation;

- Security abilities in a virtual enterprise (Gunasekaran and Yusuf, 2002) to control the access to its core knowledge assets and to protect from losing information and knowledge.

Part V contains questions related to agility and consists of five constructs (the first four adopted from a study by Sharifi and Zhang (1999)):

- Speed, emphasising quick responses to market opportunities;
- Flexibility, which incorporates not only design and volume, but also people, resources, and organisation flexibility to enable an enterprise to respond to changes;
- Responsiveness, that is the capability to identify, respond to and recover from changes,
- Competency to operate efficiently, produce high-quality and high-performance products, deliver on time, innovate, and manage core competence;
- Quality (Yusuf *et al*., 2004) of goods and services, that customers are prepared to accept as a 'one-off' competitive source of supply.

4.3.1.2 Effect of relationship among drivers, providers and capabilities

Section 3 covers eight questions related to the business performance factor. Seven of them adopted from Agarwal *et al*. (2007) and include: customer satisfaction, quality improvement, cost minimisation, delivery speed, new product introduction, service level improvement; and lead time reduction. The possibility of entering a world market is added to the list.

4.3.2 Data pre-processing

To ensure that the data is useful, reliable and valid for further statistical analyses, preliminary screening is conducted for the collected data. The statistical package SPSS® (version 20.0 for Windows) (IBM Corporation, 2011a) is used to carry out the statistical analysis of the data collected in the study. First, missing data (IBM Corporation, 2011b) is explored and some questionnaires that contain insufficient data are eliminated for further analyses. Then, the graphical tools of histogram, normal curve, Q-Q plot, P-P plot, and boxplot are used to check visually the normality of the distribution of data. To assess the characteristics of the distribution of the data as to whether the variables are normally distributed, distribution function statistics are estimated. Since the dataset is smaller than 2000 elements, the Shapiro-Wilk statistics result is chosen to explain normality. The result of statistic test for aggregated average value of six main factors is shown in Table 4-3. When the significant value of the Shapiro-Wilk Test is greater than 0.05, the data is assumed normal. For five factors of external change, enterprise capability, virtual enterprises, ICT adoption and agility in the supply chain, the significance value of the Shapiro-Wilk Test is greater than 0.05 therefore the null hypothesis is rejected.

That means the data comes from a normal distribution. However, the statistical significance value for the business performance is lower than the threshold. The null hypothesis cannot be rejected for that dataset distributed normally.

Table 4-3: Shapiro-Wilk test for normality

Factors	Statistic	Degree of freedom	Significance
Enterprise internal capacity	0.994	205	0.510
Ability to join in VE	0.990	205	0.156
External changes	0.987	205	0.058
ICT adoption	0.981	205	0.007

4.3.3 Identification of underlying constructs for proposed factors

Exploratory factor analysis is used as a variable reduction technique that identifies the number of latent variables (constructs) and the underlying structure of a set of variables, estimates latent variables which influence responses on observed variables. Principle component analysis was applied for factor extraction. The constructs were rotated using varimax rotation to maximise the variance of the squared loadings of a construct on all the variables in a matrix, which has the effect of differentiating the original variables by the extracted constructs. Some variables without strong correlations are eliminated from the data set. Then the remaining variables are distributed into constructs with the related factors. Hair *et al*. (2010) suggest the variable elimination criteria consists of (a) factor loading equal or above 0.50; (b) eigenvalues greater than 1.0; and (c) results of the principle component analysis explaining usually 60% or higher of total variance. Exploratory factor analysis was performed using the statistical package SPSS® (IBM Corporation, 2011).

The exploratory factor analysis was performed based on the importance rating of the constructs in six main factors, separately. Items related to the main factors were extracted into constructs within its factors. The items have loadings below 0.60 were removed from set and the remaining items were extracted perfectly into corresponding constructs within the related factors. In the result of the exploratory factor analysis, some constructs were integrated with each other as shown in Table 3-4. The Kaiser-Meyer-Olkin (KMO) measure (Kaiser, 1974) of sampling adequacy is calculated for main factors. The KMO values which is greater than 0.8 are generally accepted as being significant and he results show high KMO values, which indicates that the components of factor analysis are acceptable.

Table 4-4: Factor loadings and its reliability for constructs

Factors/ Constructs / Items		Mean	S.D.[a]	Factor loading	Cronbach's alpha
External changes (KMO[b] = 0.755)					
Changes in marketplace (EX_A)					
EX_A1	Decreasing new products time to market	2.927	0.995	0.693	0.733
EX_A2	Product lifetime shrinkage	2,833	0.976	0.831	
EX_A3	Increasing rate of change in product models	3,308	1.076	0.782	
Changes in competition (EX_B)					
EX_B2	New initiatives of competitors	3.469	1.072	0.847	0.774
EX_B3	Competitors technological advance	3.590	1.065	0.803	
EX_B4	Increasing pressure on cost	3.590	1.145	0.774	
Changes in customer requirements (EX_C)					
EX_C1	Quality increasing and price decreasing expectation	3.203	1.135	0.797	0.674
EX_C2	Quicker delivery time and time to market	3.115	1.016	0.771	
EX_C3	Advanced technology in product model	3.402	1.033	0.649	
Changes in technology and innovation (EX_D)					
EX_D1	Time decreases on introduction of new soft technologies (software and methods)	2.957	0.871	0.894	0.871
EX_D2	Time decreases on introduction of innovation	2.947	0.864	0.901	
Dynamic capabilities (KMO[b] = 0.915)					
Strategy and human related competency (DC_AE)					
DC_A2	Manager's skills to make quick and perfect decision	3.737	0.727	0.754	0.809
DC_A3	Employees' skills and knowledge to use new technology	3.859	0.801	0.816	
DC_E1	Sensing/identifying changes and fast response	3.537	0.866	0.621	
DC_E2	Fast operation time	3.226	0.833	0.651	
Information quality (DC_B)					
DC_B1	Information accuracy	3.532	0.937	0.786	0.919
DC_B2	Information availability	3.566	0.930	0.828	
DC_B3	Real-time information	3.576	0.902	0.819	
DC_B4	Frequency for updating information	3.532	0.998	0.679	
DC_B5	Information accessibility	3.444	0.898	0.663	
Technology competency (DC_C)					
DC_C1	Usage percentage of new technologies for operations	3.517	0.932	0.743	0.893
DC_C3	Frequency to update technology	3.260	0.998	0.872	
DC_C4	Level of automation in operations	3.361	1.046	0.720	
DC_C5	Technological innovation in product and process	3.309	0.989	0.732	
System integration competency (DC_D)					
DC_D1	Integration of operation system	3.541	0.877	0.661	0.865
DC_D2	Hole internal system integration	3.644	0.993	0.842	
DC_D3	Integration of internal and external connectivity	3.556	0.956	0.801	
ICT adoption (KMO[b] = 0.879)					
Information system (ICT_A)					
ICT_A1	Supplier relationship management (SRM)	3.431	1.057	0.757	0.905
ICT_A2	Production IS	3.399	0.987	0.711	
ICT_A3	Finance IS	3.780	1.027	0.774	
ICT_A4	Advanced ISs to track and/or expedite shipments	3.385	1.077	0.800	
ICT_A5	Customer relationship management (CRM)	3.673	0.998	0.765	
ICT_A6	Usage of own web	3.761	1.079	0.644	
ICT_A7	Integration of IS	3.561	1.113	0.710	
Usage of information technology (ICT_B)					
ICT_B1	PC usage and capability to connect internet	4.337	0.923	0.892	0.834
ICT_B3	Utilization of other devices (e.g. scanners, printers, pocket PC)	4.385	0.836	0.878	
ICT_B4	Internal and external communication network	3.882	1.022	0.701	
Smart technology (ICT_C)					
ICT_C1	Radio Frequency Identification (RFID) and sensor	2.691	1.252	0.641	0.805
ICT_C2	Touchscreen technology	3.127	1.292	0.695	
ICT_C3	Global Positioning Systems (GPS)	2.937	1.325	0.760	
Decision support system (ICT_D)					
ICT_D1	Intelligent Agent (IA) application for data and information processing	2.580	1.176	0.867	0.945
ICT_D2	Analyse basic data and information (factors, numbers, and characteristics)	2.569	1.149	0.891	
ICT_D3	Model analyse of factors, numbers, and characteristics with user criteria	2.554	1.093	0.884	
ICT_D4	Make decision itself and interface to user	2.619	1.106	0.847	
Virtual enterprise (KMO[b] = 0.880)					
Ability to share business opportunity (VE_A)					
VE_A2	Actively share intellectual property (technology and innovation) with partners	3.279	0.947	0.667	0.731
VE_A3	Concurrent execution of activities throughout the SC	3.610	0.992	0.652	
VE_A4	Share resources (human, technology, information and finance)	3.400	0.937	0.743	
Ability to affiliate or organize the VE and to share information and knowledge (VE_BD)					
VE_B3	Ability to make right decision quickly	3.727	0.888	0.680	0.878
VE_B4	Ability to choose right partner quickly	3.667	0.916	0.666	

VE_D1	Information sharing with supplier is timely, accurate, complete, adequate and reliable	3.756	0.939	0.802	
VE_D2	Information sharing with customer is timely, accurate, complete, adequate and reliable	3.805	0.886	0.810	
VE_D3	Knowledge creation, development and sharing	3.800	0.893	0.703	
Ability to share risk (VE_C)					
VE_C3	Financial flow risk (exchange rate risk, price and cost risk, financial strength of SC partners)	3.185	1.050	0.759	0.833
VE_C4	Material flow risk (sourcing flexibility risk, supply product monitoring/ quality, SC ability, product and process design risk, operational disruption, demand volatility/ seasonality, balance of unmet demand and excess inventory)	3.148	0.984	0.671	
VE_C5	Transportation disruption (accident, transportation union strike, etc.)	3.249	1.143	0.750	
VE_C6	Man-made disasters (e.g. terrorism and political instability)	2.961	1.056	0.723	
VE_C7	Natural hazard (e.g. earthquakes, storms, floods, fires, diseases)	2.824	1.061	0.697	
VE_C8	Insurance consumption	3.283	1.209	0.619	
Time and cost reduction (VE_E)					
VE_E2	Inbound logistics time reduction	3.434	0.856	0.718	0.927
VE_E3	Inbound logistics cost reduction	3.245	0.894	0.821	
VE_E4	Manufacturing or distributing time reduction	3.273	0.832	0.833	
VE_E5	Manufacturing or distributing cost reduction	3.161	0.899	0.816	
VE_E6	Outbound logistics time reduction	3.285	0.957	0.791	
VE_E7	Outbound logistics cost reduction	3.260	0.972	0.819	
Prevent, detect, respond and recover from a contamination/security event in VE (VE_F)					
VE_F1	Information sharing security process management	3.350	0.996	0.760	0.917
VE_F2	Partner security management	3.365	0.905	0.846	
VE_F3	Service provider security management	3.304	0.914	0.770	
Agility in supply chain (KMO[b] = 0.920)					
Responsiveness and competency (agility in the supply chain_AB)					
ASC_A1	Fast response to changing market requirements	3.702	0.920	0.825	0.937
ASC_A2	Fast response to changing competitors' activities	3.732	0.919	0.765	
ASC_A3	Quick and right decision-making capability	3.878	0.852	0.842	
ASC_A4	Create appropriate and right information and communication	3.844	0.872	0.830	
ASC_B1	Skill and knowledge enhancement	3.902	0.834	0.743	
ASC_B2	Appropriate ICT and smart technology usage	3.634	1.014	0.721	
ASC_B3	Quick new product introduction	3.688	0.950	0.606	
ASC_B4	Right strategy development	3.756	0.868	0.716	
ASC_B5	Right coordination of operation	3.917	0.833	0.727	
Flexibility/ adaptability (agility in the supply chain_C)					
ASC_C1	Flexibility/ adaptability in order	3.746	0.941	0.726	0.867
ASC_C2	Adjustment of worldwide delivery capacity/ capability	3.639	0.937	0.776	
ASC_C3	Flexibility/ adaptability in payment	3.712	0.950	0.801	
ASC_C4	Level of customization	3.639	0.983	0.712	
Quickness/ speed and quality (agility in the supply chain_DE)					
ASC_D3	Reduction of supply time	3.473	0.872	0.702	0.919
ASC_D4	Reduction of manufacturing time	3.391	0.934	0.707	
ASC_D5	Reduction of distributing time	3.488	0.831	0.743	
ASC_E1	Product and service quality	3.293	0.830	0.736	
ASC_E2	Producing performance quality	3.332	0.827	0.847	
ASC_E3	Information sharing quality	3.325	0.769	0.803	
ASC_E4	Decision making quality	3.327	0.802	0.851	
Business performance (KMO[b] = 0.902)					
BP_A1	Customer satisfaction	4.029	0.766	0.863	0.916
BP_A2	Quality improvement	3.902	0.817	0.864	
BP_A3	Cost minimization	3.546	0.936	0.778	
BP_A4	Delivery speed	3.808	0.850	0.812	
BP_A5	New product introduction	3.764	0.904	0.783	
BP_A6	Service level improvement	3.995	0.783	0.874	
BP_A7	Lead time reduction	3.902	0.897	0.759	

[a] S.D is standard deviation, shows how much variation or dispersion exists from the mean.
[b] Kaiser-Meyer-Olkin measures the sampling adequacy.

To test the reliability of internal consistency of constructs during exploratory factor analysis, the Cronbach's alpha coefficient was used. A commonly accepted rule of thumb for the scale of Cronbach's alpha is above 0.7 (Kline, 2011). Cronbach's alphas are calculated for all constructs and ranges from 0.674 to 0.945, which is indicating acceptable internal consistency as shown in . However, the Cronbach's alpha value of construct of the changes in customer requirements (0.674) is slightly below the threshold. Although this low alpha value could pose a problem, the study included this construct in the establishment of factors for the hypothetical model, as it was an important characteristic in the research.

4.3.4 Assessing of the measurement model

In this section, confirmatory factor analysis was performed to test whether the data fits the hypothesised measurement model whether the measures of a latent variable are consistent with the nature of observed variable. The SPSS® AMOS (Arbuckle, 2013) was used to calculate the formation of the causal relationship among the concepts that comprise the hypothetical model, and to analyse the level of influence among the causal relationships. This study confirms the structural model by verifying its appropriateness from the results of the covariance structural analysis. The maximum likelihood method is used for calculating the covariance matrices between two variables in a measurement model. Several fit indices are produced and moderated. AMOS allows for the use of modification indices to generate the expected model fit, when adequate fit was not achieved. Two methods could have been used to moderate the fit. The first method involved deleting the path that showed a low causal relationship, and the second method involved an additional causal relationship. The second method was chosen by establishing an additional causal relationship to the measurement model.

Generally, it is recognised that to support the model fit, a consensus among the following fit indices is sought and compared with threshold suggested by (Hair *et al*., 2010). Absolute fit indices measure how well the model is specified by the observed data. That includes χ^2:df ratios on the order of 3:1, SRMR is below 0.09, and RMSEA is below 0.08. Incremental fit indices measure how well the estimated model fits relative to some alternative baseline model. A commonly-accepted rule of thumb for the incremental fit indices of CFI, IFI, NFI, and NNFI is to be above 0.9.

The order factor consists of items resulting from exploratory factor analysis that are loaded above 0.6 and are extracted from constructs within related factors. To assess whether all 1st order constructs reflected the 2nd order factors, the 2nd order confirmatory factor analysis was conducted for five 2nd order factors by using extracted 1st order constructs. The results in Table 4-5 indicate that all the higher order measurement models have an acceptable fit. In this research, a measurement model is developed with five 2nd order factors and one 1st order.

Table 4-5: Fit indices of measurement model

GOF measure	χ^2	df	χ^2/df	SRMS	RMSEA	Lower bound	Upper bound	CFI	IFI	NFI	NNFI
Threshold			< 3	< 0.09	< 0.08			> 0.90	> 0.90	> 0.90	> 0.90
External change	65.624	40	1.641	0.051	0.056	0.030	0.080	0.965	0.965	0.916	0.951
Dynamic capabilities	208.706	92	2.269	0.047	0.079	0.065	0.099	0.949	0.950	0.913	0.934
ICT adoption	192.333	104	1.849	0.087	0.065	0.050	0.079	0.965	0.966	0.928	0.954
VE	321.518	204	1.576	0.051	0.053	0.042	0.064	0.961	0.962	0.902	0.952
Agility in the supply chain	219.880	125	1.759	0.043	0.061	0.047	0.074	0.970	0.970	0.934	0.954

Reliability and validity tests are conducted to measure the consistency and accuracy of the measurement models for confirmatory analysis. Composite reliability is a measure of the internal consistency of the latent variables and the suggested threshold is above 0.7. The accuracy of the actual measuring variable was estimated via construct validity test. Two kinds of construct validity tests were executed, including convergent validity and discriminant validity. To assess which indicators of a specific construct "converge" or share a high proportion of variance in common, the average variance extracted (AVE) (Fornell and Larcker, 1981) measure was utilised. Convergent validity was assessed by the AVE above 0.5 and composite reliability greater then AVE. Also as suggested by Hair *et al*. (2010), factors loading should be statistically significant and estimated 0.5 or higher, and ideally 0.7 or higher. Discriminant validity was assessed through identifying which construct is truly distinct from any other constructs. Discriminant validity is supported when the AVE is higher than the squared correlation between two constructs (Fornell and Larcker, 1981). The squared correlation was represented by the Average Shared Variance (ASV). Another measure is the square root of AVE value belonging to each construct needs to be higher than any correlation among any pair of constructs.

Table 4-6 summarises reliability and validity analysis for all constructs. Hence higher order factors contain more abstract level, 1st order constructs were tested as building block for the measurement model. The values of composite reliability for all constructs are above 0.7, except construct of the changes in customer requirements. Although composite reliability value of changes in customer requirements constructs is 0.685 (slightly below the threshold), this is within in accepted range (Hair *et al*., 2010). Reliability between 0.6 and 0.7 may be acceptable, provided that other indicators of a model's construct validity are good, the result represents sufficient reliability for all the constructs. However, some AVE values are slightly below 0.5, all the composite reliability values are greater than the AVE. The result indicates that the measurement model has satisfactory convergent validity. The ASV values for all constructs are lower than the AVE values in the same constructs. Also, square root of AVE is greater than the correlation among pair of other latent variables scores, with respect to its corresponding row and column value. The result indicates no construct shares more variance with another construct than with its own indicators, thus exhibiting sufficient levels of the discriminant validity.

The multi-colinearity occurs when any single independent variable is highly correlates with a set of other variables (Hair *et al*., 2010). Thus, the multi-colinearity test was conducted, because several inter-construct correlations in Table 3.5 were higher than the benchmark value of 0.60. The rule of thumb to judge the existence of multi-colinearity is if variance inflation factors (VIFs) are greater than 10 or if tolerance values are less than 0.10 (Kline, 2011). This study showed that the highest VIF was 2.480 and the lowest tolerance value was 0.403. Thus, multicollinearity did not appear to be a significant problem in this dataset.

4.3.5 Hypothesis testing

A structural model was constructed, to test hypotheses based on the measurement model that validates the data fit with the hypothetical model. This structural model assumed the statistical statements about the relation among variables of conceptual hypothetical model as proposed in section 2 in this chapter. Causal relationships or linkages between statistical variables were examined through the standardised regression weights, which were used as path coefficients. The path coefficient measures the effect from a causal variable to an endogenous variable.

Table 4-6: The correlation, reliability and validity of constructs

No	Constructs	Composite reliability	AVE	ASV	Correlation matrix																				
					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	Changes in marketplace	0.732	0.479	0.070	0.692																				
2	Changes in competition	0.786	0.554	0.037	0.350	0.744																			
3	Changes in customer requirements	0.686	0.423	0.100	0.548	0.516	0.650																		
4	Changes in technology and innovation	0.879	0.785	0.060	0.538	0.296	0.382	0.886																	
5	Strategy and human related competency	0.813	0.523	0.186	0.120	-0.010	0.018	0.201	0.723																
6	Information quality	0.921	0.702	0.173	0.053	-0.040	0.137	0.042	0.699	0.838															
7	Technology competency	0.893	0.676	0.184	0.221	0.053	0.231	0.223	0.634	0.727	0.822														
8	System integration competency	0.866	0.683	0.187	0.173	0.037	0.040	0.088	0.627	0.689	0.678	0.826													
9	IS	0.904	0.576	0.210	0.168	0.147	0.201	0.092	0.554	0.538	0.501	0.610	0.759												
10	Usage of IT	0.859	0.677	0.088	0.083	0.031	0.069	0.050	0.326	0.302	0.259	0.393	0.516	0.823											
11	Smart technology	0.810	0.588	0.103	0.050	-0.101	-0.089	-0.014	0.291	0.380	0.403	0.410	0.540	0.352	0.767										
12	DSS	0.943	0.807	0.090	0.073	0.016	-0.021	0.068	0.179	0.304	0.339	0.364	0.459	0.190	0.724	0.899									
13	Ability to share business opportunity	0.735	0.487	0.191	0.216	0.133	0.425	0.192	0.480	0.476	0.467	0.478	0.565	0.369	0.245	0.319	0.698								
14	Ability to affiliate or organize the VE and to share information and knowledge	0.880	0.596	0.238	0.235	0.105	0.411	0.224	0.589	0.499	0.486	0.481	0.616	0.426	0.189	0.254	0.688	0.772							
15	Ability to share risk	0.837	0.464	0.105	0.183	-0.068	0.042	0.141	0.362	0.346	0.352	0.451	0.398	0.165	0.403	0.294	0.396	0.434	0.681						
16	Time and cost reduction	0.928	0.682	0.197	0.249	0.083	0.331	0.233	0.471	0.429	0.503	0.445	0.563	0.346	0.307	0.301	0.430	0.570	0.471	0.826					
17	Prevent, detect, respond and recover from a contamination/ security event in VE	0.921	0.795	0.178	0.234	0.007	0.107	0.204	0.452	0.423	0.443	0.536	0.501	0.245	0.380	0.418	0.493	0.580	0.530	0.605	0.891				
18	Responsiveness and competency	0.938	0.628	0.223	0.232	0.257	0.430	0.276	0.530	0.428	0.367	0.374	0.581	0.369	0.161	0.265	0.599	0.750	0.269	0.545	0.454	0.793			
19	Flexibility/ adaptability	0.868	0.621	0.173	0.298	0.228	0.421	0.310	0.402	0.290	0.376	0.321	0.361	0.386	0.061	0.092	0.481	0.573	0.092	0.452	0.368	0.694	0.788		
20	Quickness/ speed and quality	0.921	0.625	0.145	0.262	0.158	0.304	0.301	0.346	0.138	0.339	0.263	0.280	0.150	0.110	0.173	0.441	0.413	0.271	0.617	0.493	0.565	0.617	0.791	
21	Business performance	0.920	0.621	0.172	0.295	0.218	0.483	0.320	0.389	0.272	0.335	0.277	0.367	0.244	0.052	0.148	0.425	0.609	0.187	0.504	0.392	0.687	0.696	0.627	0.788

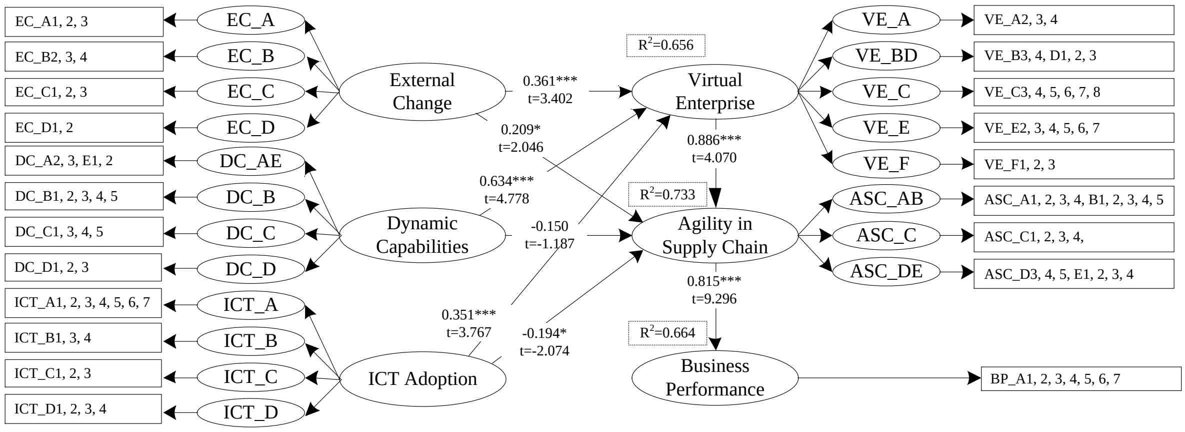
[a] The square root of the AVE on the diagonal

Statistical significance is used as a probability that an effect is not likely due to just chance alone. The statistical significance level (Fisher, 1970) sets the criteria for a decision. In statistical significance testing the p-value is used. When the p-value is less than the predetermined significance level which is often 0.05, the null hypothesis may be rejected. When a result is statistically significant, conclusion could be that the result occurs because of chance. Also, the t-value was used for checking the significance level of estimation for the structural model. A t-value is assumed the critical ratio (CR) in the AMOS output, which represents the parameter estimate divided by its standard error. A t-value > 1.96 or < -1.96 implies statistical significance (Arbuckle, 2013).

The squared multiple correlation R^2 (Hair *et al*., 2010) was computed for endogenous constructs. R^2 for the regression equation indicates the proportion of variance in the dependent variable that is accounted for by the set of independent variables in the multiple regression equation. R^2 values of 0.75, 0.50, and 0.25 are considered to be high, moderate and weak respectively. Direct and indirect relationships (Kline, 2011) between the factors are determined and discussed. The direct effect is a directional relationship between two variables, (i.e. independent and dependent variables). The indirect effect is the effect of an independent variable on a dependent variable through one or more intervening or mediating variables. The total effect is represented by the sum of direct and indirect effect.

The result from evaluation of the structural model (χ^2=7477.387; df=4167; χ^2/df=1.794; RMSEA=0.062; IFI=0.795; TLI=0.782 CFI=0.792) is shown in Figure 4-3. The values of the absolute fit indices indicate an acceptable fit between the hypothetical model and the sample data. Although, the values of the incremental fit indices slightly below the suggested threshold, these values could be accepted. Hair *et al*. (2010) suggest no single 'magic' value always distinguish good models from the bad models, thus the R^2 value should be concerned. If a minimum R^2 value of 0.5 had ever been imposed, it would be just an arbitrary limit that would exclude potentially meaningful research (Hair *et al*., 2010). shows R^2 for dependent variables and all range above 0.65, within acceptable range.

The empirical results as shown in Figure 4-3 provide validation of the conceptual model on which the research hypotheses are based previously (See Figure 3.1).



*p<0.05; **p<0.01; ***p<0.001

N.B: The meanings of the abbreviation are demonstrated in .

Figure 4-3: Structural model with five 2nd order factors and one 1st order factor

The estimated loadings of the constructs in five 2nd order factors, the standard error and the t-value are shown in Table 4-7.

Table 4-7: Regression weights and statistical significance of constructs within factors

2nd order factors	1st order factors	Standard loading	t-value
External change	Changes in marketplace	0.696	
	Changes in competition	0.544***	4.162
	Changes in customer requirements	0.800***	4.810
	Changes in technology and innovation	0.608***	4.689
Dynamic capacities	Strategy and human related competency	0.815	
	Information quality	0.857***	7.257
	Technology competency	0.823***	7.787
	System integration competency	0.810***	7.514
ICT adoption	IS	0.676	
	Usage of IT	0.434***	4.620
	Smart technology	0.870***	6.788
	DSS	0.756***	7.173
Virtual enterprise	Ability to share business opportunity	0.703	
	Ability to affiliate or organise the VE and to share information and knowledge	0.792***	5.652
	Ability to share risk	0.498***	4.457
	Time and cost reduction	0.709***	5.333
	Prevent, detect, respond and recover from a contamination/security event in VE	0.687***	5.413
Agility in the supply chain	Responsiveness and competency	0.836	
	Flexibility/ adaptability	0.800***	8.681
	Quickness/ speed and quality	0.711***	7.877

All three factors including the external change (standard coefficient (S_{CO})=0.361, $p<0.001$, $t>1.96$), the dynamic capabilities (S_{CO}=0.634, $p<0.001$, $t>1.96$) and the ICT adoption (S_{CO}=0.351, $p<0.001$, $t>1.96$) have a positive and significant influence on the virtual enterprise. These three latent factors explain 65.6% (R^2=0.656) of the total variance of the virtual enterprise. In other words, the error variance of virtual enterprise is approximately 34.4% of the variance of the virtual enterprise itself. These results support hypotheses H1a, H2a and H3a.

The analytical results reveal that external change (S_{CO}=0.209, $p<0.05$, $t>1.96$) has significant and positive effect on the agile supply chain. However, the dynamic capabilities (S_{CO}=-0.150) does not have a significant influence on the agile supply chain. ICT adoption (S_{CO}=-0.194, $p<0.05$, $t<-1.96$) negatively and significantly influences the agile supply chain. The virtual enterprise (S_{CO}=0.886, $p<0.001$, $t>1.96$) has a strong positive and significant effect on the agile supply chain. These predictors explain 73.3% (R^2=0.733) of the variance in the agile supply chain. Thus, the results support H1b, H3b, H4 but not H2b.

Similarly, agility in the supply chain (S_{CO}=0.815, $p<0.001$, $t>1.96$) has a significant and positive influence on the business performance. The t-value associated with the relationship between agility in the supply chain and business performance was strongest. The error variance of business performance is approximately 66.4% (R^2=0.664) of the business performance variance itself. This result supports H5. Table 4-8 displays the relationships between the factors. Even though all three factors (external change, dynamic capabilities and ICT adoption) have positive direct effects on the virtual enterprise, the dynamic capabilities have a stronger effect. While the virtual enterprise has a strongest positive direct effect on the agile supply chain, ICT adoption has strongest negative direct effect on agility in the supply chain. Agility in the supply chain has strong and positive direct effect on the business performance, which means that when the value of agility in the supply chain goes up by a factor of 1, the business performance goes up by 0.815.

There is no indirect effect on virtual enterprise affiliation. However, three factors (external change, dynamic capabilities and ICT adoption) have a positive indirect effect; while the dynamic capabilities have strongest indirect effect on agility in the supply chain. The total effect of ICT adoption on agility in the supply chain is 0.117. This means that in the long term, the improvement of ICT adoption provides superior achievement of agility in the supply chain more efficiently than in the short term. Finally, the four variables (external change, dynamic capabilities, ICT adoption and virtual enterprise) affect the business performance positively and indirectly. The virtual enterprise has the highest indirect effect on the business performance.

Controlling agility in the supply chain causes an improvement in the business performance index directly, while an improvement in virtual enterprise provides indirectly a high business performance for an extended period.

Table 4-8: Direct and indirect effects

Endogenous variables	Exogenous variables				
	External change	Dynamic capabilities	ICT adoption	VE	ASC
	Direct effect				
VE	0.361	0.634	0.351	-	-
Agility in the supply chain	0.209	-0.150	-0.194	0.886	-
Business performance	-	-	-	-	0.815
	Indirect effect				
VE	-	-	-	-	-
ASC	0.310	0.562	0.311		-
Business performance	0.431	0.335	0.095	0.722	-
	Total effect				
VE	0.361	0.634	0.351	-	-
ASC	0.529	0.411	0.117	0.886	-
Business performance	0.431	0.335	0.095	0.722	0.815

4.4 Discussion of results

The empirical evidence in this study offers new findings about the association between the drivers and providers and the capabilities and outcomes of the relationship between virtual enterprise and agility in complex supply chains. It is proven that the enterprises can receive benefits when they properly perform the strategy of forming a virtual enterprise to achieve more responsiveness, flexibility, adaptability and quickness with in turbulent environment. Along with the evidence of the impact of drivers and providers on virtual enterprises, this research has provided empirical evidence that external changes drive to form virtual enterprise by increasing ICT adoption and based on the dynamic capabilities. The research confirms that three factors positively and significantly influence virtual enterprise affiliation. First, the evidence strongly supports the assertion that the dynamic capabilities has the strongest and most positive influences on virtual enterprise affiliation. This finding suggests that the virtual enterprise affiliation is not only based on the core competency, but it relies on a capability for renewing competencies to address rapid changes. This research extends previous findings that virtual enterprise affiliated based on core competency (e.g. Cao and Dowlatshahi, 2005; Binder and Clegg, 2007; Camarinha-Matos *et al*., 2009) and provides evidence that to form more dynamic alliance, a virtual enterprise needs to join an affiliation based on the dynamic capabilities of the member enterprises. Secondly, the result confirms that ICT adoption has a positive impact on forming a virtual enterprise. These findings are therefore consistent with those of prior studies that propose the notion that ICT is a main provider of virtual enterprise capability (Byrne *et al*., 1993; Cao and Dowlatshahi, 2005; Rezgui, 2007; Camarinha-Matos *et al*., 2009; Esposito and

Evangelista, 2014). To be flexible and to react quickly, part or full integration of ICT increases the propensity of virtual enterprise to receive benefits from the formation of temporary alliances. The issue of the integration of different objectives, such as those of agents, software developments, activities and systems, and the interoperability and negotiations to make virtual enterprise autonomous could extend this study further. Thirdly, the result also supports the proposition that external changes have a positive and significant impact on virtual enterprises. This finding is consistent with previous assertions by Katzy *et al*. (2004), Esposito and Evangelista (2014) that indicate that external changes can drive enterprises to explore new inter-firm organisational relationship models (such as virtual enterprises) that fit better the new conditions of the competitive scenario and maintain competitive advantage (Byrne *et al*., 1993; Bolton, 1996). Even so, enterprises joining in a virtual enterprise need to handle environmental changes carefully to achieve better outputs.

This study also identifies the impact of drivers and providers on agility in the supply chain. This result proves that external changes directly drive agility by virtual enterprises to respond quickly to fast-changing business opportunities. Firstly, the empirical study gives evidence that the virtual enterprise is the strongest and most positive influencing factor on agility in the supply chain. This result also confirms the statements of many researchers, e.g. Kidd (1994), Cao and Dowlatshahi (2005), and Cruz-Cunha and Putnik (2006), that the virtual enterprise is a main provider of agility, reconfiguring organisations dynamically and virtually to react effectively to changing markets. Correct coordination and integration among independent enterprises in virtual enterprise supports agility in the supply chain to a high degree. Secondly, the result supports the proposition that external changes have a positive impact on agility in the supply chain. This finding is consistent with prior studies, e.g. Yusuf *et al*. (2004), Zhang and Sharifi (2007), Vázquez-Bustelo *et al*. (2007) and Tseng and Lin (2011). The current study has proven empirically how external changes drive agility in complex systems. Thirdly, the result indicates that ICT adoption has a negative impact on agility in the supply chain. This finding is *not* consistent with prior studies of Ngai *et al*. (2011), Liu *et al*. (2013), DeGroote and Marx (2013) etc, as it shows that ICT adoption has a stronger indirect effect on agility in the supply chain. A possible explanation of this phenomenon could be that ICT adoption is having an impact on agility through mediating factors such as the virtual enterprise providing more efficient business performance. Continuous ICT adoption is more effective in providing agility in the supply chain. However, although the study does not prove that there is any direct impact of dynamic capabilities on the agility in the supply chain; the indirect effect analysis reveals that dynamic capabilities have a totally positive effect on agility in the supply chain. This means that over an extended period, an improvement in dynamic capabilities affects the achievement of agility in the supply chain more efficiently through the right strategy than over a shorter time span.

The survey result demonstrates that agility in the supply chain has a strong and positive impact on the business performance. This agrees with previous studies by Swafford *et al*. (2008), Liu *et al*. (2013) and DeGroote and Marx (2013). On the other hand, virtual enterprise affiliation has a strong indirect effect on business performance. The business performance measures the efficiency and effectiveness of actions such as providing agility capability using the virtual enterprise strategy within SC. The study verifies that virtual enterprise is an important strategy in achieving agility in the supply chain to provide efficient business performance. Thus, from the resource-based view perspective, the results have indicated that enterprises should select an informal, dynamic strategy of forming a virtual enterprise to acquire valuable, rare and inimitable network resources like agility and sustain competitive advantages.

4.5 Conclusion

To fulfil the research aims, the driving and providing factors and outcomes from the relationship between virtual enterprise and agility were identified and hypotheses were developed together with a novel conceptual model based on the literature review. An empirical study was conducted to test the hypotheses and to provide insights for practitioners and researchers alike. Several important findings that emerged from the research have both theoretical and managerial contributions and summarised in Section 7.2. Empirical evidence from this study supports the research hypotheses that the drivers have a significant and positive influence on both virtual enterprise and agility in the supply chain. Although the dynamic capabilities have a strong positive influence on virtual enterprises, they do not affect agility in the supply chain. ICT adoption has a positive direct effect on virtual enterprise affiliation but affects agility in the supply chain negatively. Neither is there strong impact from virtual enterprise affiliation on agility in the supply chain and agility in the supply chain on business performance. The result shows enterprises need to pay attention to their dynamic capabilities, and ICT adoption as well as the changing environment to give success when they form virtual enterprise and hope to receive the benefits. This research also provides evidence that the structural equation model offers many benefits and can handle this type of analysis. However, although higher-order factor models are not particularly difficult to construct and evaluate, it is necessary to proceed step-by-step, otherwise, the model does not give a satisfactory result.

CHAPTER 5: THE ACHIEVEMENT OF AGILITY THROUGH DIFFERENT ENTERPRISE CLUSTERS

5 Introduction

This chapter discusses the second stage of the primary study that was conducted with the aim of analysing the effectiveness of virtual enterprise formation based on pre-tested factors. When ever-changing markets, global competition, and technology developments put pressure on enterprises to be agile in supply chains by distinguishing themselves from other competitors to achieve better business objectives, it becomes necessary to collaborate with other specialised enterprises with distinguishing but complementary skills. A trend can be observed towards more interest in skilled and specialised enterprises as part of the desire to improve the benefits from collaboration. Thus, enterprises that have the capacity to achieve better performance are more attractive to capable business partners. Strategies that enterprises take involving driving and enabling factors as identified in the previous chapter can distinguish an enterprise's capacity for collaboration. To investigate how the distinguishing characteristics of enterprises facilitate the various levels of agility in the supply chain, the chapter shows that clustering initiatives have emerged to define a taxonomy of enterprises based on their implementation strategies. The identification of the right partners from various potential enterprises in a supply chain brings the benefits of effective collaboration that deliver agility to the whole supply chain.

Unfortunately, little empirical evidence has been found that investigates how different levels of agility can be achieved depending on the influencing factors of drivers and providers. For instance, Zhang and Sharifi (2007) analyse a numerical taxonomy of agility, and observe three distinct clusters of strategy groups; quick, responsive and proactive players. They suggest that these three strategic groups are shaped by pressures coming from the business environment. Narasimhan *et al*. (2006) clustered firms into three distinguishing groups; agile, lean and low performers, based on their manufacturing practice, performance, demographic variables and measurements of their performance. Kisperska-Moron and Swierczek (2009) explored the main agility capabilities of Polish companies in supply chains and envisaged the main factors contributing to the agility of companies as; relationships with suppliers and customers, IT technology and relations with competitors. The result shows that relations with customers, suppliers and service providers play the most important role in achieving inter-organisational agility. Bottani (2010) extends the study by Narasimhan *et al*. (2006) to investigate the main characteristics of agile enterprises and the enablers that are adopted by companies to achieve agility. All four studies used hierarchical cluster analysis and K-means clustering methods. By contrast, the expectation maximisation algorithm is rarely used in similar studies. This research, however, uses the expectation maximisation algorithm, but adapts it to work with grouped enterprises. Through the analysis, a number of clusters are identified and analysed and the results provide rich empirical evidence of the enterprises' characteristics regarding their strategy of collaboration. Also, the study contributes substantive research methodologies and a taxonomy that may be used in further studies into agility in the supply chain.

5.1 Analysis techniques

For analysing different groups, a clustering technique has been adopted because of its feasibility and 'fitness for purpose'. The clustering technique known as cluster analysis refers to an area of multivariate statistics and is an analytical technique for developing meaningful subgroups of individuals or objects (Hair *et al*., 2010) from data. It has the goal of discovering the natural grouping(s) of set(s) of points and objects that are compact and isolated (Jain, 2010). Clustering algorithms can be broadly divided into two groups; hierarchical and partitional (Jain, 2010). While hierarchical clustering algorithms recursively find nested clusters, partitional clustering methods relocate instances by moving them from one cluster to another, starting from an initial partitioning. Hierarchical clustering algorithms consist of two contrasting strategies; agglomerative, a 'bottom up' approach where each observation starts in its own cluster and pairs of clusters are merged (i.e. based on measures of distance between pairs of observations as one moves up the hierarchy) and divisive; a 'top down' approach where all observations start in one cluster and 'splits' are performed recursively based on the dissimilarity of sets as a function of the pairwise distances of observations in the sets as one moves down the hierarchy.

Partitional clustering algorithms find all the clusters simultaneously as a partition of the data and the observations are not pre-labelled into defined numerical or categorical classes. However K-means analysis (Jain, 2010) is very popular partitional clustering algorithm and is used in various studies, the expectation maximisation algorithm (Demster *et al*., 1977) is more powerful and recently is receiving more attention from researchers. For the K-means clustering k groups need to be chosen *a priori* then each data point is assigned to the cluster with a centre that is closest to that point. Each cluster centre is replaced by the mean of all the data points and this process is reiterated until no data point is reassigned to a different cluster. K-means is deterministic method but on the contrary, the expectation maximisation algorithm is a probabilistic method, so a data point always belongs to multiple clusters and a probability is calculated for each combination of data point and cluster. Depending on a cluster, each data point is assigned a different probability. Also, K-means clustering is sensitive to outliers and noise. The expectation maximisation algorithm is considered to be powerful in computing the maximum likelihood (Xu and Wunsch, 2009) with incomplete data and is a very efficient and robust procedure for learning about parameters from observations. When performing K-means, it is important to run diagnostic checks for determining the number of clusters in the data set. Otherwise, an inappropriate choice of K may yield poor results. Different initial partitions can result in different final clusters. Insofar, it is helpful to compare the results of K-means clustering with other clustering algorithm. Although the expectation maximisation algorithm is very complex in nature, sometimes it is converged very slowly. Additionally, k-means cannot be used with unbalanced data while expectation maximisation can be applied to unbalanced data properly (unbalanced data means that the sample sizse are significantly different for different clusters).

K-means can be regarded as special case of the expectation maximisation algorithm, when the data are continuous, using the Gaussian Mixture Model. During K-means algorithm, two steps of the expectation maximisation algorithm proceed until the cluster becomes stable In the E-step version, the data points are assigned to the closest cluster, while in M-Step, the prototypes of the clusters are updated according the current partition (Xu and Wunsch, 2009).

Both K-means and the expectation maximisation algorithm were used to classify the dataset into clusters. Canonical discriminant function analysis indicated that both clustering techniques resulted in very similar accuracies of clustering, so the result of the expectation maximisation algorithm is adopted to classify data based on the maximising of inter-cluster similarity while minimising the intra-cluster resemblance for further analyses. The reason for this was that the expectation maximisation clustering algorithm had some advantages to classify the dataset into a proper number of clusters and is not sensitive to noise and outliers like K-means. Therefore, this technique is more suitable for automatic clustering of a dataset. Also, the implementation model proposed in the framework needs to cluster datasets into further clusters, so clustering analysis with the expectation maximisation algorithm is employed to partition the general population of enterprises into strategic partners to better understand the relationships between different groups and to explore the achievements of different strategic groups of enterprises with different pressures and abilities.

5.1.1 Expectation Maximization Algorithm

In statistics or machine learning, an expectation maximisation algorithm is adopted widely as an iterative method for finding the maximum likelihood estimation of parameters in models, where the model depends on unobserved latent variables. Xu and Wunsch (2009) state that one of the most important statistical approaches for parameter estimation is maximum likelihood estimation as it considers the best estimation to maximise the probability of all observations.

The expectation maximisation technique could be summarised as follows; given a set of data observations, identify a set of k populations in the data and provide a density distribution model of each of the populations. It is useful to fit a statistical model with unknown parameters to a given set of data, where a popular underlying model is an m-component Gaussian Mixture Model (Lin and Zhu, 2004), for clustering purposes. Lin and Zhu (2004) indicate that the expectation maximisation algorithm has been used for parameter estimation while the Gaussian Mixture Model is used for model-based clustering. In statistics, a Gaussian Mixture Model uses a linear mixture of Gaussian distributions to model the phenomenon of interest.

In the mixture approach (Wu and Kumar, 2009), the observed d-dimensional data $x_1, \dots, x_n$ are assumed from a mixture of K component densities (also known as the number of clusters) in some unknown proportions $\omega_1, \ldots, \omega_K$, which sum to 1. The mixture probability density function for observed x_i is expressed as

$$f(x;\theta) = \sum_{k=1}^{K} \omega_k p_k(x_i;\theta_k) \qquad \text{with} \qquad \sum_{k=1}^{K} \omega_k = 1 \tag{1}$$

where the component density $p_k(x_i;\theta_k)$ is specified the density of x_i from the kth component and θ_k is the corresponding mixture component parametric description. Here, the vector of unknown parameters is given $\theta = (\omega_1, \dots, \omega_{K-1}, \theta_1^T, \dots, \theta_K^T)^T$, where the superscript T denotes vector transpose. When estimating the parameter vector θ by maximum likelihood estimation, objective has focused to maximise the likelihood $L(x,\theta)$, equivalently, the log-likelihood $\log L(x,\theta)$, as a function of θ, over the parameter space. From the observed data $x = x_1, \dots, x_n$, the log-likelihood is given

$$\mathrm{L}(x,\theta) = \log f(x;\theta) = \sum_{i=1}^{n} \log\left(\sum_{k=1}^{K} \omega_k p_k(x_i;\theta_k)\right) \tag{2}$$

Equation (1) is used as the typical Gaussian Mixture Model, when $f(x_i;\theta)$ are multivariate Gaussian distribution with parameters of mean vector μ_k and covariance matrix Σ_k of the kth Gaussian distribution probability density function p_k, for $1 \le k \le K$. The expectation maximisation algorithm is an iterative algorithm to maximise $L(x,\theta)$, in each iteration of which there are two steps including the expectation step (E-step) and maximisation step (M-step). Thus, a series of parameter estimates $\theta^0, \theta^1, \ldots, \theta^t$ have being generated during standard expectation maximisation algorithm until the converge criterion is reached at the final step. The conditional expectation computation and the parameter estimates alternated expectation maximisation algorithm steps are summarised as below.

1. Initialise $\omega^0$and θ^0 by the parameters of mean vector μ^0 and covariance matrix Σ^0 and set $t = 0$;

2. E-step, compute the conditional expectation of the complete data log-likelihood. The log $L(x,\theta)$ is replaced by the Q –function, so-called conditional expectation given x, using the current fit for $\theta^{(t)}$. This step reduces to the computation of the conditional density of the $\phi_{ik}^{(t)}$.

$$\mathrm{Q}\left(\theta,\theta^{(t)}\right) = \sum_{i=1}^{n}\sum_{k=1}^{K} \phi_{ik}^{(t)}\{\log(\omega_k) + \log p_k(x_i;\theta_k)\} \tag{3}$$

Where

$$\phi_{ik}^{(t)} = \frac{\omega_k^{(t)} p_k\left(x_i;\theta_k^{(t)}\right)}{\sum_{j=1}^{K}\omega_j^{(t)} p_j\left(x_i;\theta_j^{(t)}\right)}$$

3. M-step, compute $\theta^{(t+1)}$ maximizing $\mathrm{Q}\left(\theta,\theta^{(t)}\right)$. This leads to

$$\omega_k^{(t+1)} = \frac{1}{n}\sum_{i=1}^{n}\phi_{ik}^{(t)} \tag{4}$$

$$\mu_k^{(t+1)} = \frac{\sum_{i=1}^{n}\phi_{ik}^{(t)} x_i}{\sum_{i=1}^{n}\phi_{ik}^{(t)}} \tag{5}$$

$$\Sigma_k^{(t+1)} = \frac{\sum_{i=1}^{n}\phi_{ik}^{(t)}\left(x_i - \mu_k^{(t+1)}\right)\left(x_i - \mu_k^{(t+1)}\right)^T}{\sum_{i=1}^{n}\phi_{ik}^{(t)}} \tag{6}$$

4. Increase $t = t + 1$. Repeat steps 2 and 3 until the convergence condition is satisfied.

As shown in Figure 5-1 the data analysis involved three steps of (1) identify the underlying factors using the factor analysis; (2) clustering the observed data using the hierarchical clustering and expectation maximisation algorithm; and (3) delineate the cluster characteristics using ANOVA or the Kruskal-Wallis test based on data distribution normality.

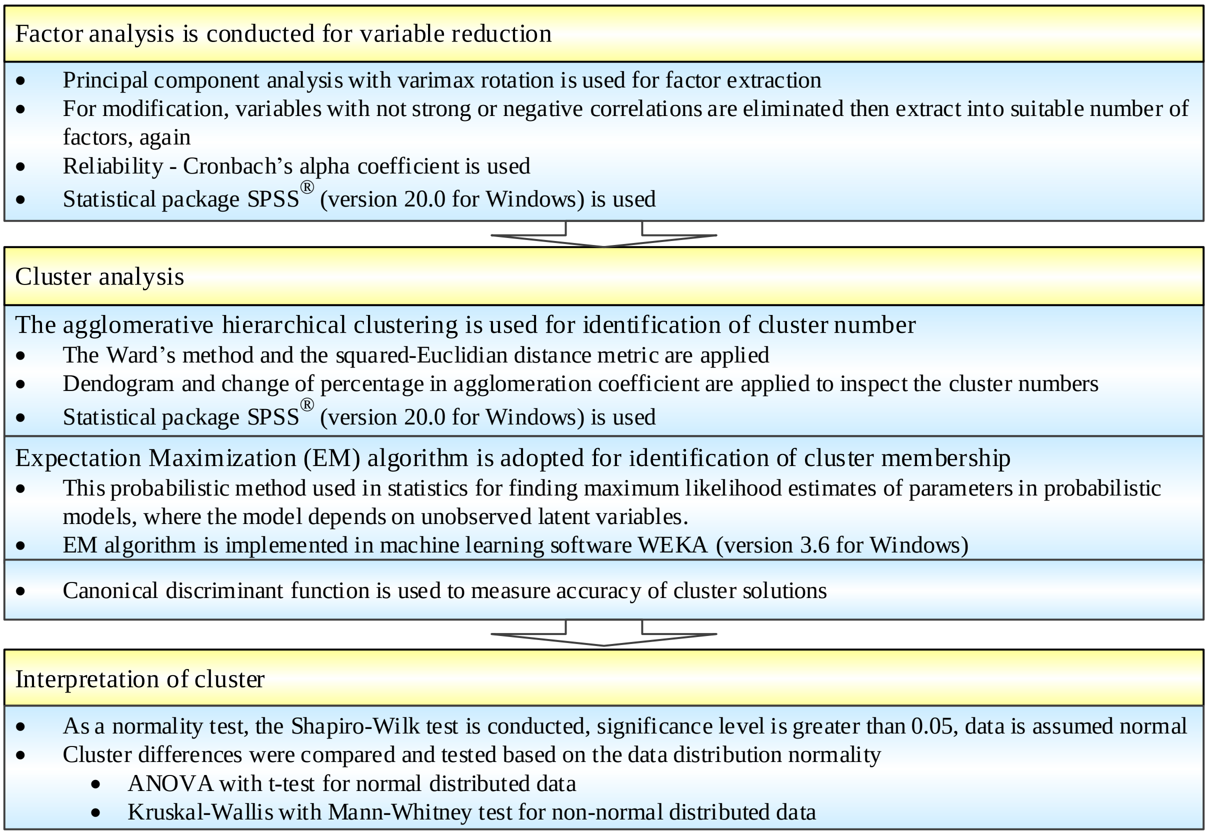


Figure 5-1: **Schema for clustering analysis**

5.2 Empirical study

To achieve the proposed objectives an empirical study was conducted to verify if enterprises use different drivers and providers to achieve to differing levels of agility in the supply chain-based agility using a structured questionnaire as indicated in Chapter 3.

5.2.1 Identification of underlying factors for cluster analysis

The factor analysis was applied with the principal component analysis and varimax rotation, to identify the underlying factors for clustering. In this study, factor analysis is used to reduce the variables that result in a relatively small number of factors that account for most of the variance in a set of observed variables. For the elimination of variables, criteria suggested by Hair *et al*. (2010) are used, as indicated in Section 3.4.2. Also, Cronbach's alpha coefficient was calculated as a reliability parameter to indicate the internal consistency of the new set of variables within the underlying factors.

Factor analysis was performed in the statistical package SPSS® version 20.0 for Windows® (IBM Corporation, 2011). Twenty observed variables, as derived from the literature search in Chapter 3, were inserted into factor analysis and five latent factors with eigenvalues greater than 1 were produced. The last latent factor contains two variables; 'changes in competition' and 'changes in social factors' and this yielded a relatively low reliability coefficient, with a Cronbach alpha value of 0.464. The variable 'changes in competition' loaded in two factors, so the variable 'a change in social factors' was eliminated for further factor analysis. Also, the other two variables with low factor loading (below 0.5) were excluded.

In the final factor analysis solution was obtained with eigenvalues greater than 1 that resulted in four factors describing 65.21% of the total variance as show in Table 5-1. A KMO measure was calculated to 0.877, and a Bartlett's test of sphericity showed high significance ($p< 0.001$), both demonstrating a high confidence in conducting a factor analysis with the variables chosen. Overall, Cronbach's alpha for all variables was 0.873, and for the four specified underlying factors ranges from 0.697 to 0.880, indicating that the internal consistency of variables within factors is good. All the variables of the main factors were extracted exactly into related factors.

The first factor incorporated five variables related to the internal capabilities of enterprises as fundamental providers of agility, labelled 'enterprise internal capacity'. This factor exhibited most of the variance (37.62%) with a reliability coefficient of 0.880. The relatively large proportion of the total variance is explained by this factor. The second factor includes variables related to the ability to join temporary alliances for sharing business opportunities, information and knowledge to achieve agility. This factor explains 13.34% of total variance and is labelled 'ability to join in virtual enterprise'. Cronbach's alpha coefficient of 0.865 indicated variables belong to this factor have good internal consistency.

Changes in technology and innovation, marketplace, customer requirements and competition had questionable internal consistency of 0.697, were included in the third factor named 'external changes'. 8.10% of total variance is explained by this factor. The final factor was labelled 'ICT adoption', accounting for 6.15% of the variance in the data. Variables related to smart technology and DSS were included in this factor and showed high internal consistency.

Table 5-1: Factor analysis: factors, variables and statistics[a]

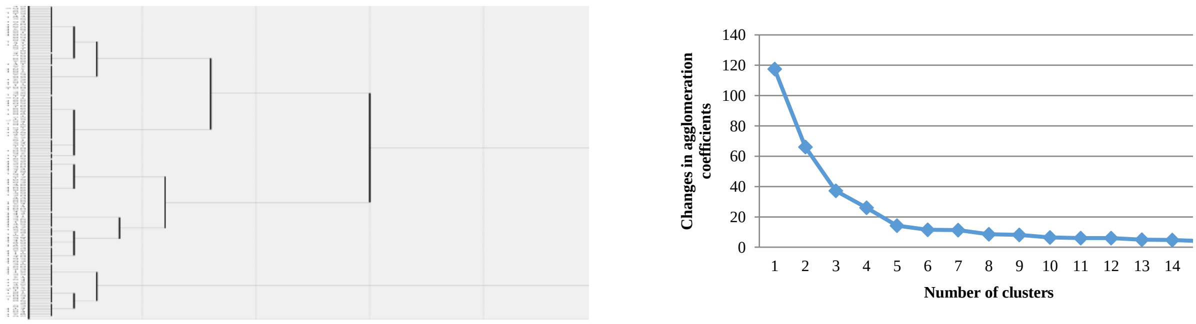
Factors	Variables	Factor loading	Mean	S.D.	Eigenvalue	Variance explained	Cronbach's α
Enterprise internal capacity	Information quality	0.797	3.530	0.811	6.395	37.62	0.880
	Technology competency	0.792	3.460	0.789			
	Strategy	0.775	3.397	0.633			
	Human related competency	0.772	3.798	0.635			
	System integration competency	0.702	3.580	0.837			
Ability to join in VE	Ability to share information and knowledge	0.793	3.620	0.755	2.269	13.34	0.865
	Prevent, detect, respond and recover from a contamination/security event in VE	0.731	3.340	0.870			
	Ability to share business opportunity	0.692	3.487	0.744			
	Ability to affiliate or organize the VE	0.688	3.538	0.798			
	Ability to share risk	0.609	3.073	0.744			
	Time and cost reduction	0.606	3.305	0.755			
External changes	Changes in technology and innovation	0.765	3.033	0.693	1.377	8.10	0.697
	Changes in customer requirements	0.760	3.264	0.800			
	Changes in marketplace	0.686	3.022	0.821			
	Changes in competition	0.657	3.368	0.846			
ICT adoption	Smart technology	0.884	2.855	1.067	1.046	6.15	0.826
	DSS	0.844	2.580	1.049			
Total variance extracted (%)						65.21	
Cronbach's α for all variables							0.873

[a] Factors and variables were arranged according to results of factor analysis (eigenvalue>1 and factor loading>0.5)

5.2.2 Clustering observed dataset

In the next analytical step, the cases were grouped using two analyses of hierarchical clustering and the expectation maximisation algorithm, creating a situation of homogeneity within groups and heterogeneity between groups. The identified underlying factors were used as input variables for clustering. At the beginning, the agglomerative hierarchical clustering was carried out to specify the cluster numbers, using the squared-Euclidian distance metric and Ward's method. The result of the hierarchical clustering is presented as a tree-structured graph or dendrogram to visualise the proper number of clusters as shown in Figure 5-2a. The distance in the dendrogram depends on selected squared-Euclidian distance metric. The dendrogram shows that two to five cluster solutions were possible solutions for this study. To support the result on the dendrogram, the percentage change in the agglomeration coefficient was calculated and the related graph or scree plot is shown in Figure 5-2(b). According to Hair *et al*. (2010) the sharp increase in distance when switching from a one to a two-cluster solution occurs in almost all analyses and must not be viewed as a reliable indicator for the decision regarding the number of clusters. The scree plot shows that there is a clear 'elbow' indicated in the five-cluster solution, that is a suitable number of clusters.

Then, the expectation algorithm was implemented to classify the cases and identify the memberships of clusters. The machine learning software WEKA version 3.6 for Windows® (Hall *et al*., 2009) has advantage in defining an appropriate cluster number by itself, when using the expectation maximisation algorithm. The mean score of the previously-specified four factors in 205 observations is fed into the WEKA data mining tool. The expectation maximisation algorithm successfully clustered the dataset into five distinct groups by itself (log-likelihood value is -3.4403). The result approved the appropriate cluster numbers that are identified in the dendrogram and scree plot as shown in Figure 5-2 (a) & (b).



(a) Dendrogram

(b) Change of percentage in agglomeration coefficient

Figure 5-2: Appropriate cluster number identification

The final cluster solution was validated by canonical discriminant function analysis to assess how accurately the cases were classified into the clusters. In the predictive canonical discriminant function, statistical significance tests using chi-square show how well the function separates the groups. This canonical discriminant function analysis is useful in determining which factors discriminate between clusters from each other.

5.2.2.1 Canonical discriminant function analysis

Four canonical discriminant functions were calculated for the result of expectation maximising clustering by using discriminant analysis on all four factors. The results of the discriminant analysis are summarised in Table 5-2. The standardised canonical coefficient is used to interpret the functions. In principle, standard coefficients represent the relative contribution of the associated variable to the discriminant function. The magnitude of these coefficients indicates how strongly the factors affect the discriminant function.

According to the eigenvalues of 4.126 related to the canonical correlations of 0.897, first function has strongest discriminating ability represented 81.9% of total variance. The proportion of discriminating ability of second and third functions was accounted only 18.1%.

A Wilks's *lambda* test and a univariate F test were conducted to determine the significance of each of the four factors. The resulting discriminant functions were subjected to a chi-square test to determine the significance of the functions. The tests showed that four underlying factors analysed made a statistically significant contribution to the discriminant function.

Table 5-2: Summary of canonical discriminant analysis

	Function 1	Function 2	Function 3	Function 4
Standardized Canonical Coefficients				
Enterprise internal capacity	1.099	-0.160	-0.524	0.337
Ability to join in VE	1.179	0.212	0.097	-0.573
External changes	0.363	0.858	0.300	0.384
ICT adoption	0.661	-0.548	0.674	0.229
Eigenvalue	4.126	0.616	0.293	0.005
Variance explained (%)	81.9	12.2	5.8	0.1
Canonical correlation	0.897	0.618	0.476	0.071
Wilks' Lambda	0.093	0.476	0.769	0.995
Chi-square (χ^2)	474.150	148.088	52.296	0.995
Degree of freedom	16	9	4	1
Significance	0.000	0.000	0.000	0.319

With the help of four identified discriminant functions, the cases were classified and compared with the actual classified cases. Classification indices were examined by two separate analyses to validate the cluster stage. Firstly, discriminate analysis was conducted using the entire sample data set to predict membership in the clusters. A more useful measure to assess the utility of a discriminant model is classification accuracy that is illustrated in Table 5-3. Overall, 91.2% of original grouped cases were correctly classified. More specifically, among Cluster 1 (total=56), 83.9% of the cases were correctly classified; among Cluster 2 (total=29), 93.1% of the cases were correctly classified; among Cluster 3 (total=72), 95.8% of the cases were correctly classified; among Cluster 4 (total=34), 91.2% of the cases were correctly classified; and among Cluster 5 (total=14), 92.9% of the cases were correctly classified.

Table 5-3: Classification result from discriminate factor analysis

Clusters	Predicted Group Membership					Total
	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	
Cluster 1	47 (83.9%)	0	4 (7.1%)	0	5 (8.9%)	56 (100.0%)
Cluster 2	0	27(93.1%)	1 (3.4%)	1 (3.4%)	0	29 (100.0%)
Cluster 3	0	1 (1.4%)	69 (95.8%)	0	2 (2.8%)	72 (100.0%)
Cluster 4	0	1 (2.9%)	2 (5.9%)	31 (91.2%)	0	34 (100.0%)
Cluster 5	1 (7.1%)	0	0	0	13 (92.9%)	14 (100.0%)

In the second analysis, the entire sample is split into two samples. The first sample contains 138 randomly selected cases (67.3% of the population). An analysis of this sample indicates that 92.0% of the cases were correctly classified. The remaining 67 cases (32.7%) belong to the second sample and the correct classification index was 91.0%. The results of these validation procedures suggest an excellent predictive validity for the underlying factors.

5.2.3 Interpretation of the clusters

The underlying factors were found again for the cluster analysis, during the third stage, a normality test was conducted again for the four underlying factors identified. As the ANOVA technique requires that the population means from each cluster need to be roughly equal and variances from each cluster also roughly equal; during lack of this application in the real world, non-parametric Kruskal-Wallis test is assumed alternative method to obtain a strong base to accept or reject the null hypothesis. To decide whether to use ANOVA or the Kruskal-Wallis test, the normality of data distribution was checked. Since the dataset is smaller than 2000 elements, the Shapiro-Wilk test (Shapiro and Wilk, 1965) was conducted as a test of dataset distribution normality. When the significant value of the Shapiro-Wilk test is greater than 0.05, the data is assumed to be normally distributed. By introducing the factor loading scores as composite variables into an exploring procedure, the normality test led to results demonstrated in Table 5-4. For first three underlying factors, the significance value of the Shapiro-Wilk Test is greater than 0.05 therefore the null hypothesis is rejected that means the data comes from a normal distribution. However, the statistical significance values for the ICT adoption were lower than the threshold, thus the null hypothesis is not rejected for the normally distributed data set.

Table 5-4: Shapiro-Wilk test for normality

Factors	Statistic	Degree of freedom	Significance
Enterprise internal capacity	0.994	205	0.510
Ability to join in VE	0.990	205	0.156
External changes	0.987	205	0.058
ICT adoption	0.981	205	0.007

Then, either ANOVA or Kruskal-Wallis tests were conducted to examine the difference between clusters. To check the cross-cluster heterogeneity of the resulting solution on the normally distributed underlying factors of enterprise internal capacity, the ability to join in virtual enterprise and external changes, ANOVA was carried out on mean scores of factors to indicate that the identified clusters are significantly different from each other. Otherwise, for non-normally distributed underlying factor of ICT adoption, the Kruskal-Wallis test was performed comparing the cluster mean ranks. Like most non-parametric tests, the Kruskal-Wallis test compares multiple groups based on their ranking. For ANOVA, the F-test is used for comparing the factors with normal distribution, and p-value tests the null hypothesis that data from all groups are drawn from populations with identical means. Conversely, for the Kruskal-Wallis test, asymptotic significance based on the chi-square distribution is used to test the null hypothesis. As shown in Table 4.5, the results of ANOVA and Kruskal-Wallis tests reveal that all four factors contribute to differentiating the five enterprise clusters ($p < 0.01$).

Following one of the main assumptions in ANOVA, Levene's tests were conducted to analyse the homogeneity of variances for three normally distributed factors. To test that the variances are equal across groups, the option of 'Equality of variance tests' in the ANOVA results window for SPSS® version 20.0 for Windows® (IBM Corporation, 2011) is analysed. This test provides an F-statistic and a significance value (p-value). When the significance value is greater than 0.05 (i.e., $p > .05$), the group variances can be treated as being equal. In this situation, the 't' value from the 'Equal variance assumed' row is selected for further analysis. From this result, the null hypothesis (i.e. that there is no difference in the variance between the groups) is rejected and the alternative hypothesis that there is a statistically significant difference in the variances between groups is accepted. On the other hand, if $p < 0.05$, the assumption of homogeneity of variances is violated. In this case, the alternative hypothesis could not be accepted and conclusion is made that there are no statistically significant differences between means.

ANOVA and Kruskal-Wallis tests do not identify where the differences occur or how many differences occur, further pairwise t-test and Mann-Whitney tests were conducted. The t-test would help analyse the specific pair of clusters for significant differences. The t-test is performed by factor scores of first three normally distributed underlying factors for pair groups. Contrary, the Mann-Whitney U test with 2-tailed asymptotic significance was conducted on the factor scores, as a pair comparison test for the non-normally distributed sample. Then, to examine differences between clusters with respect to each factor, emphasising the importance of each cluster, clusters were compared with each other by ascending mean order. The results of pair comparison tests are demonstrated in Table 5-5.

Table 5-5: Cluster differences by factors

Factors	Cluster 1 (n=56/27.3%)	Cluster 2 (n=29/14.1%)	Cluster 3 (n=72/35.1%)	Cluster 4 (n=34/16.6%)	Cluster 5 (n=14/6.8%)	F or chi-square test	Rank
Enterprise internal capacity	**4.1768**[a]	3.0027	3.6251	2.8021	3.6521	F: 95.192**	4 = 2 < 3 = 5 < 1
Ability to join in VE	**3.9490**[a]	3.0307	3.3757	2.5552	**4.0536**	F: 112.725**	4 < 2 < 3 < 1 = 5
External changes	3.1209[a]	2.9678	3.1749	2.9245	**4.3818**	F: 27.715**	4 = 2 = 1 = 3 < 5
ICT adoption	**3.3821**[a]	**3.2617**	2.6186	1.4693	2.4732	χ^2: 88.436**	4 < 5 = 3 < 2 = 1
	142.57[b]	**136.78**	96.35	29.65	87.07		
Cluster label	**Skilled, ICT aware joiners**	**ICT aware non-joiners**	**All-rounders**	**Low performers**	**Sensitive joiners**		

**p<0.01, significance level

[a] Mean score for representing importance for factors.

[b] Mean rank for representing importance for factors.

NB: '=' means there is no significant difference is exist between clusters. Numbers in bold indicate the significant highest mean for that measuring factor.

The t-test of pair clusters for normally distributed underlying factor of enterprise internal capacity is resulted three significantly different level in importance ranking. However, Cluster 4 has lowest mean score, it is not differed significantly mean score of Cluster 2. Thus, these two clusters belong to low level of internal capacity importance rank. Mean score of Cluster 3 was significantly higher than low level clusters (i.e., Cluster 3 versus Cluster 4, $t=5.693$, $p<0.001$; Cluster 3 versus Cluster 2, $t=-9.474$, $p<0.001$). But there is no significant difference was found between Cluster 3 and Cluster 5, which both belong to middle level. For the top level, mean score of enterprise internal capacity for Cluster 1 (i.e., Cluster 1 versus Cluster 5, $t=2.541$, $p<0.05$; Cluster 1 versus Cluster 3, $t=5.367$, $p<0.001$) was significantly higher than clusters in the middle level.

A pairwise t-test for second normal factor of ability to join in virtual enterprise indicated that there are significant differences between clusters with low mean scores (i.e., Cluster 4 versus Cluster 2, $t=2.525$, $p<0.05$; Cluster 2 versus Cluster 3, $t=-2.618$, $p<0.01$; Cluster 3 versus Cluster 1, $t=4.654$, $p<0.001$). Although no statistical difference was found between Cluster 1 and Cluster 5, across clusters, these two clusters give significantly higher score to the ability to join in virtual enterprise. The t-test result indicated first four clusters with low mean scores were not differed significantly with each other by ranking pair for factor of external changes. However, mean score on external changes for Cluster 5 (i.e., Cluster 5 versus Cluster 3, $t=2.541$, $p<0.05$; Cluster 5 versus Cluster 1, $t=-13.046$, $p<0.001$; Cluster 5 versus Cluster 2, $t=-13.085$, $p<0.001$; Cluster 5 versus Cluster 4, $t=-11.281$, $p<0.001$) is significantly high.

The results of the Mann-Whitney test for pair comparison on a non-normal factor of ICT adoption, indicate three significantly different levels of ICT adoption. While the mean score of cluster 4 is the lowest, this cluster belongs to low level of ICT adopters and mean rank of cluster 4 is significantly lower than clusters in middle level (i.e., Cluster 4 versus Cluster 5, $U=151.000$, $p<0.05$; Cluster 4 versus Cluster 3, $U=466.000$, $p<0.001$). However, mean rank for Cluster 5 and Cluster 3 were not differed significantly, Cluster 3 has higher mean score and mean rank for this cluster was significantly lower than the high level of importance ranking of ICT adoption (i.e., Cluster 3 versus Cluster 2, $U=422.000$, $p<0.001$; Cluster 3 versus Cluster 1, $U=1414.000$, $p<0.01$). Cluster 2 and Cluster 1, belong to high level, were not differed significantly and had highest mean rank.

5.2.3.1 Cluster labeling

Based on the pairwise test of significant differences between two clusters, factors were ranked for each cluster as identifying importance for the cluster. The relative ranking of the importance of factors within clusters was used to label clusters. As shown in , significant highest mean of measuring factors for clusters were inked in bold. Based on this relative importance ranking, clusters have been labelled as shown in bottom row of , and explanations are followed:

- **Cluster 1:** *Skilled, ICT aware joiners*: A total of 56 enterprises are classified into this cluster, representing 27.3% of the sample. Compared with the other clusters, members of Cluster 1 significantly emphasised the factors 'internal capacity', and 'ability to join in VE' and 'ICT adoption' that indicated its critical concerns of the three factors when selecting strategy to achieve agility. However, *Skilled, ICT aware joiners* do not suffer highly from pressure from external changes, as they have an ability to form temporary alliances based on their internal potential and high technology adoption to better respond to business opportunities;
- **Cluster 2:** *ICT aware non-joiners*: A total of 29 enterprises belong to this cluster, representing 14.1% of the sample. Members placed a significantly high importance on 'ICT adoption'. Although no statistically high mean scores were found on 'internal capacity', 'ability to join in virtual enterprise' and 'external changes', *ICT aware non-joiners* rely on adopted intelligent technologies to co-ordinate operations in supply chains to achieve agility;
- **Cluster 3:** *All-rounders*: This is the largest cluster, containing 35.1% of sample (72 enterprises). However, members of this cluster significantly emphasised none of the underlying factors; the mean scores of the factors in this cluster belong to the middle ranking for each factor. Thus, the cluster is labelled *All-rounders* as versatile enterprises, having the ability to join in temporary alliances formed to exploit fast-changing opportunities;
- **Cluster 4:** *Low performers*: A total of 34 enterprises are classified as low performers. The mean score for each underlying factor for this cluster is well below the overall sample mean, and members in this cluster do not emphasize any attributes given by the predicting factors;
- **Cluster 5:** *Sensitive joiners*: This is the smallest group of respondents, containing 6.8% of the sample (14 enterprises). Members of this cluster valued highly the ability to join in virtual enterprise and to respond to external changes. However, the internal capability and high technology adoption of *Sensitive joiners* are not significantly high, but they are able to anticipate external changes in proper time and to affiliate temporary alliances as an opportunistic exploitation of existing resources distributed among traditional companies.

5.2.3.2 Demographic profile of clusters

To understand more about the clusters' characteristics, the cross-validation test is executed to determine the difference between clusters by comparing the basic profiles of respondents, as shown in Table 5-6. Chi-square statistics were employed to determine the statistically significant association between the clusters. The result of cross-tabulation indicates that the type of industry (χ^2=78.139, $p<0.05$) is significantly different for clusters. Also, members of clusters have significantly different number of employees (χ^2=34.400, $p<0.01$) and produce significantly different annual turnover (χ^2=28.976, $p<0.01$).

The cluster *Skilled, ICT aware joiners* consist of the sectors mining and quarrying (13/56=23.2%), transport and freight forwarders (14.3%), services (10.7%) and the manufacturing of food products and beverages (10.7%). However, enterprises in this cluster include the smallest companies having fewer than 9 employees (19.6%) and the biggest companies, with over 50 employees (53.6%). In this cluster, 51.8% of companies produce less than 1 billion *tugriks* of annual turnover while 39.3% have annual turnover over 1.5 billion *tugriks*. Enterprises belong to transport and freight forwarders (31.0%), contruction and materials (13.8%), mining and quarrying (10.3%), information and communication (10.3%), and the processing wood and wooden products (10.3%) constitute 75.7% of *ICT aware non-joiners*. 58.6% of this cluster belong to small enterprises with 19 or fewer employees and 55.2% produce less than 250 million *tugriks* of turnover annually.

The *All-rounders* cluster mostly includes enterprises in the sectors transport and freight forwarders (23.6%), mining and quarrying (12.5%), wholesale and retail trade (12.5%), services (9.7%) and hotels and restaurants (9.7%). Although 50% of the enterprises belonging to the *All-rounders* cluster have between 10 and 50 employees, and 69.4% of the enterprises produce less than 1 billion *tugriks* annually.

The *Low performers* cluster includes businesses in contruction and materials (23.5%), wholesale and retail (17.6%) and mining and quarrying (11.8%). While 44.1% of its members are SMEs, 70.6% of the enterprises have an annual turnover of less than 1 billion *tugriks.*

The *Sensitive joiners* cluster includes businesses in the sectors wholesale and retail trade (14.3%), hotels and restaurants (14.3%), apparel and textile (14.3%) and wood and wooden products. Of these, 57.1% of members have employees 10 to 19, and 71.4% of the enterprises have an annual turnover between 250 million and 1.5 billion *tugriks*.

Table 5-6: Comparison of clusters by demographic profile

Profile variables	Clusters						Pearson χ^2
	Total and percentage	Skilled, ICT aware joiners (n=56/27.3%)	ICT aware non-joiners (n=29/14.1%)	All-rounders (n=72/35.1%)	Low performers (n=34/16.6%)	Sensitive joiners (n=14/6.8%)	
Total	205/ 100%						
Type of industry [a]							
Transport & Freight Forwarder	37/18.0%	8/14.3%	9/31.0%	17/23.6%	3/8.8%	0	78.139*
Mining & Quarrying	29/14.1%	13/23.2%	3/10.3%	9/12.5%	4/11.8%	0	
Construction & Materials	23/11.2%	5/8.9%	4/13.8%	6/8.3%	8/23.5%	0	
Wholesale & Retail trade	20/9.8%	2/3.6%	1/3.4%	9/12.5%	6/17.6%	2/14.3%	
Other services	17/8.3%	6/10.7%	2/6.9%	7/9.7%	2/5.9%	0	
Hotels & Restaurants	15/7.3%	3/5.4%	1/3.4%	7/9.7%	2/5.9%	2/14.3%	
Information & Communication	13/6.3%	4/7.1%	3/10.3%	4/5.6%	1/2.9%	1/7.1%	
Tourism	5/2.4%	3/5.4%	0	1/1.4%	0	1/7.1%	
Oils & Gas	2/1.0%	1/1.8%	0	0	1/2.9%	0	
Manufacturing/ Processing							
Food products & Beverages	13/6.3%	6/10.7%	2/6.9%	2/2.8%	2/5.9%	1/7.1%	
Apparel & Textile	10/4.9%	2/3.6%	0	6/8.3%	0	2/14.3%	
Wood & Wooden products	6/2.9%	0	3/10.3%	0	1/2.9%	2/14.3%	
Publishing, Printing & Reproduction of recorded media	6/2.9%	1/1.8%	0	3/4.2%	1/2.9%	1/7.1%	
Pharmaceuticals, Medical products & Biotechnology	5/2.4%	1/1.8%	0	1/1.4%	2/5.9%	1/7.1%	
Paper & Paper products	4/2.0%	1/1.8%	1/3.4%	0	1/2.9%	1/7.1%	
Number of employees [b]							
1-9	48/23.4%	11/19.6%	10/34.5%	11/15.3%	15/44.1%	1/7.1%	34.400**
10-19	49/23.9%	9/16.1%	7/24.1%	20/27.8%	5/14.7%	8/57.1%	
20-49	33/16.1%	6/10.7%	4/13.8%	16/22.2%	4/11.8%	3/21.4%	
50-199	31/15.1%	11/19.6%	2/6.9%	13/18.1%	4/11.8%	1/7.1%	
over 200	44/21.5%	19/33.9%	6/20.7%	12/16.7%	6/17.6%	1/7.1%	
Company annual turnover (tugrik) [b]							
Less than 250 million	72/35.1%	17/30.4%	16/55.2%	23/31.9%	13/38.2%	3/21.4%	28.976**
Less than 1 billion	61/29.8%	12/21.4%	6/20.7%	27/37.5%	11/32.4%	5/35.7%	
Less than 1.5 billion	19/9.3%	5/8.9%	3/10.3%	3/4.2%	3/8.8%	5/35.7%	
More than 1.5 billion	53/25.9%	22/39.3%	4/13.8%	19/26.4%	7/20.6%	1/7.1%	

* p<0.05, **p<0.01, significance level
[a] Type of industry was defined based on Mongolian Statistical Yearbook 2010
[b] Classification regarding to the Mongolian Law on SMEs

5.2.3.3 Agility achievement and business performance of clusters

To study the achievement of agility and the performance of five distinguished clusters, the mean difference of the variables of agility and performance were compared. As before, to choose parametric or nonparametric methods for the tests, the normality test is conducted and the results are given in Table 5-7.

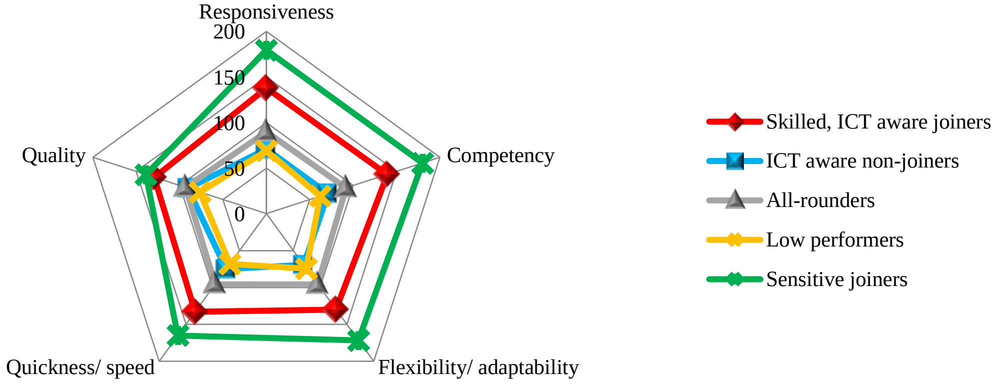
Table 5-7: Shapiro-Wilk test results by mean ranks

Factors	Shapiro-Wilk test			Clusters					Chi-square test	Rank
	Statistic	Degree of freedom	Significance	Skilled, ICT aware joiners (n=56/27.3%)	ICT aware non-joiners (n=29/14.1%)	All-rounders (n=72/35.1%)	Low performers (n=34/16.6%)	Sensitive joiners (n=14/6.8%)		
Agile capability										
Responsiveness	0.938	205	0.000	137.89	71.03	89.85	69.12	179.54	67.454**	4=2=3<1<5
Competency	0.957	205	0.000	139.41	71.12	91.88	62.12	179.89	72.595**	4=2<3<1<5
Flexibility/ adaptability	0.956	205	0.000	129.80	69.45	95.77	74.50	171.68	49.426**	2=4<3<1<5
Quickness/ speed	0.967	205	0.000	132.79	74.95	95.53	68.12	165.07	49.439**	4=2<3<1<5
Quality	0.939	205	0.000	129.14	90.45	93.22	76.62	138.82	27.259**	4=2=3<1=5
Business performance										
Customer satisfaction	0.820	205	0.000	120.51	79.64	98.06	78.31	166.71	38.977**	4=2=3<1<5
Quality improvement	0.844	205	0.000	119.55	78.14	100.51	73.88	171.79	43.215**	4=2=3<1<5
Cost minimization	0.882	205	0.000	116.50	78.81	96.88	92.82	155.29	22.765**	2=4<3<1<5
Delivery speed	0.866	205	0.000	123.77	84.45	99.25	77.54	139.46	24.605**	4=2=3<1<5
New product introduction	0.878	205	0.000	125.30	76.71	97.43	78.32	156.82	35.184**	2=4<3<1=5
Service level improvement	0.839	205	0.000	121.27	77.86	94.35	84.07	172.43	40.686**	2=4=3<1<5
Lead time reduction	0.862	205	0.000	125.64	82.33	92.27	75.59	177.00	48.317**	4=2=3<1<5
Possibility to enter world market	0.899	205	0.000	119.51	90.71	103.05	74.06	132.46	18.527**	4=2=3=1=5

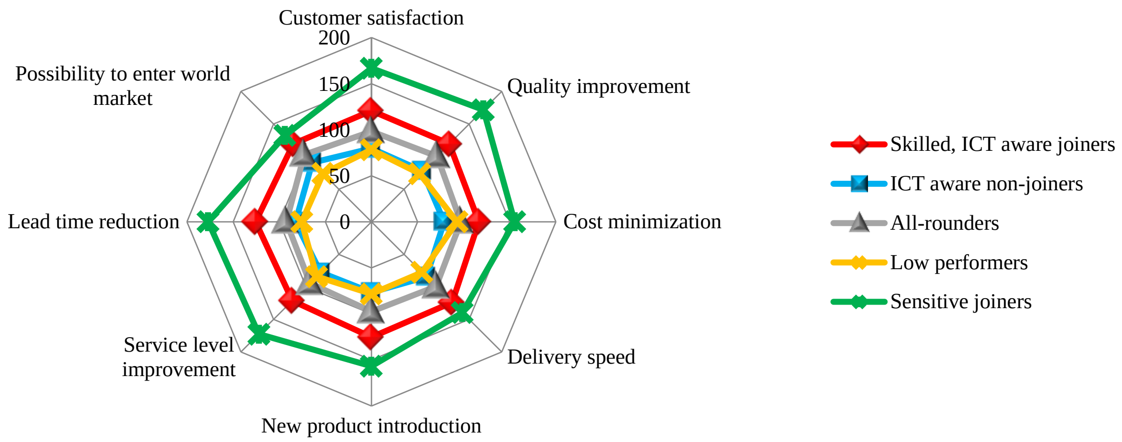
**p<0.01, significance level

NB: '=' means there is no significant difference is exist between clusters. Numbers in bold indicate the significant highest mean for that measuring factor.

The result of Kruskal-Wallis test indicates that the clusters have significantly different effects on agility and business performance. More specifically, *Low performers* and *ICT aware non-joiners* have the lowest mean for agile capability and performance, and mean ranks indicated that two clusters were not significantly differed with each other by capabilities of agility and performance indicators. However, responsiveness and quality capability for the *All-rounders* were not significantly differed from *ICT aware non-joiners* and *Low performers*, mean rank for other agile capability of the *All-rounders* were significantly higher than those two clusters. Comparatively, the mean rank for the performance indicators of cost minimisation and new product introduction of the *All-rounders* were significantly higher than those given by the *ICT aware non-joiners* and *Low performers*. But remaining indicators of performance were not differed significantly from those two clusters. The mean ranks for most variables of agility capability and performance for *Skilled, ICT aware joiners* were significantly higher than *ICT aware non-joiners*, *Low performers* and the *All-rounders* except performance indicator of the possibility to enter world market. Compared to the others, the *Sensitive joiners* have the highest mean ranks for agility capability and performance. Although the relative mean rank of 'quality' does not significantly differ from the *Skilled, ICT aware joiners*, the *Sensitive joiners* have significantly higher scores for their agility capabilities. However, the indicators of performance of the *Sensitive joiners* for new product introduction and the possibility to enter world markets were not significantly different from the *Skilled, ICT aware joiners*; the remaining indicators were ranked significantly higher. To compare the mean ranks of clusters, the 'radar charts' of agility capabilities and performance indicators are shown in Figure 5-3 (a) and (b).



(a) Radar chart of agility for clusters



(b) Radar chart of performance indicators for clusters

Figure 5-3: Cluster differences for the achievement of agility (a) and performance (b)

5.2.3.4 Assessment of clusters by observed variables

The differences between the clusters are evaluated along with seventeen observed variables that are used for factor analysis for the identification of the underlying factors. The Shapiro–Wilk test for variables was identical with previous normality tests for the underlying factors, and the specified variables belong to the first three factors; enterprise internal capacity, ability to join in virtual enterprise and external changes distributed normally as before. However, the variables included in ICT adoption were distributed abnormally. Both the results of ANOVA with pairwise t-test for normally distributed variables and the Kruskal-Wallis test with pairwise test of Mann-Whitney test for not normally distributed variables are shown together in Table 5-8 and that supports the outcome of the clustering procedure described in the previous part and validates that the clusters were identified properly. The results are consisted with the results given in Table 5-8.

5.3 Discussions of results

The empirical evidence in this study offers new findings on how the five distinct types of enterprises characterised by the different factors of drivers and providers achieve different levels of agility and business performance. Significant differences in the findings support the explanation of the clusters' characteristics. Enterprises with best achievement for agility and performance are discussed in the beginning and its implications are specified.

Table 5-8: Cluster assessment by observed variables

Factors	Skilled, ICT aware joiners (n=56/27.3%)	ICT aware non-joiners (n=29/14.1%)	All-rounders (n=72/35.1%)	Low performers (n=34/16.6%)	Sensitive joiners (n=14/6.8%)	F or chi-square test	Rank
	1	2	3	4	5		
Enterprise internal capacity							
Information capability	**4.229**[a]	2.828	3.606	2.741	3.714	F: 45.208**	4=2<3=5<1
Technology competency	**4.129**[a]	2.763	3.572	2.659	3.600	F: 47.967**	4=2<3=5<1
Strategy	**3.991**[a]	2.952	3.406	2.816	3.304	F: 41.698**	4=2=5=3<1
Human related competency	**4.238**[a]	3.345	3.880	3.235	3.929	F: 26.168**	4=2<3=5<1
System integration competency	**4.298**[a]	3.126	3.662	2.559	3.714	F: 49.431**	4<2<3=5<1
Ability to join in VE							
Ability to share information and knowledge	4.131[a]	3.103	3.634	2.843	**4.464**	F: 41.672**	4=2<3<1<5
Prevent, detect, respond and recover from a contamination /security event in VE	**4.014**[a]	3.058	3.287	2.376	**3.833**	F: 34.458**	4<2=3<5=1
Ability to share business opportunity	**4.049**[a]	3.187	3.425	2.713	**4.054**	F: 33.667**	4<2=3<1=5
Ability to affiliate or organize the VE	4.156[a]	3.034	3.489	2.612	**4.607**	F: 66.506**	4<2<3<1<5
Ability to share risk	**3.530**[a]	2.865	**3.155**	2.222	**3.313**	F: 26.259**	4<2<3=5=1
Time and cost reduction	**3.813**[a]	2.936	3.263	2.565	**4.051**	F: 31.557**	4<2<3<1=5
External changes							
Changes in technology and innovation	2.997[a]	2.792	3.050	2.809	**4.125**	F: 12.977**	2=4=1=3<5
Changes in customer requirements	3.236[a]	2.927	3.267	3.007	**4.679**	F: 17.308**	2=4=1=3<5
Changes in marketplace	2.945[a]	2.890	3.031	2.618	**4.548**	F: 19.804**	4=2=1=3<5
Changes in competition	3.305[a]	3.262	3.351	3.265	**4.176**	F: 3.703**	2=4=1=3<5
ICT adoption							
Smart technology	**3.543**[a]	**3.396**	2.782	1.551	2.518	χ^2: 82.412**	4<5=3<2=1
	139.41[b]	**136.74**	98.81	31.49	82.71		
DSS	**3.221**[a]	**3.127**	2.455	1.387	2.429	χ^2: 72.140**	4<5=3<2=1
	138.86[b]	**132.93**	95.60	37.22	95.39		

**p<0.01, significance level
[a] Mean score for representing importance of variables.
[b] Mean rank for representing importance of variables.
NB: '=' means there is no significant difference is exist between clusters. Numbers in bold indicate the significant highest mean for that measuring factor.

According to the evidence, *Sensitive joiners* is the smallest cluster (n=14/6.8%) in this study, and the members significantly emphasise their 'ability to join in virtual enterprise' and to respond to 'external changes', and hence they have significantly higher achievement in terms of agility and performance. The result indicates that enterprises that have a better ability to predict external changes and to adopt these changes and that have the ability to join in temporary alliance as virtual enterprise based on core competencies and technology can achieve the highest level of agility in a supply chain, thus providing the best performance. This result confirms the statement in studies of Van Hoek *et al*. (2001), Gunasekaran and Yusuf (2002) and Cruz-Cunha and Putnik (2006), in which they demonstrated that when enterprises survive unprecedented threats from the business environment and convert the changes into opportunities (Sharifi and Zhang, 1999) by establishing virtual enterprise (Cao and Dowlatshahi, 2005), they achieve the best level of agility in their supply chain. It also validates the proposition that the ability to join in a virtual enterprise is one of most important enablers (Cruz-Cunha and Putnik, 2006) of enterprises to exploit profitable opportunities in volatile business environments. By reacting quickly and effectively to changing markets, using temporary alliances, the achievement of agility significantly provides the best performance (Cao and Dowlatshahi, 2005). In the kind of enterprises involved in the wholesale and retail trades, hotels and restaurants, apparel and textile, and processing wood and wooden products sectors, where customer requirements are often unpredictable and supplier capabilities and innovations are difficult to control. Most of these medium sized enterprises have chosen a more responsive or agile approach, based on innovative products, as an appropriate operational strategy. While, they respond to market changes as quickly as possible they value quality to a lesser extent. As suggested by Sherehiy *et al*. (2007) these medium sized enterprises operating in unstable, changing, and unpredictable environments could have an organic design, which is less formal, less hierarchical, and less mechanistic. Enterprises having decentralised organisation with low formalisation and high complexity often exhibit higher innovation characteristics, but still there is evidence of a lack of effort to penetrate international markets for this kind of enterprise.

Skilled, ICT aware joiners emphasise 'internal capacity', 'ability to join in virtual enterprise' and 'ICT adoption', and their achievement of 'agility' and 'business performance' were lower than the *Sensitive joiners* but higher than other three clusters. This result verified research of Kidd (1994) and Yusuf *et al*. (2012) who view agility as being achieved through their internal capabilities. These internal capabilities are changeable and are manageable by the organisation itself, and underlie specific ability as a provider to respond quickly and effectively to dynamic and unpredictable changes. Providers of the factor 'ability to join in virtual enterprise' (Gunasekaran and Yusuf 2002; Cao and Dowlatshahi 2005; Cruz-Cunha and Putnik 2006) and 'ICT adoption' (Cao and Dowlatshahi 2005; DeGroote and Marx 2013; Liu *et al*. 2013) increased their agility which should in turn provide more efficient business performance. Although enterprises only emphasised their 'ability to join in virtual enterprise' based on their core competencies and technology, without paying unusual attention to sensing their business environment can achieve decent levels of agility as well as performance. Enterprises in the sectors; mining and quarrying, transport and freight forwarders, services and the manufacturing of food products and beverages are defined by this characteristic. However, where the products in this industry exhibit high volume and predictable demand with a high degree of supply certainty, the 'lean approach' operates to create functional products. But some specific conditions are occurring recently in this industry. Since, activity in the Mongolia mining and quarrying sectors started to intensify, this industry has received daily attention from domestic and foreign enterprises. The government viewed this industry is having the potential to boost the national economy, thus providing beneficial opportunities to enterprises. So, enterprises in this type of industry are distinguished by agility as a source of competition. Transport and freight forwarders have followed the mining and quarrying industry and consider mass customisation as the ability to provide individually-designed services to every customer through high process agility, flexibility and integration. The food and beverage industry has the same drive of mass customisation and has achieved a better level of agility. Small enterprises having a less hierarchical organisational structure can adopt an organic organisational form (Sherehiy *et al*. 2007) to interact successfully with their environment. On the other hand, however, the biggest enterprises have mechanistic design processes, highly hierarchical structures and formal management operations with centralised authority, a large number of formal rules and procedures, precise division of labour, a narrow span of control, and a formal means of coordination (Sherehiy *et al*. 2007) based on their high levels of ability have also taken advantages of agility.

This study points to the fact that two type of enterprises have the potential to attract more attention from partners to work together for a desired goal in a virtual enterprise to respond quickly to the rapidly changing business environment. On the other hand, three other clusters of enterprises risk not being assumed to be viable strategic partners.

The third cluster is *All-rounders*, accounting for 35.1% of all respondents. However, members of this clusters do not emphasise any specific strategies, they rather have versatile strategies for 'external changes', 'internal capacities' and 'ability to join in virtual enterprise' to achieve agility. This result confirms that however good enterprises are at recognising unexpected environmental changes and responding to them effectively based on their internal capabilities and establishing the temporary alliances, the achievement of agility and performance levels could be higher compared to enterprises which have no significant emphasis on specific driver and the providers' impact on agility in the supply chain is still questionable.

The fourth cluster, *ICT aware non-joiners,* significantly emphasise advanced ICT utilisation, not linked to 'internal capacity', and their 'ability to join in virtual enterprise' and to respond to 'external changes' and to achieve high levels of agility and business performance are significantly lower. This result indicates that an 'ICT adoption' strategy cannot be the only agility factor for organisations. However this finding is not consistent with studies by Ngai *et* *al*. (2011) and Liu *et al*. (2013) that demonstrate that ICT is regarded as a major facilitator of agility, and found that enterprises should actively engage in a strategic ICT plan together with other drivers or providers to achieve better performance in the supply chain. According to DeGroote and Marx (2013), ICT impact on supply chain agility is influenced by the firm's external environment, internal resources, capabilities, and other antecedents. Therefore, a combined strategy of ICT adoption with other drivers/providers provides advantages for an enterprise to achieve a better level of agility and to receive attention as a potential strategic partner in a supply chain.

The final cluster was labelled *Low performers*, because the enterprises in this cluster have low mean scores for driver and providers as well as for agility and performance. *Low performers* still exhibit distinctive core competencies, especially talented personnel who can easily be redeployed as the 'windows of opportunities' open and close (Yusuf *et al*. 1999) using their better ICT capability. Lack of basic internal capabilities and to sense the changing environment could hinder their ability to be chosen as a partner in virtual enterprise affiliations in the supply chain. Enterprises not exhibiting any drivers and providers also achieve a very low levels of agiilty and business performance and to survive in the market, they enhance their ability to predict unanticipated changes and convert them into business opportunities and improve their skill base of knowledgeable and empowered people and flexible and intelligent technologies, they could be assumed to be viable partners in virtual enterprise affiliation to achieve better levels of agility in a supply chain. These enterprises need to pay attention to enhancing their competitive advantages to survive in a turbulant market.

5.4 Summary

The purpose of this chapter is to develop a taxonomy through investigating how different enterprises achieve different level of agility by surveying enterprises in the Mongolia with regards to their characteristics. The study contributes specific underlying factors of drivers and providers that distinguish enterprises as characteristics and agility capabilities and performance as identified in the literature. Several important findings that emerge from the research have both theoretical and managerial contributions, which are summarised in section 7.2.

Based on the widely accepted concept of agility and its attributes, drivers, providers and measures in the literature, this empirical study analyses different clusters of enterprises and their different achievement levels of effectiveness. Four factors with 20 variables were indicated as the specific underlying factors that distinguish enterprises. Five distinguished clusters with different driver and provider's levels are identified alongwith a cluster analysis based on underlying four factors. The results of this study provide the empirical evidence that the enterprises emphasise differently the driving forces and providers and also have different achievements in terms of of agility and performance. More specifically, when enterprises focus on external changes and their ability to join in virtual enterprise or their internal capability and level of ICT adoption they are most capable of agility within supply chains, together with high performance. Otherwise, without any specific emphasising driver or providers, enterprises can lose their competitve advantage of agility in the supply chain and decrease the performance it delivers.

The analysis methods used in the research, including factor analysis, unsupervised expectation maximisation clustering , ANOVA with a t-test or the Kruskal-Wallis technique with the Mann-Whitney test based on the normality of distribution of the dataset, may be regarded as a methodological contribution for scholars to study data clustering, market segmentation and strategic partner grouping.

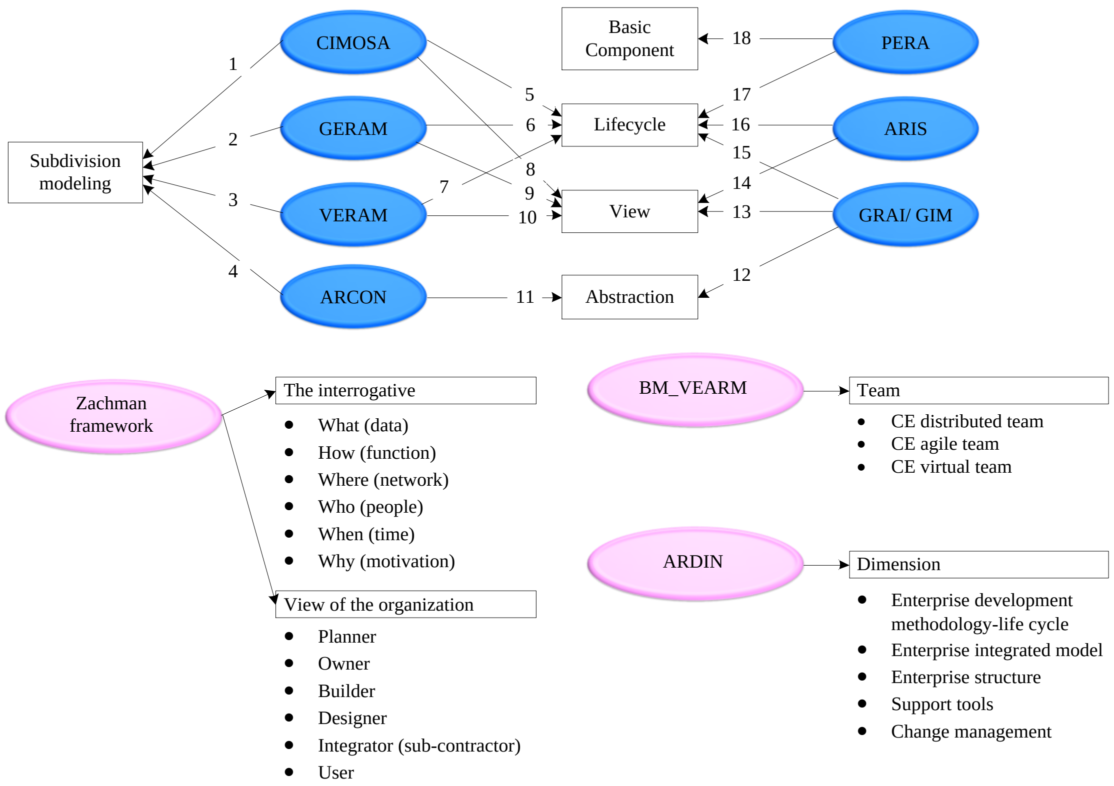
CHAPTER 6: ADAPTIVE FRAMEWORK FOR IMPROVING THE EFFECTIVENESS OF VIRTUAL ENTERPRISES IN THE SUPPLY CHAIN

6 Introduction

In this chapter, an adaptive framework will be discussed together with the fundamentals of framework development, its design and implementation for virtual enterprise formation. The main purpose of this research is to develop a framework that is simple to adopt for enterprises to join in virtual enterprises to improve their effectiveness in a supply chain. Forming a virtual enterprise to exploit fleeting opportunities in the market by forming a temporary network and implementing an integrated system is an extremely complex process. It will involve many different human, technological and organisational components. Therefore, to understand the set of concepts, principles and practices, to study the existing system and to design advanced systems more easily, it is necessary to adopt a step-by-step development methodology to reduce the complexity (Patankar and Adiga, 1995). With the proper knowledge related to virtual enterprise formation, effective collaboration offers the potential for obtaining truly an optimal solution for the achievement of temporary network objectives. However, success depends on the implementation of effective support systems and a careful application of the principles of collaboration. Based on the findings of this study, a main reference architecture is proposed and an adaptive framework is developed and discussed in this chapter.

6.1 Fundamentals of the architecture

A virtual enterprise is an example of enterprise integration, so virtual enterprise formation frameworks need to adopt common reference architectures. The most well-known architectures and frameworks as discussed in Chapter 1, are analysed by their structure as is shown in Figure 6-1. An analysis shows that the reference architectures and frameworks mainly employ multi-dimensional and layered approaches. The integration lifecycles of most of the enterprises' reference architecture models fit into three main subdivisions; generic, partial and particular. For every model in a subdivision, the main perspectives of function, information, resource and organisation are determined to improve decisions by evaluating operational alternatives at each of the lifecycle stages. Some architectures consider the abstraction dimension while others include basic components in their structure, but the Zachman, BM_VEARM and ARDIN architectures have different structures and do not fit into the existing categories produced by the research in 5-1.



Description of the dimensions

- Subdivision modelling: 1, 2, 3 – Generic, Partial, Particular; 4 - General concept, Specific modelling, Implementation;
- Lifecycle: 5, 16 - Requirements definition, Design specification, Implementation description; 6 – Identification, Concept, Requirements, Preliminary design, Design, Detailed design, Implementation, Operation, Decommission; 7 – Identification, Concept, Requirements, Preliminary design, Detailed design, Implementation, Operation, Decommission; 15 – Analysis, Design, Technical Design, Development; 17 – Identification, Concept, Definition, Functional Design, Detailed Design, Construction and Installation, Operation and Maintenance, Renovation or Disposal, Enterprise Dissolution;
- View: 8, 9, 10 – Function, Information, Resource, Organization; 13 - Functional, Physical, Decisional, Informational; , 14 – Control, Product/ Service, Data, Function, Organization;
- Abstraction: 11 – Structural, Componential, Functional, and Behavioral dimensions in CNO, Market, Support, Societal, and Constituency dimensions about CNO abstraction; 12 – Conceptual and Structural abstraction in User Oriented design, Structural and Realizational in Technology Oriented design
- Basic Component: 18 – Production Facilities, People/Organization, and Control and Information Systems;

Figure 6-1: Comparison of reference architectures, by dimensions

6.2 Modelling the framework

As discussed in Chapter 1, the 'second wave' of reference architectures is targeted specifically at collaborative networked organisations, these architectures are highly abstracted thus specific models needed to be developed to guide enterprises more clearly. Therefore, this study considers that there is a need to simplify the abstraction level of reference architectures by using a specialised and instantiated framework to model the enterprises involved. To carry out the stated objective of improving the effectiveness of virtual enterprises, it is necessary to develop a framework that is invoked by the reference architectures and is applied specifically in targeted domains. However, finding the suitable sets of framework components to pick the most appropriate ones is the main problem.

Starting from the evaluation and summarises of existing architectures, the new adaptive framework is developed by sharing a common structure of the main concepts and principles of the developed architectures, and narrowed down systematically with methodologies for virtual enterprise formation. As is shown in Figure 6-2, the existing complementary approaches have been synthesised in to a proposed framework incorporating specific models, techniques, and methods. An adaptive framework aims to clarify the range of concepts, models, techniques and methodologies of virtual enterprise formation and to guide the formalisation and implementation of business integration for enterprises to improve their collaboration effectiveness by following a structured methodology. A multi-dimensional matrix is mixed with a layered approach for the general architecture. Specifically, three integration views cross the five life cycle stages within three levels of the model. The adaptive framework is specifically focused on the generic, partial and particular models of the business integration at the identification stage of the proposed reference architecture.

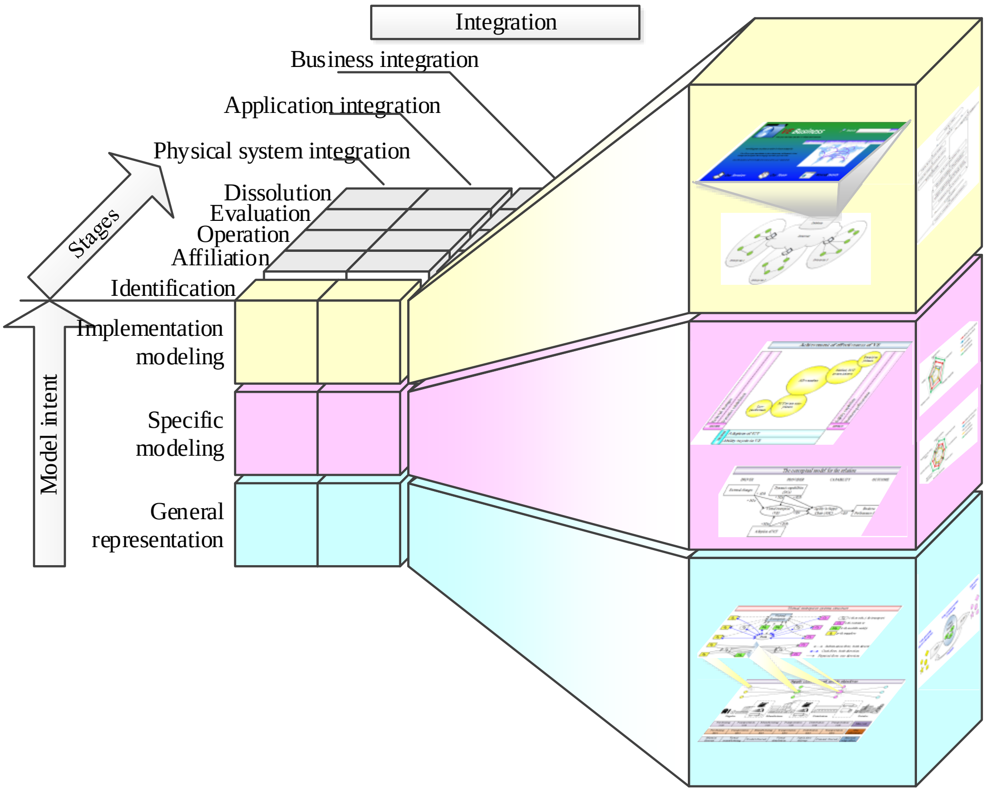


Figure 6-2: **Adaptive framework with common reference architecture structure**

The life cycle stages are unique and vital for the integration of enterprises, especially temporary alliances, and to achieve the integration targets, every stage needs to be defined and integrated properly. As discussed in Chapter 2, the four life cycle phases for virtual enterprises are identified in the literature and models and developed frameworks on those phases are found in practices. However, successful practical implementations of virtual enterprises based on those developed models and frameworks are rare, so this study includes an additional identification phase for reference architectures. Since this initial step has important influences on the outputs of the system, the research has focused on this identification stage and has made an effort to support virtual enterprise effectiveness from the first stage of the lifecycle. This phase aims to evaluate the issues involved in the preliminary preparation of enterprises, their objectives to collaborate and their ability to associate in the short term, so that the collaboration has less chance of failure in subsequent stages. The scope of activities includes processes starting with the identification of businesses, the evaluation of their ability to join in virtual enterprise considering the driver and providers. In addition, it identifies ICT resources needed to enable the necessary information to accelerate the material flow effectively and efficiently, and an evaluation of the agility capability of the virtual enterprise. This stage supports stable and robust virtual enterprise formation.

A virtual enterprise is an integration of enterprises with the purpose of synchronising operations within a supply chain based on core competencies, resources and technology to achieve an emerging business target, so integration levels may need to be determined at the identification stage to improve the efficiency of the virtual enterprise. According to Vernadat (2002) enterprises are integrated at three levels:

1. The physical system at the lowest level (i.e. through the interconnection of devices and machines *via* a computer network);

2. The application at the middle level (i.e. involving the interoperability of software applications);

3. Business integration at the highest level (i.e. business process management including planning, motivating, organising and coordinating, controlling and monitoring).

To successfully operate a virtual enterprise, inter-enterprise integration involving multiple enterprises is required (Gou *et al*., 2003). Many examples are found in the literature of discussions about the integration and interoperation of virtual enterprises at the physical and application levels, so the most suitable ones could easily be adapted for the proposed reference architecture. However, the business integration level is the most important for the identification stage and so the adaptive framework will attempt to establish a way to integrate businesses with other enterprises based on their characteristics.

Like the common reference architectures, the proposed adaptive framework consists of generic, specific and implementation modelling levels. The main concepts and basic constructs of collaboration ensuing from the general level, are specified at the partial level and are narrowed down at the particular level improve the effectiveness of the temporary collaboration. The following sections explain general, specific and implementation modelling in more detail.

6.2.1 General representation modelling

General representation modelling defines the generic concepts related to a virtual enterprise, its forming situation and environment and the requirement to form a virtual enterprise in the first place. The general representation model is demonstrated in **Figure 6-3**. The model supports general virtual enterprise formation based on virtual breeding environment, with its objectives of value chain, and members, and physical, cash and information flow within virtual enterprise. Like other reference architecture, the general representation modelling involves the following views; firstly, structural, addressing the virtual enterprise and virtual breeding environment network structure in terms of its constituent elements such as actors, roles and their relationships, as well as the network topology, secondly component-based, focusing on the virtual enterprise and virtual breeding environment resources composition such as human, technological, information, knowledge, and ontologies, etc. and thirdly functional, attending the virtual enterprise processes, procedures and methodologies as the base functions/operations related to the different Virtual Enterprise lifecycle stages; and finally behavioural, covering the virtual breeding environment principles, policies and governance rules that drive and constrain the virtual breeding environment and its members behaviour.

As considered in Chapter 2, a virtual breeding environment is a perceived network of enterprises within a supply chain that have a long-term collaboration and the adoption of common operating principles and infrastructures, with the main goal of providing a base level of trust and increasing their preparedness to join in potential virtual enterprises. A virtual breeding environment consists of four components:

1. **A consortium of (persistent) partners**: The main sources of value available in the virtual breeding environment network is a pool of enterprises (e.g. suppliers, manufactories, warehouses, wholesalers, retailers and customers). The virtual breeding environment is open to any enterprise, so new members can adhere to the association, but they must comply with its general operating principles. A loosely associated member of the virtual breeding environment may need to adhere to nothing more than a minimum level of organisation 'preparedness' that is necessary for getting involved in a virtual enterprise, and to make some minimum information available to the virtual breeding environment administration (e.g. about their activities related to the virtual enterprise). Typically, a fully active member of the virtual breeding environment contributes to its promotion, growth,

and the enrichment of its collection of resources (see below) and can take an active role from brokerage and planning of virtual enterprises in a niche market to being involved in the expansion of the virtual breeding environment into new sectors and stimulating virtual enterprises towards innovation;

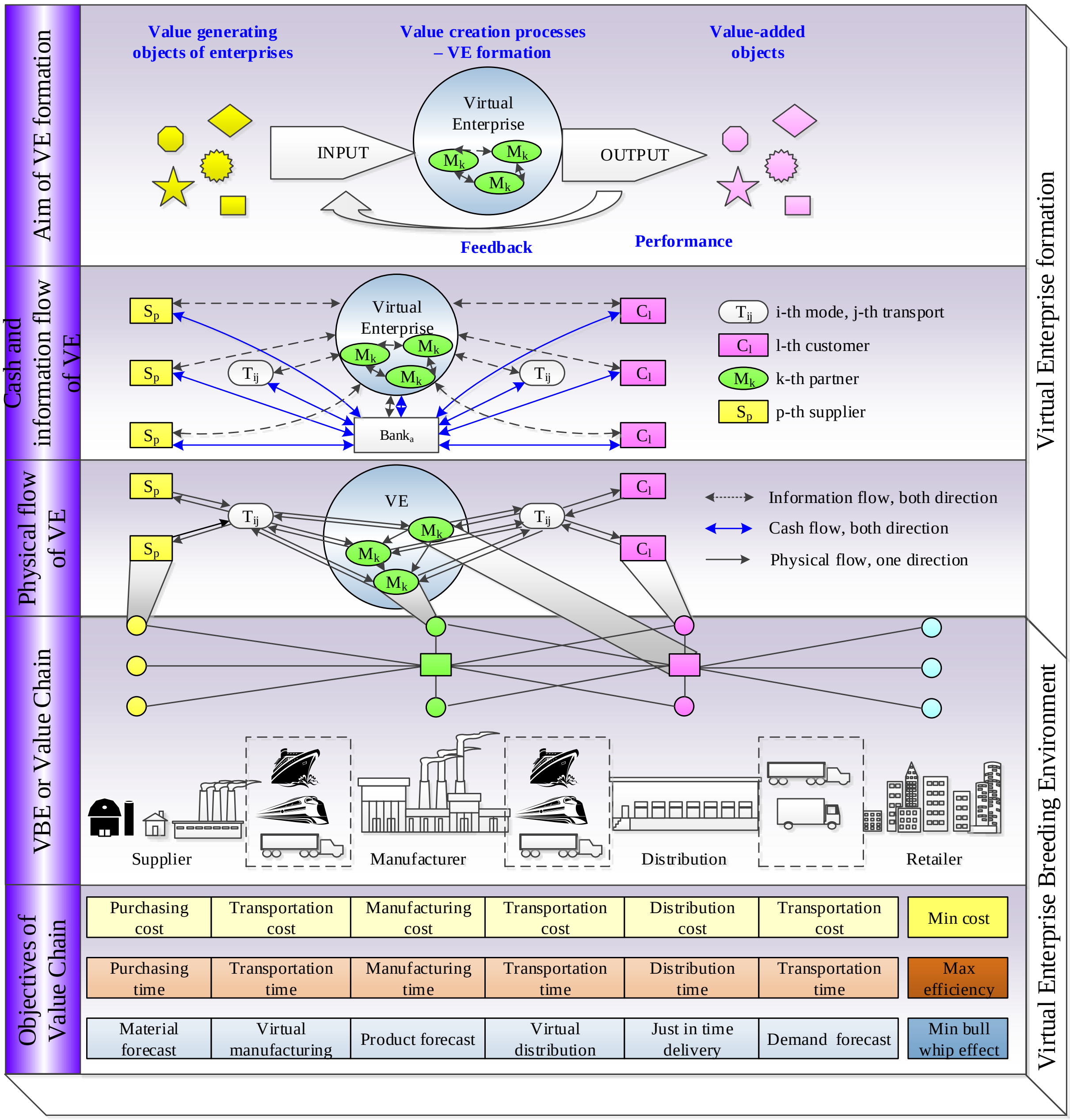


Figure 6-3: General representation of virtual enterprise structure

2. **A collection of resources:** Resources that are a source of benefit can include; materials, energy, services, staff, knowledge, etc. as the primary aim of any virtual enterprise is value creation using network resources. Romero *et al.* (2010) view a virtual breeding environment as a value system with the main purpose of identifying the sources of value

that are available in the virtual breeding environment, which can be measured in terms of tangible (e.g. economic, productivity related etc.) and intangible (e.g. strategic, social, etc.) values or benefits. Value systems are a useful strategic management tool for the identification, measurement and configuration of value generation objects and activities inside the virtual breeding environment (Romero *et al*., 2010). The general representation modelling intends to identify the possible partners in the virtual breeding environment who can combine their knowledge, resources and activities in a value creation system;

3. **A set of policies**: These constrain the way resources can be shared and the partners agree to do business together, including rules for the consortium to expand for establishing specific virtual enterprises. However, every networked system has the purpose of reducing cost and time and while satisfying unstable customer demand. Since a virtual enterprise is a highly dynamic and flexible collaboration network, to create value by joining in a virtual enterprise, modelling and optimising the supply chain is an important way of reducing the cost and time and improve its effectiveness and efficiency.
4. **Agreed supporting tasks:** These operate the processes (management or otherwise) that serve the roles enacted within the virtual breeding environment (e.g. ICT infrastructure governance) to evaluate and offer proper partners by optimising and synthesising the value chain.

6.2.2 Specific modelling for the framework

The middle layer consists of the specific models for the improvement of business configuration that are offered by the virtual breeding environment at a specific moment in time. The current business configuration is understood as; firstly, a pool of enterprises that is organised at that time in terms of virtual enterprises to exploit competitive advantages, secondly, the collection of resources and competence to create value, thirdly the task that support the roles of the partners and their resources, by improving effectiveness of collaboration; and finally, the policies that apply to their instantiation and their coordination at any given time.

Creating a new virtual enterprise may involve identifying partners or the criteria that will need to be observed for discovering such partners ‘on the fly’, depending on the nature of the customers that procure the service (in which case each service may involve different partners). Tasks and virtual enterprises may rely on complementary partners that join the virtual enterprise to provide specific business services and remain in the virtual enterprise only while those services are required. Figure 6-4 aggregates all the concepts related creating of virtual enterprise, its drivers, providers and effectiveness. The scope of the general representation modelling is extended in the specific model and it represents the logical and recursive relationship between factors that has influence on improvement for the effectiveness of virtual enterprise formation. As discussed in the primary study in Chapter 3, drivers lead enterprises to achieve competitive advantage by joining in virtual enterprises and providers increase the positive effect when that strategy is followed. Different levels of agility capability can be achieved by different mixes of the components of drivers and providers. Improvement of the effectiveness of a virtual enterprise can be measured by the difference in the business performance. Likewise, as is analysed in Chapter 4, drivers and providers help to make the differentiation between enterprises and those different clusters of enterprises can achieve different level of effectiveness. Partners can be selected from different clusters or fixed at the time of virtual enterprise creation to be able to accommodate the needs of specific clients.

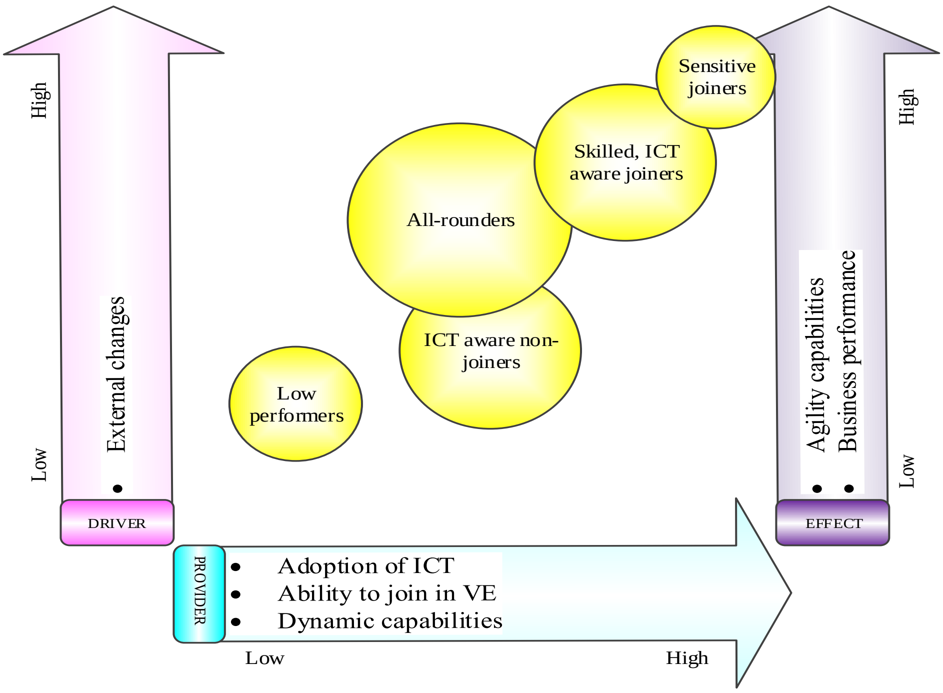


Figure 6-4: Model of driver-provider-effect matrix for enterprise clusters

However, clusters have different levels of achievement in terms of agility and business performance, so to improve the effectiveness of the formation of the whole virtual enterprise, businesses belonging to clusters with low agility levels need to improve their own capabilities. According to Gunasekaran (1998) every partner in a virtual enterprise needs to concentrate on improving their own agility to improve the effectiveness of whole value chain. Structural, ‘componential’, functional and behavioural views go into detail in this specific modelling phase, looking at broad-based strategies with the objective of determining the implementation details to build capabilities for enterprises to improve the effectiveness of a virtual enterprise.

6.2.2.1 Strategies to improve enterprises' ability to support virtual enterprise effectiveness

According to Barney (1991) firms that are willing to obtain initial competitive advantage from being 'first movers' and to sustain that advantage over other firms must be heterogeneous in terms of the resources they control. In the resource-based view, firms are heterogeneous with respect to their resources, capabilities and endowments (Teece *et al*., 1997). However, the resource-based view also considers that managerial strategies for developing new capabilities; the acquisition of skills and the accumulation of intangible assets have the greatest potential for contributing the informal and emergent strategies that can improve the effectiveness of control over scarce resources and this in turn can create superior performance (Chen *et al*., 2012). To improve virtual enterprise effectiveness, the participating enterprises need to have proper capabilities and knowledge of appropriate strategies for collaboration based on ICT and company core competencies to satisfy customer demand 'at the right time, in the right place, at the right price'. The strategies a firm can follow are discussed below.

6.2.2.2 Strategies to handle external changes

Turbulence and uncertainty in the business environment are among the main causes of failure in enterprises (Tseng and Lin, 2011). Even so, by identifying and responding rapidly and effectively to unanticipated changes, enterprises have been able to obtain strength to be competitiveness in the market. A strategic model for external environment and exploiting opportunities or neutralising threats can help to specify which attributes of a firm can be considered as valuable resources (Barney, 1991). Numerous academic and practitioners' models and frameworks to assist in strategic decision making in the context of complex environments and competitive dynamics can be found in the literature. To respond to uncertainty and external changes, strategies need to be dynamic with feedback loops to monitor the execution of the strategy and to inform the next round of planning. Different organisations experience different sets of changes and different levels of pressure resulting from the changes, and therefore require different combinations of strategies, practices and tools to cope with the changes (Sharifi and Zhang, 1999). Some of these strategies are as follows:

- **Market orientation strategies:** To achieve a central set of objectives through continuously changing circumstances, enterprises need to obtain a better understanding of their market as well as their customers, and market-oriented strategies need to be adapted to plan and deploy business resources. The three major components of market orientation are;

customer orientation, competitor focus, and cross-functional coordination, all entailing collecting and coordinating information on customers, competitors and other significant market influencers. Two complimentary market-driven approaches to implementing a market orientation strategy are (Chen *et al*., 2012); firstly the reactive approach, focusing on existing customer preferences within an existing market structure, although companies adopted this strategy are doomed to fall increasingly further behind as they react to customer needs that will surely change by the time they deliver an ultimately out of date product (Stein, 2012). Secondly, the proactive approach, which focuses on shaping the market structure or market behaviour. Enterprises adopted this approach are disruptive to markets, surprising customers with value, are agile, decisive and dynamic (Stein, 2012).

- **Strategies to increase the rate of innovation:** Innovation is the creation and implementation of new value through new business models, new products or services, innovative processes, and 'leading edge' systems in an organisation. Innovation is an important staple in management practice and research (Winby and Worley, 2014). The management of continuous innovation must be as much a part of an agile organisation design as the management of ongoing operations (Winby and Worley, 2014). Enterprises need to set the boundaries by deciding whether they make, buy or make-buy R&D activities to obtain the technological innovations needed to successfully compete (Cruz-Cázares *et al*., 2013). All three strategies have their strengths and weakness that include:

  1. The make strategy is a high-cost approach whose results cannot be clearly foreseen; however, it gives rise to a unique source of knowledge and enables innovative responses to the firm's real needs;

  2. Although the buy strategy is relatively less expensive, has more predictable results and solves capacity problems, it does not in itself yield a competitive advantage, since what is bought on the market is also available to the firm's competitors;

  3. The make-buy strategy contains the individual characteristics of both the make and buy strategies, but it also creates synergies between them. The decision for trade-off between make or buy options is more complex and has focused on a limited set of activities (manufacturing, services, IT, or retail activities, etc) and has provided insight into what determines whether make or buy.

Firms that lack organisational resources but competing in stable markets prefer the 'buy' strategy, whereas firms with technological resources that are immersed in high-technology industries are prone to select the make-buy strategy and internationalised firms with high levels of appropriability prefer the make strategy (Cruz-Cázares *et al*., 2013). When selecting the make-buy strategy, SMEs need to consider the following factors (Daneshgar *et al*., 2013):

- **Strategy and competitive advantage** – has low influence on the decision of SMEs as to larger organisation;
- **Cost** – has an overwhelmingly high influence on the decision;
- **Scale and complexity** – utilisation of standard software is fine, SMEs avoid complex systems;
- **Requirements fit, 'commoditisation', flexibility and change** – have an importance of customised account receivable and accounts payable packages;
- **Time** – a major factor but it depends on the type of the system;
- **In-house IS expertise** – the presence of expertise will motivate in-house development;
- **Risk** – however this factor refers to the probability of a negative outcome such as poor system performance, it was not ranked highly;
- **Support structure** – ranked highly and SMEs interested in get a free copy of the software, this factor will be completely irrelevant;
- **Operational factors** – factors seem to be relevant to SMEs they do not like to be dependent on an outsourced programmer due to the low level of trust between the SME and the programmer;
- **Intellectual property** – SMEs cannot trust outsourcers with the development of systems with high strategic impact, but should build them 'in-house'.

- **Cooperation strategies:** As a strategic alliance, cooperating with other potential partners rather than in competition with them in turbulent environments supports the main benefits of virtual enterprise formation. The cooperation between partner firms within a virtual enterprise is important to improve the responsiveness of the whole organisation to the customer's demand and to be competitive in terms of offering quality goods and services, at keen prices (Gunasekaran, 1998). A cooperative strategy can offer significant advantages to enterprises that are lacking in specific competencies or the resources to achieve business goals. There is a need to create a circle that consists of key members of each partner-organisation so that cooperative work can be organised to respond to the changes in markets in a short timespan (Gunasekaran, 1998). Co-operation strategies can be improved with following features (Gunasekaran, 1998):

- Effective communication system that includes training and education on advanced IT, (e.g. Multimedia, the Internet, CAD/CAM and case tools);
- Supply chain re-engineering can be adopted as a strategy to improve the co-operation among various physically distributed firms in a value chain;
- To obtain best co-operation for creating value to the customers by reducing the cost of production, the company must maintain a database or access online information available on the profile of potential partnering firms;
- The lead firm should consider the organisational structure when deciding about the team and co-operative supported activities between partner-organisations in a co-operation;
- The 'co-operation assurance' system of each firm should be evaluated based on a set of criteria, e.g. the capital and skills available in the company, and the experiences of the company in the past with other virtual companies and their overall performance;
- Since firms are either distributed locally or globally, there is a need to consider each firm's organisational structure and employees' culture in determining the partnership for a co-operation;
- Also, standards are to be established both for the information exchange, software and hardware, and goods exchanged between partner-firms to resolve any communication and delay problems.

- **Sustainable development strategy:** While, collaborating enterprises face more economic, ecological and social challenges, sustainability and sustainability management are increasingly becoming important strategic tasks for enterprises (Leyh *et al.*, 2014). Industries currently face pressures on environmental initiatives from both government regulations and global competition in addition to customer pressure (Diabat *et al.*, 2014). Consumers are seeking sustainable products and services, while investors consider that external resources, such as carbon dioxide emissions, waste management and water consumption, are important to a firm's performance. Stakeholders expect companies to share information about sustainable strategies, and thousands of companies are innovating products and services to promote energy efficiency, renewable power, resource productivity and pollution control. In general, company-wide sustainability management is mandatory for any enterprise wishing to fulfil these demands from customers and business partners (Leyh *et al*., 2014). Sustainability issues can be a source of competitive advantage but even more can sustain the competitive advantage once it is achieved. Therefore, to provide for consumer’s needs, virtual enterprise leader companies will consider the sustainability capabilities of potential partners. However, enterprises attending in the empiric survey conducted by this study have not emphasised sustainability issues. These may include the emergence of new markets, image improvement, increased employee motivation, and the reduction of production costs (Leyh *et al*., 2014).

Recently, more enterprises are recognising the need to deal with sustainable development to facilitate their own economic development while fostering environmental protection and meeting with social request. Most researchers suggest the adoption of green technology, reduction of raw material and energy use, and ‘discovering innovative pathways for recovery and reuse of waste streams in place of virgin resources’ (van Hoof and Thiell, 2014). Collaboration capacity applications include adjusting operational procedures, technologies and/or developing new activities among supply chain partners, such as product re-use or waste recycling, and the implementation of these collaboration capacity measures in and among firms requires specific knowledge of the technical tools needed for priority setting, and the capability to change organisational routines. Diabat *et al*. (2014) identified thirteen enablers of sustainable supply chain management and empirically proven in the textile industry that is helpful for easy implementation of an effective sustainable supply chain management. Recommended enablers can give power, means, competence, or ability to the enterprises and include; employment stability, health and safety issues, community economic welfare, adoption of safety standards, adoption of green purchasing, adoption of green practices, eco-design, government regulations, hazard management, customer satisfaction, environmental cost, economic input to infrastructural development, and improvement of product characteristics.

6.2.2.3 Strategies to improve dynamic capabilities

Teece *et al*. (1997) view 'dynamic capabilities' as an ability to achieve new forms of competitive advantage. The term 'dynamic' refers to the capacity to renew competences to achieve congruence with the changing business environment; certain innovative responses are required when time-to-market is critical, the rate of technological change is rapid, and the nature of future competition and markets difficult to determine. The term 'capabilities' emphasises the key role of strategic management in appropriately adapting, integrating, and reconfiguring internal and external organisational skills, resources, and functional competences to match the requirements of a changing environment. Every organisation has actual and potential strengths and weaknesses, and firms need to determine what they are and can distinguish one from the other to pursue strategies for the improvement of dynamic capabilities at firm-level based on resources the organisation can muster. Strategies to develop firm-specific capabilities and renew the competencies to respond to shifts in the business environment include:

- **Strategies to improve employees' competencies:** A knowledgeable, skilled and well-trained workforce is critical to a temporary collaboration's success. Improving employees' competencies enhances enterprises' competency simultaneously and allows enterprises to remain adaptable and competitive. Thus, integrated human resource policies for the improvement of employees' competencies need to be focused on the individual abilities of knowledge (i.e. conceptual or theoretical knowledge), skills (defined as procedural or applied knowledge)and personal traits (e.g. attitude, behaviour, physical ability) (Succar *et al*., 2013). However, hiring skilled and knowledgeable employees may be difficult and expensive, so it is better that enterprises can establish mechanisms such as training and educating to add individual competencies and create the human capital on their own. The following competencies of employees have been validated in different countries for thirty years in research conducted by the McBer and Hay Groups (Spencer *et al*., 2008):
    - Innovation competency to be able to provide new and original ideas to promote organisational objectives;
    - Adaptation competency – the individual can work efficiently in a variety of situations, with diverse individuals and groups;
    - Customer-orientation competency – understanding the diverse, opposing and even changing perspectives of a subject, knowledge of customers' needs, the purchasing processes of consumers and means of communication for the exchange of information between the company and the customer;
    - Results-orientation competency – refers to the setting of objectives and priorities to maximise the use of resources and the connection between the results obtained and the organisational objectives;
    - The competency of technical expertise is linked to learning and personal development through the acquisition and perfecting of the technical and professional skills needed in those areas related to the workplace, meaning a specialisation in the individual's expert knowledge. Because of the information-intensive nature of the tasks, there is a

need to invest in training and educating people in IT, modelling techniques and concepts (Gunasekaran, 1998).

- **Creation of information and knowledge models:** Since virtual enterprise effectiveness depends on the participating individual enterprises, well-designed information and knowledge models for enterprises need to be noticed to efficiently capture, hold and retrieve the required information and knowledge within and across company boundaries to meet the requirements of dynamicity and agility. The quality of information communicated throughout the supply chain is the basis for coordinated decision making and action (DeGroote and Marx, 2013). Strategic information management systems can enable organisations to create more flexible and efficient structures so that the organisational memories and knowledge of the cooperating parts are available wherever they are needed, thus leading to the age of the virtual enterprise as a new organisational form (Pollalis and Dimitriou, 2008). Besides, knowledge is a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information (Davenport and Prusak, 2000). For sharing implicit and explicit knowledge of 'know-what', 'now-how' and 'know-why' is difficult to enterprises, thus the trust and security issues need to be dealt with before virtual enterprise formation. Pollalis and Dimitriou (2008) suggested the six ways of knowledge creation and dissemination across virtual enterprises. These general knowledge management initiatives include; the creation of knowledge teams, the sharing of best practices, the development of knowledge databases; the creation of knowledge centres, the selection and use of collaborative technologies and the creation of teams to develop intellectual capital.
- **Investment for technology adoption and technology transfer:** To achieve agility through forming virtual enterprises, businesses may need to make intensive use of emerging technology that can include nanotechnology, robotics and artificial intelligence. ICT alone does not guarantee responsiveness as it is too imitable (Gunasekaran, 1998). Thus, specific machining, robotics and artificial intelligence need to be considered by enterprises to enhance automation level to join in dynamic and flexible collaboration. Technology adoption is the implementation of the transferred knowledge about an innovation, and is the end product of extension and the technology transfer involves the moving of technical knowledge, ideas, services, inventions and products from the origin of their development (or other location), to where they can be put to use (Guerin, 2000). Most technologies are consequently termed 'labour-saving', 'time-saving' or 'energy-saving' (Bortamuly and Goswami, 2014). Poor adoption of technology in the supply chain hampers the expansion of

material, information and cash flow and forces the enterprises out of the market (Bortamuly and Goswami, 2014). The timing of technology adoption differentiates the enterprises' capability as a proper partner for virtual enterprise.

- **Organisational changes to develop system integration:** Gunasekaran (1998) states that the organisational structure in an agile context should encourage team work and integration in the partner- organisations in physically distributed enterprises within a short-period by handling high IT content, employing knowledgeable workers with adequate skills in computers and achieving flexibility that is enough to reconfigure itself whenever the market opportunity shifts over time. To bring the component subsystems together into one system and ensure that the subsystems function together as a system, the organisational-level changes should be modelled as a comprehensive approach to developing capacity to implement new technologies or knowledge to successfully engage clients (Guerrero and Kim, 2013). Claiborne *et al*. (2013) state that when organisations embark on deliberate efforts to pursue organisational-level changes, those that demonstrate a greater readiness for change tend to have better outcomes than those that are less ready in terms of the implementation of the proposed change, the effort invested in the change, the persistence for the change, and the degree of co-operation among employees. However organisational change initiatives are time consuming and costly, the initiating, planning, monitoring, executing and evaluating the change programme should be systemically developed to be not failed. To really understand organisational change and begin guiding collaboration successfully, firms should have a broad understanding of the basic systems and organisation structures also leadership and management of the firms. According to Gunasekaran (1998) organisational changes are to be based on matrix organisational structure, and require training and education, employee empowerment and leadership to support agility.
- **Enterprise strategies for changes and cost-efficiency:** Recently, mass customisation is perceived one of the main production strategy to provide products or services through modularised design, flexible processes, integration between supply chain members at low cost (Molina *et al*., 2007; Fogliatto *et al*., 2012). Enterprises select the strategies that maintain flexibility-efficiency 'trade-offs' while choosing between a strategy of dynamic effectiveness through flexibility and an alternative strategy of static efficiency through more rigid discipline. The four enablers of mass customisation are (Fogliatto *et al*., 2012):

  1. Methodologically, mass customisation implementation must rely on agility to respond to personalised demands in timely fashion; besides, the use of lean principles becomes mandatory to provide affordable customisation;

2. Mass customisation processes may be divided into four stages, namely order elicitation, design for postponement or product platforms, manufacturing, and supply chain co-ordination;
3. Advanced manufacturing technologies improve products or processes;
4. ICT was identified as another provider that was followed by the adoption of Internet and e-commerce by almost all sectors in the past decade to be fulfilled correctly through the integration of information flows, while constructing a database of customers' demands and preferences by monitoring the configuration process and to integrate customers in the production process through product configuration, product specification and co-designing.

Molina *et al*. (2007) summarise the different manufacturing production models and conclude that Build-to-Order model can achieve mass customisation ideals, in such a way that the customer will have a customised product within the time, quantity and quality required.

6.2.2.4 Strategies for ICT adoption

To facilitate the flow of knowledge and information across the supply chain and maintain competitive advantage, firms need to invest in ICT as it opens the possibility of integration of ICT with suppliers and customers and reduces trade barriers, providing numerous opportunities for SMEs to compete equally with large corporations. Fast and accurate information exchange can support the goal of forming the virtual enterprise during its dynamic lifecycle. In this study, strategies to improve ICT and investment in ICT adoption for enterprises are discussed within the identified scope in the structured questionnaire.

- **Strategies for integrated and interoperated IS:** To exchange information loosely and accurately in a brief period to exploit fast-changing opportunities, enterprises that are willing to join in a virtual enterprise need to select appropriate strategies on integration and interoperation of their IS to enable the flexible and dynamic structure for agility. Agility requires interoperable enterprise systems to interface with the information and functionality of other systems by adhering to common standards (Vernadat, 2007). An integrated and interoperated strategy which uses an open system approach to recover data from the existing manufacturing system components and transfer data into a common format should be adopted in agile systems (Gunasekaran, 1998). When building interoperable systems enterprises should address five issues (Vernadat, 2007):

  1. How to interconnect services.
  2. How to orchestrate their execution in an orderly fashion.

3. How to synchronise processes.
4. How to control security.
5. How to share data and services with partners.

The following are key components for interoperable enterprises systems that businesses need to consider when they are implementing integrated, IS strategies (Vernadat, 2007):

- **Enterprise portals;** web gateways that provide users with a single point of entry to a large collection of information sources and services;
- **Single sign-on and identify management**; to avoid having to login several times a day on different systems with different usernames and passwords, user authorisation to access IT resources should develop more complex security measures;
- **Workflow engines;** the automation of business processes (even including human activities) and the orchestration of the use of ICT services supporting business services require the use of a workflow engine in the case of well-structured or semi-structured processes;
- **Service registry;** as a metadata repository that maintains a common description of all services, that are described by their name, their owner, their service level agreement and quality of service, their location, and their access method, registered for the functional domain for which it has been set up;
- **Message and service buses;** these are the key to building interoperable enterprise systems and SOAs that are reliable and scalable is to ensure loose coupling among services and applications exchange messages in a neutral format (preferably XML) using simple transport protocols (e.g., XML, SOAP on TCP/IP, etc.).

- ***Investment for advanced ICT and smart technologies.*** To enable the dynamics and flexibility by reacting to the surrounding conditions specifically through adjustment, sense, inference, learning, prediction and self-organisation in virtual enterprise co-operation, enterprises can invest for advanced ICT and smart technologies to increase their capability. Embedded systems such as sensors, controllers, RFID, Bluetooth devices and wearable computers, along with the wireless mobile communication technology are the key factors (Li *et al*., 2009) for smart appliance for supply chains. However, as smart technologies enable real time monitoring and control of whole systems, facilitating collaboration between partners, saving time and costs, they require high purchasing and installing costs and highly educated employees with the necessary knowledge and skills. Poor ICT investment decisions can have a critical impact on organisational profitability, especially in the case of SMEs, so enterprises need to consider more emerging and suitable ICT to enhance the productivity and performance of business. Before investing in advanced ICT and smart technologies, enterprises need to forecast and analyse the cost and risk of ICT adoption, as defined by Gunasekaran (1998):

- Customer interactive computer systems that allow the customer or the representative to configure a design;
- Groupware that enables people located remotely from each other to work co-operatively;
- Greatly improved multimedia human-interface systems;
- Enterprise-wide concurrence that covers all the functions of a company;
- Electronic commerce on international multimedia networks;
- Widespread use of networked distributed databases;
- Software ‘agents’, or ‘burrowing’ programs, which will constantly look for data on a network, look for request for proposals to reply to, order items, continuously update network-based catalogues, etc.;
- Most open IS in companies that will make information much more widely and openly accessible than it is today;
- Software and computers that are much more powerful than those available today, which will enable rapid and powerful simulation and modelling to be carried out for the analysis and approval of design and production plans;
- Better mathematical understanding of representation methods used in design;
- Agreed communication and software standards.

- ***Investment in decision support systems.*** To support business or organisational decision-making activities interactive computer-based DSS need to be adopted to help decision makers utilize the data, models, visualisations and the user interface to solve structured, semi-structured or unstructured problems. Recently, many researchers have agreed on an agent-based system as one of the decision support systems in virtual enterprise formation that promise to offer both problem solving services and the flexibility required for virtual enterprise applications (Aerts *et al.*, 2002; Gou *et al.*, 2003; Akanle and Zhang, 2008). Multi-agent systems are conceived as computerised systems composed of multiple interacting intelligent agents with either similar or different roles within an environment. To make information understandable to the multi-agent system, ontology and semantic technologies adopted. Agent intelligence or decision-making systems mostly adopts tools of search algorithm and mathematical optimisation, logic programming and automated reasoning, probabilistic methods for uncertain reasoning (e.g. Bayesian networks, statistical classification and machine learning, neural networks and control theory). Improvement of DSS gives opportunities to enterprises to be identified as a proper candidate to join in virtual enterprise.

6.2.2.5 Strategies to improve ability to join in virtual enterprises

Since virtual enterprise formation has the purpose of exploiting fast-changing opportunities in a market by incorporating proper partners based on their ability, enterprises that are willing to join in such dynamic networks need to follow strategies to be selected to share the benefits arising from collaboration. Relying only on core competencies and resources to better respond to business opportunities when forming a virtual enterprise is not enough to build trust among potential partner enterprises. To improve their own capabilities to be selected as a proper candidate and to be selected, enterprises need to consider the following strategies based on issues previously identified in Chapter 3:

- ***Strategies to improve possibilities to share business opportunities and trust building.*** When enterprises cannot stand alone to exploit business opportunities they need to share the opportunities with others to receive collaboration rents and to achieve or sustain competitive advantages. Mutual trust can contribute to sharing business opportunities while sharing knowledge, resource, and taking joint risks, thus many research efforts have focused on how to evaluate the trust value of an enterprise when it is considered as the potential partner of a VE (Mun *et al*., 2009). Trust facilitates cooperation by reducing overall opportunistic behaviours as well as by keeping a trustworthy partner in the relationship. Without this, the virtual enterprise can never achieve the full promise of its potential partner (Wei *et al*., 2008). Trust is built through the repeated delivering on their promises by the members (Kumar and Becerra-Fernandez, 2007).

  Sako and Helper (1998) state that information sharing, long-term commitment, technical assistance and reputation will enhance trust in inter-firm network. Nielsen (2002) identifies some pre-alliance formation factors including; prior experience with partners, transparency, reputation, and post-alliance formation factors including; risk, protectiveness, interdependence, longevity, longevity and cultural distance for international strategic alliances. In the multi-agent system, trust can be modelled with three categories (Ramchurn *et al*., 2004); learning-based models using game theory, reputation-based models using past collaboration performance, and socio cognitive-based models assessing the outcome of interactions between agents.

- ***Risk sharing strategy.*** When forming virtual enterprises in short periods with different enterprises, mistakes or failures can happen and adversely affect the performance of the virtual enterprise. Risk measurement and risk management for a virtual enterprise have received considerable interest among researchers and managers of enterprises (Huang *et al*., 2011). In the paradigm of virtual enterprises, there are various sources of risk that may threaten the security of the virtual enterprise, such as market risk, credit risk, operational risk, liquidity risk and others. It is critical for enterprises to take systematic approaches to identifying and interpreting collaboration risks as early as possible, and to implement appropriate strategies to manage the risk propagation throughout the evolution of collaboration (Wulan and Petrovic, 2012). As a virtual enterprise is a complex system temporarily composed of many stand-alone enterprises, the traditional risk model no longer works for a virtual enterprise (Huang *et al*., 2008). Although virtual enterprises may not have historical data available for risk analysis and assessment, Wulan and Petrovic (2012) investigate the potential benefits of applying fuzzy logic-based estimations of risk factors in the areas of supply chains, construction industry, software development and virtual enterprises. They identified and categorised fifteen risks factors that could occur in four phases of pre-creation, creation, operation and termination of virtual enterprise. The listed risk factors can be ranked according to their probabilities of risk occurrence and severities of impact at certain phases under the certain collaboration circumstance, and it includes;
  - Business objectives,
  - Core competences,
  - Partner selection,
  - Trust,
  - Diversity of organisational culture,
  - Collaboration agreement and interest allocation,
  - Communication,
  - Information and knowledge sharing,
  - Collaboration project design,
  - Collaboration project management,
  - Enterprise interoperability,
  - Financial risk,

- Demand risk,
- Supply risk,
- Process risk.

A fuzzy logic-based risk evaluation algorithm is proposed by Wulan and Petrovic (2012), that imprecisely specifies the probabilities of an identified risk and the risk impact to evaluate the likelihood and impact of an overall collaboration risk, then a software prototype Collaboration Risk Evaluator is used as a web service to help either a collaboration facilitator or enterprise users to predict and analyse the risks in their collaboration. Enterprises forming a virtual enterprise need to identify a risk and assess it then select an appropriate way to reduce or share the risk with other members within the collaboration network to mitigate the uncertainty. Risk sharing could reduce the vulnerability of a supply chain, in the both cases of normal operation and disruption.

- ***Concurrent engineering strategy.*** To increase the ability to join in virtual enterprise, members need to consider the methodology based on the parallelisation of tasks to provide mass customisation to enhance the competitiveness and agility in the supply chain. To keep the time while designing complex products or projects with long development times, concurrent engineering strategy could be selected to achieve success for formation of virtual enterprise. Concurrent engineering is defined as a 'systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support' (Prasad, 1995). This approach is intended to cause the developers, from the outset, to consider all elements of the product life-cycle from conception through disposal, including quality, cost, schedule, and user requirements. According to Camarinha-Matos and Afsarmanesh (2003) once a virtual enterprise infrastructure is available, concurrent or collaborative engineering where teams of engineers, possibly located in different enterprises, co-operate in a joint project such as the co-design of a new product. With help of large number of computer supported cooperative tools, synchronous co-operation is becoming available and it supports loosely coupled environment to implement flexible co-ordination of activities for collaborative processes. Rouibah and Ould-Ali (2007) viewed, since design is performed in parallel, concurrent engineering principles force partners to ease the collaboration through the following requirements:
    - Extensively share data needed for design co-operation and hosted by different partners;

- Provide location transparency, i.e. system supplying a user of the virtual engineering community with request data, and users do not need to know at which site those data are located;
- Provide easy access to product data of the business partners if granted;
- Require a notification service to inform users of the virtual engineering community about design progress and its problems; and
- Monitor the progress being made towards the design objectives.

Prasad (1995) identifies seven agents that influence the domain of concurrent engineering:

1. **Talents** – one of main factor to select team member;
2. **Tasks** – one of the primary team issues in concurrent engineering is the decomposition of tasks;
3. **Teams** – often used to cooperatively solve the problem;
4. **Techniques** – a procedure to complete a task;
5. **Technology** – issues arise in concurrent engineering due to drive for competitiveness;
6. **Time** – concurrent engineering has the goal of reducing the length of the product cycle time;
7. **Tool** – include computer networks, hardware and software required to make geographically separated teams to work together.

- ***Improvement the ability to share information and knowledge.*** Since a fundamental of virtual enterprise formation is the intensive use of ICT and knowledge, enterprises that sustain competitive advantages through virtual enterprise should share information and knowledge in rapid manner. The successful outcome of teamwork in a dynamic virtual enterprise relies on how well the members are able to share and create knowledge across disciplinary, spatial and/or cultural boundaries either asynchronously or in real-time (Liu *et al.*, 2011). However, with the aid of virtual networks, business activities are usually conducted automatically by online applications. Establishing trustworthy and cooperative relationships with other organisations can help to protect knowledge and prevent information loss. In many cases, the existing IS of the partners in the virtual enterprise are differentiated by structure, language or operating system. Compared to knowledge sharing within a non-virtual enterprise, knowledge sharing in a dynamic virtual enterprise is more challenging due to the following considerations (Liu *et al.*, 2011):

- A dynamic virtual enterprise represents a dynamic organisational structure where members may join or leave freely, which hinders the establishment and development of a solid infrastructure for knowledge sharing among its members;
- Different members might adopt different knowledge management strategies and technologies. The heterogeneity of knowledge representation inhibits direct interaction and exploitation of the shared knowledge;
- The risk of losing core competences by sharing knowledge with partners requires a balance between controlling access to each member's knowledge resources and opening up these resources to partners to maximise the added value of business activities.

Knowledge can be explicit or implicit (Liu *et al*., 2011). Explicit knowledge within an organisation can be represented using rules, ontologies, cases, models, data, manuals or other forms. It is usually stored in knowledge repositories which can be directly exploited by knowledge-based systems or humans to solve specific problems. Implicit knowledge, on the other hand, is subjective, experience-based and often context-specific, making it hard to be expressed in a specific language. Implicit knowledge is mainly stored in the brain of each individual and cannot be handled by knowledge based systems. The social nature of humans needs to be incorporated into the knowledge sharing mechanism to help the right people locate the right knowledge at the right time.

For knowledge protection, knowledge access control model should have the following four functions (Chen, 2008):

1. **Flexibility:** The model should be adaptable to various virtual enterprise environments and task requirements and enable sign-on and sign-off of enterprise members on an *ad hoc* basis;
2. **Secure inter-organisational services**: User access permissions should be valid across enterprise boundaries;
3. **Centralised authorisation management**: A centralised design should be based on the roles and tasks of users in a virtual enterprise, thus enabling enterprises to concurrently participate in several virtual enterprises, which means user access permissions must consider user relationships with the competition and level of co-operation between enterprises;
4. **Incorporation of knowledge dynamics**: As knowledge, far from being static, is gradually formed and modified over time, knowledge access permissions for users should be updated regularly.

- ***Business process re-engineering strategies to reduce time and cost.*** As a rapidly-forming collaborative network, a virtual enterprise need to be constantly looking at how to run its business more effectively and efficiently. Virtual enterprise reengineering aims to overcome the uncertainty associated with various aspects of the chain, including the changing needs and demands of customers, the quality of the information, and inherent delays that affect purchasing and ordering decisions (Changchien and Shen, 2002). However, although elements of strategy, policy, business process, information, material and cash flow, human resource and responsibility, etc. are usually included in the contract in formation of virtual enterprise, there are many things left need to interpret and deal with in implementing stage for virtual enterprise. Enterprises wishing to join a virtual enterprise need to review their business processes and rethink how they do their work to be agile through cutting operational costs and time to be more competitive, reliable and stable. Business process re-engineering is conceived as the fundamental rethink and radical redesign of business processes to generate dramatic improvements in critical performance measures such as cost, quality, service and speed and Changchien and Shen (2002) propose an integrated business process re-engineering framework that includes:
  - Creating vision,
  - Identifying core processes to be redesigned,
  - Analysing current core processes,
  - Designing for innovation,
  - Evaluating the new processes,
  - Selecting the best, and
  - Transforming and implementing the resulting design; and a core process analysis matrix to identify the critical processes.

  In respect of the selection of a key process target for redesign, the virtual enterprise process need to be assessed and planned outputs and real outputs need to be compared. The most likely objectives for process redesign can be measured by cost reduction, time reduction, output quality, learning, etc. According to Prasad (1999) to complete a hybrid re-engineering strategy for process improvement, the following six factors need to be considered and assessed:

  1. **What to change** (inputs, outputs, and process steps including measures and decision points);
  2. **How to change** (techniques, tools, process boundaries and process flow);

3. **Who to change** (talents, teamwork, customers and supply chain);
4. **Why to change** (techniques, process, purpose, function, and rationale for decision making);
5. **When to change** (time, process order and structure);
6. **Where to change** (technology gaps, process relationship and its context to the whole).

- ***Security strategies to networked enterprises.*** Because of a temporary association of existing or newly created business entities offered by several companies to form a new agile business, the communication and collaboration is at the highest level in virtual enterprises, so the need for interoperability, portability and security is the highest in these organisational architectures (Mezgár and Rauschecker, 2014). The problems related to the virtual enterprise security challenges enterprises when joining in virtual enterprise (Djordjevic *et al*., 2007) include the following:
  - Collaborating services and resources may be based in different security domains;
  - On-demand collaboration implies trust must be established in real time on a P2P basis;
  - Collaborators need protection from other virtual enterprise members, as well as from outsiders;
  - The same service or resource may participate in different virtual enterprises, and hence different (potentially conflicting) security policies may apply;
  - Security conditions for a service or resource may differ throughout the life of the virtual enterprise;
  - No centralised administrative point implies a devolved policy management scheme combined with distributed enforcement at a peer level.

  In addition three areas form the basis of information security (Pulkkinen *et al*., 2007):

  1. **Authentication** – the process of validating the credentials of a subject of access to guarantee the identity of a subject;
  2. **Authorisation** – a right or a permission to use a system resource and it is the process of granting access;
  3. **Audit** – a review and examination of logs to test the characteristics of security procedures, to ensure compliance with established access policy and operational procedures, and to recommend any necessary changes.

  To deal with challenges several communication security scenarios should take place in a standardised way (Mezgár and Rauschecker, 2014):

- **User Registration;** during the registration process it is necessary to uniquely identify a user (organisation) and to make sure that he really belongs to the organisation as stated, that the given (personal) information is correct;
- **Certificates;** a unique software certificate is distributed to each user;
- **Authentication;** the authentication of users and organisations take place;
- **Encryption of messages;** the encryption of messages is based on certificates;
- **Exchange of messages;** between the ManuCloud infrastructure components which takes place via the Internet to apply standards.

Liu *et al*. (2011) addresses the need to adopt a centralised security control architecture to place the access to its core knowledge assets under strict control to protect itself from losing core competences to rival organisations. The administration agent of the target enterprise performs the security control at the message level before routing the message to the target agent within its enterprise. By implementing security control at both the message and object access levels through each enterprise's administration agent, the protection of core competences is guaranteed. Chen (2008) determines a role-based access control that is made up of the core model, which has six sets of basic elements; user, role, permission, operation, object and session, and a hierarchical model, in which a high role may inherit all access rights of lower roles in the role structure.

- ***Sustainable enterprise interoperability as a collaborative strategy.*** To deal with challenges introduced by changes in the potential weakening of internal and external interoperability displayed by the enterprises within collaborative networks, businesses forming a virtual enterprise need to focus on the interoperability issues in a more sustainable way. As collaborative networks are seen as a working paradigm for the more short-lived exploitation of business opportunities, it is essential to have methods to achieve sustainable interoperability, where seamless collaboration can evolve and adapt in response to rapid and sometimes highly disruptive changes in either the network or its business environment (Jardim-Goncalves *et al*., 2012). To take into account the rapid evolution of enterprises in a supply chain, enterprise interoperability domain must be extended towards Sustainable enterprise interoperability (Ducq *et al*., 2012).

Cretan *et al*. (2012) define sustainable enterprise interoperability as 'the ability of maintaining and enduring interoperability along the enterprise systems' and applications' life cycle' and believe that achieving sustainable enterprise interoperability in this context requires a continuous maintenance and iterative effort to adapt to new conditions and partners and a constant check on the status and maintaining existing interoperability. Sustainable interoperability focuses on novel strategies, methods and tools to maintain and sustain the interoperability of enterprise systems in networked environments as they inevitably evolve with their environments (Jardim-Goncalves *et al*., 2012). The concept addresses:

- **Discovery capabilities;** detecting when a new enterprise system is added, or updated in the network, leading to harmonisation failure**;**
- **Learning capacity;** after detecting harmonisation failure a learning process should be triggered to analyse and understand the changes which occurred and the node adaptation required;
- **Adaptability;** enabling the adaptation of systems and the optimisation of the maintenance process, using knowledge representation technologies applied to the model management domain;
- **Transient analysis;** to understand how a network, as an integrated complex system will suffer during the transient period, and how this affects the overall behaviour;
- **Notification/communication;** informing all network nodes as to how they should react, to obtain information for the adaptations that are needed to enable the system, as well as the entire network, to evolve and adapt to a new interoperable state.

Reaching a state of sustainable enterprise interoperability means not only accounting for changes that are needed in the technology, but also in business and people interactions (Coutinho *et al*., 2013). Specifically:

- **Business changes;** organisations should actually be most accountable for this, as they usually convey deep-impacting changes on the supporting technology;
- **Human behaviour;** flows and interactions acting on the enterprise also play a key role in the interoperability that is required towards other enterprises;
- **'Sustainability';** in this context is a synonym for robustness, maturity and self-preserving activities.

Achieving and improving sustainability in enterprise interoperability involves a constant recursive effort in checking and maintaining the existing interoperable status in the current environment (Coutinho *et al*., 2013). Jardim-Goncalves *et al*. (2012) indicate that one of the major causes of enterprise network failure arises from the structure and membership of the network, thus a wise selection of network partners and careful structuring of network processes, knowledge and communications leads to more sustainable (and therefore successful) networks, whether they are designed for the long-term exploitation of business opportunities or a short-term response to tendering opportunities. Lezoche *et al*. (2012) present research on sustainable interoperability by facilitating knowledge conceptualisation and 'structuration' into a set of discovered semantic blocks, then improving learning capacity to take into account changes when adaptation is required. They believe that this structured model creates the deep analysis of interoperability requirements and the specifying of the way in which a network node should react. To enable the system, as well as the entire network, to evolve for the better sustainable interoperable state Ducq *et al*. (2012) applied system theory to support the development of sustainable enterprise interoperability that need to continuously be considered and solved to reach a sustainable interoperability in the continuous evolution of enterprises in the supply chain. To implement strategies for sustainable enterprise interoperability, enterprises need to focus following areas:

- **Whole system;** of business, human, information and material (Coutinho et al., 2013);
- **Enterprise network configuration**; specially internet connection (Jardim-Goncalves *et al*., 2012);
- **Standardised formats;** to overcome barriers within interoperation (Noran, 2012);
- **Ontology;** enabled negotiation between enterprises (Cretan *et al*., 2012);
- **Conceptualising and structuring** semantics in co-operative enterprise ISs (Lezoche *et al*., 2012).

6.2.3 Implementation modelling

This section presents the implementation modelling for the proposed framework. A framework implementation model is systematically structured to integrate effectively an application and business components of the organisational structure and individual end-user. The implementation model aims to represent an implementing platform based on the Internet and implementation subsystems, their functions and specific configurations as they are to be implemented. The Internet-based implementation model as illustrated in Figure 6-5 enables the possibility of the automatic integration of distributed autonomous systems with independently-designed data and behaviour models of enterprises.

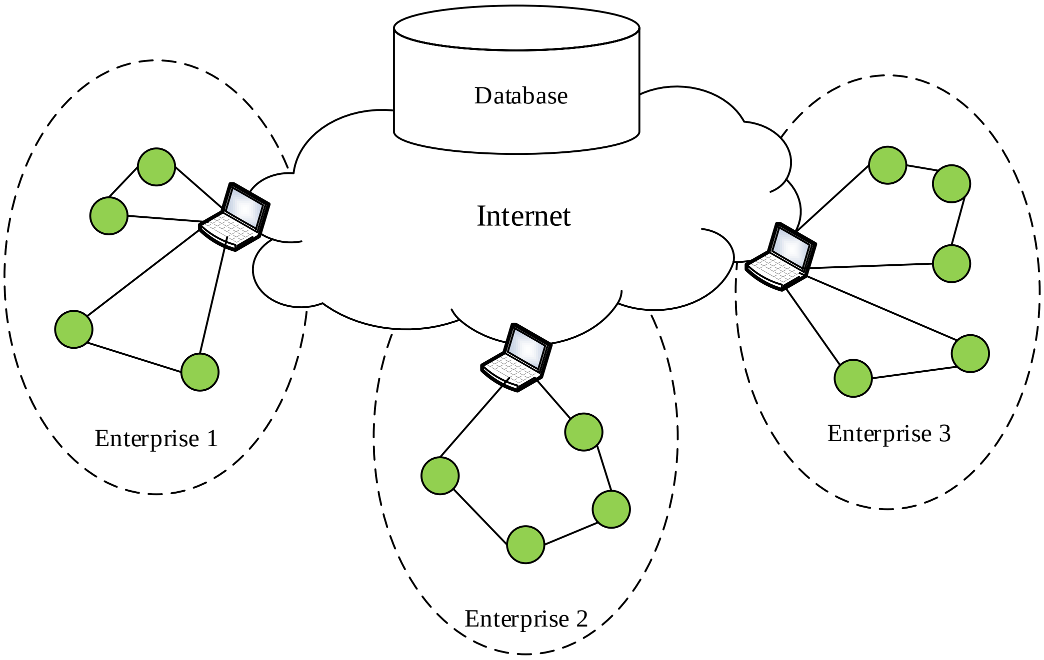


Figure 6-5: The implementation model

6.2.3.1 Implementation platform

Virtual enterprise formation and its operational system requires interactive computer systems that will bring the potential enterprises closer to each other to exchange the necessary information in a short period without difficulties. Grefen *et al*. (2009a) propose that a single technology paradigm does not provide an ideal basis for instant virtual enterprise support, but a combination of workflow, agent, and service technologies on top of an Internet infrastructure does constitute a good hybrid platform. Internet-enabled tools such as web-based technologies can be used to promote collaboration and co-ordination between business partners (Xu *et al*., 2005). Web services have emerged as a serious technology to provide the middleware platform to support effectively the operations of a virtual enterprise (Rezgui, 2007) and represent a step forward in enabling collaborations between various entities on the web and in overcoming the interoperability problems that may appear (Jagdev *et al*., 2008). Web services are self-contained, web-enabled applications, capable not only of performing business activities on their own, but also possessing the ability to engage other web services in order to complete higher-order business transactions (Rezgui, 2007).

The main thrusts of web-based virtual enterprises are concurrency, collaboration, real-time simulation and integration with manufacturing resources, which forms a key to enhancing the agility in the 21st century business environment (Chung and Peng, 2008). Internet technology has been a powerful integration platform for collaborative networks and the framework for improving the effectiveness of virtual enterprises has been facilitated by the web-based technology. According to Chung and Peng (2008) a virtual enterprise built on the Internet is called a web-based virtual enterprise or networked virtual enterprise.

Many implementations of web-based platforms can be found related to virtual enterprise formation; Berlak and Weber (2004) introduced practical web platform www.virtueller-markt.de, encompassing three competence networks for rapid prototyping services (www.rp-net.de), product development services (www.engineering.net), and mechanical processing (www.produktionsnetz.de). The process of web-based enquiry and offer preparation is standardised and automated in a user-friendly way by competence/network/specific forms using interactive switching surfaces. Also, Orion Logic LLC develops networked software called StarActive that ensures responsive supply chains[11].

To support collaboration and interoperation in a networked enterprise, web-based platform needs to achieve the following targets:

- The platform should monitor and control services access (call and response) on the Internet;
- The platform can encapsulate non-web service applications as web services;
- Web services managed by the platform can be deployed in different that is independent service orchestration of enterprises;
- The platform can be deployed in any enterprise service bus and can easily be transferred from one enterprise service bus to another one;
- The platform should protect service access and relative data between partner companies through the Internet;
- The platform shall provide methodology to map business process models to service logic and orchestrate 'atomic' services located in different partner companies to support complex business. The orchestration can be deployed as a web service in different enterprise service bus. The service developed by orchestration can be orchestrated as an atomic web service by another orchestrating process.

Web-based business networking platform will be more suitable to create a global enterprises profile to create lists of user enterprises as virtual breeding environment. Hence, web is a

[11] http://www.orionlogic.com/default.htm

hypermedia-based system that provides a means of browsing information on the Internet in a non-sequential way using hyperlinks (Connolly, 2010) to establish a virtual breeding environment and to enable collaboration and negotiation between enterprises, a web-based platform contains web user interfaces . A web user interface is developed to accept input and to provide output by generating web pages which are transmitted *via* the Internet and are viewed by the user using a web browser. The user interface platform (which supports any web browser) is shown in Figure 6-6.

Shang *et al*. (2012) suggest that several platforms such as Hadoop (White, 2012) and Pig (Olston *et al*., 2008) are suitable for enabling the large-scale preparation and processing of web-scale data sets, to analyse 'web crawler' data or to process personal messages. Such platforms enable automation for data repositories *via* polices that can process data based on time, events, data age and data content. Information repositories feature robust, client-based data search and recovery capabilities that can enable end users to search the information repository, view its contents (including off-line data) and recover individual or multiple files to their original or another network computer.

Figure 6-6: Virtual enterprise web site and enterprise registration on the web

6.2.3.2 Functions of the implementation model

Since the proposed network focuses on the interconnection of proper candidates for the formation of a virtual enterprise, the web site provides the main virtual breeding environment for value chains and gives options for partners to collaborate with optimum time and cost. As a composite, comprehensive artefact which encompasses all logical design needed to build and manage the virtual enterprise system in the run-time environment, the schema of function of implementation modelling is shown in Figure 5-7, which depicts the process of registering enterprises who are willing to collaborate through a virtual enterprise, the evaluation of potential members for inclusion with respect to cost, time and quality.

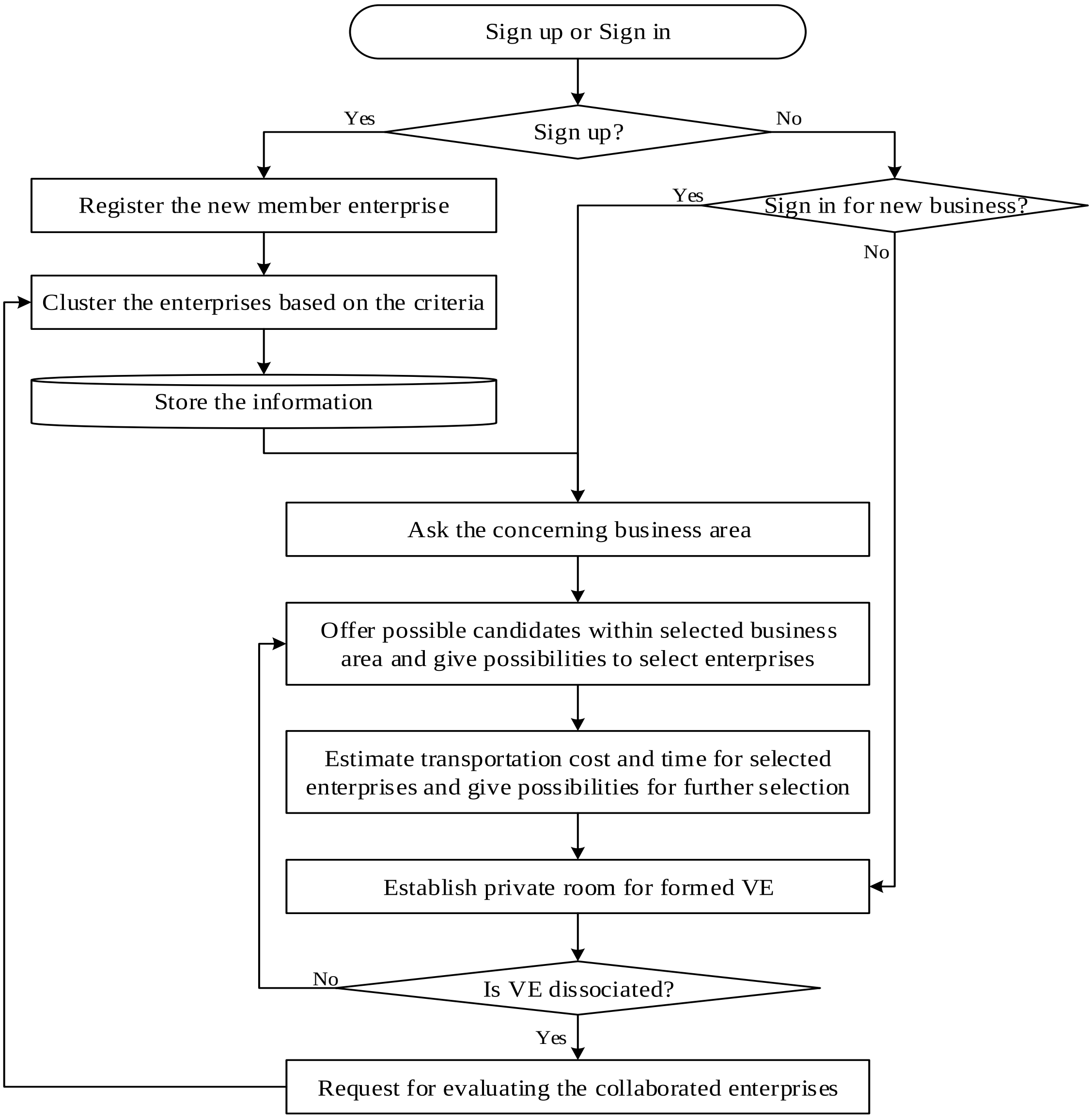


Figure 6-7: Steps in building the virtual enterprise business website

NB: This represents the registering, clustering, offering and evaluating processes and not the process of determining the necessary actions to improve the organisation's implementation methods.

To generate a virtual breeding environment and to collect information about involving enterprises, the web-based virtual enterprise system registers new members for legal and legislative compliance reasons. To facilitate the seamless sharing of production data among various application programs including business-oriented and engineering-oriented systems in the virtual enterprise, web-based knowledge management concepts could be adopted to perform the following functions:

- Register enterprises and store data;
- Service offer to the members to suggest appropriate partners by business type or region;
- Offer communication systems for collaborating enterprises;
- Cluster enterprises based on methodologies as discussed in Chapter 4;
- Evaluate members based on some predetermined criteria.

When enterprises register on the site (as shown in Figure 6-8), the system requires the enterprise name and location of facilities to estimate travelling time and cost. To cluster newly registered enterprises and keep information safely, the system requests the enterprises to complete a self-estimating questionnaire and to accept the terms and condition of the arrangement. As the primary study conducted in Chapter 4 indicates, enterprises are clustered into five specific clusters using the expectation maximisation algorithm. All the collected information is stored in the data centre and is retrieval when it is needed.

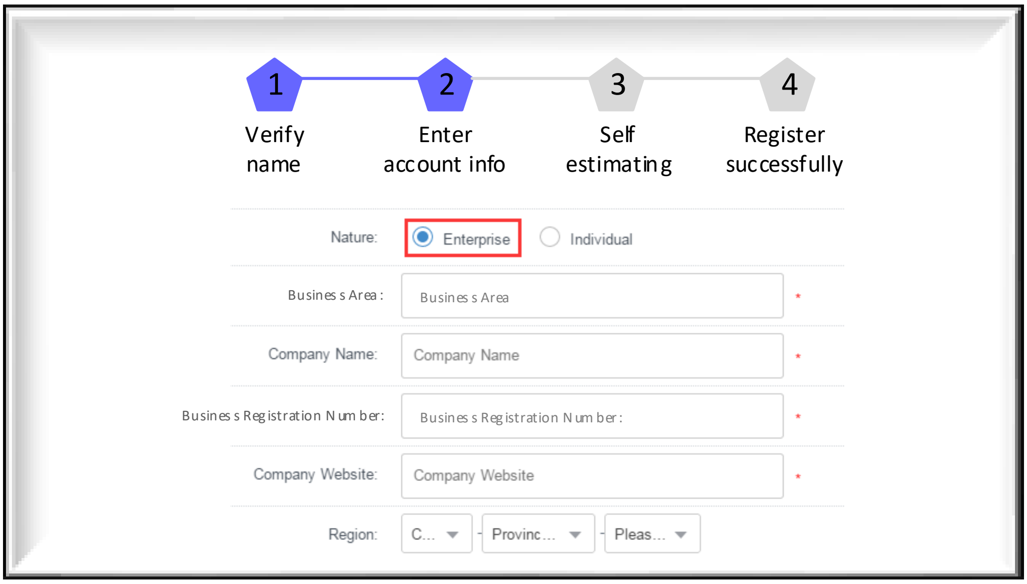
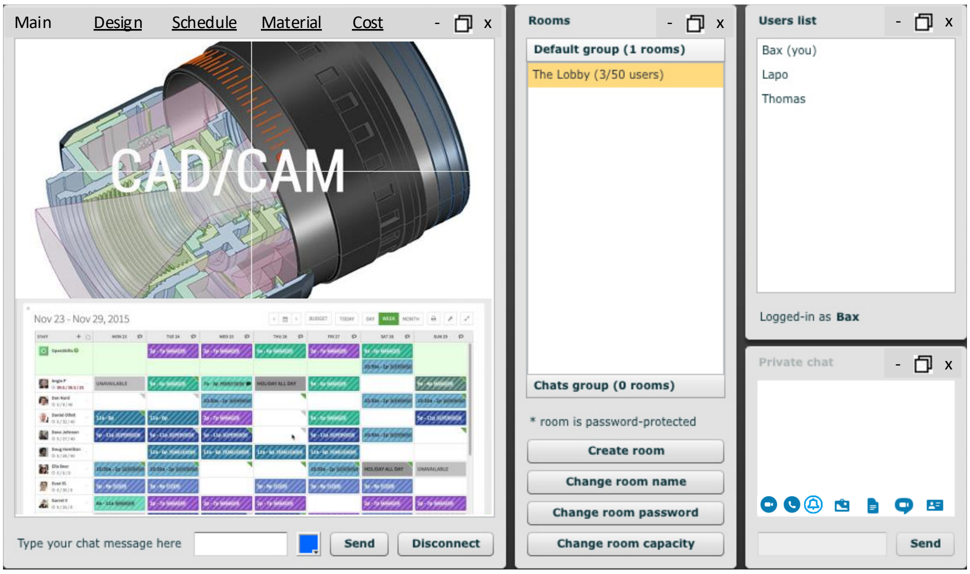
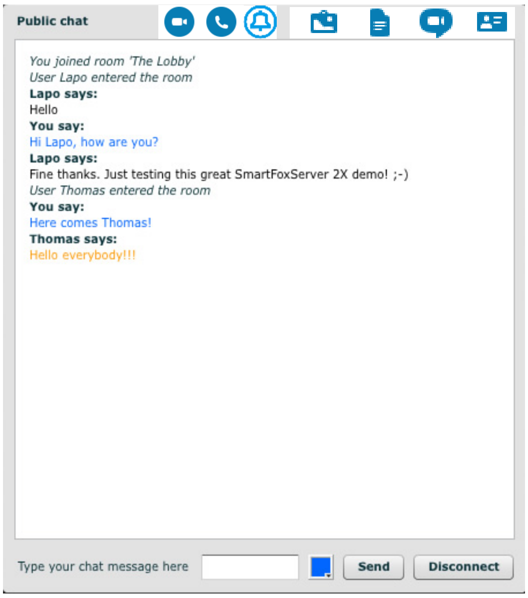


Figure 6-8: Registering window

After registering to use the site, users can use the web as a logged-in member who visits the site, or accesses it through a third-party site connected to virtual breeding environment, at least once a month. Since the web has a purpose to interconnect the enterprises, fake accounts and users with incorrect information are removed by web continuously. The web offers keep the sign-in for actively logged-in members and enables users to choose their own privacy settings and who can see specific parts of their profile. If a logged-in member wants to start a new business, the web site offers logged-in members the appropriate business area that is described in Chapter 3. Logged-in members can select many enterprises with whom to collaborate from the relevant industry types. Based on the selected enterprises, the web site estimates the travelling costs and time and shows this to logged-in members virtually. Then any logged-in member can work as a Leader for forming the virtual enterprise and changing their selected partners. After the final selection of partners, the web site offers a 'private room' as shown in Figure 6-10. In that private room, enterprises can work together as a virtual enterprise, creating and designing products and services, exchanging messages and information, posting updates, videos and photos, and negotiation to achieve the same goals and receive notification when others update their information. Also, the work schedule can be edited, revised and saved. Users can then control who sees the other information they have shared, as well as who can find them in searches, through their privacy settings. The user can see or enter process definitions or process-related data 'anytime anywhere' from a browser of his or her choice including hand-held devices. Similar tools with Skype or Facebook social media capability are included in the private room. When members leave the private room or when they have accomplished the business objectives, the web site requests them to evaluate (i.e. rate) the effectiveness collaborated enterprises, based on which the web site updates the enterprises' profile.



(a)



(b)

Figure 6-9: Main private room (a) and chat room (b)

6.2.3.3 *Registration for enterprises*

Since each organisation has its own security mechanisms and policies to protect its business processes, the web site has its own security realm that consists of a group of principals which are registered with an authentication authority and are managed through a consistent set of security processes and policies for knowledge and information sharing. Authentication is a critical measure for any security realm and an authentication authority is a trusted principal that performs reliable authentication functions, the registration of an enterprises' name and address has become fundamental for building trust for enterprises that want to collaborate virtually and temporarily. Registration on the web-based business network enables secure communication between business networking administration and the network members. Enterprises registered with web-based business networks become potential members in the pool of enterprises (i.e. the virtual building environment) with given authentication usernames and passwords. Before a principal can access the knowledge and information in a realm, its identity must be verified. Once it registers a members' service, members will be authorised for the creation of a virtual enterprise in a more secure and reliable way.

To establish trust for enterprises attempting to join in a virtual enterprise, the contract should be completed during the registration phase by a lawful agreement entered voluntarily by two or more parties, each of whom intends to create one or more legal obligations between them. A contract is a legally enforceable promise that involvers all the collaborating sides having the legal capacity to exchange knowledge, to information and innovation and to create 'mutuality of obligation'. Registration and contracts build legal evidence if something goes wrong. Enterprise registering should:

- Perform the registration and keeping of the relevant registers for enterprises and their representations and representatives, insolvent entities, legal protection and measures of insolvency proceedings and the enterprises' profiles, manufacturing and commercial pledges, collaboration property relations and arbitrage;
- Provide information regarding the registered entities and legal facts;
- Perform other functions prescribed by regulatory enactments; and
- Collect information related companies to build pool of potential enterprises to enable to be selected for virtual enterprise;
- Hold consented agreement from registered enterprises.

For the enterprises' registration function, two types of information need to be collected regarding each enterprise. The first type of information is related to the profile of individual enterprises as legal entities that include:

- The name, registration number and date of the enterprise (company);
- The main type of activity and additional types of activity of the enterprise (company);
- The term for which the enterprise (company) has been established;
- The legal address of the enterprise (company);
- The given name, surname, address, personal identity number and position held of the officials and shareholders of a partnership, who have been granted the right to represent and sign [the agreement].

The second type of information is related to enterprises' assessment that includes; the ability to deal with external pressures, dynamic capabilities of individual enterprises, ICT adoption level and ability to join in temporary alliance. The structured questionnaire used in this study could be used for self-estimation for enterprises (see Section 1.4).

6.2.3.4 Managing the database

The collected data about enterprises is stored and shared with members from the database system, which is a single large repository of information about the member enterprises and that can be used by many users simultaneously. With the availability of millions of users' accesses and requests from across the world, a web-based database would be preferable for the dissemination of data-centric, interactive applications (Connolly, 2010). However, for organisations more interested in building database applications to take advantage of the web as a strategic platform, the access control mechanisms should be flexible to support a wide spectrum of heterogeneous protection objects. The management of these large-scale distributed enterprises' datasets requires the use of specialised architectures, techniques and tools as shown in Figure 6-10.

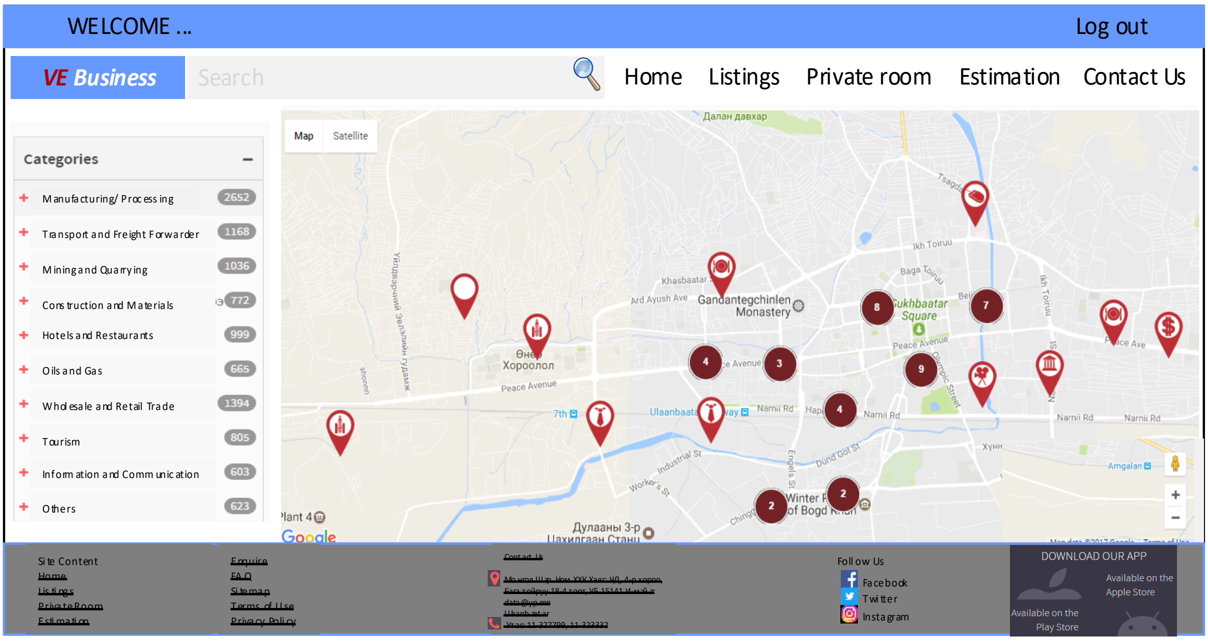


Figure 6-10: **Main window for enterprise, selected enterprises are indicated**

Software systems such as database management systems (DBMS) provide a way to store and retrieve database information that is both convenient and efficient (Silberschatz *et al*., 2006) for defining, creating, maintaining and controlling access to the database (Connolly, 2010). The DBMS also facilitates the process of defining, constructing, manipulating and sharing databases among various users and application which requires the following functions:

- Collecting and storing data through registration by defined data types, structures, and constraints of the data to be stored in the database;
- Manipulating data function that allows users to insert, update, delete, and retrieve data and generating report from data;
- Sharing a database through controlled access to users and program simultaneously for a security of system, concurrency control system, recovery of system, and integration of system.

The web-DBMS approach has advantages and disadvantages (Connolly, 2010). The advantages consist of simplicity, platform independence, graphical user interface, standardisation, cross-platform support, transparent network access, scalable deployment and innovation. The disadvantages include reliability, security, cost, scalability, limited functionality of HTML, statelessness, bandwidth, performance and the current immaturity of possible development tools.

A 'cloud database' also could be used running on a cloud-computing platform such as Google, Microsoft or Salesforce.com. In this case the database stores information, knowledge and innovation potential of enterprises, so the access authorisation should be controlled more carefully. Authorisation is the granting of a right or privilege that enables a subject to have legitimate access to a system or a system's object (Connolly, 2010). Privilege should be granted differently for users depending on their responsibility for creating or accessing some database objects or running certain DBMS utilities. Role-based access control is accepted as a flexible and effective control method, the main principle of which is to grant access permissions to users by firstly setting up relationships between access permissions and roles and then by assigning suitable roles to users (Chen *et al*., 2008a).

6.2.3.5 Deployment for information and knowledge

Enterprises' dataset collections, usually stored as multi-dimensional arrays, require unique technology for easy storage, retrieval, management and analysis. To share many objects of many different types that are defined, created, manipulated, and managed by variety of tools used by enterprises, the repository need to be utilised. An information repository is a straightforward way to deploy a secondary tier of data storage that can comprise multiple, networked data storage technologies running on diverse operating systems, where data that no longer needs to be in primary storage is protected, classified according to captured metadata, processed, de-duplicated, and then purged automatically, based on data service level objectives and requirements. In web-based business networking platform, data storage could be virtualised as composite storage sets and operate as a federated environment. Federated data repositories provide a model for structured datasets storage and sharing among heterogeneous sources and users (Adeleke and Otoo, 2014). The notion of federalism has increased the adoption of geographically distributed data repositories which comprise different data centres under different administrative domains and these data centres contain multiple independent servers running several composite services that need to be integrated for computational purposes and problem solving (Adeleke and Otoo, 2014). The real-time acquisition of datasets is required to ensure seamless operation between peers that require resources from neighbouring peers to perform other operations.

To develop an information repository to mitigate problems arising from data proliferation and to eliminate the need for separately deployed data storage solutions, because of the concurrent deployment of diverse storage technologies running diverse operating systems. The use of standards to address the problems of data heterogeneity, technical issues in repositories, assessment mechanisms regarding data quality, possibilities to streamline user access to the repository and sustainable data storage need to be determined. The repositories will be centralised but self-contained to reduce storage capacity, support heterogeneous storage resources, support resource management to add, maintain, recycle, and terminate data, track of off-line data, while operating autonomously. Some state-of-the-art web-based business networking data repositories could be adopted as models, such as:

- The computer science repositories of CiteSeerX (CiteSeerX, 2007) that provide vast free Web digital library and search engine of mainly computer science papers that have been automatically acquired from various Web sites, stored, and analysed to allow for searching and exploring its bibliographic data (Fiala, 2012);
- Centre for Applied Internet Data Analysis (CAIDA), which is founded on principles of co-operation and collaboration (CAIDA, 1998);
- SNAP - Stanford Large Network Dataset Collection – largest network using the library was the Microsoft Instant Messenger network from 2006 with 240 million nodes and 1.3 billion edges (Leskovec, 2004);
- SourceForge is an Open Source community resource dedicated to helping open source projects be as successful as possible and thrive on community collaboration to help create a premiere resource for open source software development and distribution (SourceForge, 2014);
- Project Hosting on Google Code provides a free collaborative development environment for open source projects (Google Project Hosting, 2006), etc. In Project Hosting on Google Code each project comes with its own member controls, Subversion/Mercurial repository, issue tracker, wiki pages, and downloads section. This project hosting service is simple, fast, reliable, and scalable, so that members can focus on your own open source development.

Repositories could represent web-based archives to store information about individual enterprises, the organisation and management of digital and documentary materials; and the long-term preservation of materials.

6.2.3.6 Clustering enterprises to select appropriate partners from the pool of enterprises

The proposed web site will suggest possible partners, based on the evaluation of enterprises. In this context, data mining is helpful for identifying the characteristics of enterprise in the pool of enterprises through the automatic or semi-automatic analysis of large quantities of data to extract previously unknown interesting patterns such as groups of data records (cluster analysis). These patterns can then be seen as a kind of summary of the input data. Based on the information that enterprises input during the registration stage, the web site classifies enterprises into five distinguishing clusters that are identified in Chapter 4. Grouping enterprises in this way is helpful in creating a more relevant set of search results compared to normal search engines like Google as shown in Figure 6-11 for the selection window.

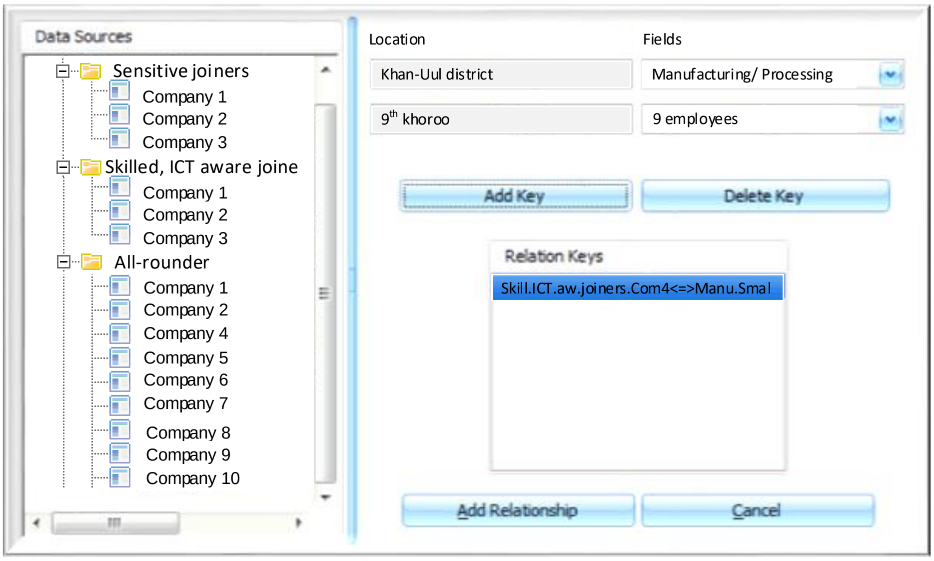


Figure 6-11: Selection window

Large-scale IT has been evolving separate transaction and analytical systems, and data mining provides the link between the two software analyses relationships and patterns in stored transaction data based on open-ended user queries. Several types of analytical software are available; statistical, machine learning, and neural networks. Data mining consists of five major elements:

1. Extracting, transforming and loading transaction data onto the database (i.e. the extract-transform-load);
2. Storing and managing the data in a multidimensional database system;
3. Providing data access to business analysts and IT professionals;
4. Analysing the data by application software;
5. Presenting the data in a useful format, such as a graph or table.

6.2.3.7 Estimating the transportation cost and time

Transferring inventory between the point of origin and the point of destination is one of the key issues for supply chains, so the web estimates the transportation costs and times for the flow of goods based on the addressed of the trading enterprises. Transportation plays a connective role among the enterprises, so a transport system is the most important economic activity among the components of business logistics systems. Since the role that transportation plays in logistics system is more complex than carrying goods for the proprietors, the web site optimises the decision-making and costing of transportation to support the selection of proper partners with minimum costs and time for transportation. This function includes:

- Requesting additional information related to transportation that includes transportation mode, vehicles, goods type and size, date and requirement of product transportation;
- Modelling the customer-specific route and simulate freight costs and time based on service provider tariffs then find the most profitable variants; and
- Visualising the route and deliver meaningful figures, comprehensive evaluation and reporting functions for controlling.

6.2.3.8 Evaluating partner enterprises after dissolution of the virtual enterprise

Running a successful collaborative process in a brief period may not be easy, as the members of a virtual enterprise may be struggling to make the most of their collaborative potential. Commonly, other than assessing if enterprises achieve their ultimate goals, most collaborative networks lack a reliable way to determine how well their collaborative process is working or what they can do to make it work better. Hence, successful collaboration enables a group of enterprises to combine their complementary knowledge, skills, and resources to accomplish more together than they can on their own, evaluating collaborated enterprises after dissociation of virtual enterprise gives more confidence and reliability for further virtual enterprise formation. Virtual enterprise effectiveness depends on the synergy of collaborative processes and when a collaborative process achieves a high level of synergy, the members can think in new and better ways about how it can achieve its goals, carry out more comprehensive, integrated interventions; and strengthen its relationship with the broader community. By enabling a virtual enterprise to think and act in ways that go beyond the capacities of its individual participants, synergy makes all the time and effort involved in collaboration worthwhile.

Hence, the relevance ranking plays a crucial role in both for evaluation of enterprises and search engines, the web requests enterprises rank each other after dissolution of the virtual enterprise. The task of ranking is to establish trust and convenient environment for collaborating enterprises. This ranking provides assessment to how well the virtual enterprise operates and evaluate either of the abilities of enterprises collaborate or actions the members have undertaken in brief period collaboration to achieve business goal. Beyond evaluating whether the virtual enterprise has achieved the outcomes it set out for itself, assessment of partners can be evaluated by structured questionnaire developed in this study. Questions are ranked with a five-point Likert scale (i.e. very low rate to very high rate) as discussed in Chapter 3. Although this kind of ranking provides not only positive feedback, partner evaluation can be helpful to revise over assessment of self-estimation of enterprises.

6.3 Summary

This chapter mainly focuses on a development of framework for improving the effectiveness of virtual enterprise in the supply chain. To give the framework adaptive features, knowledge of CIMOSA, GERAM, VERAM and ARCON frameworks (through the literature review) is used to integrate and coordinate all the elements involved in the life cycle of a virtual enterprise. A modelling framework based on the three dimensions; the life cycle, integrations, and 'genericity dimensions'. Identifying proper partners at the initial stage of virtual enterprise formation helps to promote successful and effective collaboration over a short time span. Models are often more concerned with the identification stage of life cycle of virtual enterprise. Hence, there are many different approaches, and models have been proposed to integrate enterprises and to support virtual enterprise formation from the engineering side, so this research work is focused mainly on business integration.

Through the setup of the network, the genericity dimension allows the development of dedicated models for the network enterprise entity and partial models for the business enterprise entity. In generic modelling, enterprises are perceived as a pool of potential candidates for combining to achieve the business objectives. Collaboration in supply chains by joining in a virtual enterprise while creating value is included in the model to support competitive advantages for enterprises. Furthermore, the factors influencing the effectiveness of temporary collaborations are considered in the specific model. Also, strategies to handle the influence factors for enterprises are proposed to support the whole success of the virtual enterprise while improving the individual ability of enterprises and finally the implementation model is outlined. As web-based business receives more attention from academics and practitioners, in this research a web-based virtual enterprise affiliation system is proposed and its implementation platform and functions are discussed. The next chapter sets out to validate the proposed framework through the statistical analysis of a case study.

7 Introduction

The main objective of this part of the thesis is to validate the proposed framework by using a simulation based on a case study to understand the role of the factors affecting the relationship between virtual enterprise and supply chain agility. A case study of the Mongolian Meat Program is presented and the results of fulfilling the demand for meat are simulated and then compared with a real case study. The programme is conducted by enterprises collaborating temporarily to supply meat to the market during a shortage period. A specific case of a programme executed in 2013 (for which data is available) is selected as an example of virtual enterprise formation as the collaborative network was established to convert the shortage in the market into a business opportunity. In 2013 members were selected from the pool of enterprises with a record of long-term collaboration by using specific criteria. A leader company made attempts to integrate the IS of members in a temporary alliance and provide consumers with information related to meat supply by using a web site. Altogether 426 entities involved in the programme are classified into five clusters as outlined in Chapter 4. The effectiveness of clusters is then discussed critically to validate the proposed framework.

A simulation technique is combined with the case study to observe the real situation during the supply process during this time. The simulation-based case study employs the following stages in this research including; case study instruction, conceptual discrete event simulation model development, validation and verification, experimentation and output analysis and implementation and discussion. In the first activity, the overall objectives of the study and specific questions to be answered are defined, related to selected case study. These specifications will determine the appropriate level of model detail and its scope (i.e. the system boundaries). In the next stage, the system is modelled, first in conceptual terms, using the system description and flowcharts, then, the conceptual model is translated to a computer-based simulation. The next activities are of major importance, since they provide model validation and verification, ensuring that the model behaviours are as expected and in accordance with the actual system. In this section the simulation is described and the results that were collected are analysed and discussed. The combination of a case study (the Mongolian Reserve Meat Program) and a simulation are held to be an effective method of validating the major deliverable from this research project.

7.1 Experimental technique

Thomas (2011) gives the following definition of a case study;

> '… [an analysis] of persons, events, decisions, periods, projects, policies, institutions, or other systems that are studied holistically by one or more method. The case that is the subject of the inquiry will be an instance of a class of phenomena that provides an analytical frame - an object - within which the study is conducted and which the case illuminates and explicates.'

This fits the purpose of validation well, and the Mongolian Meat Program case is selected for two reasons; firstly, the subject is a one of the key cases of virtual enterprise performance in Mongolia and secondly the researcher is familiar with it through local knowledge and this will be particularly relevant to the research. The object of using the case study is to assess the enterprises' performance during the programme period by triangulating multiple sources of data such as observing the process through simulation (Saunders *et al*., 2009). Triangulation refers to the use of several different data collection techniques within one study to ensure the validity of the data.

Shannon (1975) defines simulation as the process of designing a model of a real system and conducting experiments with this model for the purpose of understanding the behaviour of the system and/or evaluating various strategies for the operation of the system. Liotta, (2012) observes that simulation is a method for tackling a problem by constructing a model of the related system while Kleijnen and Smits (2003) distinguish four types of issue in simulation from the viewpoint of methodology. These types are; validation and verification, sensitivity or 'what-if' analysis, optimisation, and robustness and risk or uncertainty analysis.

Simulation techniques can be classified using different perspectives. With the perspective of modelling of time, they can be classified as continuous and discrete (Jain *et al*., 2013). From the perspective of the representation of the underlying phenomenon, researchers classify simulation technique differently. For instance, Kleijnen and Smits (2003) identify four simulation techniques for supply chain management analysis including spreadsheet simulation, system dynamics , discrete-event dynamic system simulation, and business games; McLean *et al*. (2012,p. 20-32) sort into system dynamics, discrete event simulation, agent-based simulation, physical-sciences-based simulation and gaming system; Liotta (2012) categorise for discrete event simulation, system dynamics, Monte Carlo simulation, agent-based simulation, business simulation games and hybrid/ integrated approaches.

Discrete event simulation and system dynamics are two widely used modelling tools which underpin DSS in the logistics and supply chain context (Tako and Robinson, 2012; Liotta, 2012; Jain *et al*., 2013). Tako and Robinson (2012) observe that in discrete event simulation, state changes occur at irregular but discrete time steps, while in system dynamics state changes are continuous, approximated by small discrete steps of equal length. Tako and Robinson (2012) observe that discrete event simulation is considered to be more suitable for modelling problems at the operational and tactical levels, whereas system dynamics is more suited to modelling problems at a strategic level.

Forrester (1961) developed industrial dynamics, which he later extended and called system dynamics (Kleijnen, 2005). System dynamics modelling and simulation is aimed at modelling systems at a high level of abstraction for supporting high level decision making (Jain *et al*., 2013). System dynamics models represent a system as a set of stocks and flows where the state changes occur continuously over time (Brailsford and Hilton, 2001). The causal loops for conceptual modelling that are enhanced into stock-and-flow diagrams for setting up the framework and the computer implementation then converts the causal and 'stock-and-flow' relationships into differential equations that are used to calculate the change in system parameters over the simulated time horizon (Jain *et al*., 2013). Tako and Robinson (2012) state that in system dynamics individual entities are not specifically modelled but instead are represented as a continuous quantity in stock and system dynamics models are generally deterministic and its variables usually represent average values.

Discrete event simulation is suitable for modelling system operations to evaluate system configurations and resource allocations to achieve desired system performance or to investigate causes of less than desired performance (Jain *et al*., 2013). Discrete event simulation models systems as a network of queues and activities where state changes occur at discrete points of time (Tako and Robinson, 2012). It is generally used to model systems at medium to low levels of abstraction (Jain *et al*., 2013). In discrete event simulation, entities (e.g. objects or people) are represented individually and specific attributes are assigned to each entity, which determine what happens to them throughout the simulation (Tako and Robinson, 2012). Discrete event simulation models are stochastic in nature and deal with distinct entities, scheduled activities, queues and decision rules (Brailsford and Hilton, 2001), where randomness is generated through the use of statistical distributions. Jain *et al*. (2013) identify two major views for discrete event simulation; the process view and the event view. The process view essentially uses flow charts of process of interests and models them using corresponding simulation software features while the event view model uses the actions that happen following an event.

Simulation software provides the development environment in which the model is implemented, verified, validated, and experimented with to evaluate different scenarios of interest which depend on the goal of the simulation (Liotta, 2012). The purpose, approach and visualisation of the simulation are different , so the application is also different for commercial software[12]. The educational version of the SIMUL8 (Concannon *et al*., 2003) program is selected for this study. SIMUL8 is an integrated environment for working with simulation models. It has a powerful language and visualisation capabilities that allow the creation of accurate, flexible, and detailed simulations in a reasonable time. It also has several features (e.g. trials, a 'warm-up' period, random sampling, etc) that allow a statistical analysis of the simulation output to be conducted.

7.2 Case study

This section introduces the selected case study that is used to validate the proposed framework. Martinez *et al*. (2001) identify four possible options that can be setup for virtual organisation formation; maximising flexibility and adaptability to respond to environment changes, developing a pool of competencies and resources, reaching a critical size to be in accordance with market constraints and optimising the global supply chain. The case study of the programme conducted in 2013 in Ulaanbaatar is presented in this study because that corresponds to the statements of Martinez *et al*. (2001) as the members' enterprises in the programme are trying to respond to environment changes and to increase the flexibility in the supply chain, to fulfil the market demand at an appropriate time in a global setting. More specifically, the enterprises participating in the program were collaborating temporary based on their capacity to convert the meat shortage into a business opportunity.

The Mongolian Meat Program was initiated as a government intervention seeking to manage the market supply of a staple food commodity, to limit seasonal price variations to consumers. The Government of Mongolia sought partly to subsidise the winter storage costs for meat (which enters the supply chain in summer and autumn) to reduce the impact of storage costs on retail prices in late Winter and in Spring. Also, the programme was represented as a food

[12] A commercial simulation software survey can be found at http://www.orms-today.org/surveys/Simulation/Simulation1.html

security enhancement measure, intended to guarantee the stable availability of meat to urban consumers, thereby creating a supply that would be resilient to the impact of ecological crises, social instability, or market failure. Although the programme has been conducted for 10 years, the selected case of temporary alliances that was executed in 2013 sought possibilities of integrating a database of suppliers and providing information related to the Mongolian Meat Program to the public using a web site. When meat supply companies integrate their daily logistics operations with partners by affiliating in a virtual enterprise, they receive the benefits of speed, flexibility, quality and profitability.

7.2.1 Background

Mongolia is one of the leading countries in terms of livestock numbers and meat consumption per capita and home to 50 million head of livestock. In 2013, agriculture accounted for 25.9% of Mongolian employment and 13.6% of GDP. About 80% of agricultural production is animal-based and more than 80% of Mongolia’s land area is used for livestock herding. At present, 68.1% of Mongolia's population lives in the cities and 31.9% are rural; 9.7% of the population still herds. Table 7-1 provides the production figures for beef, horse, sheep mutton, goat and camel. For instance, Mongolia’s total annual meat production in 2013 was approximately 249,700 tons from the slaughter of over 10.2 million livestock.

Table 7-1: Livestock numbers in various years and recent meat production

	1989	1999	2009	2010	2011	2012	2013
Total Number of livestock	24674900	33568900	43657100	32729528	36335781	40920915	45144324
Livestock consumed for meat	7583500	8743900	11299000	8373700	8283200	8365000	10205000
Total meat production (tons)	239600	289000	245000	204400	208000	220400	249700
Beef	72800	104600	60000	47500	54800	59700	56400
Horse	-	-	38000	23000	25500	31200	29300
Sheep mutton	121900	128900	97000	77400	78400	67200	92400
Goat			50000	49100	44700	56300	64100
Camel	-	-		5800	6200	5300	6700
Meat processed through abattoirs (tons)	61700	4300	18300	12000	13200	13200	19800
Exported meat (tons)	30500	15000	16050	23800	10600	3700	3673.8
Preserved meat (tons)	-	-	2800	12000	12700	14000	14000

(Source: Report of Ministry of Food Agriculture and Light Industry (MFALI) of Mongolia [13])

As Mongolia has such numerous livestock, meat export is one of the main possibilities for penetrating world markets to increase economic activity. Currently meat processing companies export meat to Russia (e.g. horse meat, beef), Turkey, Jordan etc. (e.g. mutton, lamb), China (e.g. mutton, goat), and Japan (e.g. horse meat). This shows increasing diversity, as during the

[13] Ministry of Food Agriculture and Light Industry (MFALI) of Mongolia. Available at: http://www.mofa.gov.mn/new/

socialist period, Mongolian meat export revenues were largely dependent on Russia as the main buyer. Mongolian companies now export meat in the form of very low value-added products such as frozen carcasses of large animals. Unfortunately, the Russian Ministry of Agriculture developed a strategy to reduce the market share of imported meat in Russia to 20% by 2010 from 30% in 2003 (Everett, 2005) so currently only few meat processing companies have been allocated quotas to export beef, horse meat and meat by-products to Russia. Exports of meat are projected to increase in coming years, presumably to the Middle East and 20,000 tonnes of mutton and 20,000 tonnes of goat meat are expected to be exported through Tianjin in China, which is the closest port to land-locked Mongolia and it is planned to establish a 3,000 tonnes cold storage facility in Tianjin. However, it will be necessary for the Mongolian Government to negotiate with the Chinese Government for this to take place. The export of mutton to the Middle East faces significant challenges, including the necessity to slaughter younger animals (less than 2 years old) in contradiction with Mongolian custom and the *halal* slaughtering requirements that are needed to comply with Muslim custom. Also, over the past 50 years, many competing counties' meat industries have been developed to comply with international meat trading standards for product management in terms of hygiene, processing, packaging and presentation. Mongolia has fallen behind in this regard, so to become internationally competitive it must emulate the meat processing systems of competing countries and follow international safety standards.

According to report of UNIDO (2011) the meat industry is considered to be one of the industry sectors with the most potential for future development. Since Mongolia currently faces an issue of overproduction of meat due to an increase in the domestic animal population; some commentators suggest that the increase in animal numbers is an indication of the success of the market economy concept. However, many other commentators express concern that the country is not capable of supporting this number of livestock, when the long winters, the very short plant growing season and the need to produce animal products (meat and fibre) that will be acceptable in both the international and domestic markets are all considered. The main characteristics of the Mongolian meat market are therefore:

- The livestock industry is the main foundation of Mongolia's economy and it still plays an important role in the economy, employment and to export revenues;
- Mongolia is home to 50 million head of livestock, consisting mostly of goats, sheep, horses, cattle, and camels. Livestock number is predicted to be increased in the future. But heavy snow damage could cause decreases in number of domestic animals substantially;

- Annually, Mongolia produces 200-250 thousand tonnes of meat from around 10 million head of livestock and is self-sufficient in terms of its domestic meat consumption;
- Most abattoirs were built during the command economy (i.e. Socialist) period, with assistance from Russia, East and West Germany, Hungary, Bulgaria, Finland, the United Kingdom, Denmark and Yugoslavia and all are therefore of an old design. After the transition to a market economy in the 1989-1991 period, privatisation was undertaken, but difficulties arose. Lack of capital and operational finance forced the closure of many of the abattoirs (UNIDO, 2011).
- However, 32 abattoirs have an annual slaughter capacity of 85,000 tonnes of meat, and cold storage capacity of 42000 tonnes, all located in the north side of Mongolia, where only 10% of the meat is processed through abattoirs., creating difficulties in storing the meat;
- Meat supply in Mongolia has the characteristic of intense seasonal fluctuation. Herders tend to sell livestock in the months between July and December when livestock has the heaviest weight and fat. Because of traditional pasture breeding is highly influenced by climate, the main slaughter season is from September to December. There is a supply shortage between January and June and supply is exceeded between July and December;
- The seasonal fluctuation of meat supply causes an increase in meat price during the shortage period. Unofficially, meat prices have been kept as low as possible, particularly in the spring, to increase household consumption and normal demand in the market. The programme is one example of an attempt to stabilise prices during the shortage period;
- The meat supply chain is not integrated. Many independent participants are included in the meat supply chain, including: herder households, intermediaries, slaughterhouses, meat processors, wholesalers and retailers. The profit margins in the meat supply chain are not sufficient to allow any traders/abattoirs to invest in infrastructure improvements;
- The average meat consumption of the population has been approximately 75-85 kg. per capita per year, which is among the highest in the world;
- The Mongolian population prefers fat-tailed or fat-rumped sheep, and fat beef, horse, goat and camel that is prepared by traditional wet-cooking methods. Red meat produced from those livestock mostly comes from animals slaughtered outside the abattoir system. By international food preparation standards, such cooking methods are uncomplicated and do not demand the differentiation of meat on the basis of tenderness, colour, age, sex, fat marbling, etc.

Additionally, the Mongolian Government approved the National Programme on Food Security by Resolution No.32, February 2009, to support the meat supply chain and quality[14]. Phase 1 of this programme was implemented between 2009 and 2012, and Phase 2 is undertaken in 2013 to 2016. This programme was intended to formulate and implement a meat sub-programme of support to intensified meat farms, meat processing facilities and meat exporters, to establish comprehensive agriculture and food production complexes (complying with international standards) and to increase exports by producing healthy and safe meat and meat products and improve processing to meet international standards. This involved applying HACCP (a quality assurance programme) and international standards such as ISO9001, ISO22000:207 in meat processing (UNIDO, 2011).

7.2.2 Current situation and motivation to fill scarcity of supply

The Mongolian meat industry consists a meat production and selling system that are not integrated in the industrial form normally seen in international marketing systems as meat production is done mainly through extensive livestock pasture breeding. While this method has the advantage of low production costs and ecologically clean products, it suffers from low productivity levels and high exposure to climate risks. Compared with major meat exporting countries, Mongolia has a non-integrated supply chain with no coordinated strategy. Businesses along the Mongolian meat supply chain appear to consider their individual interests only and not the interests of the whole supply chain (UNIDO, 2011).

The meat supply chain in Mongolia is a multi-echelon network that encompasses several independent actors as shown in Figure 7-1. The upstream end of the supply chain starts with herders, who typically breed and manage five primary species of livestock – sheep, goats, horses, cattle, and camels. Most livestock in Mongolia continues to be herded by small-scale, mobile pastoralists, whose holdings range from as few as 100 to upward of 1000 animals. Mobility such as moving between seasonal camps and grazing their herds on shared lands, remains a significant dimension of most herders' adaptive strategy, particularly in the arid and semi-arid regions of the Gobi Desert, though patterns of movement differ according to geographic circumstances in different parts of the country. Since, herding is a domestic

[14] Some meat processing industries monitored for the international hygiene standards and valued "AA" rate (license to export their processed meat and meat production under the country's criteria) and valued "AAA" (met those industries operate with international hygiene standards and have the right to export their meat and meat production to international market) export meat to contracted countries.

economy, herders do not own storage facilities to keep meat, so they sell their livestock or meat, when they need cash or after the slaughtering season.

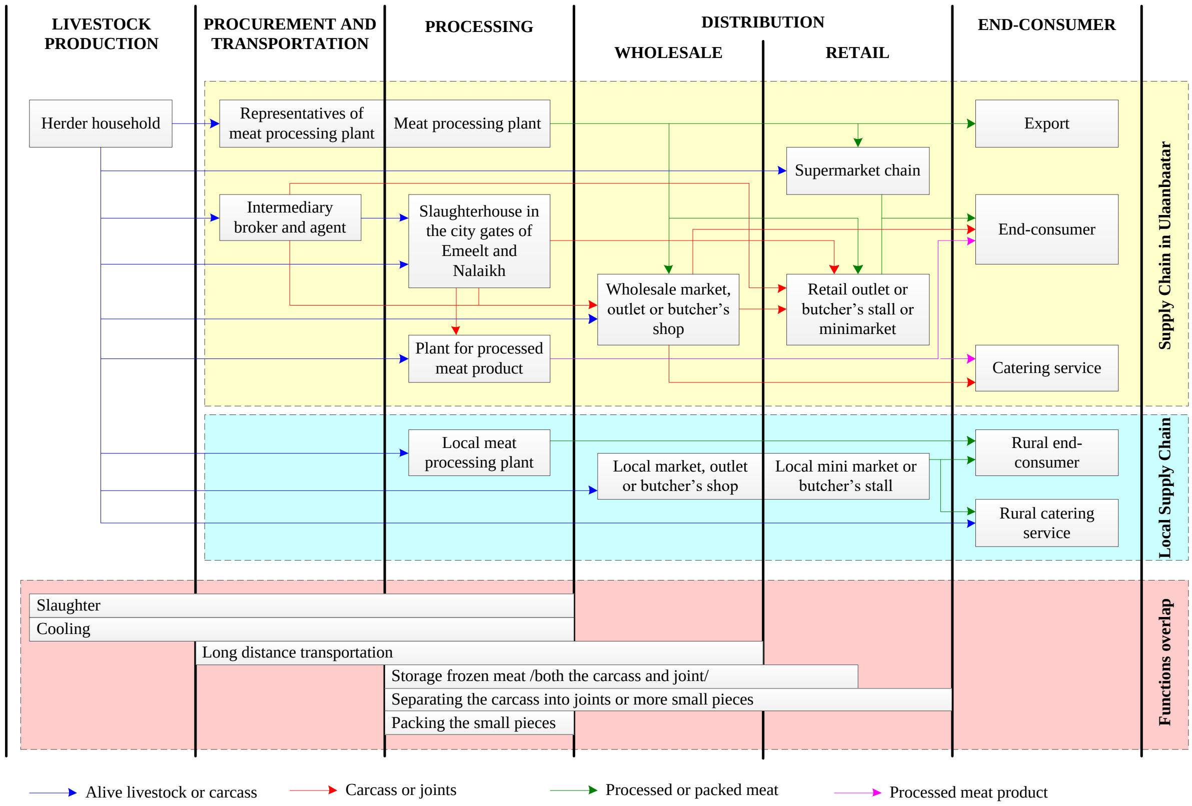


Figure 7-1: Meat supply chain

The second and third echelons of the meat supply chain consist of procurement, transport and processing enterprises. In the case of the biggest processing plants, the functions in the second and third echelon of the supply chain are integrated. The processing plant representatives, private intermediary brokers and agents, collect meat from herders located all around the Mongolia. The processing plant representatives buy meat or livestock from herders in two ways; collection from the herders' location and transport to a processing plant by themselves or collection in their own processing plant. Most meat processing plants are now located in suburban areas, due to livestock transport in urban areas being prohibited by order of many City Governors in 2005. Meat processing plants have the functions of slaughtering, meat processing, cooling and freezing and packing. Intermediary brokers and agents buy meat or livestock from herders in same way as the processing plant representatives do and consolidate them before reselling to slaughterhouses, livestock markets, processing plant or consumer food markets. Such brokers offer substantially below-market buying rates in exchange for upfront cash payments and in some cases cash advances or the provision of dry goods on credit. Some brokers maintain facilities at city logistics gates such as Emeelt or Nalaikh, one of the commodities markets situated outside the city limits of Ulaanbaatar, buying livestock, wool, and hides, and selling dressed carcasses at wholesale prices to merchants at consumer markets. Such brokers have the functions of slaughtering, cooling and freezing and sometimes packing. Herders and brokers typically prepare carcasses in November as they can be inexpensively stored without artificial refrigeration until March. Some plants produce meat products like sausage, ham, and canned meat and supply them direct to the market. These meat product companies buy meat either from herders or intermediary brokers.

In the fourth echelon of the meat supply chain, two types of wholesale merchants are in the market. Firstly, some wholesalers bring the ‘branch meat’ to the market by buying directly from rural brokers or acquire meat from livestock owners so they can be named ‘merchant intermediaries’ and secondly, some wholesalers carry out transactions just inside the market, so they could be called ‘domestic merchant intermediaries’. Some ‘merchant intermediaries’ only transfer meat from the countryside to a wholesale market then sell it to ‘domestic merchant intermediaries’ or sell the meat to the ‘meat salespersons or butchers inside the market’, who rent stands inside the market. Others sell meat to retailers inside the meat market, such as butchers, small meat stores, restaurants and fast food outlets and to consumers who want full carcasses of meat. ‘The domestic merchant intermediaries’ carry out slaughtering and butchering, cooling in small storage and reselling. Sometimes the functions of the two types of wholesalers are integrated and some of the wholesalers own a small space in a storage area close to the wholesale market.

The fifth echelon of the supply chain involves retailers who buy either carcasses from herders, wholesalers and slaughterhouses or processed meat from plants and resell it to household consumers or food services. Many supermarket chains run their business-like meat retailers as most of them own storage areas and employ butchers in their stores. Alternatively, red or pre-packaged frozen meat is sold either in the butchery sections of retail outlets, large stores or in independent stores and there are lots of retailing options from cut pieces, pre-ground meats to sausages and dumplings. Household consumers, the catering services of restaurants and fast food outlets and exports are included in the downstream end of the meat supply chain in Mongolia. A small number of the household end-consumers prepare for their annual meat consumption during the slaughtering season in December. The rest of them buy meat from the market frequently in small portions because they are not able to pay for large sizes of meat all at once.

Similarly, some large catering services buy meat from wholesalers and store it in their own freezers inside the business area. However, most small catering services buy meat frequently from wholesalers. The current meat supply chain is discussed more specifically below to examine the formation of temporary alliances to fulfil transient demand.

6.1.1.1.Meat supply

Meat production in Mongolia is entirely seasonal and is largely dictated by climate. As the price of livestock depends on the live-weight, herders are most willing to sell their livestock in the 'fattened' season. As previously described most livestock is slaughtered in late autumn and early Winter either at meat factories, temporary slaughterhouses in rural areas and near city gates, or at herder household sites. Peak supply therefore occurs in the early winter period (September to December) as this is when the animals are in peak condition following grazing on summer and autumn pastures and in late November and December when meat can be slaughtered and stored frozen in ambient conditions. Low supply occurs in early summer (April-July) when animals are in poor condition following difficulty in accessing good feed during the Winter.

According to research conducted by the Mongolian Capital Market Association (2010), only 12% of meat is supplied in the market between January and May, 18% is supplied between June and August, 31% is supplied between September and October, and 40% is supplied between November and December. Monthly meat supply is calculated and shown in Table 7-2 based on the Mongolian Capital Market Association survey (2010). Total annual meat production data for the recent past is obtained from the website of MFALI[15]. For 2012, for instance, nationwide average meat production was 80.7kg *per capita*, increasing to 89.4kg *per capita* in 2013.

7.2.2.1 Meat demand

Nearly all the meat consumed in Mongolia is produced domestically. The Mongolian population consumes approximately 85-95% of all the meat produced in the country (UNIDO, 2011). According to the Mongolian Capital Market Association (2010), annual meat consumption per capita is 92.6 kg in rural areas and 88.8 kg in Ulaanbaatar. Consumption of meat is now all year round, especially in urban areas, rather than the traditional practice of primarily eating meat from late summer through to winter. Mutton and goat are the preferred

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[15] **http://www.mofa.gov.mn/new/**

meat in all parts of Mongolia, followed by beef, or yak meat among residents of mountainous areas. Camel meat is consumed infrequently in the Gobi, and hardly at all in the northern steppe and forested ecological zones, where camels are rare. Mongolia was ranked 32nd in the world by goat meat consumption and 56th by mutton consumption, 121st by beef consumption in 2012 (FAOSTAT, 2015).

Table 7-2: Meat supply, by tonne, by month, and 5 types of livestock

Month	1	2	3	4	5	6	7	8	9	10	11	12	Total[a]
2012													
Total	**13703.3**	**0.0**	**0.0**	**1964.0**	**9161.2**	**10970.8**	**15609.9**	**19122.0**	**29470.2**	**36286.3**	**37165.2**	**46247.0**	**219700**
Beef	5685.7	0.0	0.0	0.0	0.0	2842.9	5685.7	5685.7	5685.7	8528.6	11371.4	14214.3	59700
Mutton	2800.0	0.0	0.0	0.0	3500.0	4200.0	4900.0	5600.0	10500.0	11200.0	11200.0	13300.0	67200
Horsemeat	3466.7	0.0	0.0	0.0	1733.3	0.0	0.0	3466.7	5200.0	5200.0	5200.0	6933.3	31200
Goat	1309.3	0.0	0.0	1964.0	3927.9	3927.9	4582.6	3927.9	7201.2	10474.4	8510.5	10474.4	56300
Camel	441.7	0.0	0.0	0.0	0.0	0.0	441.7	441.7	883.3	883.3	883.3	1325.0	5300
2013													
Total	**14442.7**	**0.0**	**0.0**	**2236.0**	**10912.4**	**12932.8**	**17801.4**	**21274.1**	**33841.1**	**41216.1**	**41665.7**	**51577.8**	**247900**
Beef	5371.4	0.0	0.0	0.0	0.0	2685.7	5371.4	5371.4	5371.4	8057.1	10742.9	13428.6	56400
Mutton	3850.0	0.0	0.0	0.0	4812.5	5775.0	6737.5	7700.0	14437.5	15400.0	15400.0	18287.5	92400
Horsemeat	3255.6	0.0	0.0	0.0	1627.8	0.0	0.0	3255.6	4883.3	4883.3	4883.3	6511.1	29300
Goat	1490.7	0.0	0.0	2236.0	4472.1	4472.1	5217.4	4472.1	8198.8	11925.6	9689.5	11925.6	64100
Camel	475.0	0.0	0.0	0.0	0.0	0.0	475.0	475.0	950.0	950.0	950.0	1425.0	5700

[a] Data collected from the report of Report of MFALI of Mongolia, http://www.mofa.gov.mn/new/

Unfortunately, there is no meat consumption data gathered monthly by any organisation in Mongolia, so monthly consumption of meat is calculated and demonstrated in Table 7-3, based on population and nutritional consumption standards *per capita*. According to the 'Nutritive consumption standard *per capita'* of the Mongolian Ministry of Health, standard consumption is 200 g per day during the cold season and 150 g per day during the warm season[16].

Table 7-3: Meat consumption, in tonnes

	Year	Population[a]	Monthly consumption		Year	Population[a]	Monthly consumption	
			In warm season /4-9/	In cold season /10-3/			In warm season /4-9/	In cold season /10-3/
Total	2012	2867744	13335.01	17780.01	2013	2930277	13625.79	18167.72
Urban area		1926625	8958.806	11945.08		1995712	9280.061	12373.41
Rural area		941119	4376.203	5834.938		934565	4345.727	5794.303

(Source: Mongolian Statistical Handbook[17])

16 Nutritional consumption standard per capita/ Ministry of Health, rule 257, Aug, 2008, Ulaanbaatar/, available at http://moh.mn/moh%20db/order.nsf/fd7c492a475f2213c8257069000b6df8/25e4011794359e2b48257524002655c2/$FILE/Saidin%20tushaal.pdf

17 Mongolian Statistical Handbook available at http://www.1212.mn/statHtml/start.jsp

Likewise, meat exported to the contracted countries is determined to be consumption, thus exported meat quantity for the years under study is shown in Table 7-4.

Table 7-4: Meat exports, in tonnes, by month, by commodity

Month	1	2	3	4	5	6	7	8	9	10	11	12	Total
2012													
Total export	**1135.01**	**198.10**	**58.00**	**0.00**	**52.00**	-	-	-	**281.92**	**508.32**	**730.56**	**709.93**	**3673.85**
Frozen beef	-	-	-	-	-	-	-	-	181.92	111.13	470.56	201.47	965.09
Mutton	592.50	3.00	-	-	26.00	-	-	-	-	37.19	-	16.46	675.14
Horsemeat	0.01	192.10	58.00	-	0.00	-	-	-	100.00	360.00	260.00	492.00	1462.12
Goat	542.50	3.00	-	-	26.00	-	-	-	-	-	-	-	571.50
2013													
Total export	**362.00**	**0.00**	**144.00**	**29.22**	**0.00**	**0.00**	**2.00**	**80.00**	**120.00**	**68.00**	**724.00**	**1472.00**	**3001.22**
Frozen beef	-	-	-	-	-	-	-	-	-	-	-	-	-
Mutton	-	-	-	29.22	-	-	2.00	-	-	28.00	-	344.20	403.42
Horsemeat	362.00	-	144.00	-	-	-	-	80.00	120.00	40.00	724.00	1127.80	2597.80
Goat	-	-	-	-	-	-	-	-	-	-	-	-	-

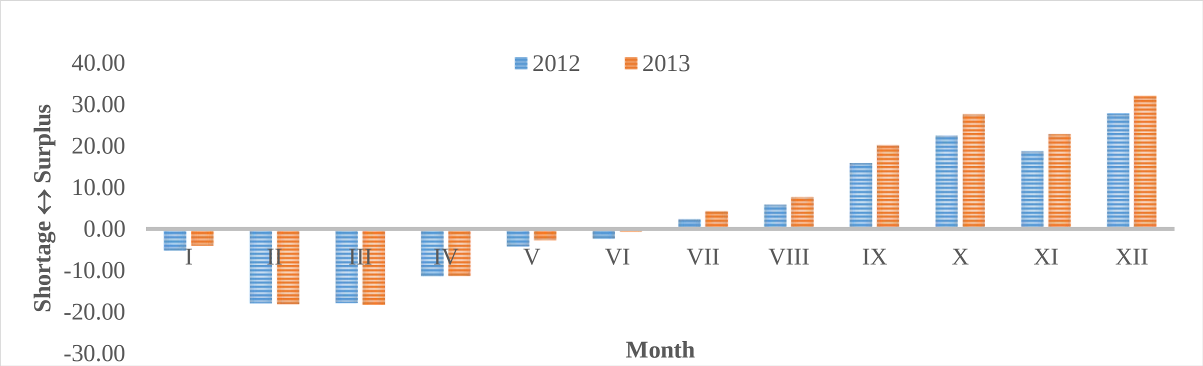
(Source: Statistics is collected from Mongolian Customs website[18])

7.2.2.2 Surplus or shortage in the meat market

Annual meat consumption is stable in Mongolia, being only differentiated by the warm or cold seasons, although meat supply fluctuates highly during these periods. The dependence of pastoral livestock husbandry on weather conditions causes the supply shortage, because of livestock losing weight and fat in the cold season. On the other hand, the slaughtering season causes a surplus of meat in the market and accordingly plants that use red meat or raw materials of livestock origin must cope with such fluctuations and consequently must maintain inefficiently high inventories of raw materials.

Figure 7-2 shows the difference between supply and demand based on data acquired previously. When meat demand exceeds meat supply, a shortage naturally occurs and prices rise, but a surplus exists and the market price is low when the meat supply is greater than the demand. There is typically a shortage between January and June and a surplus between July and December.

18 Mongolian Customs, available at http://www.customs.gov.mn/statistics/index.php?module=users&cmd=info_st



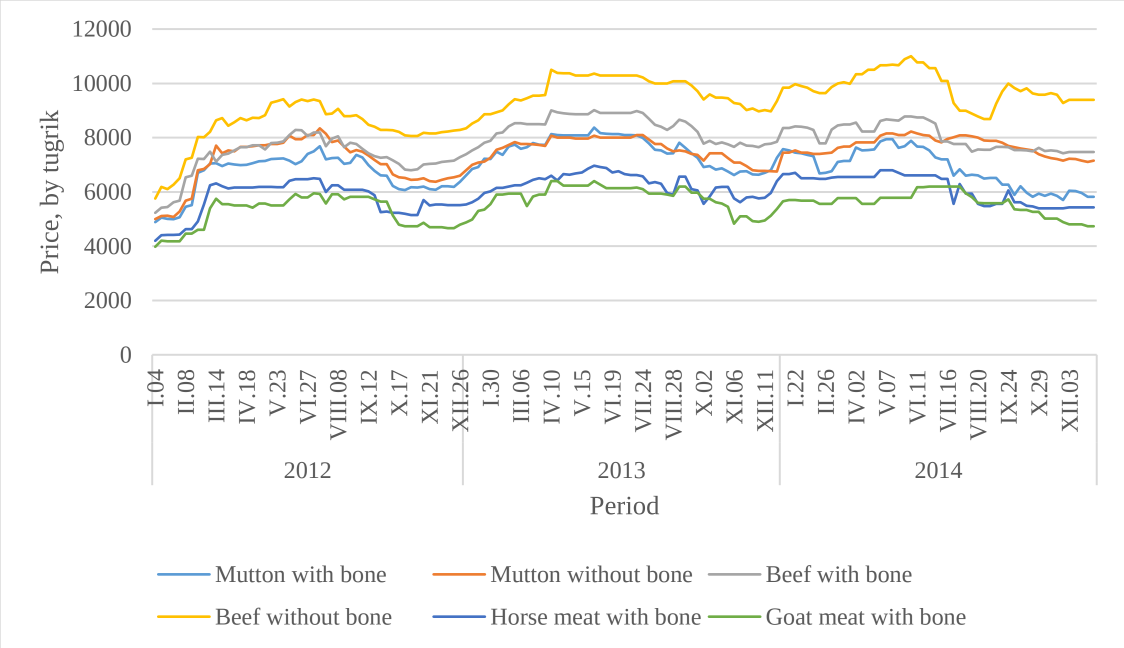
NB: Surplus/ shortage = monthly supply – monthly meat consumption – export in month.

Figure 7-2: Surplus and shortage in meat market, by two year periods

7.2.2.3 Meat price

All cuts of the animal carcass are sold for the same price, or for very slightly different prices and there is little consumer demand or pressure for price differentials to occur. This has translated into a single price per kg. paid to herders for animals of different quality. Herders increase their income either by selling more animals or bigger animals. They do not pay attention to animal quality, based on objective, measured specifications as occurs in developed international meat trading nations (UNIDO, 2011).

This stability in demand patterns reflects the urbanisation and growing wealth levels within Mongolian society with a willingness to pay for meat even during the low season (Spring and early Summer). With this flattening of demand and limited imports, the real driver of price fluctuations is supply. Prices are therefore driven by herders' decisions on when to sell animals or meat, by consumer demand and by bottlenecks in supply. Inconsistency of demand and supply has led to increases in meat price in the urban meat market. The average meat prices in the market are demonstrated in Figure 7-3, categorised by six main types that customers most frequently buy from the wholesale market or supermarkets. Prices regularly drop due to increased supply in Autumn, a time of the year when a high proportion of animals are slaughtered due to animals being at their fattest, the cooler outdoor temperatures allowing carcasses to be prepared and transported without refrigerated facilities and many herder households needing immediate cash income to pay school fees. In the Spring, Mongolians (particularly those in Ulaanbaatar) see the highest rise in meat prices as supply shrinks and herders stop selling meat while young animals are being born. Due to the combination of higher storage costs and the lack of fresh meat entering the market supply, price increases peak in May until new meat appears in the market. Beef without the bone sells at the highest price in the market, while goat and horse meat are valued lowest.



NB: Average meat price in Ulaanbaatar is collected from weekly report of National Statistical Office of Mongolia [19].

Figure 7-3: Meat price dynamic in the meat market, by month

Since a need exists during the shortage period in the meat market, enterprises belonging to the meat supply chain form networks with their partners to supply demand in the market and improve customer satisfaction in a short period with low costs. However, the Mongolian Government recently attempted to reduce shortages by reserving meat when there is plenty in the market and selling it back to the market when there was a supply shortage and meat price increases. Unfortunately, both prior to and following the intervention meat prices continue to follow a predictable cyclical pattern.

7.2.3 The Reserve Meat Program

In an effort to fulfil the shortage by moderating prices and by smoothing extreme seasonal price fluctuations, the Government of Mongolia introduced a meat reserve programme. The policy was introduced in 2005 under the Government's 211th resolution 'Measure on meat supply stabilisation' (September 29, 2005). In 2006, this was followed up with the 178th

[19] National Statistical Office of Mongolia. Available at: http://www.1212.mn/

resolution[20] of the Government with the stated purpose of stabilising the meat supply for the cities of Ulaanbaatar, Darkhan and Erdenet and introducing regulations on related preparing, storing and selling meat at the price included in the agreement, which was established in 2010 between the government, meat industrial companies, wholesalers and retailers (Goodland, 2010).

The Mongolian Meat Reserve Program operates through the provision of subsidies to large-scale private meat packers, who are contracted by the state to procure beef, mutton, and goat carcasses, store them over the winter and release set quantities to the consumer market at fixed prices in late winter and early spring. The distribution of meat is conducted through a network of market, grocery and convenience stores in residential areas, with limits on the amounts that can be purchased by a given household. Agents authorised by the Government buy meat from herders between late November and early December, save it over winter and release it in early spring at an affordable price. All agents involved must have certification from the State Inspection Agency, as well as being accredited by the MFALI.

To meet the needs of growing meat demand in Ulaanbaatar, reserve meat preparation has been planned regularly for several years, especially during harsh Winters. A specific window for releasing the reserves was set between January 25 – July 10 every year according to an approved schedule set by province and city mayors. Table 6.4 depicts the actual level of meat reserves under this policy since it was introduced. In the beginning of this programme, around 3000 tonnes of meat were reserved, but the quantity increased fourfold in 2011 and 2012. Around 7.5% of total meat production was stored for the urban market under this programme. While some customers have complained in the past that the quality of the reserved meat is poor, officials claim that the standard of the meat is seasonal and that in recent years reserves are better due to the inspection system being improved.

The premium promotion that meat preparing agents receive from the Government to reserve meat has increased from 500 *tugriks* per kg. of meat to 1000 *tugriks* since 2006. In the period 2006-2010, the Government of Mongolia spent a total of 7.7 billion *tugriks* in subsidies (officially termed "incentives") to meat reserve companies, transferring a further 8 billion *tugriks* to 20 companies in 2011, 16 billion *tugriks* to 21 companies in 2012, and 11.4 billion

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[20] Available at: http://www.legalinfo.mn/law/details/3094

tugriks to 12 meat companies in 2013. Unfortunately, meat prices have not stabilised but have in fact increased (from 3,790 to 7,350 *tugriks*) since this threefold increase in government spending. The Government price interventions are shown in Table 6-5.

Table 7-5: Meat supply and price stabilisation interventions 2006-2015

Year	Contractor	Reserving meat, /ton/	Premium promotion		Total meat production, mil.tonnes	Meat storage as % of total meat market	Contracted selling price, *tugriks*		
			per kg, tug	Total, mil.tugs			Beef	Mutton	Goat meat
2006	11	3000	500	700	170.7	1.76	n/a	n/a	n/a
2007	8	3300	500	835	191.2	1.73	n/a	n/a	n/a
2008	13	7000	500	2400	221.3	3.16	2200	2200	-
2009	6	7000	500	2400	264.4	2.65	2800	2400	-
2010	9	2800	650	1400	204.4	1.37	-	2900	1900
2011	20	16000	800	8000	212.6	7.53	3500	3000	2400
2012	21	16000	1000	16000	220.4	7.26	3700	3200	2600
2013	12	11446	1000	11446	249.7	4.58	5950	5750	4850

(Source: Numbers collected from the daily news on the website of MFALI of Mongolia[21])

7.2.3.1 Criticising issues of implemented meat supply projects

Due to the poor and fluctuating supply of meat, the lack of an integrated supply chain and its coordination, as well as insufficient financial resources and meat storage areas and the lack of monitoring systems for supplying meat, the Mongolian Meat Reserve Program has been criticised in recent years. The State Auditor’s report in 2013 concluded that there may have been many elements of fraud and corruption in the allocation of subsidies and selection of participating companies. The inadequate quality of reserved meat and the questionable hygiene factors (i.e. the preparing and storing conditions) were the main considerations of consumers who were willing to buy reserved meat at the fixed price. These concerns are perhaps unsurprising, given that the meat packers participating in the reserve programme were effectively guaranteed a fixed income regardless of the quality of the product, thus having no economic incentive to procure high-quality meat, store carcasses under optimal conditions, or to package the meat in such a way as to appeal to consumers. Fortunately, the MFALI detected this weakness and reacted to the critical conditions and established a middle term strategy that aimed to provide consumers with healthy and safe meat over the whole year with proper and stable prices. As a consequence, there was also an increase in the exports of meat slaughtered under the more hygienic conditions according to internationally-accepted hygiene and animal welfare standards.

[21] MFALI of Mongolia figures available from http://www.mofa.gov.mn/new/

The fact that the Mongolian meat reserves were managed by corporate meat packers, rather than by the state itself, appears to have facilitated corruption and price manipulation. More significantly, however, the programme seems to have been undermined by its focus on storage and retail distribution alone. Since the procurement of meat for the national reserves was not directly managed by the state, meat packers effectively diverted meat from existing market supply chains, which pushed up retail prices. This case study suggests, therefore, the need for food reserves to be managed as a complete process chain, rather than being managed simply at the point of storage and distribution. Without this integrated governance of supply, storage, and distribution, such a reserves system cannot be effective at stabilising prices and assuring the provision of quality meat for consumers.

7.2.4 Collaborative network creation

With revised monitoring systems, the programme conducted in 2013 was improved in 2015-6 and one more step towards a recovery of efficiency in the meat supply chain. The case chosen in the research was selected for analysis to understanding better the selection of appropriate partnerships to improve the performance of the participating enterprises and the effectiveness of the collaboration. As with previously-implemented programmes, meat reserves are managed by corporate meat processing and storing companies officially called ‘Reserve Meat Managers’ (afterwards called ‘manager organisations’). For the first implementation of the programme in 2015 a non-governmental organisation formed from the Association for Protecting Consumers’ Rights, the Mongolian Meat Association and the Union for Health, Safety, and Food Self-Sufficiency monitored the distribution and sale of meat. To avoid the failures that occurred in previous years, managers developed an IS that integrates the information of partner companies and information related to distribution. A web page is operated during temporary collaborations to receive blanket complaints from consumers and to inform them of the dates and places that reserve meat will be released.

7.2.4.1 *Selecting the partners in the network*

The selection of participants is an important aspect of a virtual enterprise, so the storage and meat processing facility-owning companies were chosen as an enterprise pool to conduct the first step of the programme. As one of the main trends characterising supply chains is cost and time reduction in the supply process; the enterprise location is selected as another criterion for inclusion in the pool of enterprises. For practical reasons, the targeted group was then narrowed down to include only companies owning facilities located near to Ulaanbaatar. Then the final selection of proper ‘manager organisations’ (i.e. Reserve Meat Managers) from this pool or virtual breeding environment was performed based on criteria that were developed by MFALI. The main selection criteria include an organisation's trustworthiness, its technological capability to prepare and store meat to the related standards and its capacity to store, sort, pack, and distribute meat. However, in the enterprise clusters, all the members belong to the meat industry, which could lead to barriers in information sharing because of the competition between them. According to the MFALI website, 12 meat processing companies participated in the programme in 2013 and 8 of them were responsible for supplying the meat market in Ulaanbaatar through 410 convenience stores and outlets in the wholesale market.

7.2.4.2 *Incentive for companies to join in virtual enterprises*

The selected meat processing companies were provided with 87 billion *tugriks* by the Government as low interest loans to prepare meat in the slaughtering season and to store it until it could be released into the market. As the current meat supply chains are highly dependent on the expense of buying livestock then slaughtering and transporting the meat to urban areas, the Government also attempts to supply the companies with funds for storing enough meat to maintain supply during shortages in the market. The selling price of meat in the market is determined by the Government and manager organisations in a contract. Also, the distribution companies added value per kg. is constantly determined through a trilateral agreement between the Government, managers and wholesalers or retailers. This means that the revenue-sharing policy of the virtual enterprises is contracted to achieve the main goal of the programme while the members will receive the benefits related to the increased quantity they have for sale.

7.2.4.3 Selecting the leader for virtual enterprise governance

This temporary alliance is developed to convert the meat shortage into a business opportunity and while it consists of many members; the leader plays a key role not only in the creation and distribution of value, but also in the coordination of the network. From a strategic perspective, the coordination of a network requires some degree of centralisation to ensure an efficient use of resources, rapid decision making and the emergence of a global vision driving the network. Based on the proposal for a meat supply tender and the experience gained in the previous (i.e. 2013) programme, Makh Market LLC is selected as the manager organisation with responsibility for organising other managers to supply meat to contracted wholesalers and retailers, to integrate the related information from all the participants, to announce special offers to the public and to update news *via* the web site, receive public complaints and act to solve them. The creation and coordination of a virtual enterprise requires a considerable amount of expertise and the selected company (i.e. Makh Market LLC) has the required level of competence and experience to integrate and to manage the other participants, to provide information to assist the virtual enterprise's members in its activities (i.e. competence mapping, partner selection, supply scheduling, public relations, etc.). Additionally, the manager organisation clearly demonstrates its record of managing conflicts in the meat supply to sustain network relationships with consumers, which again qualifies it for the leader/manager role.

7.2.4.4 *Management of collaborative operations*

One of the main advantages in this network is the possibility of supplying meat without any other unexpected expenses and maintaining the flexibility of the SMEs involved while achieving an increase in the effectiveness and efficiency of the core operational activities through collaboration, with the added capability of appearing as a single and larger entity in terms of the supply and procurement processes. The aim of the simulated programme was to qualify as a single supplier of a final customer to establish the fundamental framework of sustainable meat supply chains and stabilise retail prices during shortage periods. The manager organisation can take full advantage of the aggregation effect because the supplier and customer interaction is always with the manager organisation itself and never with a single member. The manager organisation always represents the whole network and naturally behaves like a larger virtual entity. However, all manager organisations have their own integrated IS, so they may not be willing to develop an interoperable joint IS during the programme period. The programme is a short-term collaboration, so all manager organisations are possible future competitors in the market (i.e. when the virtual enterprise ends). There is a chance that those manager organisations may not to be selected as managers or partners for another programme in the future, so it is difficult to build trust in such a short period of time.

A typical reserve meat supply chain is shown in Figure 7-4. in which not all eight manager companies supply meat to all the wholesalers and retailers and the manager organisation schedules which manager supplies meat to which wholesalers and retailers. The distribution of channel members for all manager organisations is based on their respective locations. To enhance channel performance by decreasing costs and time, the nearest convenience stores and wholesale markets are selected from among the contracted distributors that every manager had identified as appropriate channel members.

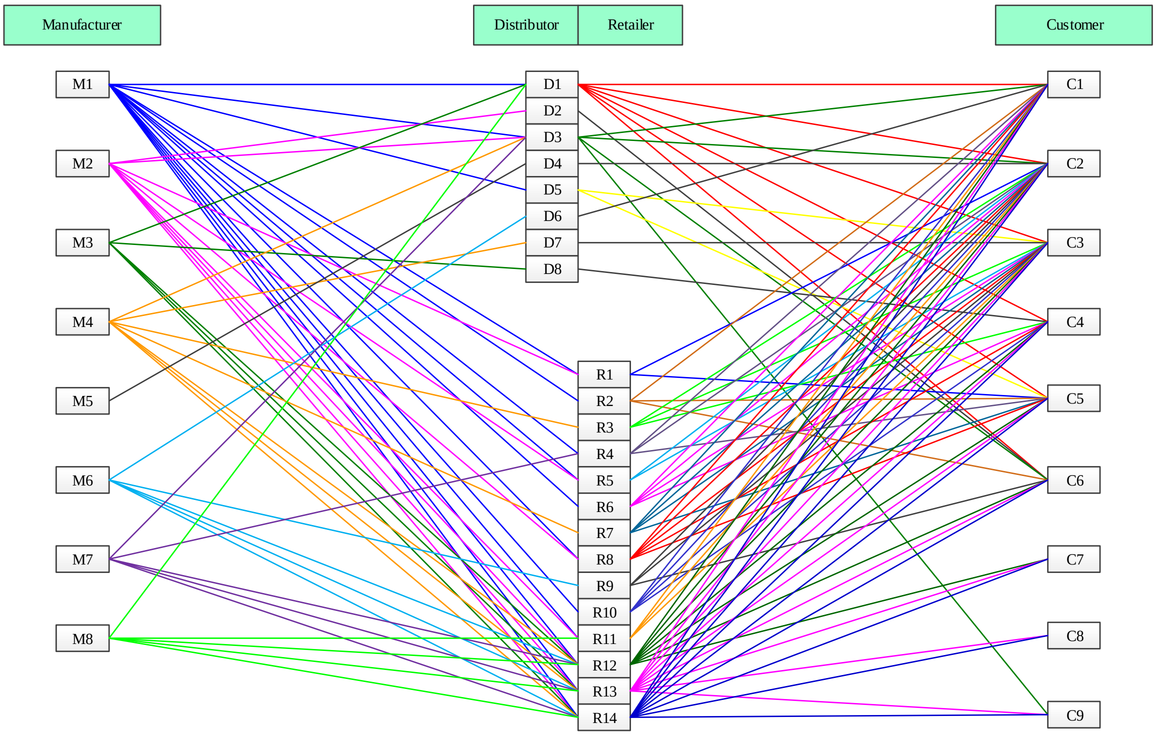

Figure 7-4: Reserve meat supply chain in urban areas

The meanings of the abbreviation are defined in Table 7-6, where 'M' is a manufacturer, 'D' is a distributor/wholesaler, etc. and the coloured lines represent the linkages between them in fulfilling their various roles in the supply chain. All managers have a responsibility to prepare meat either in the form of whole carcasses or cut and packed into small sizes of 2-3kg. and to distribute them to selected stores at predetermined dates based on received orders. Also, manager organisations should inform partners of their daily reserved meat supply quantity and distribution points to provide the public with information on the meat distribution dates, locations, type and sizes. Based on consumers' needs, some meat is distributed and sold in carcass form at the wholesale markets, which is usually 200-500 *tugriks* cheaper than cut and packed meat.

7.2.4.5 Monitoring for the temporary alliance

To eliminate negative attitudes following the previously-implemented programme, a monitoring system was developed for the whole meat supply chain in 2013. Nine inspectors from the State Specialized Inspection Agency work at ten meat reserved storage facilities in Ulaanbaatar city to check the certificate of origin, control health and safety compliance and monitor the quality of supplied meat by taking samples for inspection. Based on this examination, inspectors give certificates to verify the consistency of meat quality. Also, inspectors from the Specialized Inspection Agency based in the districts follow up the implementation of the programme and the distribution and selling process while protecting the programme from the negative influences of unsafe meat and preventing meat-borne diseases. If there is any fault or breach of the programme contract, such as packed meat containing too much bone, the advertised weight not being met or the store not selling reserved meat at the announced date, consumers can inform the information service.

Table 7-6: The meanings of the abbreviation for simulation model

Entities	Abbreviation	Enterprises and citizenship
Manufacturers	M1	Makh Market LLC
	M2	ANDM LLC
	M3	Sayan Uul LLC
	M4	Makh Impex JSC
	M5	Baataruud Tenger LLC
	M6	Mongol Makh Expo LLC
	M7	Khatant International LLC
	M8	Davshilt Trade LLC
Distributer/ Wholesaler	D1	Khuchit shonkhor market
	D2	Narantuul-2 market
	D3	Just Agro LLC distributing markets
	D4	Baatruud tenger distributor
	D5	Makh market distributor
	D6	Kharkhorin market
	D7	Makh Impex Ditributing points
	D8	Burd market
Retailer	R1	Sky supermarket chain/ Sky Trading LLC
	R2	Retailer chain/ Makh Market LLC
	R3	Sansar supermarket chain/ Altan Joloo LLC
	R4	Orgil supermarket chain/ Orgil LLC
	R5	Minii dut chain store/ EEBM LLC
	R6	Max chain store/ Max impex LLC
	R7	BOSA chain store/ BOSA LLC
	R8	Minii Delguur chain store/ Songinokhangai LLC
	R9	Well Mart chain store/ Bishrelt Holding LLC
	R10	Friendly Mart chain store/Petro Sky LLC
	R11	Sensitive joiners
	R12	All-rounders
	R13	ICT-aware non-joiners
	R14	Low performers
Consumer	C1	Bayangol district
	C2	Bayanzurkh dictrict
	C3	Songinokhairkhan dictrict
	C4	Sukhbaatar district
	C5	Khan-Uul district
	C6	Chingeltei district
	C7	Baganuur district
	C8	Bagakhangai district
	C9	Nalaikh district

7.3 Simulation model

Simulation is selected as an appropriate tool to visualise and evaluate the meat supply process in the selected case study. A discrete event simulation is developed with the objective of capturing the detailed meat supply activities of the meat manufacturers, wholesalers and retailers that are necessary to meet the need for demand in the market. A simulation model is produced using the educational version of SIMUL8 (Concannon *et al.*, 2003) to study the routing and flow of meat between the major distributors and retailers in Ulaanbaatar. In the simulation model, the logical interactions between the different simulation objects (timing and capacity setting information, routing rules, etc.) are achieved using Visual Logic, the SIMUL8 package's logic building environment. Custom dialogues are developed to extend the model's capability by displaying the simulation results and setting up resources. The 'Collect' discipline, especially 'Do not collect until available' option is utilised to obtain the results of fulfilled demand in the market. This option is only available when each feeding object contributes one Work Item to the collection list then 'routes out' that collected item. The results of the throughput of entities, the average time in the system for meat and the quantity of meat in the system queues are collected to evaluate the different performances of enterprises belonging to the five clusters.

7.3.1 Modelling the meat supply chain for the simulation

The supply chain model should consider every step involved in the flow of meat from the vendor to the final customer, representing all the actions that are required to bring a product (or a group of products that use the similar facilities) through the main flows. Boundaries for analysing the supply chain are dependent on the criticality of the processes and the flows of material and information through them (Carvalho *et al*., 2012). The meat supply chain is very complex, with hundreds of types of meat flowing from hundreds of suppliers located in different areas all around Ulaanbaatar to the hundreds of consumers who have different needs. In this study, the simulation boundaries are defined according to the manager companies' distribution.

Figure 7-5: Detailed simulation model of Reserve Meat supply chain. The subset of the meat supply chain involved in this study is a two-echelon supply chain composed of the manufacturers in the first echelon and two kinds of suppliers in the second echelon. Suppliers include eight wholesalers that sell large quantities of carcasses and cut-meat and 395 retailers that mostly sell smaller quantities of cut meat. Very few retailers can sell carcasses. The main wholesale markets in the capital city are involved in this tier, and the total purchasing quantity of customers is much bigger than that of retailers. Either individual end-consumers or catering services mostly buy lot-size meat from the wholesale market, where the meat quantity is produced to the customers' order specifications and a make-to-order policy applies. All 395 retailers made contracts with manager organisations to sell meat in nine districts of the city and the managers supplied meat to retailers based on their orders that are predicted through forecasting consumers' needs.

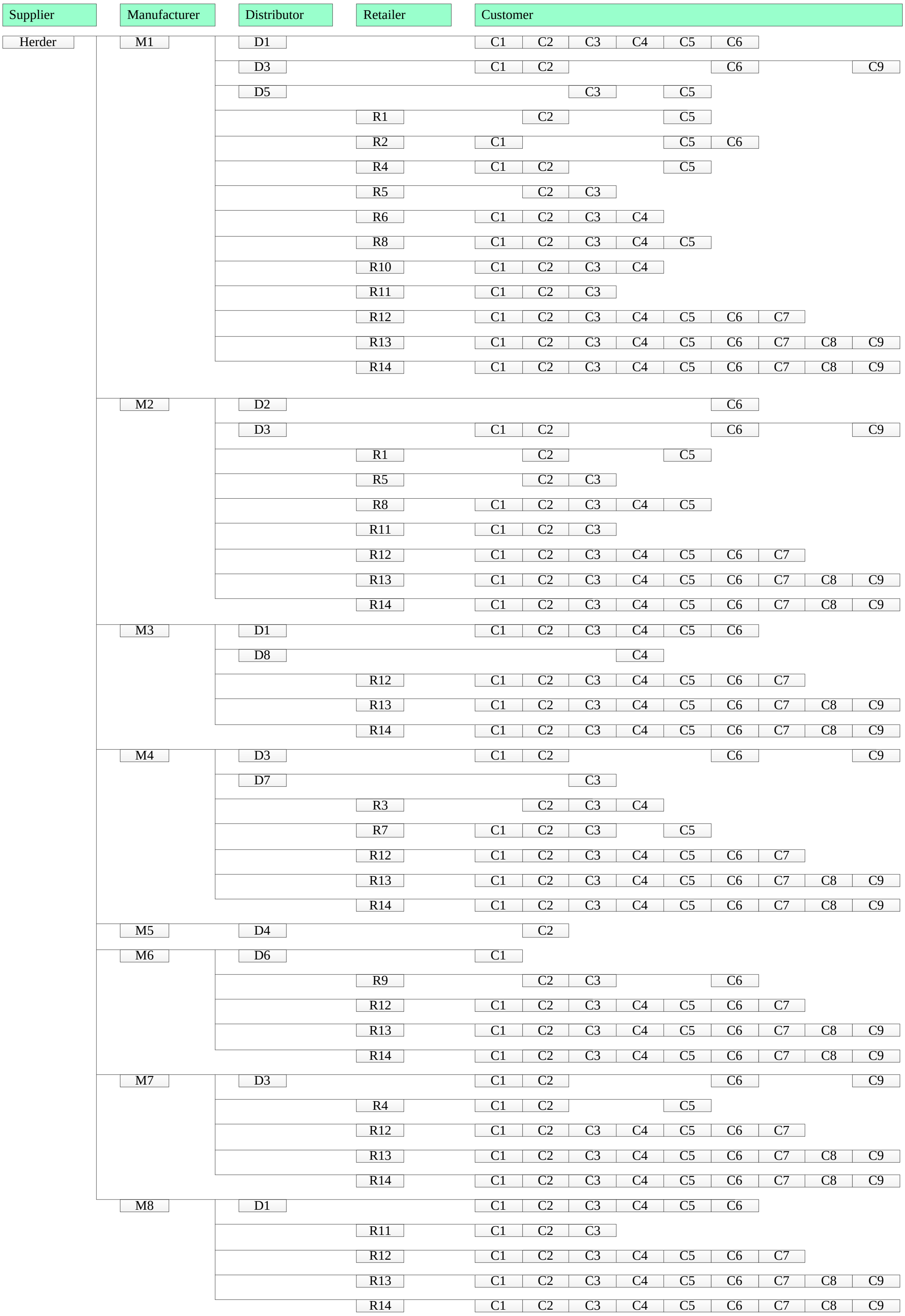

Figure 7-5: Detailed simulation model of Reserve Meat supply chain

All entities manage their operations according to a 'just-in-time' philosophy in a virtual 'zero stocks' environment and with a highly customised, demanding production system it is necessary to coordinate the meat flow along the whole supply chain, giving an assurance that the producer supplies meat at the right time to fulfil customer orders. However, in a real case the meat selling price is stabilised by the Government and quality is determined by national standards of meat preparation and storage, and meat cost and quality are not considered in the simulation model.

In this simulation, the demand is stable because the meat demand for *per* person *per* day is equalised. The maximum size of demand quantity is represented related to the population of a district and the consumers' meat consumption *per* day is calculated as shown in Table 6.3. To facilitate the use of the simulation model, the meat flow through the simulated process is shown in 1 kg. units. When the demanded meat quantity is matched by the supplied quantity from any of the suppliers, that order will leave the simulation process and it is recorded that the overall demand has been supplied. All the organisations have storage areas next to processing plants to minimise transport distances. The ordered meat is delivered to wholesalers and retailers every day from manufacturers using a simple 'milk-run' system and all manufacturers use their own transportation to distribute meat orders to the entities scheduled to receive them. Due to the lack of information related to the transportation of meat and its low-profile due to the short distances involved, the delivery time is not considered in this simulation.

7.3.1.1 Participants' characteristics

All eight manufacturers are selected according to the Government criteria that indicate that those enterprises have the capacity to procure and supply meat properly during shortages in the market. The eight participating wholesalers and the 395 retailers are assigned classifications based on the clusters determined in Chapter 4. However, it is difficult to conduct a questionnaire-based survey for all the participants, so experts are involved to cluster the enterprises based on their self-assessment, order frequency and quantity. The enterprise clustering is demonstrated in Table 7-7. Regarding the *Sensitive Joiners* of Khuchit Shonkhor Market and Narantuul-2 Market, some retailers have an ability to sense the shortage in the meat market and proactively develop solutions for these potential needs. Most of these enterprises have the objective of being competitive in a global market for an increased chance of long-term survival and greater profit potential. These enterprises are well-known in the market and can form temporary alliances easily. Although wholesalers do not have integrated IS, they adopt advanced ICT and all the retailers have well-developed internal IS for their finance, purchasing and inventory functions. However, as they work independently in the market there is the potential risk of competition with enterprises located close to their facilities so to avoid this they have multiple sourcing with delivery programs. They order large quantities of meat and the sales rate is high.

Table 7-7: Clustering of meat supplying enterprises

Entity	Enterprise internal capacity	Ability to join in VE	External changes	ICT adoption	Clusters
D1	3.92	**4.05**	**4.50**	3.50	Sensitive joiners
D2	3.42	**3.78**	**4.08**	3.00	Sensitive joiners
D3	**4.00**	**4.07**	3.25	**3.80**	Skilled, ICT aware joiners
D4	4.18	2.83	3.75	1.50	All-rounders
D5	**4.30**	**4.12**	3.63	**3.85**	Skilled, ICT aware joiners
D6	3.82	**3.88**	**3.98**	2.50	Sensitive joiners
D7	4.10	3.90	3.75	3.56	All-rounders
D8	4.18	3.60	4.28	2.80	All-rounders
R1	**3.94**	**3.90**	3.68	**4.02**	Skilled, ICT aware joiners
R2	**3.86**	**3.97**	3.48	**4.05**	Skilled, ICT aware joiners
R3	**3.96**	**3.95**	3.73	**4.10**	Skilled, ICT aware joiners
R4	**3.82**	**3.82**	3.78	**3.85**	Skilled, ICT aware joiners
R5	**3.84**	**3.85**	3.50	**3.90**	Skilled, ICT aware joiners
R6	**3.74**	**3.88**	3.58	**4.05**	Skilled, ICT aware joiners
R7	**3.88**	**3.83**	3.70	**3.92**	Skilled, ICT aware joiners
R8	**4.00**	**4.00**	3.85	**4.32**	Skilled, ICT aware joiners
R9	4.08	3.88	3.75	3.00	All-rounders
R10	4.50	3.67	3.93	2.00	All-rounders
R11	**4.16**	**4.42**	**4.88**	2.50	Sensitive joiners
R12	3.62	3.25	3.38	2.00	All-rounders
R13	3.24	2.97	2.95	**3.45**	ICT aware non-joiners
R14	3.24	2.32	2.95	1.00	Low performers

The *Skilled, ICT Aware Joiners'* cluster involves mostly supermarket chains or retailers' chains that have sound internal capacity based on employing knowledgeable and skilled people, advanced technologies and well-developed strategies. This category of enterprise has many branches located all around the city and although their IS may be integrated, branches do not make decisions, so some enterprises' headquarters share meat supplies equally among their branches, irrespective of demand. Meat to supermarkets is typically supplied by the distribution centres of their parent companies and they typically have the objective of competing based on distributing their products through their widespread branches.

However, although *All-rounders* have good internal capacity they do not pay attention to collaborating with similar enterprises and most of the enterprises in this cluster are small stores, that do not have their own integrated IS. The sales volume of these enterprises is small and there is no safety stock considered in their facilities so they have a strategy of order-to-sell. Most of them are in the uncrowded areas of the city. Lack of internal capacity and an inability to sense to changes in the market means that not surviving in the market is a potential risk for enterprises in this cluster. Although, as with All-Rounders, small stores are included in the *ICT Aware Non-Joiners* cluster, they emphasise the advanced ICT factor more than the latter cluster, although they do not develop specific strategies to survive in the competitive market. *Low* *performers* are small grocery stores mostly located in the suburbs of Ulan Bataar. To supply every consumer in the city, the virtual enterprise leader accepts the need to involve these stores in the programme. Consumers that buy from these stores buy meat in small sizes depending on their income so enterprises in this cluster order small sizes of meat for resale.

7.3.2 Supply chain simulation model development

A screen shot of the Simul8 model is shown in Figure 7-6, which depicts the overview of the flow of meat through the major supplying entities in Ulaanbaatar. The criteria for the identification of inputs and outputs are that the variables of the model whose values are obtained exogenously from other sources are classified as inputs and the variables whose values are computed by the model are categorised as outputs (Chahal *et al*., 2013). Inputs are observed from the external sources and the included variables include inter-arrival frequency, process logic (routing out), activity duration and capacity of manufacturers, wholesalers, and retailers.

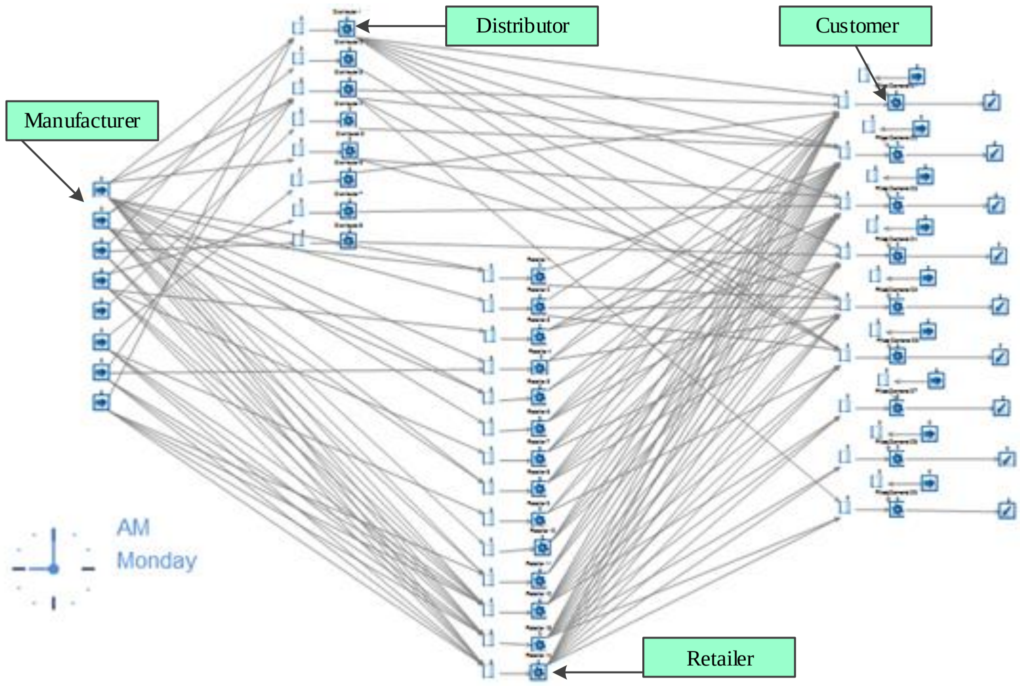

Figure 7-6: A screen shot of Simul8 model of meat supply in Ulaanbaatar

Simulation models pretend to mimic the probabilistic nature of the chosen system, so input modelling requires a close match between the input model and the underlying probabilistic mechanism of the system. Input data accurately representing the real situation being simulated is required to ensure valid simulation results. Most of the data required for the model were gathered from the official site of the Mongolian Meat Reserve Program and the sites of the main contributors to it. Also, observations and expert opinions were included in the input data. The entities included in the simulation model, the number of facilities that belong to the entities, the supply capacity or 'throughput' of the entities and the distribution or routing of the meat are shown in Table 7-8.

Table 7-8: Simulation model inputs

Entities	Facility number	Capacity (kg/day)		Supplying distribution (min/kg)
		Total	Per facility	
M1	1	24869.40	24869.40	TRIA (0.0171, 0.0283, 0.04149)
M2	1	11206.57	11206.57	TRIA (0.0371, 0.0641, 0.09162)
M3	1	6511.38	6511.38	TRIA (0.0515, 0.1123, 0.16778)
M4	1	2588.36	2588.36	TRIA (0.1818, 0.2853, 0.36799)
M5	1	2601.18	2601.18	TRIA (0.0842, 0.3374, 0.40999)
M6	1	1945.23	1945.23	TRIA (0.1455, 0.4293, 0.53850)
M7	1	937.71	937.71	TRIA (0.3955, 0.8885, 1.02850)
M8	1	357.95	357.95	TRIA (1.3646, 2.1653, 2.51990)
D1	1	22560.28	22560.28	TRIA (0.0182, 0.0315, 0.04608)
D2	1	7093.75	7093.75	TRIA (0.0552, 0.1184, 0.13140)
D3	7	2688.04	384.01	TRIA (1.6084, 1.8762, 2.14130)
D4	1	2601.18	2601.18	TRIA (0.0842, 0.3374, 0.40990)
D5	2	2114.01	1057.01	TRIA (0.1177, 0.8227, 1.10725)
D6	1	1709.89	1709.89	TRIA (0.1591, 0.4992, 0.60720)
D7	8	548.39	68.55	TRIA (5.5596, 11.3247, 14.5593)
D8	1	302.76	302.76	TRIA (1.3983, 2.6586, 3.0678)
R1	3	872.17	290.72	TRIA (0.6656, 2.9988, 3.7708)
R2	4	532.61	133.15	TRIA (2.7626, 5.9966, 7.4283)
R3	4	522.91	130.73	TRIA (3.1351, 5.9082, 7.4505)
R4	4	369.73	92.43	TRIA (4.4954, 8.6918, 10.1416)
R5	3	261.89	87.30	TRIA (4.9333, 8.9489, 10.8265)
R6	6	506.89	84.48	TRIA (4.5153, 8.4239, 12.5719)
R7	8	369.28	46.16	TRIA (9.0922, 15.9981, 21.5615)
R8	16	259.90	16.24	TRIA (20.3482, 46.9258, 65.0911)
R9	4	52.75	13.19	TRIA (25.5892, 54.6012, 81.5557)
R10	5	61.83	12.37	TRIA (20.4405, 58.2253, 93.4253)
R11	6	785.75	130.96	TRIA (3.5841, 5.8982, 7.0096)
R12	102	4549.87	44.61	TRIA (11.1513, 16.5412, 20.7405)
R13	99	1611.14	16.27	TRIA (26.3118, 44.2428, 61.8068)
R14	131	642.76	4.91	TRIA (96.5746, 155.7439, 183.0393)
C1	N/A	38364.6	N/A	AVE (0.0188)
C2	N/A	58328.6	N/A	AVE (0.0123)
C3	N/A	53151.5	N/A	AVE (0.0135)
C4	N/A	25547.8	N/A	AVE (0.0282)
C5	N/A	25126.9	N/A	AVE (0.0286)
C6	N/A	29873	N/A	AVE (0.0241)
C7	N/A	5354.4	N/A	AVE (0.1345)
C8	N/A	729.5	N/A	AVE (0.9869)
C9	N/A	6370	N/A	AVE (0.1130)

To mimic reality in the simulation model, the distributions of inter-arrival time and the processing time of manufacturers, wholesalers, retailers and customer demands are determined empirically (i.e. user-defined distribution estimates are used in the simulation model). With the arrival process for the manufacturing entities, an empirical probability profile distribution is constructed from the inter-arrival times, using information from collected data about meat supply quantity and order fulfilment frequencies. Conversely, the empirical probability distribution of inter-arrival times for customer demand entities are determined as an average distribution based on the stabilised demand generated *per* day. Meat supply and demand inter-arrival times are assumed to be independent of one another. The theoretical distributions of meat supply times in the work centres of wholesalers and retailers are modelled using triangular distributions based on data about order quantity and order frequency. A triangular distribution has a central peak (most likely); it can be skewed to the right or left and has finite limits (lowest and highest). Hence, negative durations cannot be estimated. Triangular distribution is mostly used in simulation because of it is easy to understand and requires simple calculations. Also from the collected data, minimum, maximum value and its mode of supplying distribution were found. Therefore, triangular distribution was used. This distribution allows the manager's perceptions about the critical inputs to be captured without the process being excessively time consuming (Carvalho *et al*., 2012). However, for customer distribution it was not easy to find minimum and maximum value of their buying process so the distribution is averaged.

To represent agility in the meat supply chain, the main strategy designed into this simulation model is that all routing-out alternatives are checked and the maximum stock needed by each supplier is defined, then a supplier is selected to fulfil the order. The maximum stock needed is calculated as the maximum capacity of an entity minus the current stock in the activity. (An example of the routing-out logic is demonstrated in Appendix D). The maximum capacity is defined by the capacity that a supplier can process in a day. 'Current stock in activity' is determined as the work items that are moving through the simulation process. Outputs were calculated during the simulation model run and are included in this study as follows:

- For the entire workflow system, the outputs are the overall throughput (i.e. the steady state supply rate) and the average time in the system for meat items (i.e. the supply time or lead time);
- For the different work centres the outputs are meat quantities in system queues (i.e. stock).

7.3.3 Simulation model validation and verification

Since a correct model is essential for correct results, the conceptual simulation model must be an accurate representation of the system under study. Therefore, model validation and verification needs to be conducted during the development of a simulation model with the ultimate goal of producing an accurate and credible model (Banks *et al*., 2009). Validation and verification is an iterative process that takes place throughout the development of a model. Thus, the validation and verification of a simulation model starts after the functional specifications have been documented and initial model development has been completed. The verification of a model is the process of confirming it is correctly implemented with respect to the conceptual model so that it matches the specifications and any assumptions deemed to be acceptable for the given purpose of the application (Banks *et al*., 2009). On the other hand, the validation of the model checks the accuracy of the model's representation of the real system.

According to Banks *et al*. (2009) for model validation a common three-step approach is recommended that includes:

- Step 1. Build a model that has high face validity;
- Step 2. Validate model assumptions;
- Step 3. Compare the model input-output transformations to corresponding input-output transformations for the real system.

However, as there is no standard theory on validation and verification, the design of this simulation model was examined in detail to assure the model matches specifications and assumptions with respect to the model concept. The logic of the model was analysed, its consistency was verified, and its completeness was determined carefully.

7.3.4 Simulation model assumptions and limitations

Due to a lack of available data and to simplify some aspects of the model, the following reasonable assumptions were made:

- All manufacturers, wholesalers and retailers are always available. This assumption is reasonable, because the program had been conducted for only five months, and all manufacturers have a responsibility to prepare supplying meat and distribute it when demand is generated in the market. Wholesaling markets are open every day because many renters run their business in the markets to cover the cost of renting. However, some retailers do not make up orders every day, so all retailer orders were averaged *per* day for every retailer;
- Meat is prepared and stored before distribution is started. There is no lack of meat quantity from manufacturers as they have prepared meat during the slaughter season and have stored it in their warehouses. The manufacturers have a theoretically infinite stock, and therefore they do not need to perform sourcing activities, which leads to a narrow vision of these supply chain entities;
- Manufacturers supply meat only to assigned wholesalers and retailers. The leader manager allocated wholesalers and retailers to manufacturers regarding to the locations. Meat is delivered on the same day the order is placed;
- Manufacturers, wholesalers and retailers’ capacities are limited by the distribution capacity in a day. The capacities of branch stores belonging to the same retailers are assumed to be equal;

- Customer demands are ‘pulled’ through the supply chain, and only fulfilled demand leaves the simulation process and is recorded as such. Unfulfilled demand in districts are held waiting in a queue and are recorded as shortages in the market;
- The model only considers a one-year performance cycle of the programme.;
- The stochastic processing times follow a triangular distribution.

The principal simulation model limitations, derived from the assumptions made in the modeling stage, are:

- The processes of manufacturers, wholesalers and retailers are not simulated, therefore the effects of the lack of meat quantity that needs to be supplied are not measured;
- All supply chain entities’ production planning follows a make-to-order policy and orders are scheduled for production using a first in first out (FIFO) rule. No priority rules were introduced;
- Since the meat industry is driven by rigorous health and quality standards the reverse flow of materials was not modelled due to the assumption that no overtime was used or meat was spoiled, although this represents an oversimplification of reality;
- The meat type is assumed to be all the same and the flow of meat through the simulated process is represented by 1 kg. units;
- The model does not consider the cost of transportation or the meat quality.

7.3.5 Results and discussion

The simulation model was run using one year’s worth of historical general meat supply data. To achieve the research objectives, the appropriate use of a simulation model requires accurate measures of model performance to be taken, and without this accuracy the prediction of ‘real life’ behaviour cannot be trusted even if the model itself is valid. Thus, to collect the proper results, a warm-up period and result collection periods are considered. The warm-up period is amount of time allowed for the simulation to reach a steady state (Concannon *et al*., 2003). If the warm-up is too short, bias will be introduced into the results obtained from the simulation model. If it is too long, useful data are wasted and either the precision of the steady-state parameter estimates is reduced or longer simulation runs are required. There are several methods for estimating the warm-up period, but there is no single method that can be recommended. In this work, a graphical method was used, by visual inspection of time-series of the simulation output. Thus, the warm-up period was set to seven days (5040 min) and the calculation of the performance measures starts in time period 5041 minutes to avoid bias from starting conditions. The result collection period is the amount of simulation run time following the completion of the warm-up period (Concannon *et al*., 2003). The run-length of the simulation was determined by reference to the real case. The program was conducted from 27th January to 30th June 2013. Therefore, each simulation runs for 154 time periods (i.e. days) of 12 hours duration.

Multiple replications were used for confidence interval construction. Therefore, it was necessary to indicate the number of replications needed to achieve a confidence interval of a specified precision, using a significance level (α=5%) for the confidence interval calculation. The steady state characteristics of the workflow are determined using the simulation model, assuming non-terminating simulation. A point estimate and a confidence interval of the steady state mean of the 22 weeks' throughput and the time in system (in minutes) are derived for meat items to measure the performance of the entire system. To determine the number of runs to use for trials, the Trials Calculator was used and 83 replications were recommended.

7.3.5.1 *Throughput of entities*

The simulation was run for 83 replications using common random numbers, with the mean throughput for all entities as the output of interest. To validate the simulation model based on predicted and historical data for the program, the observed performance measurements of the total throughput of all manufacturers, wholesalers and retailers are compared pairwise with real data using a paired-t test. Since there is no *a priori* correlation between the real-life data and the simulation output and it is not known if the data sets have equal variances, the independent-samples t-test compares the means between two unrelated groups with the same continuous dependent variables; throughput of manufacturer, wholesaler and retailer. The statistical package SPSS® version 20.0 for Windows (IBM Corporation, 2011) was used and 95 per cent confidence intervals were constructed for the difference between the actual and simulated number of throughputs. The results of pair comparison (shown in Table 6.9) indicates that the difference between the actual data and the simulation output is not statistically significant. Therefore, the simulation model is held to be valid.

More specifically, Table 6.9 shows that a wholly negative confidence interval indicates that the simulation replication has a higher throughput than the average mean of the real case with 95% confidence. However, 95% confidence intervals are useful compared to other statistical hypothesis tests in that the confidence intervals provide the range of estimates that are consistent with the observed data. This extra information is useful, as it provides a better understanding of the similarity between the simulated data and the real case data.

Table 7-9: The result of pairwise t-test

Entities	Mean for simulation output	Average of case study	95% of confidence interval of the difference		Levene's Test for Equality of Variances	t-test for Equality of Means	
			Lower	Upper		t	Sig. (2-tailed)
M1	4000658.0	4003973.0	-6656.122	25.205	115.766**	-1.974	0.052
M2	1805221.0	1804257.2	-1220.724	3147.745	96.725**	0.878	0.383
M3	1047485.0	1048332.9	-1699.516	3.829	70.925**	-1.980	0.051
M4	416579.3	416725.6	-293.327	0.682	73.469**	-1.980	0.051
M5	418754.1	418789.2	-72.266	2.107	119.641**	-1.877	0.064
M6	313397.4	313182.8	-2.089	431.415	106.515**	1.970	0.052
M7	151421.3	150971.4	-7.423	907.217	181.899**	1.957	0.054
M8	57576.7	57630.0	-106.678	0.128	154.910**	-1.985	0.051
D1	3632050.0	3632205.2	-1128.744	817.83	53.167**	-0.318	0.751
D2	1142423.0	1142094.3	-1066.979	1724.12	98.459**	0.468	0.641
D3	433115.0	432774.4	-2.384	683.552	125.615**	1.975	0.052
D4	418756.8	418789.2	-68.359	3.495	100.246**	-1.796	0.076
D5	340679.1	340356.4	-3.434	648.794	136.545**	1.968	0.052
D6	275147.0	275292.1	-291.93	1.706	103.401**	-1.966	0.053
D7	88236.6	88291.0	-109.712	0.905	185.336**	-1.957	0.054
D8	48705.3	48743.6	-96.056	19.485	110.383**	-1.318	0.191
R1	140420.1	140550.8	-2.176	263.673	141.889**	1.957	0.054
R2	85750.2	85783.3	-4.085	70.243	96.125**	1.771	0.080
R3	84187.9	84126.3	-124.093	0.892	160.720**	-1.961	0.053
R4	59526.2	59537.5	-0.243	22.711	104.918**	1.947	0.055
R5	42164.8	42160.7	-56.959	48.644	126.314**	-0.157	0.876
R6	81609.2	81650.8	-1.434	84.432	76.716**	1.923	0.058
R7	59454.4	59406.4	-99.812	3.731	135.673**	-1.846	0.069
R8	41844.1	41872.0	-0.999	56.705	180.619**	1.920	0.058
R9	8492.2	8493.2	-13.283	15.388	195.370**	0.146	0.884
R10	9954.5	9963.8	-7.849	26.526	141.322**	1.081	0.283
R11	126505.8	126452.7	-106.825	0.791	42.788**	-1.960	0.053
R12	732529.1	732189.0	-685.021	4.869	148.702**	-1.961	0.053
R13	259393.5	259469.0	-0.528	151.352	60.941**	1.975	0.052
R14	103484.0	103560.4	-1.695	154.366	174.427**	1.946	0.055

**p<0.01, significance level

To inspect the model visually, the total throughput of manufacturers of the case study and the results indicated at three levels; lower-level (with 95% confidence level), average level and higher-level (with 95% confidence level) are depicted in Figure 7-7. The total throughputs of wholesalers and retailers are illustrated in Figure 7-8 and Figure 7-9 respectively. Equally simulated throughput and case study throughput indicate that the supply distribution time of entities is defined correct and supply through these entities are flowing without any conflicts.

7.3.5.2 Waiting queue length and quantity

In this simulation model, a work in process monitor has been utilised for real-time observation of the situation of supply. The upper limit of work in process for different suppliers set equally to reflect the realistic capacity of each supplier. To this end, the results of work in process, waiting time, and working contents for a determined period of 120,960 minutes (excluding a warm-up period of 5,040 minutes) for each supply chain entity are presented in Appendix E-1 and Appendix E-2, respectively.

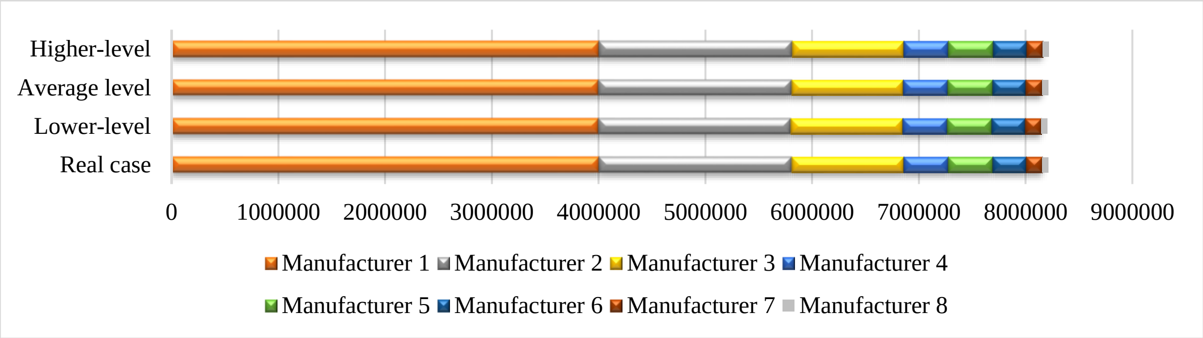

Figure 7-7: Comparison of total throughput of manufacturers

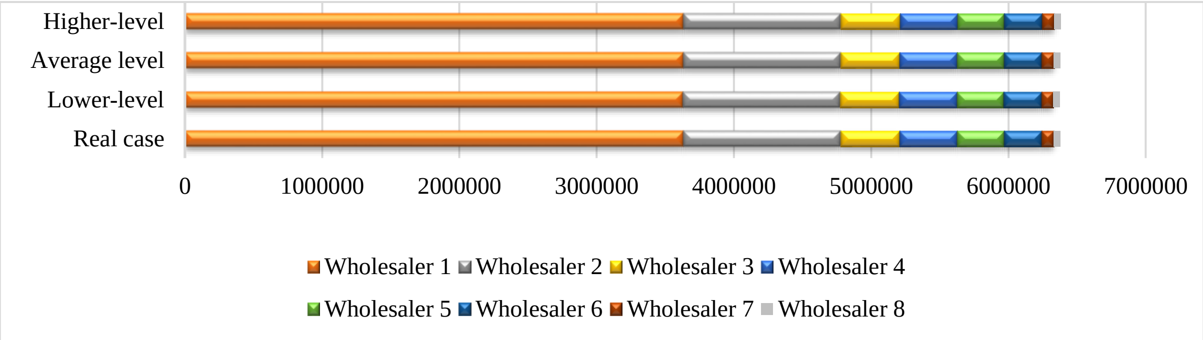

Figure 7-8: Comparison of total throughput of wholesalers

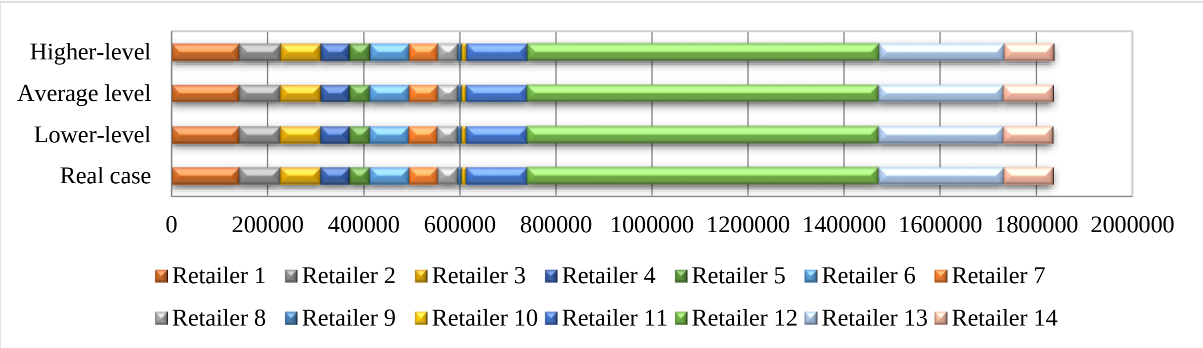

Figure 7-9: Comparison of total throughput of retailers

In the simulation model, suppliers have sufficient stock to satisfy the customer's orders by the promised date. In the scenarios that involve supplying meat to entities who have the lowest stock, it is possible to observe that all the entities in the supply chain present some fluctuations in their behaviour derived from day-to-day uncertainty in their processes. In relation to the other supply chain entities, it appears that while some suppliers' stock increases, others' stock decreases. A comparative analysis of the simulation results concerning the real-time observations shows that during low stock periods, some entities are not working as shown in the last column of the tables. This suggests that while the flexibility strategy makes the supply chain more resilient, the agility level of those entities that are not working entities is low and needs to be improved. It should be noted that these results are dependent on the supply chain parameters (capacity, time durations, stock level, and so on) associated with each activity undertaken in the supply chain. So, if the supply chain parameters are different, then the results and consequently the conclusions may vary. In this study two performance measures, stock-in-system queues and average time for holding stock in the system were used. However, since the analysis of individual values of performance measures may lead to specific conclusions, the simulation model should be extended and it will take more time to collect larger number of performance measures.

7.3.5.3 Unfulfilled demand

However, enterprises joining in temporary alliance have an objective to decrease shortage in the meat market, very small portion of demand is fulfilled. Figure 7-10 shows the fulfilled percentages of consumers in each district. This indicates that there are still more opportunities to supply meat to fulfil demand during shortage periods.

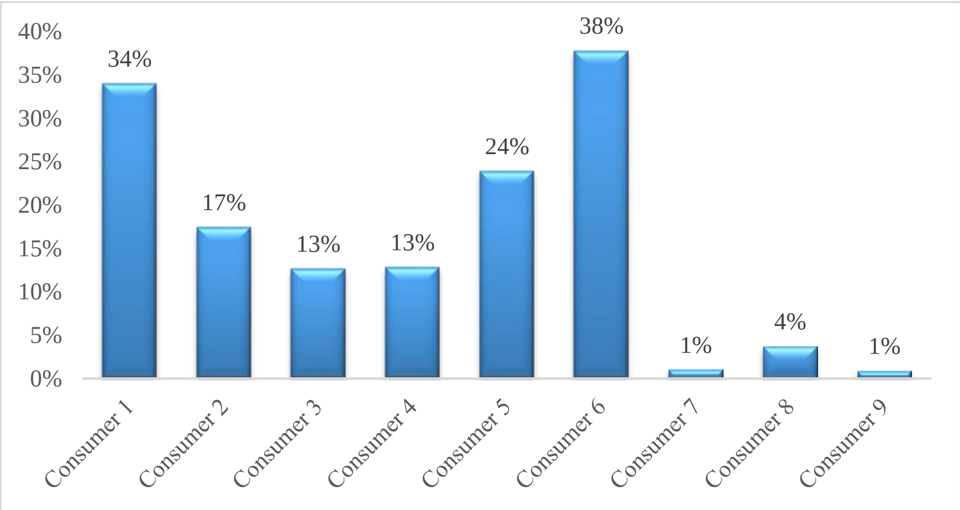

Figure 7-10: Fulfilled demand percentage of districts

7.3.5.4 Participants' characteristics

Based on the observations of the supplied meat pathways and fulfilled demand regarding modelled simulation, enterprises' cluster performance was examined. As is discussed in Section 6.3, temporary alliance affiliation provides a mutual performance to the cluster enterprises in this study. By adopting such an approach, information across the whole supply chain (or virtual enterprise) is shared properly through the dedicated information platform. In this connection, it is found that the responsiveness of the supply chain has been improved as they have successfully shortened the order-to-market lead time. The virtual enterprise approach delivers the expected consequences promptly. The implementations of the clusters and their performance implications are discussed further.

Figure 7-11 shows the ‘working percentages’ of wholesalers and retailers. The working percentage of enterprises belonging to different clusters can differ, as some wholesalers and retailers do not supply meat when there is not sufficient demand ‘pull’ (i.e. they are not ‘working’). Not surprisingly, the *Sensitive joiners* have the highest working percentage and supply larger quantities of meat because they proactively respond to the meat demand in the market. Many consumers have found the *Sensitive joiners* to be quick and reliable meat suppliers so the lead time is the shortest for the distributors and retailers belonging to the *Sensitive joiners’* cluster. It is interesting to note that in the simulation the working percentage of wholesalers and retailers reduced due to a shortage of meat stock in the system, which means in practice that the optimisation of stock levels needs to be considered to improve the performance of the members of this cluster.

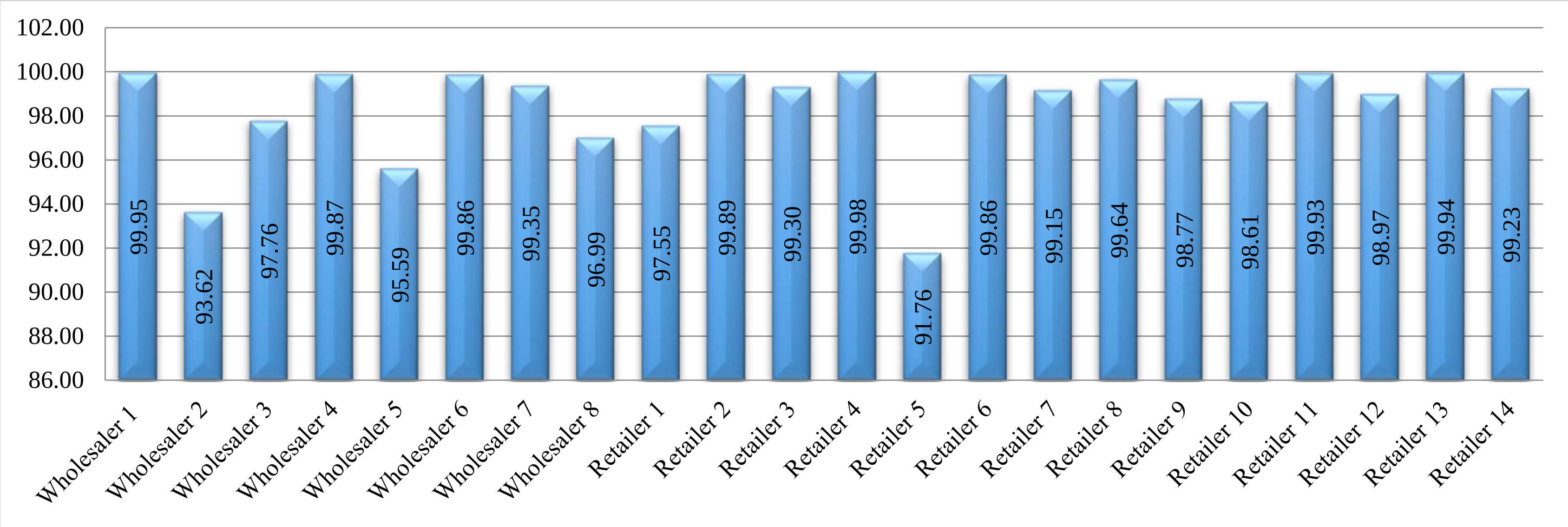

Figure 7-11: Working percentage of wholesalers and retailers

Skilled, ICT aware joiners distribute meat using their local branches that are in many districts to achieve better levels of agility. Some chain store branches do not sell meat because of a lack of supply, which causes a reduction in the working percentage of this cluster. However, in some stores the lead time for meat supplies is shown to be very long as is shown in Appendix E-1 and Appendix E-2.

All-rounders have lower working percentage than two above clusters. However, they are not emphasising any specific strategy to improve their performance, *All-rounders* order meat in small sizes and when it is needed, and some of them increase their safety stock to ensure that they can meet demand. *All-rounders* are perceived to be one of the main sources of supply.

ICT aware non-joiners order meat in larger sizes than *All-rounders*, and the lead time is also longer than that applying to *All-rounders*. Members of this cluster could be become some of the main sources of meat if they can improve their capability to supply.

Low performers order the smallest pack sizes of meat and their lead time is much longer than the *ICT aware non-joiners* and *All-rounders*. However, distributing meat to these stores is more expensive and the programme has a goal of supplying meat using as many stores as possible. These stores can be eliminated as candidates from the pool of potential collaborators for the next temporary alliance formation.

7.4 Summary

The main purpose of this part of the research is to study a real case of temporary alliances to exemplify how firms make use of the virtual enterprise approach to integrate their activities to balance the demand from the market side (i.e. 'demand pull') and supply from the manufacturing side (i.e. 'supply push'). A meat supplying chain in Ulaanbaatar is selected as a proper collaboration that has taken a virtual enterprise approach to covering temporary shortages in the market. The case demonstrates that the integration supports responsiveness in the supply chain and flexibility in response to fluctuations in market demand.

To analyse the effectiveness of the temporary collaborations in the case, a simulation model is utilised to visualise the performance of the clusters of wholesalers and retailers etc. A discrete event simulation model is developed to simulate the processing of the different suppliers with different capacities and speeds of order fulfilment. The simulation model is supported by a queuing network formulation that offers a versatile method for understanding the meat distribution chain and the members' participation in it and the fundamentals of to how to design the next programme. The simulation model is verified and validated by network representation and logic of the workflow and checked by comparing the results to real-life data. From a statistical analysis of the discrete event simulation results, it was found that the proposed simulation model performs similarly to the real case with 95% confidence, and the supporting evidence validates the premise that, depending on the members, the clusters have different levels of achievement, which affects the whole performance of a virtual enterprise. Agility is modelled in the simulation and supply chain performance measures are defined and computed for each entity and the throughput and the average supply time are addressed for the total network. For the detailed queues in the supply chain, the steady state queue length is calculated. The workflow supply rate and lead times of suppliers and the supplied levels of demand are analysed for different enterprise clusters to understand how all the types of enterprise in the virtual enterprise perform and how the clusters create and then supply demand in the market.

The results of the simulation allows a comparison of clusters' performance in the supply chain, indicating that the working percentage and performance of *Sensitive Joiners* and *Skilled, ICT Aware Joiners* is higher than the other three clusters. The simulation shows that the performance of the whole supply chain can be improved by eliminating enterprises that have a poor record of performance and by supporting enterprises that have higher levels of performance. However, as all of these strategies are expected to reduce lead times and increase the potential to fulfil every consumer's demand, the *Low Performers* located in suburban areas should become more involved in the supply chain. In this case, to improve the performance of the whole supply chain by taking advantage of location factors, the leading enterprise should request the *Low performers* and *ICT Aware Non-Joiners* to improve their capability to join in alliances or should select enterprises with more advanced capabilities.

This chapter successfully addresses a complex real-world workflow problem by simulating the supply and demand network of the Mongolian meat supply chain. However, the study has some limitations, in that the research is related to the 'real' Meat Reserve Program from 2013 and the findings may not be applicable to programs in different years. Since only one subset of the supply chain was analysed, the results may not apply to other industry sectors. Further expansion of the model is needed to include more complex cost and transport effects and to optimise the number of suppliers. It is also important to analyse how the individual behaviour of supply chain entities affects the performance of the whole supply chain. To do this, the meat supply during periods of shortage must be simulated and other performance measures must be developed. The revised model can then be easily applied to study similar workflow problems in other industries and cases of virtual enterprise formation.

CHAPTER 8: CONCLUSIONS AND FUTURE WORK

8 Introduction

This chapter summarises the conclusions drawn from this research. The main contributions are highlighted and the primary studies and their results are discussed. Future research work is suggested.

8.1 Contribution

The research work has both significant theoretical and managerial contributions. The theoretical contributions of the work are as follows:

1. The study bridges separate studies on virtual breeding environments, virtual enterprises, and agile supply chains by applying the resource-based view, and develops an aggregated research schema. The research theory is grounded in the overlapping areas of three main theoretical concepts. In the proposed aggregated research schema, a virtual breeding environment is assumed to be a base that can be used to build trust and allow enterprises to join temporarily to exploit fast-changing business opportunities. As a temporary alliance, a virtual enterprise is perceived to be a competitive strategy for enterprises that is not easily capable of imitation by potential competitors, thereby achieving and sustaining competitive advantage. Agility is interpreted as a rare, valuable, imperfectly imitable and non-substitutable network resource, which could become heterogeneous and immobile with the support of the virtual enterprise. Business performance measures are suggested to gauge the output of the strategy and the effectiveness of the use of resources.

2. The original conceptual model produced by the research hypothesises the relationship between virtual enterprises and agile supply chains in complex systems, defining the drivers, providers, capabilities and outcomes of agility. The conceptual model is intended to investigate how the drivers influence the achievement of agility through a virtual enterprise, and how providers improve agility to assure better business performance in a supply chain. External changes were chosen as the drivers. Dynamic capabilities, ICT adoption and the ability to join in a virtual enterprise were selected as the providers. As few studies have examined the relationship between virtual enterprises and agility, hypotheses were proposed and tested through a survey based on a structured questionnaire. This was processed and distributed among Mongolian companies which are active in export

and imports and use the world wide web. To test the hypotheses, the structural equation model technique is employed in three stages; the identification of underlying constructs, model measurement and structural modelling. Rich empirical evidence is provided by the research that supports the research hypotheses, enriches the understanding of the relationship between virtual enterprises and agility in complex situations and provides insights for managers.

3. Five clusters with different characteristics are identified as an another contribution using cluster analysis based on four underlying factors. A cluster analysis was conducted with the probabilistic clustering technique expectation maximisation algorithm (rarely found in the literature), which is adapted to classify datasets into an appropriate number of groups. Cluster analysis was performed in three steps with successive analysis methods including; factor analysis, the application of an unsupervised expectation maximisation clustering algorithm and either ANOVA with a t-test or Kruskal-Wallis with the Mann-Whitney test based on the normality of the dataset distribution. The result of this research provides empirical evidence that the enterprises place a different emphasis on the driving forces and providers and have different levels of achievement of agility and performance.

4. A novel adaptive virtual enterprise framework is proposed, inspired by the common reference architectures, which enables and supports temporary collaborations for enterprises to achieve agility and competitive advantage in the supply chain. Using the framework, the following system components are modelled and optimised:

- A general representation of a pool of enterprises is modelled, with the main goal of providing a base level of trust and increasing both the chances of readiness and improving the chances of selection for enterprises seeking to join in a potential virtual enterprise. As a main goal for a supply chain, the fundamental requirements of reducing costs and time and improving the effectiveness and efficiency of enterprises when they join in a virtual enterprise are considered;
- Specific models to improve the effectiveness of virtual enterprises are proposed, with a representation of the logical and recursive relationships between the factors that have a positive influence on the effectiveness of virtual enterprise formation. Strategies that can be taken by enterprises to improve their readiness for collaboration are discussed;
- A systematically structured implementation model is proposed, which can be adopted easily by enterprises who are ready to collaborate temporarily and dynamically to

achieve competitive advantage. The functions of the implementation model and its required platform are discussed.

5. An emerging market case study, set in Mongolia, is analysed to evaluate the situation of virtual enterprise formation. Examples of temporary collaboration are investigated and participants in the virtual enterprise are analysed, based on primary research (i.e. a survey). A simulation is then employed to understand the process of virtual enterprise affiliation. Then participating enterprises and the characteristics of their effectiveness in the virtual enterprise are discussed and compared by clusters.

As well as the academic contribution, the research has some practical implications for managers and planners in organisations that may be evaluating the potential for them to become involved in virtual enterprises:

1. The resource-based approach considers the combined set of resources of the alliance partners rather than a single firm. To exploit ownership of advantageous resources and to create competitive advantage in a rapidly-changing marketplace, firms have developed many collaborative strategies to allow partners in a supply chain to receive relational rents. To sustain competitive advantage, a firm needs to consider the informal and emerging strategies such as forming a temporary alliance to exploit business opportunities and to make network resources heterogeneous and fixed (or ‘immobile’). Joining a virtual enterprise could be a strategy that supports agile supply chains and provides better business performance. Agile capabilities are a network resource formed by temporary alliance formation and are considered to be rare, valuable, imperfectly imitable and non-substitutable as a source of sustained competitive advantage;
2. The findings suggest to managers that by selecting an informal strategy of joining in a virtual enterprise in a turbulent environment they could achieve higher performance in their business through the agile supply chain. Therefore, the partners’ dynamic capabilities are the most important factor to consider when forming a virtual enterprise. However, this research indicates that these dynamic capabilities do not influence agility directly, although the indirect effect is strong. While managers investigate the possibilities of exploiting business opportunities and focus on the adoption of ICT, they also need to improve their dynamic capabilities if they are to be selected ‘from the pool’ when a virtual enterprise is formed to provide more capabilities and to receive higher relational rents;
3. To enhance agility and to improve performance, empirical evidence suggests that enterprises need to predict external changes and pressures and then adapt to them or respond to them.

Furthermore, they could convert those changes into business opportunities if they were so prepared, so enterprises need to improve their ability to sense changes in customer requirements and in the marketplace. The findings reveal that joining in a virtual enterprise can be a key accelerating facilitator in improving business performance. Virtual enterprise participation could therefore be one of the proper strategies for enhancing an agile supply chain and providing greater output, although forming a virtual enterprise requires advanced ICT ability and sound core competencies in this area. When selecting the strategies to form virtual enterprise, enterprises need to pay more attention to affiliation factors and the organisation of the virtual enterprise and their ability to share information and knowledge with partners;

4. The empirical study suggests that when enterprises emphasise external changes and have the ability to join in a virtual enterprise or have higher internal ICT capabilities, they provide the greatest potential to combine agile capability with high performance. Otherwise, without any specific drivers or providers, enterprises can lose their competitive advantage and decrease their performance and it can cause potential partners to avoid collaborating with them in a virtual enterprise;
5. The findings suggest that SMEs with low formalisation and high complexity, which belong to 'traditional' supply chains with unpredictable customer requirements and high competition could achieve better performance in an agile supply chain. Also, skilled large-scale enterprises with many resources, a highly hierarchical structure and formal centralised authority could enhance their agility in the supply chain as well as their performance.

8.2 Future research

There are several research aspects to investigating possibilities for improving the effectiveness of virtual enterprises in supply chains and extending their potential. These aspects are outlined as follows:

- Factors that influence the relationship between virtual enterprise formation and its effectiveness and measurement can be further developed or expanded. Only six factors have been analysed in this study, so the future research can expand the conceptual model by considering additional factors and their relationships.
- The target group can be changed, as this empirical study only targets Mongolian enterprises. Primary data can be collected from other countries to test the hypotheses and to analyse taxonomies of enterprises that are willing to join in virtual enterprises in other countries.

- The research methodology can be extended or changed. Every analysis technique has its limitations and different techniques can be adapted to analyse either the same empirical data or new data. For instance, nested models can be produced and compared with each other to provide further validation of the hypothetical model. Also, besides the soft clustering technique (i.e. the expectation maximisation) that automatically generates the optimal number of latent classes from the sample, alternative techniques may give different results. Therefore, further work is required to confirm this empirical study, to clarify the clusters and to validate the findings.
- Although a set of components for the framework has been proposed in Chapter 5, several gaps are left to build a coherent and exhaustive engineering framework. These gaps are related to the enrichment of the modelling framework by other modelling views to consider other types of needs, the development of partial models, and the confrontation of our methodology with several real cases.
- Each cell of the proposed reference architecture could be filled by more general, specific and implementation models. Although this framework is focused on business integration at the identification stage of virtual enterprise formation, other cells of physical and application integration at the affiliation, operation, evaluation and dissolution stages of virtual enterprise can be identified, based on the literature, and the results can be evaluated.
- The simulation model can be expanded or changed. As there is no common simulation model for analysing virtual enterprise formation and measuring its effectiveness, the model developed in this study can be expanded with more functions to produce different results.
- Alternatively, software can be used to support the analysis and the results could be compared.

8.3 Summary

This study aims to develop an adaptive framework for improving the effectiveness of virtual enterprises in supply chains through increased agility. The secondary research, which examined enterprise collaboration and integration within supply chains, and temporary alliances in a developing country (Mongolia), the subject was chosen as a proper domain for PhD research. The study suggests that the recent turbulent global business environment and advances in technology development are pushing enterprises to collaborate with each other virtually, either to survive or to achieve common business objectives. Virtual enterprise formation is therefore perceived to be one of main strategies that enterprises pursue to exploit transient business objectives and to receive competitive advantages from temporary opportunities. Unfortunately, forming a virtual enterprise is not an easy task for enterprises that are willing to follow this strategy.

Chapter 1 addresses the background to the problem and the fundamental issues arising from it that challenge virtual enterprise formation are reviewed . Although the collected evidence reveals that the coordination, integration and implementation of a virtual enterprise can be achieved at a certain level, the readiness of organisations to form a virtual enterprise is rarely studied. Additionally, a lack of suitable frameworks and infrastructures for ensuring the effectiveness of virtual enterprises is discussed. These conditions create the motivation to study the possibilities for improving the effectiveness of virtual enterprises, based on the readiness of organisations to join a virtual enterprise. Therefore, a suitable adaptive framework is developed to accomplish the research objectives.

Chapter 2 reviews the relevant knowledge base for a virtual enterprise, the fundamental conditions for forming a virtual enterprise and measures of effectiveness of for virtual enterprise performance. By applying the resource-based view as an underpinning theory, three main research domains are reviewed and aggregated. The literature suggests that a virtual breeding environment is one of the fundamental conditions for forming a virtual enterprise because it establishes co-operation agreements, common operating principles, common interoperable infrastructures, common ontologies and mutual trust with the objective of preparing members for working in the virtual enterprise. Based on a comparison of the various concepts and definitions of virtual enterprises, the research has developed a set of working definitions. Also, the structure and lifecycle of a virtual enterprise are examined closely and an Internet-based hybrid network with agent-based coordination and data integration tools is recommended as being appropriate for the effective and efficient formation of a virtual enterprise. is identified as agility. The main benefit of virtual enterprise formation is agility, because it increases business performance and enhances mutual competitive advantages for the individual enterprises involved.

Chapter 3 reviews and evaluates candidate research philosophies, approaches and methods and justifies their inclusion in a research methodology that is appropriate for the research. The inputs to this chapter are the definition of the research in Chapter 1 and the literature review in Chapter 2,

Chapter 4 addresses the primary research to investigate the relationship between the drivers and providers relating to virtual enterprise formation and its influence on business effectiveness.

This research examines the successful formation of a virtual enterprise when contributing to an agile supply chain and suggests that the effectiveness of the outcomes of the process can be measured by assessing the business performance of the individual enterprises. To this end, a survey based on a structured questionnaire was produced and distributed among a sample of Mongolian enterprises as listed in the Mongolian Yellow Pages to collect empirical data. A conceptual model was subsequently developed that hypothesises a relationship between the main factors in virtual enterprise formation and an empirical study was conducted to understand the real case and to provide insights for practitioners and researchers alike. Rich empirical evidence was provided by this study that supports the research hypotheses. The three-step structural equation model technique was adopted with the rarely- used higher-order factor analysis in a supply chain agility context.

Chapter 5 includes a taxonomy of the enterprises' ability to achieve better effectiveness by forming a virtual enterprise was analysed and the primary study investigated how different enterprises achieve differing levels of agility. The drivers and providers that were identified and validated as the influencing factors on virtual enterprise effectiveness in Chapter 3, were used to distinguish the enterprises in terms of their characteristics, their agility capabilities and their achievement were compared. The rigorous and systematic data analysis can be regarded as an original methodological contribution to the subject research for scholars to study data clustering, market segmentation and strategic partner grouping.

Chapter 6 proposes an adaptive framework for improving the effectiveness of virtual enterprises in supply chains. Based on material from the secondary study related to the development of frameworks for virtual enterprise formation, some common issues are adopted and used in the proposed Reference Architecture. To develop specific models for the framework, the findings from the primary research are embedded in the reference architecture that is developed by this project. Most frameworks developed previously have made attempts to solve the physical problems of application integration during the stages of virtual enterprise operation. However, the adaptive framework proposed in this study focuses on the business integration of enterprises joining a virtual enterprise. The reference architecture developed by the research adopts a multi-dimensional layered approach with a three level model and three integration views across five life cycle stages of virtual enterprise formation. The adaptive framework models generic, partial and particular modelling objectives. At the generic representation level, a description of a virtual enterprise formation 'breeding' environment is modelled. At the next level, the factors that influence virtual enterprise effectiveness are represented dynamically and some possibilities for improving the effectiveness of the virtual enterprise are identified and evaluated. Then, at the final level, the framework employs a web-based business network as an implementation model for enterprises that are willing to collaborate virtually. To establish trust and a common structure for enterprises, a virtual breeding environment is built up by registering potential enterprises. Then enterprises that have business ideas can select partners from among the registered enterprises by ranking them according to their potential for collaborative effectiveness. Additionally, a ‘virtual room’ is proposed to conduct virtual enterprise operations after the affiliation of the virtual enterprise with negotiation models that can be adopted from the literature. Finally, to suggest further uses for this website and to improve the effectiveness of future virtual enterprise formation, an evaluation system and its implementation platform is proposed.

Chapter 7 uses a simulation-based case study to validate the proposed framework and to demonstrate the performance difference between enterprises that have different abilities and strategies to respond to external changes, virtual collaboration, and ICT adoption. A programme is selected (The Mongolian Meat Program) as a suitable case study, as meat supplying enterprises collaborate temporarily to fill demand during shortage periods. Under these conditions the ability to supply promptly consumers who have demands for meat can be considered as an agility capability for enterprises. A simulation is used to analyse the performance of enterprises with different characteristics using the framework developed in the research. A simulation-based case study then validates the framework and indicates that enterprises with different abilities have differing levels of performance.

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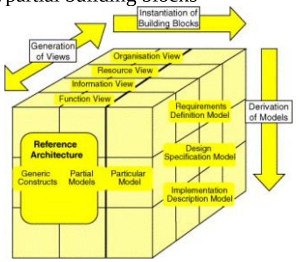
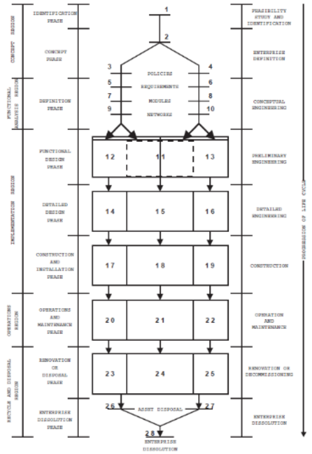
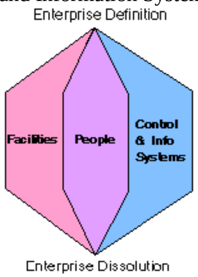
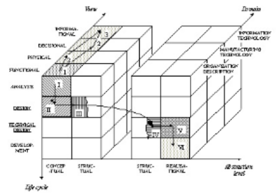
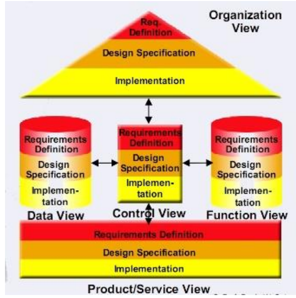
Appendix A

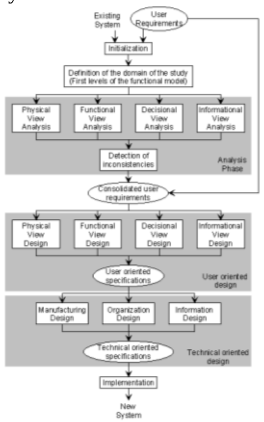
Comparison of first wave reference architectures and frameworks of enterprise integration

<table>
<tr><th>CIMOSA</th><th>PERA</th><th>Zachman framework</th><th>GRAI/ GIM</th><th>ARIS</th></tr>
<tr><td>http://www.cimosa.de/</td><td>http://www.pera.net/</td><td>http://www.zachman.com /about-the-zachman-framework</td><td>http://www.atb-bremen.de/projects /prosme/Doku/oqim /grai_old.htm</td><td>http://www.bpm-agu.com/ downloads/ Summary_ARIS.pdf</td></tr>
<tr>
<td>Three-dimensional matrix: Four modelling views across three derivations of models within generic/partial building blocks


CIMOSA consists of:
• Enterprise modelling framework (RA)
• Enterprise modelling language
• Integrating infrastructure
CIMOSA cube-RA has
• Three Architectural Levels
o Generic Level - a reference catalogue of basic architectural constructs (building blocks) for components, constraints, rules, terms, service function and protocols.
o Partial Level - a set of partial models applicable to a specific category of manufacturing enterprises.
o Particular Level - Model of a particular enterprise built from building blocks and partial models.
• Three Modelling Level
o Requirements Modeling - for gathering business requirements
o Design Modeling - for specifying optimized and system-oriented representation of the business requirements</td>
<td>Two-dimensional matrix: Three main components of any enterprise described in nine life cycle stages

The PERA Generic Enterprise Model is comprised of three basic components:
• Production Facilities,
• People/Organization, and
• Control and Information Systems.

</td>
<td>Two-dimensional classification matrix: the intersection of six communication questions (What, Where, When, Why, Who and How) crossed with six levels of reification, successively transforming the most abstract ideas (on the Scope level) into more concrete ideas (at the Operations level)

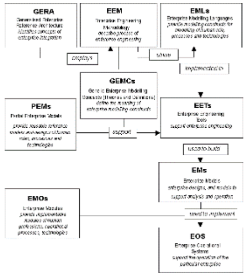
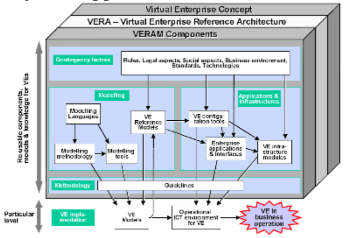
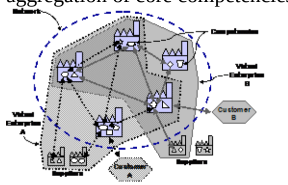
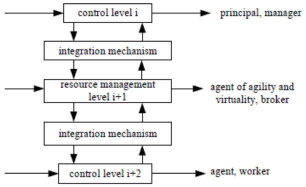
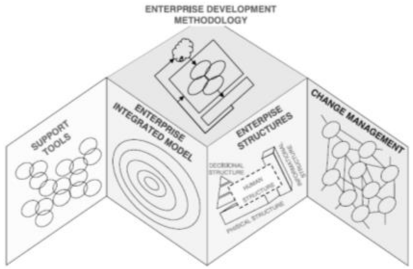
The columns represent the interrogatives or questions that are asked of the enterprise.
• What (data) – what is the business data, information or objects?
• How (function) – how does the business work, i.e., what are the business' processes?
• Where (network) – where are the businesses operations?
• Who (people) – who are the people that run the business, what are the business units and their hierarchy?
• When (time) – when are the business processes performed, i.e., what are the business schedules and workflows?
• Why (motivation) – why are the processes, people or locations</td>
<td>Three-dimensional matrix: Four modelling views across four lifecycles in two abstractions level the left, on the right three domains across four modelling views and two abstraction level.

GRAI-GIM includes:
• GRAI conceptual reference model,
• GRAI-GIM modelling framework, and
• GRAI-GIM structural modelling method
In GRAI-GIM, an enterprise consists:
• A physical system,
• A decision system and
• An information system.
A cubic structure was proposed with the four views on the left:
• Functional,
• Physical,
• Decisional, and
• Informational.
Three domains on the right:
• Manufacturing,
• Organization and
• Information
Life cycle as the vertical axis:
• Analysis,
• Design,
• Technical design, and</td>
<td>Multi-layer - multi-view approach: The ARIS House is divides into 5 views. All views have interaction view each other.


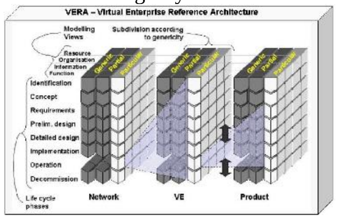
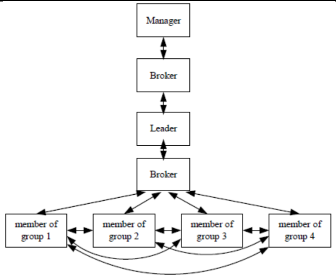
It offers methods for analysing processes and taking a holistic view of process design, management, work flow, and application processing.
The ARIS approach not only provides a generic and well-documented methodological framework but also a powerful business process modelling tool.
ARIS provides four different aspects of applications:
• The ARIS concept is the architecture for describing business processes.
• The ARIS concept provides modelling methods, the meta structures of which are comprised in information models.
• The ARIS concept is the foundation for the ARIS Toolset</td>
</tr>
</table>

○ Implementation Modeling - for describing a complete CIM system and all its implemented components • Four Integrated Views ○ The Function View describes the expected behaviour and functionality of the enterprise ○ The Information View describes the integrated information objects of the enterprise ○ The Resource View describes the structure of resources (Humans, machines, and control and information systems) ○ The Organisation View defines authorities and responsibilities. *These Views are reflected in the Services of the CIMOSA Integrating Infrastructure (IIS):* • Business Services define an Interpreter for the Function View. This allows control of work flow as defined in the Function Model. • The Information Services define a set of Generic functions for the handling of the information defined in the Information View. • The Dialogue Services define an Interpreter for dialogue control programs. These make the link between the Function Model, executing in the Business Services and the heterogeneous set of resources defined in the Resource View. • The System Management Services provide Generic functions to allow system managers to intervene as defined in the Organisation View, e.g. to change, release, activate, start, stop etc. models, both off-line and on-line. • The Common Services are used for communication handling providing the location transparency required for the interactions between the IIS Services. The framework furthermore offers an "event-driven, process-based modelling approach with the goal to cover essential enterprise aspects in one integrated model. The main aspects are the functional, behavioural, resource, information and organizational aspect".	These are depicted as three "columns" which begin with Enterprise Definition and end with Enterprise Dissolution PERA divides the enterprise life cycle into "phases". During each phase of the enterprise, different diagrams are used to reflect the developing detail as the enterprise moves from initial Definition to Operations Phase, to Dissolution. At the end of each development phase, a set of "Deliverables" are produced. [Note these deliverables are typical of a process industry facility such as a refinery, power plant, pipeline, etc., however similar deliverables would be produced for a service industry, or discrete manufacturing enterprise.] Since PERA represents the full life cycle of the Enterprise, all existing Enterprise documents and tools can be fit within its structure. As the Enterprise is developed, and increasing levels of detail are defined, it is possible to see how each of the contributing groups and their "deliverables" are related to the others. Although formats for documenting of each of the three model components (Facilities, People and Information Systems) vary, the intent is the same: to provide a coherent and coordinated representation of the enterprise during that phase. It is also true for all three model components, that additional detail is added in each successive phase by building on the information defined in the previous phase. PERA separates a single overall Enterprise Entity into several sub-entities by going through a separation of the overall mission into its different components. Each of the separate organizational entities of information, manufacturing, warehousing etc. would have its own architecture as described by the PERA.	important to the business, i.e., what are the business drivers or business objectives? Each row represents a distinct view of the organisation, from the perspective of different audiences. These are ordered in a desired priority sequence. • Planner – understands the business scope and can offer a contextual view of the enterprise. • Owner – understands the business model and can provide a conceptual view of the enterprise. • Builder - develops the system model and can build a logical view of the enterprise. • Designer – produces the technology model and can provide a physical view of the enterprise. • Integrator (sub-contractor) – will understand detailed representations of specific items in the business, although they will have an out-of-context view of the enterprise. • User – provides a view of the functioning enterprise, from the perspective of a user (e.g., an employee, partner or customer). The Zachman Framework provides the thirty-six necessary categories for completely describing anything; especially complex things like manufactured goods (e.g., appliances), constructed structures (e.g., buildings), and enterprises (e.g., the organization and all its goals, people, and technologies).	• Development. Three levels of abstraction: • Conceptual level: Aims at asking the question "what?" without any technical or organisational consideration. • Structural level: Integrates and organisational point of view and asks the questions "Who?", When?" and "Where?" • Realisation level: most specific level. Integrates the technical constraints and enables the choice of real components. The GRAI-GIM contains a user-oriented method and a technically-oriented one. The user-oriented method express user requirements specification in terms of functions, information, decisions and resources. The technically-oriented method transforms the user specifications into technical specifications in terms of information and manufacturing technology components needed to implement the system.  	software system for the support of modelling. • The ARIS house of Business Engineering (HOBE) represents a concept for comprehensive computer-aided Business Process Management Views and their interrelationships: • Data view. What information is important? (e.g.: customer, supplier, product, material calculation) • Function view. Which functions will be performed? (e.g.: production plan creation, order processing) • Organization view. Which organizational units exist? (e.g.: Purchasing, Sales, Accounts) • Control view. The relationship between data, function and organizational units • Product/ Service View. Which product/ service are important? (e.g.: checked order, customer invoice) Three phases: • Requirement definition - Standardized technical description of the company's concepts • Design specification - Application of the technical requirements in the descriptive language • Implementation - Description of the hard and software components that will be used to apply the company concepts

Appendix B

Comparison of second wave reference architectures and frameworks of enterprise integration

GERAM	VERAM	BM_VEARM	ARDIN	ARCON
http://www.ict.griffith.edu.au /~bernus/taskforce/geram /versions/geram1-6-3/v1.6.3.html	http://cic.vtt.fi/projects/globemen/	http://seer.ufrgs.br /ProdutoProducao /article/view/8999/5169	http://www3.uji.es/~rchalmet/paper2.pdf	http://ltodi.est.ips.pt /det2006/papers/Keynote /DET2006_LCamarinha.pdf
Layered Approach mixed with Multi-dimensional Matrix  GERAM framework consists: • GERA (Generalised Enterprise Reference Architecture) - identifies concept of enterprise integration. These concepts can be categorised as: ○ Human oriented concepts 1. to describe the role of humans as an integral part of the organisation and operation of an enterprise and 2. to support humans during enterprise design, construction and change. ○ Process oriented concepts for the description of the business processes of the enterprise; ○ Technology oriented concepts for the description of the business process supporting technology involved in both enterprise operation and enterprise engineering efforts (modelling and model use support) • EEM (Enterprise Engineering Methodology) – describe process of enterprise engineering	Multi-dimensional Matrix mixed with Layered Approach  Two levels in VERAM are: • General level – re-useable components, models and knowledge for VEs; and • Particular level – specific components, models and knowledge for VEs. VERAM consists of three layers. • VE concept. VE is defined as a customer solution delivery system created by a temporary, re-configurable, and ICT enabled aggregation of core competencies.  • VERA-VE reference architecture. VERA organises the VE related generic concepts recommended for use in VE engineering and integration projects. VERA also organises other essential VERAM components, such	Multiple levels hierarchical model of VE.  The specific architecture of the BM_VEARM, through the specific role of the broker, should provide the highest level of the VE configurability dynamics (and, consequently, of the CE teams organization based on BM_VEARM). The broker acts as an interface between two hierarchical controls layers in a way that one layer is hidden from the other and with the capability to reconfigure the VE architecture without interruption of the operation on the other control level, to avoid any loss of time due to the reconfiguration. The broker action between two operations, which obviously implies interruption of the process, is permitted by BM_VEARM but it is a relaxed case in terms of the VE, i.e. VE CE teams, reconfiguration dynamics requirements. Aiming at integration of CE concept with the concept of VE by the BM_VEARM model, the model of CE teams based on BM_VEARM is conceived follows:	Multi-dimensional architecture  The ARDIN architecture is organized in five dimensions. • First dimension – enterprise development methodology: shows the life cycle of a company and supported by this presents a methodology to guide the construction of an integrated enterprise system. The first dimension breaks down the project of enterprise integration into four phases: (1) the conceptual phase, which correspond to the identification of business mission, vision, strategy, objectives, etc., (2) the enterprise design phase, using a business process vision, (3) the enterprise implementation phase, and (4) the execution and continuous improvement phase. • Second dimension – support tools: describes how to develop an integrated enterprise model, which aids decision-making during the enterprise design process. • Third dimension – enterprise integrated model: that is based around the formalization of the enterprise implementation process from the model.	Multi-dimensional Matrix mixed with Layered Approach  Three perspectives are identified and defined in the ARCON framework. The first perspective (CNO-Life-Cycle – vertical perspective) addresses the timing cycle for different CNO stages, to capture the diversity and evolution of CNOs during their entire life cycle. The following main stages are considered: • Creation phase, • Operation phase, • Evolution phase, • Dissolution or Metamorphosis. A second perspective focuses on capturing the CNO environment characteristics (as a horizontal perspective). This perspective includes two subspaces (points of view) to comprehensively cover, the internal (In-CNO) characteristics as well as the external (About-CNO) characteristics that are related to the logical surrounding of the CNOs. From the In-CNO point of view the following dimensions are considered: • Structural dimension,

• EMLs (Enterprise Modelling Languages) – provide modelling constructs for modelling of human role, processes and technologies
• PEM (Partial Enterprise Models) – provide reusable reference models and design of human roles, processes and technologies,
• GEMCs (Generic Enterprise Modelling Concepts) – define the meaning of enterprise modelling constructs. They can be defined as:
  ○ Natural language explanation of the meaning of modelling concepts (glossaries);
  ○ Some form of meta model (e.g. entity relationship meta schema) describing the relationship among modelling concepts available in enterprise modelling languages;
  ○ Ontological Theories defining the meaning (semantics) of enterprise modelling languages, to improve the analytic capability of engineering tools, and through them the usefulness of enterprise models. Typically, these theories would be built inside the engineering tools.
• EETs (Enterprise Engineering Tools) – support enterprise engineering,
• EMs (Enterprise Models) – enterprise designs, and models to support analysis and operation,
• EMOs (Enterprise Modules) – provide implementable modules of human professions, operational processes, technologies,
• EOS (Enterprise Operational Systems) – support the operation of the particular enterprise
	as Reference Models, configuration tools, applications, and some of the Contingency factors.
	
	
	• VERAM components includes:
	  ○ Contingency factors
	  ○ Modelling includes languages, methodology, tools, and reference models
	  ○ Applications and infrastructures consist of VE configuration tools, enterprise application, and VE infrastructure modules
	  ○ VE methodology guidelines
	  ○ VE Implementation (Particular level) includes VE models, operational ICT environment for VE, and VE in business operation
		
		
		• Manager: in charge of all operations at the macro level and for action strategy of the enterprise. The manager has global supervision, delegating lesser and detailed responsibilities to the leaders;
		• Leader: in charge of the execution of tasks in details and coordination of work groups;
		• Broker: the element selected by management/leader to obtain necessary resources for the execution of tasks, integrating selected resources, dynamically reconfiguring concurrent engineering resources.
		• Group members: components that form work groups. They execute the tasks.
			• Fourth dimension – enterprise structure: identifies a set of support tools, which assist in the process of designing, evaluating, implementing, and controlling the integrated enterprise.
			• Fifth dimension – change management: discusses efficient change management, to transform and organize the enterprise resources (including the human resources, which may have different objectives, criteria, formation and culture), in a continuous improvement system.
				• Componential dimension,
				• Functional dimension,
				• Behavioural dimension,
				From the About-CNO point of view 4 dimensions are also considered in ARCON:
				• Market dimension,
				• Support dimension,
				• Societal dimension,
				• Constituency dimension,
				The third perspective (diagonal perspective) is related to different intents for the modelling of CNOs:
				• General concepts level
				• Specific modelling level
				• Implementation modelling.

Appendix C

This section gives a brief overview of some relevant projects in the virtual enterprise domain that have been launched in the USA, Europe and Japan. Although the economic and demographic situations in Mongolia are very different and most of the examples do not concern supply chains, a comparison with the Mongolian Meat Reserve Program case study may be made.

1. Projects in the United States

1.1 The TOVE Project[22]

The TOVE (TOronto Virtual Enterprise) project was conducted to develop an ontological framework for enterprise integration based on and suited for enterprise modelling. It was initiated by Mark S. Fox and others at the University of Toronto at the beginning of the 1990s.

Purpose and scope. The goal of the project was to create a data model that has the following characteristics:

1. It provides a shared terminology for the enterprise that each agent can jointly understand and use;

2. It defines the meaning of each term (i.e. the semantics) in a precise and as unambiguous manner as possible;

3. It implements the semantics in a set of axioms that enables TOVE to automatically deduce the answer to many 'common sense' questions about the enterprise;

4. It defines symbols for depicting a term or the concept constructed thereof in a graphical context.

Highlights of the project. TOVE was not only a research project but a testbed and was used to implement a virtual company the purpose of which was to research into enterprise integration. TOVE was implemented in C++ using the ROCK@+[TM] knowledge representation tool from the Carnegie Group. TOVE operates 'virtually' by a knowledge-based simulation.

[22] Link: http://www.eil.utoronto.ca/tove/comsen/intro11.html

The first goal of the project was achieved by defining a generic level representation in which the application representations were defined in terms of time, causality, activity, and constraints. The generic level was defined in terms of a conceptual level based on the `terminological logic' of KLONE.

The second and third goals were achieved by defining a set of axioms (i.e. rules) that defined some ‘common-sense’ meanings of the terminology (i.e. more obvious definitions/deductions about the entities and attributes in their ontology). Since there does not exist a standard for determining the competence of a model in English, a set of questions and the axioms were defined to be used to determine the accuracy of a representation.

According to Ted Williams[23] the model is ‘multi-level, spanning conceptual, generic and applications layers’. The generic and applications layers are also stratified and composed of ‘micro theories’ spanning the activities, time, resources, constraints, etc. Critical to the TOVE effort is enabling the easy instantiation of the model for a particular enterprise TOVE models will be automatically created as a by-product of the enterprise design function’. By the year 2000 TOVE had been used to model a computer manufacturer and an aerospace engineering firm.

1.2 The NIIIP project[24]

The NIIIP (National Industry Information Infrastructure Protocols) project, initialised by the National Institute for Standards and Technology (NIST), was one of the most complete realisations of a VE architecture (Gunasekaran, 2001). The NIIIP Consortium consisted of a group of thirteen leading United States IT suppliers and users with a common interest in developing a software architecture and providing technologies to enable virtual enterprises to function. The NIIIP Consortium developed a reference architecture and reference implementation for the technology needed for industrial virtual enterprises. The main goal of the NIIIP RA is to help establishing and operating of virtual enterprises in the industry by applying standardised solution for:

- Virtual enterprise connectivity;
- Industrial information modelling and exchange;

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[23] http://www.pera.net/Methodologies/TOVE.html

[24] http://www.eda.org/rassp/documents/newsletter/html/96q1/news_5.html

- Management of VE projects and tasks.

The NIIIP reference architecture is based on the application of three methodologies and technologies:

- Communication technology – (i.e. the Internet);
- Object Technology – application interoperability;
- IT – information exchange based on STEP.

Purpose and scope. The aim of NIIP was to adopt and integrate the technologies of Internet Engineering Task Force (IETF), the Object Management Group (OMG), STEP, and Work Flow Management Coalition (WFMC) to develop, reuse, and integrate implementations and help to accelerate the development and adoption of standards. The goal of the NIIIP project was to define and demonstrate *via* the OMG and the Internet an integrated infrastructure based on object technology, which could achieve the following:

- It could interconnect industrial virtual enterprises with extended security and availability, via the Internet;
- It could provide transparent access to other application environments;
- It could support industrial information sharing *via* STEP;
- It could provide virtual enterprise work and knowledge management *via* the OMG.

Highlights of the project. NIIP intended to bring together various product realisation process integration efforts by developing general global protocols for the technical standards of product data definition, communication, and object technology and workflow management. The NIIIP did not intend to develop a new system, but rather to apply existing standards to consolidate, harmonise and integrate many sets of existing protocols.

The mission of NIIIP was to enable U.S. Industrial virtual enterprises to provide globally competitive products, services, and solutions cost-effectively and promptly regardless of organisational, geographical and technical boundaries or company size and to make U.S. manufacturing the global standard that other nations try to emulate.

The technical vision of NIIIP was to define ways for existing applications to inter-operate and to make the technologies fit together in a useful manner based on existing, emerging, and *defacto* standards. NIIIP focused on the following:

- Establishing a computer system infrastructure that made virtual collaborative computing pervasive among U.S. manufacturers;
- Providing state-of-the-art software technologies to allow participants to effectively collaborate;
- Allowing companies within virtual enterprises to share costs and skills;
- Accessing global markets with each participant contributing its core expertise.

2. Projects in Europe

2.1. The ARDIN project [25]

The research Group in Systems Integration and Re-Engineering (IRIS) began to work on the ARDIN (a Spanish acronym standing for RA for INtegrated Development) project in 1994 in Spain. The mission of the group was to establish a stable framework in which to carry out research in the fields of enterprise organisation and computer systems, working according to the condition that the goals and results of the research activities have to be always oriented towards solving the real problems facing companies and public organisations (Chalmeta and Grangel, 2003). The ARDIN project developed the ARDIN reference architecture.

Purpose and scope. The objective of the project was to develop and validate a step forward in the state of the art of the reference architectures for enterprise integration.

Highlights of the project. The IRIS group has applied the methods and techniques developed in the ARDIN project to enterprises in different sectors including the tile industry, construction, transport, textiles, IT and government. Once the problem of the integration of a single enterprise had been solved, the next research project conducted by the IRIS group was oriented at extending ARDIN for virtual enterprise integration, improving the performance of a temporary alliance of globally distributed independent enterprises that participate in the different phases of the life cycle of a product or service by efficiently managing the interactions among the participants - a very complex task that involves different approaches concerning technology, management and cultural elements.

[25] http://ceur-ws.org/Vol-125/paper12.pdf

2.2. The PRODNET II project [26]

PRODNET II was an ESPRIT IV project (No. 22.647).

Purpose and scope. This project aims at the design and development of an open platform and adequate IT protocols to support virtual industrial enterprises. PRODNET was focused mainly on SMEs, to provide them with means to inter-operate within several value chain networks and to support them with tools to inter-operate with other networks.

Highlights of the project. The architecture of PRODNET I combine advanced technologies for communication, information management and distributed decision-making. According to Gunasekaran (2001) PRODNET dealt with a number of virtual enterprise environmental requirements and included many necessary steps, as listed below:

- Study and structure of the business data and the information that needs to be communicated between partners in a Virtual Industrial Enterprise;
- Design and develop a software infrastructure to provide and environment for these data and information to be exchanged, shared and managed in the virtual industrial network;
- To promote the utilisation of international standards (e.g. STEP and EDIFACT) were followed to help SMEs to maintain and improve their competitiveness;
- Support the implementation of open, standards-based software components that are easy to use, low in cost and which provide high value-added benefits.

A main aspect of virtual collaboration is the flow of orders between nodes (enterprises) in the network, and the monitoring of their evolution. Through the PRODNET-II system, enterprises can quickly respond to market opportunities as they arise, irrespective of the independent heterogeneous systems used by the customers and therefore they can have a significant advantage over their competitors. In this project, the University of Amsterdam (UvA) designed and implemented the Distributed Information Management Subsystem that handles the management and exchange of information between different autonomous and heterogeneous nodes in the network of enterprises.

[26] http://www.fcngroup.nl/research/projects/prodnet/

Description of the infrastructure. The PRODNET Cooperation Layer (PCL) contains the basic functions to connect the company network. It represents the communication role and works as the interlocutor of the company within the net.

The PRODNET Communication Infrastructure module is responsible for handling all communication with the other nodes in the network. It includes functionalities such as: selection of communication protocols and channels; basic communications management; privacy mechanisms (cryptography); authentication and safety. This module is responsible for the implementation of safety and authentication mechanisms, at the virtual enterprise level.

The infrastructure supports a production scenario consisting of a network of nodes, in which each node adds some value on the production chain of a product; namely in an industrial virtual enterprise. This infrastructure handles features such as the follow up of orders status, monitoring the efficiency of order flows, distributed and dynamic scheduling, incomplete and imprecise order management and exchange of order information among SMEs, network-wide workload optimisation, and open communication of total product data.

2.3. The MASSYVE project [27]

MASSYVE (Multiagent Agile Manufacturing Scheduling Systems for Virtual Enterprise) was a keep-in-touch (KIT) initiative in the framework of the INCO-DC programme funded by the EU. This co-operative action was centred around the application of the MAS paradigm to agile scheduling in manufacturing systems. According to the KIT philosophy, MASSYVE was designed to facilitate and promote the scientific and technological interactions between a member in Brazil and three other European partners.

Purpose and scope. The main objective of the project is the evaluation and preliminary development of an advanced layer on top of agile scheduling system prototype, previously developed at The New University of Lisbon (UNL) with the participation of the Brazilian partner from Federal University of Santa Catarina (UFSC). The following specific objectives were included in this project:

- The implantation and extension of the MASSYVE system prototype at UFSC, to be experimented for low cost computational platforms, mainly devoted to SMEs;

[27] http://www.fcngroup.nl/research/projects/massyve/

- The use, evaluation and possible adaptation of the European IT and some software from the partners, in the development of the MASSYVE prototype, tailored to Brazilian conditions;
- Information dissemination and exchange of expertise in the field of production and advanced IT, between the Brazilian members / institutions and those of the EU, as well as getting a feedback from the Brazilian industry about its current views, problems, needs and trends;
- Continuous dissemination of the advanced IT technologies coming from the project, by means of teaching and post-graduation activities;
- Ongoing research in the field of manufacturing scheduling, also contributing to other related projects;
- Launching a research group on VEs in Brazil and contribute to the establishing of links between Brazilian companies and EU industry;
- Promotion of EU standards and codes of best practice in Brazil.

Highlights of the project. The advanced MASSYVE layer extended the system towards a virtual enterprise. The extension of this layer with PEER-federated database management system, developed at The University of Amsterdam (UvA) and the production planning and control system, developed by the CSIN company, was evaluated and several information dissemination actions were organised. The Massyve Kit 2.2[28] was developed to enable the easy and rapid construction and derivation of small MASs compliant with the C++ Builder 5.0. software, orientated towards education and training. In general terms, Kit 2.2. provided users with an interactive system through which a 'skeleton' of MASs could be built up, including some basic configuration and communication functionalities. Specifically, in the 2.2 version, the user could carry out activities such as the following:

- Configuring some systems' options;
- Creating reference models;
- Designing the system architecture *via* a graphical editor;
- Launching and managing the agents in the local or remote computers (e.g. PCs in a local area network).

Also, the functions to support sending and receiving messages (*via* secure sockets) were available. As far as the higher-level protocol is concerned, the Massyve Kit provided a simple

[28]http://user.das.ufsc.br/~rabelo/Ensino/DAS6607/Ferramentas/MASSYVE-KIT/MASSYVEv22-UserManual.pdf

and context-free protocol. Therefore, the programmer could either use it or extend it or even develop his or her own protocol (or use KQML, for instance). Being a general-purpose kit, the agents' content (i.e. the domain and the agents' knowledge) as well as the control flow between the agents was entirely up to the user.

2.4. The GLOBEMEN project[29]

GLOBEMEN (Global Engineering and Manufacturing in Enterprise Networks) was a three year IMS project (2000-2003) that brought together leading specialists from Australia, the EU, Japan, and Switzerland. IMS Globemen is an inter-regional project aiming to develop methods, tools and architectures to support inter-enterprise operations in one-of-kind industries, in different lifecycle phases.

Purpose and scope. The aim of GLOBEMEN is to support the integration of business and engineering processes executed by a virtual manufacturing Enterprise in a global and multicultural environment. GLOBEMEN addressed the following virtual enterprise functions; sales and services, inter-enterprise delivery process management, and distributed engineering. The main goals of GLOBEMEN were to:

- Provide a reference architecture that harmonises ICT support requirements;
- Develop guidelines for setting up and operating virtual enterprises;
- Demonstrate the business benefits resulting from the harmonised ICT architecture.

Highlights of the project. GLOBEMEN consisted of 5 work packages (WP1-WP5) and a project management package, as follows:

WP1. Sales & services in dynamic networks: Management of distributed sales, services and operation, maintenance & renewal support.

WP2. Inter-enterprise resource management: Inter-enterprise resource planning and SC management, integration of planning and manufacturing.

WP3. Distributed engineering: Product and process engineering in a distributed global environment.

WP4. Global architecture and implementation: Definition of generic architecture and reference model, in collaboration with WP 1-3. Specification and implementation of an

[29] http://cic.vtt.fi/projects/globemen/public.html

integrated demonstration. Project deliverable describes an architectural framework VERAM including a description/ elaboration of its elements. The emphasis in this deliverable is to define an architectural framework, which will be a body of knowledge that supports future practical work in global engineering and manufacturing in enterprise networks, supported by methodologies or guidelines. (For information on VERAM see Appendix B).

WP5. Dissemination & exploitation planning: Organisation of workshops, publishing electronic newsletter, maintenance of public web site preparation of public presentations, promotion of proposed business processes and commercial results etc.[30]

2.5. The BIDSAVER Project[31]

BIDSAVER (Business Integrator Dynamic Support Agents for Virtual Enterprise) was an EU project completed between 2000 and 2002 and funded under the FP5-IST programme.

Purpose and scope. The project aimed at the assessment and development of a framework for the constitution and operation of virtual environments, with the participation of SMEs identified through web-based information agents, dynamically organised according to 'best-fit' criteria. The objective was to develop a methodological, technological, and legal framework to support SMEs by helping them to increase their competitiveness and business potential through the constitution and operation of virtual environments. The latter were managed on the basis of competition-orientated criteria by means of the adoption of the original concept of the 'business integrator' (Putnik, 2005).

Highlights of the project. The general phasing concept for the operational scenario was derived from the results of the VIVE project, which provided the conceptual framework and schema for the constitution and operation of a 'generic' or typical virtual enterprise. BIDSAVER concentrated on specific industrial sectors and was aimed at supporting the operational issues of specific sectors, as addressed in a pilot project. The methodology generalised in BIDSAVER addressed the methods for developing models dedicated to new specific sectors and also covered the dynamic aspects and nature of a virtual environment in terms of supporting the selection of optimised sets of partners through Internet searches, developed and validated

[30] http://cic.vtt.fi/projects/globemen/public.html

[31] http://cordis.europa.eu/project/rcn/54837_en.html

through two pilot projects; one in the microsatellite area and one in the mechanical engineering area (Putnik, 2005). The BIDSAVER project's overall objective was to show how industrial users could boost their competitiveness in collaboration with web-based virtual enterprises. Also, to promote their readiness to enter virtual enterprises and to increase their awareness of the potential associated with the use of tools and methodologies of the 'information society'.

2.6. The ECOLEAD Project[32]

ECOLEAD (European CNOs LEADership) is an 'Integrated Project' co-funded by the European Commission within 6th Framework Programme (2002-2006). Commencing in April 2004, ECOLEAD was a 4-year project involving 20 partners from 14 countries across Europe.

Purpose and scope. The project aimed to create strong foundations and mechanisms needed to establish the most advanced collaborative and network-based industrial society in Europe, stating, 'In ten years most enterprises will be part of some sustainable collaborative networks that will act as breeding environments for the formation of dynamic virtual organisations in response to fast changing market conditions'.

Highlights of the project. The fundamental assumption in ECOLEAD was that networked collaborative business ecosystems require a holistic approach. The complexity of the area and the multiple inter-dependencies among the business entities, social actors, and technologies, means that substantial breakthroughs cannot be achieved with incremental innovation in isolated areas. On the other hand, project plans must remain manageable. Therefore ECOLEAD addressed the most fundamental and inter-related areas of focus, which formed the basis for dynamic and sustainable networked organisations; Virtual Organisation Breeding Environments, Dynamic Virtual Organisations and Professional Virtual Communities. In addition to these three 'vertical' focus areas, the holistic approach is reinforced and sustained in two 'horizontal' areas; the theoretical foundation for collaborative networks and the horizontal ICT infrastructure (Camarinha-Matos and Afsarmanesh, 2008).

The horizontal activities support and affect all three vertical focus areas. The theoretical foundation provided the basis for a technology-independent understanding of the area and its phenomena. The existence of an invisible, low cost ICT infrastructure was a pre-condition for

[32] http://ecolead.vtt.fi/

the establishment of truly dynamic collaborative networks. ECOLEAD was intended to have an impact on industrial competitiveness and societal mechanisms by providing the means to exploit opportunities effectively by the deployment of virtual organisations and by designing and enabling new professional work paradigms capable of enacting the knowledge-based society throughout Europe.

2.7. The GloNet Project [33]

GloNet (Glocal enterprise network focusing on customer-centric collaboration) was a cooperative project funded by the European Commission within FoF-ICT (2011-2015). 6 countries are involved in this project across Europe.

Purpose and scope. GloNet was aimed at designing, developing, and deploying an agile virtual breeding environment for networks of SMEs that were involved with highly customised and service-enhanced products through end-to-end collaboration with customers and local suppliers (i.e. the ‘co-creation of value’). GloNet implemented the global enterprise concept by value creation from global networked operations and involving global supply chain management, product-service linkage, and management of distributed manufacturing units.

Highlights of the project. In specific terms GloNet aimed to achieve the following:

- To develop a novel way to commonly represent and provide information and knowledge (e.g. catalogues of products, brochures, process descriptions, best practices, company profiles, etc.) which need to be shared or exchanged among different stakeholders in the collaborative environment as dynamic software services;
- To generate user-customised interfaces which were adjustable to the needs of different stakeholders, supporting their access and visualisation functions;
- To provide these services through the Cloud to be available to anyone at anytime from anywhere;
- To demonstrate how a broker in very close contact with a customer placing an order can iteratively retrieve all the required information to fulfil the customer order;
- To support the negotiation process among all the involved parties;

[33] http://www.glonet-fines.eu/

- To generate workflow from the accepted negotiated solution, which could then be automatically monitored by the stakeholders during its execution.

The guiding use case is focused on the deployment and maintenance and life cycle support of solar parks. The adopted strategy for developing the agile virtual enterprise support environment followed a holistic approach. Through a detailed analysis of the project objectives three main interacting 'pillars' were identified for the technical approach; Organisational Structures, Technological Platforms and Governance Models. As was also identified in the FInES 'roadmap' an enterprise network is a complex socio-technical system so GloNet addressed technology development and socio-organisational aspects simultaneously.

2.8. The BIVEE Project [34]

BIVEE (Business Innovation for Enterprise Environment) was funding by European Commission within the FP7 and among the theme FoF-ICT, between 2011 and 2014.

Purpose and scope. The project proposed an integrated software environment aimed at promoting and supporting production improvement and enterprise innovation for networked SMEs and virtual enterprises. BIVEE aimed at building a distributed, collaborative, knowledge-intensive framework where innovative business models, novel management methods, and emerging ICT solutions will be integrated to the benefit of interoperable virtual enterprises.

Highlights of the project. The BIVEE project developed an IT platform and tools to enable enterprises to jointly, rapidly and virtually catalyse ideas for production system improvements and novel products as a response to the inflexibility of currently prevailing paradigms. The BIVEE platform was based on a Mission Control Room for monitoring the virtual enterprises' value production activities, a Virtual Innovation Factory for continuous innovation production and an advanced knowledge repository (PIKR) that included sharable and accessible knowledge about technology, models, business domains and competitors, etc. The objectives were:

- To monitor and assess value production processes to identify innovation needs;
- To monitor world innovation proposals, solutions, etc. to identify innovation opportunities;
- To simulate and analyse 'big data' through data analytics to understand the advantages and disadvantages of competing innovation options.

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[34] http://bivee.eu/

3. Other projects

3.3. The VIRTEC Project [35]

The VIRTEC (Virtual Organisation of Technology) project began in the Nucleus of Advanced Manufacturing (NUMA) located in the Engineering School of São Carlos, University of São Paulo as one of the pioneer projects in the formation of virtual organisations in Brazil (Bremer *et al*., 2001). The VIRTEC project included nine different SMEs, each providing technological products and services, with high added value.

Purpose and scope. The project was aimed at the structuring of a common basis for cooperation, where its members could find trust within a specific cultural environment – the necessary infrastructure for exploiting new business opportunities. The goal was to assume a global behaviour in the collaboration not only in terms of doing business, but also in performing the manufacturing processes of each partner, stressing the value of 'teamwork' (i.e. knowing how the companies within a virtual organisation will act).

Highlights of the project. To exploit the advantages of, 'being global but using local competencies', the VIRTEC project was based on the Framework for Global Virtual Business (GVB) (Bremer *et al*., 2001). The Framework for GVB has the following objectives:

- To identify the processes and competencies that are necessary for the configuration of a virtual environment;
- To combine competencies and processes, assigning them to well-defined roles inside the virtual environment.

As a GVB environment the VIRTEC project was composed of the following business entities; a Virtual Industry Cluster (VIC), a Virtual Enterprise Broker (VEB) and a Virtual Enterprise. In this framework, a virtual environment was created when a business opportunity could be exploited by a VEB through the selection of the appropriate competencies from members of a VIC. The creation of the VIRTEC website was another benefit brought to the members, because it allowed openings to the global market.

Due to the different areas of VIRTEC members, it was necessary to supply information to support the management and operational processes of VIRTEC and to develop a common

[35] http://www.virtec.com.br

culture for the global virtual enterprise. These were done by different activities such as obtaining the profile of each company in VIRTEC, the benchmarking and evaluation of cooperative capabilities, identifying the main abilities of each company and considering their socio-cultural aspects. Based on experience gained of the VIRTEC project in its first year, revised objectives were adopted, as follows:

- To provide VIRTEC members with a better knowledge of the market and improved access to new clients;
- To intensify the *informal* co-operation activities between VIRTEC members;
- To promote integration and knowledge transfer between universities and industry;
- To allow an improved use of companies' abilities and distinctive competencies;
- To improve the knowledge acquisition rate by sharing ideas and concepts;
- To facilitate the formation of new VICs.

Although the VIRTEC project was planned in detail, its schedule had to be extended many times, which was attributed to the contractual working nature of the member companies as they usually concentrated on the creation and management of their own processes. Allocation of trainee in the member companies

3.4. The VIRPLAS Project [36]

VIRPLAS (VIRtual industry cluster for PLAStics), was created to explore how the concept of VIC could enhanced the regional development of the plastic industrial sector of Monterrey, Mexico.

Purpose and scope. The purpose was to develop and apply a methodology to create new VIC for the plastics sector. It was intended that the creation of VIRPLAS would improve SME competitiveness by analysing which are the members' main strengths and opportunity areas. The six VIRPLAS members were SMEs who had previously carried out projects with the CSIM[37], a research centre at ITESM[38]. As the companies were visited, the concepts of VE and VICs were explained as well as the main purpose of VIRPLAS.

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[36] http://tamayo.mty.itesm.mx/virplas

[37] CSIM - Centro de Sistemas Integrados de Manufactura

[38] ITESM - Instituto Tecnológico y de Estudios Superiores de Monterrey

Highlights of project. The project included the following phases :

- The design of a website for the cluster members;
- The evaluation of cluster members to identify their level of infrastructure development (i.e. physical, informational, cultural and social, legal, etc.) using a modified IMMPAC methodology;
- The development of suitable infrastructures to carry out virtual business;
- The identification of new business opportunities for the cluster members.

An important issue identified for VIC formation was to focus on developing and increasing the members' core competencies to participate in the creation of Global Virtual Enterprises (GVEs). The creation of the VIRPLAS homepage allowed brokers to search for potential partners in the plastics industry in Monterrey.

4. The Industrial Cluster Program[39]

Industrial Cluster Program (ICP) was launched by the Ministry of Economy, Trade and Industry (METI) in Japan in 2001 with 19 projects. At the same time, the Knowledge Cluster Initiative (KCI) was launched by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) in 2002 with a further 18 projects. The Council for Science and Technology Policy of the Cabinet Office supports the co-ordination of programmes among eight Ministries in the field of regional science and technology cluster policies.

Purpose and scope. ICP was intended to be fundamental in forming networks among players having different technologies in industrial agglomerations and aimed to enhance the competitiveness of Japan through industrial clusters. The purpose of the KCI was the creation of local innovation systems where universities served as 'cores of knowledge creation' in collaboration with R&D firms in the region. The KCI was a framework in which the technological 'seeds' were provided by universities and other research institutions and the practical needs of businesses provided the stimulation. Sustainable innovations were generated in the local areas through the formation of joint research organisations comprised of industry, academia, government and human networks and various policies such as financial facilitation and establishment support are implemented.

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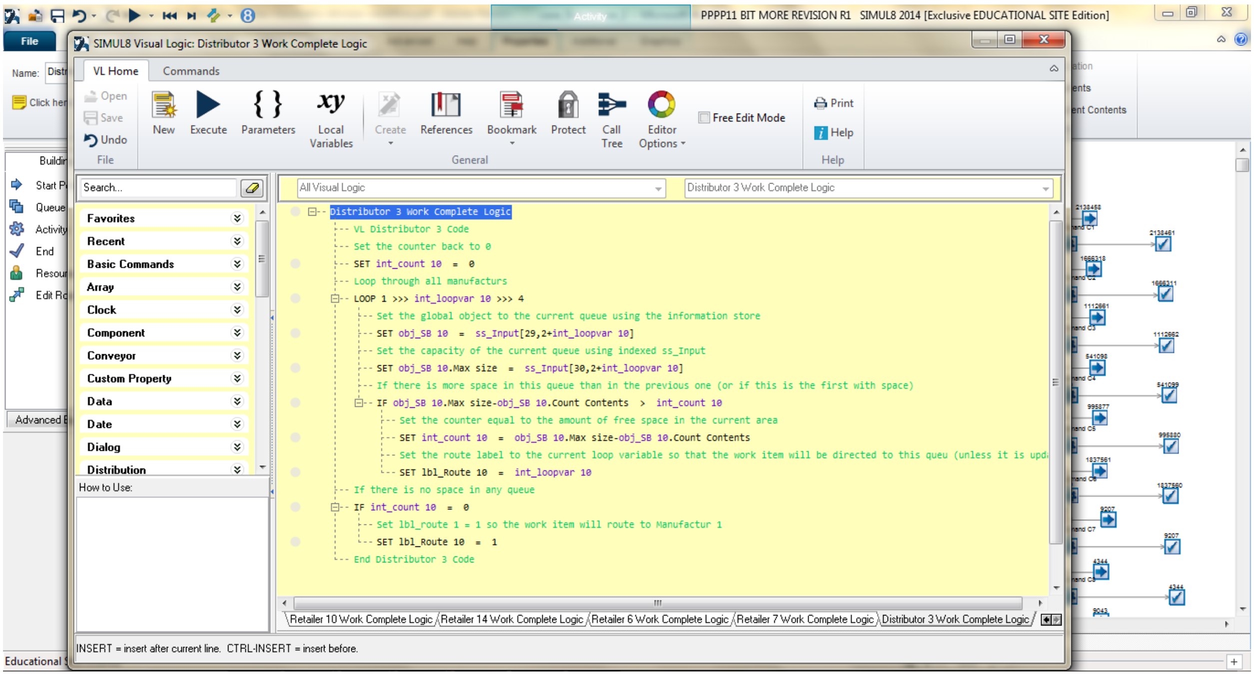
[39] http://www.meti.go.jp/policy/local_economy/tiikiinnovation/industrial_cluster_en.html

Highlights of the project. The ICP produced, 'industrial agglomeration with developed network(s) made up of technological linkages among constituent bodies in the region such as firms and universities and research institutes to generate innovation'. These 'linkages' appear to have consisted of; production linkages (e.g. supply and demand transactions in the supply chain) and technological linkages, achieved by the combination of different technologies and knowledge through collaboration between universities and firms or inter-firm collaboration for developing new technologies, new products or new businesses. The ICP had three terms or phases including:

1. **First Term** (2001-2005); the Industrial Cluster Launch Period. The Japanese government played a central role in moving the ICP forward, based on the state of existing clusters and policy needs. It launched some 20 ICPs and worked in collaboration with the clusters developed autonomously by local governments, forming "networks in which each face is visible" to serve as the foundations for industrial clusters;
2. **Second Term** (2006-2010); the Industrial Cluster Development Period. The plan called for continuing to foster network formation while also developing specific businesses. At the same time, the plan promoted reforms in corporate management and the creation of start-up companies. The implementation of this phase was flexible, with specific projects reviewed and new projects launched as needed;
3. **Third Term** (2011-2020); the Industrial Cluster Autonomous Growth Period. While further promoting the formation of networks and the development of specific businesses, the plan called for more industrial cluster activities to achieve greater financial independence and more autonomous growth.

Appendix D

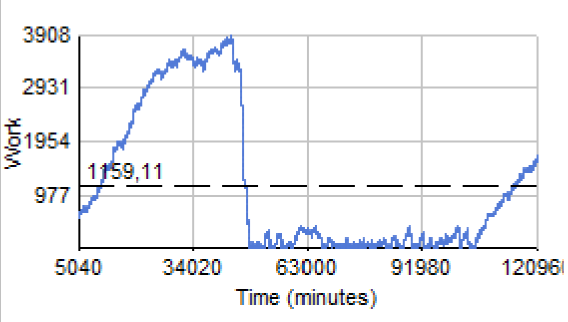
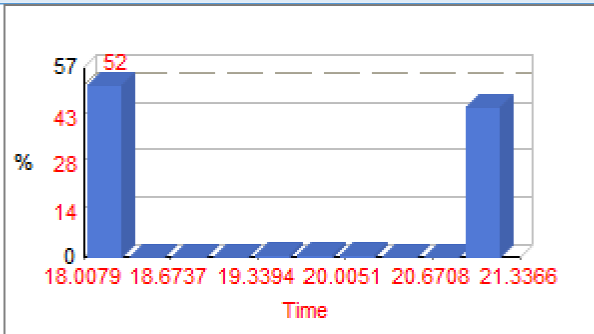
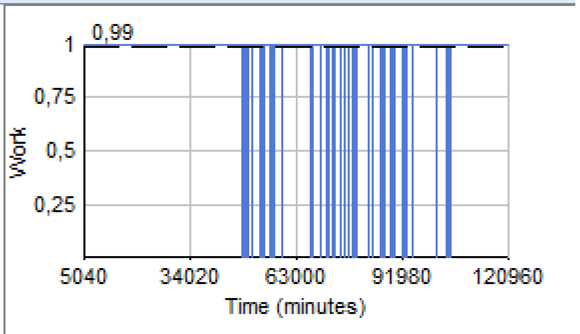
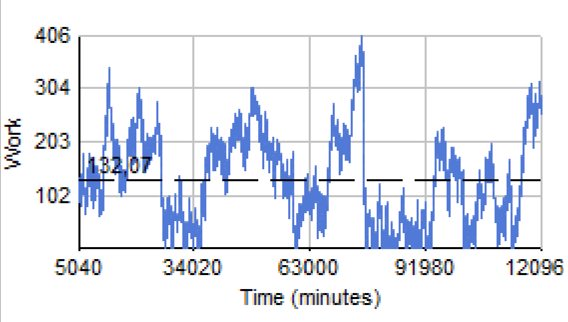
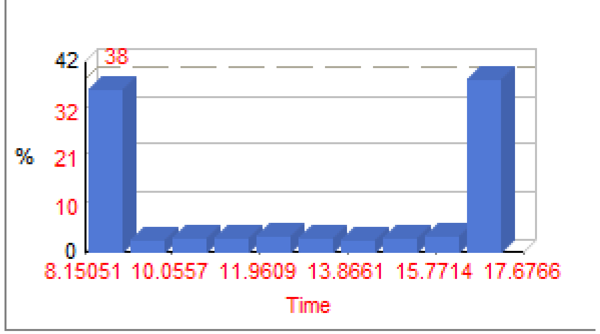
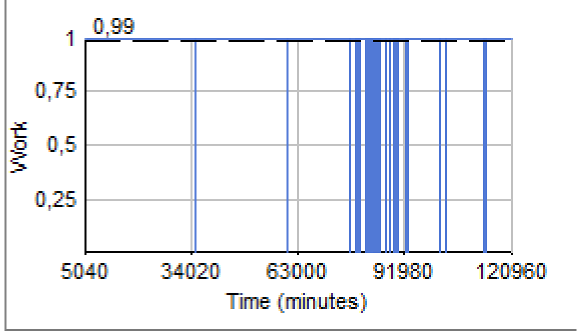
The routing-out logic



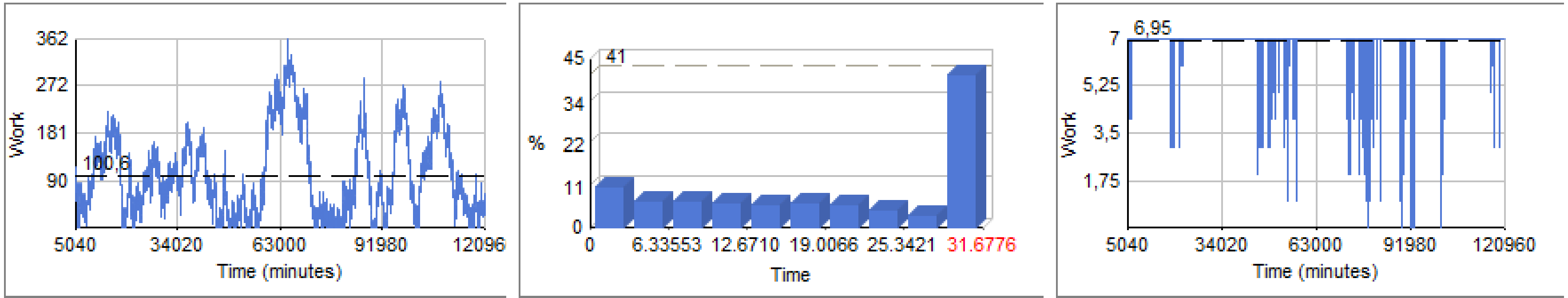
Appendix E-1

Simulation results for wholesalers

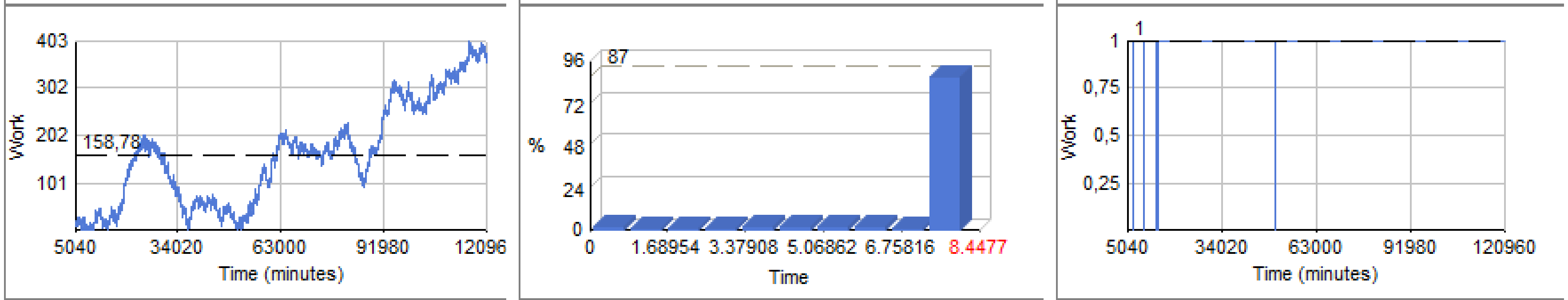
Showing the results of the simulated contents in queue, queuing time and working contents for wholesalers 1 to 8.

<table>
<tr><th></th><th>Contents in queue</th><th>Queuing time</th><th>Working contents</th></tr>
<tr><td>Wholesaler 1
working
99.95%</td><td>
</td><td>
</td><td>
</td></tr>
<tr><td>Wholesaler 2
working
93.62%</td><td>
</td><td>
</td><td>
</td></tr>
</table>

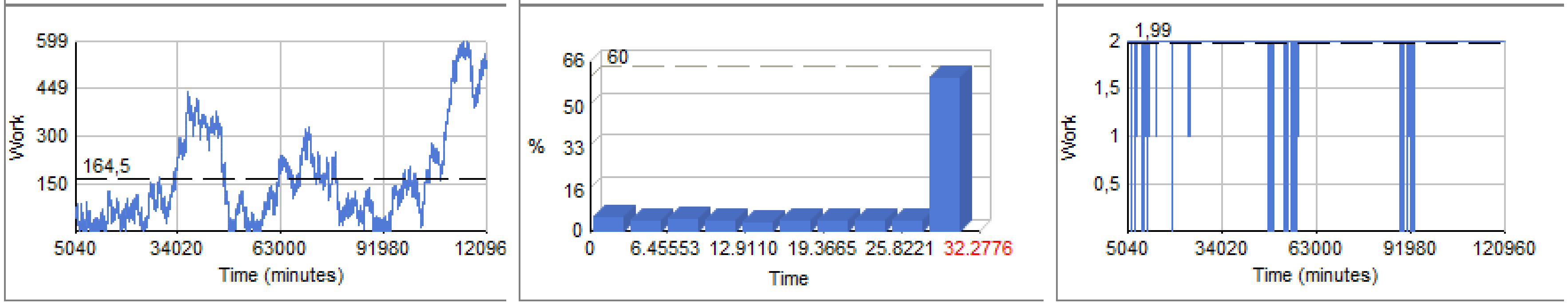
Wholesaler 3
working
97.76%



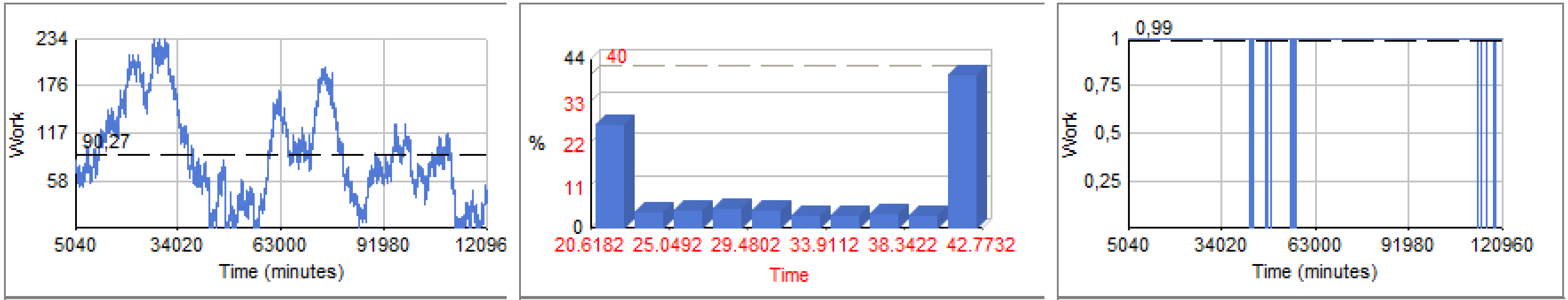
Wholesaler 4
working
99.87%



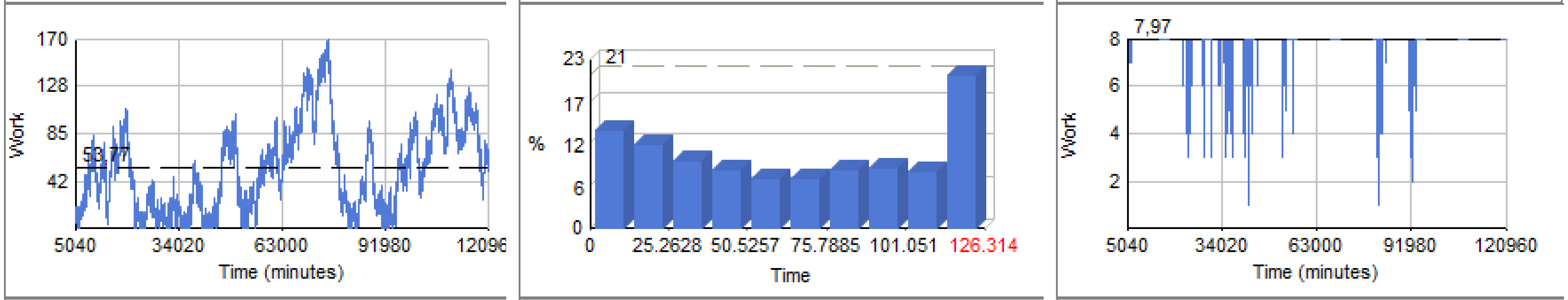
Wholesaler 5
working
95.59%



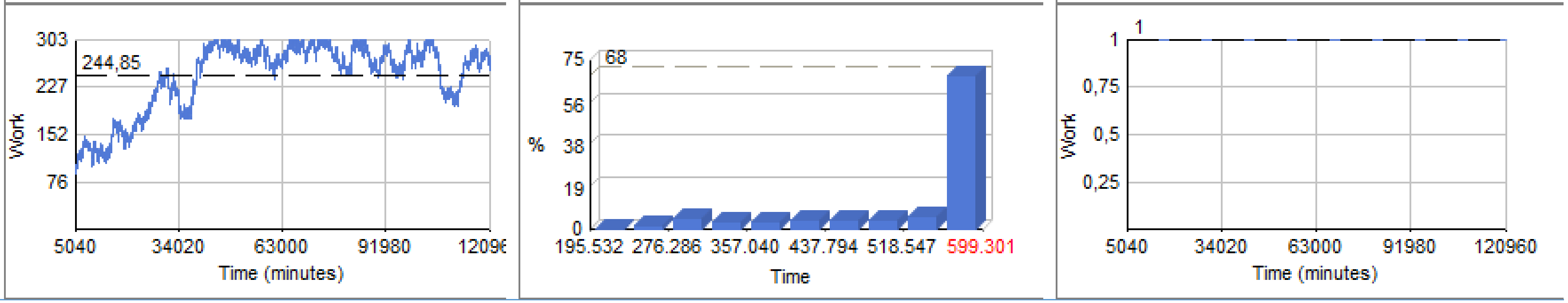
Wholesaler 6
working
99.86%



Wholesaler 7
working
99.35%



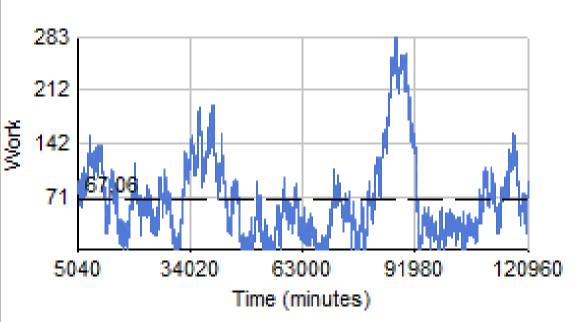
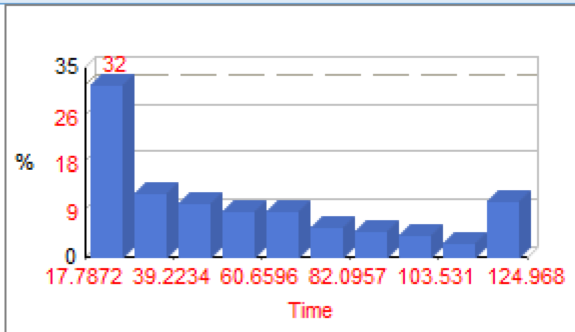
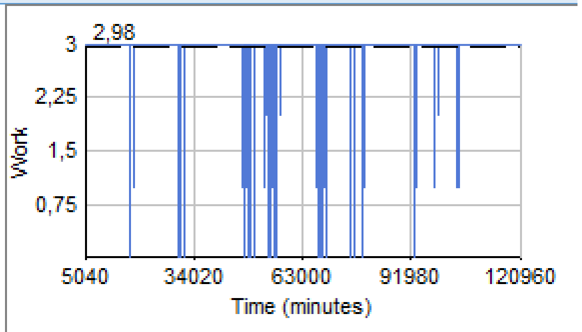
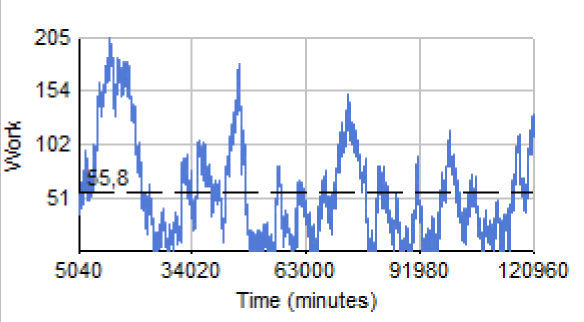
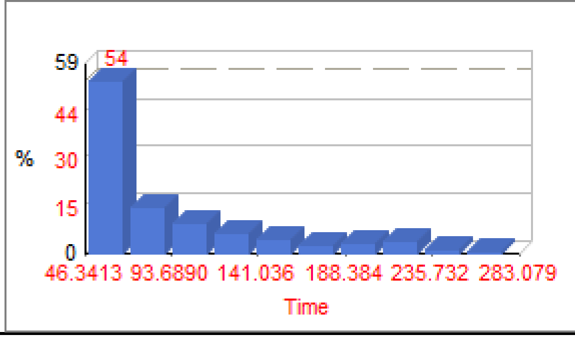
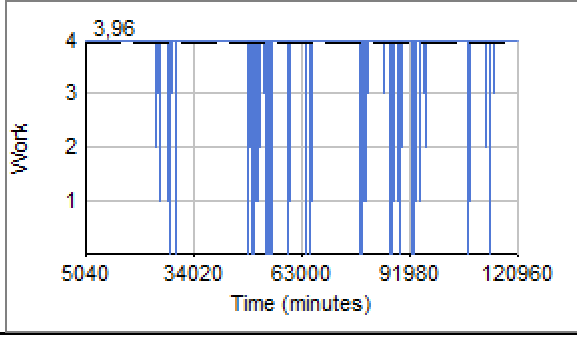
Wholesaler 8
working
96.99%



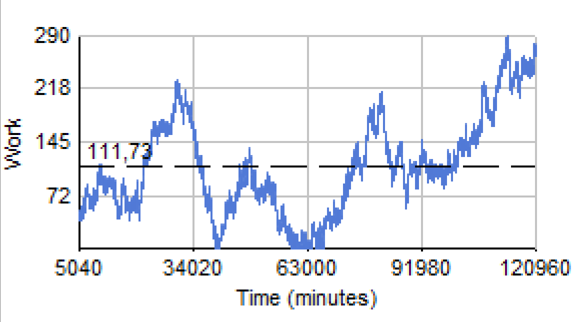
Appendix E-2

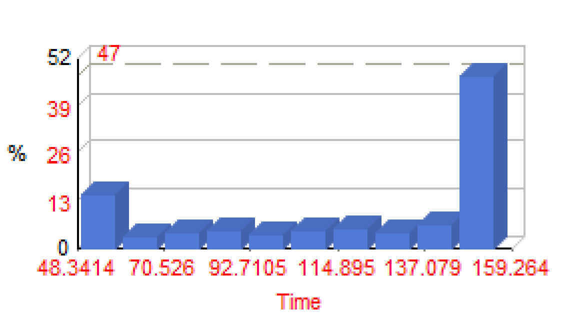
Simulation results for retailers

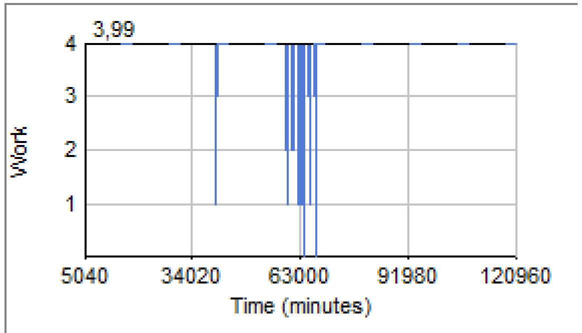
Showing the results of the simulated contents in queue, queuing time and working contents for retailers 1 to 14.

	Contents in queue	Queuing time	Working contents
Retailer 1 working 97.55%			
Retailer 2 working 99.89%			

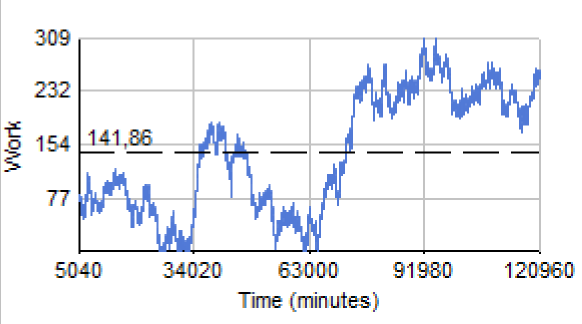
Retailer 3
working
99.30%

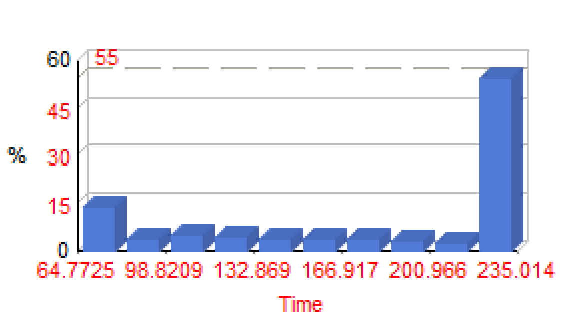


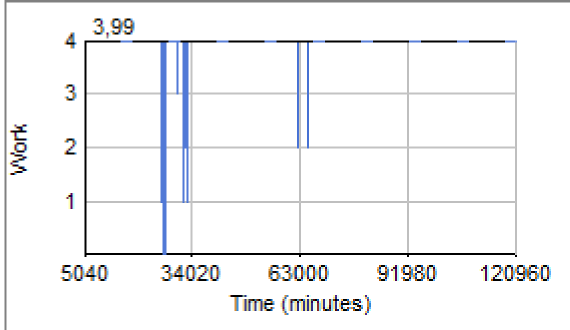




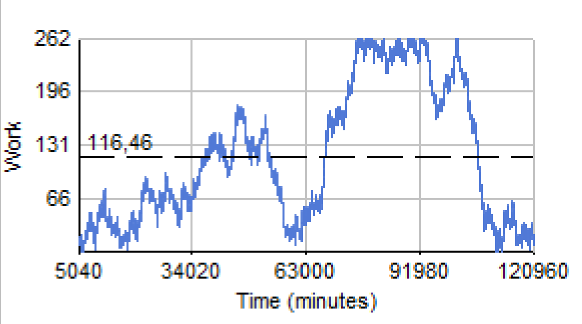
Retailer 4
working
99.98%

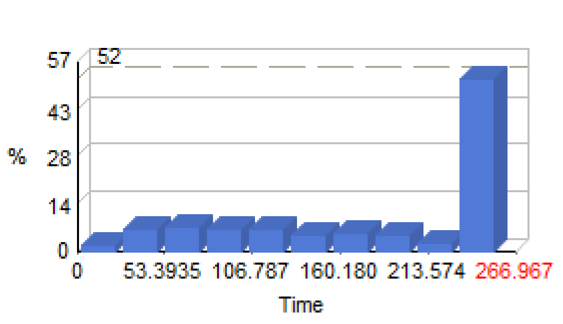


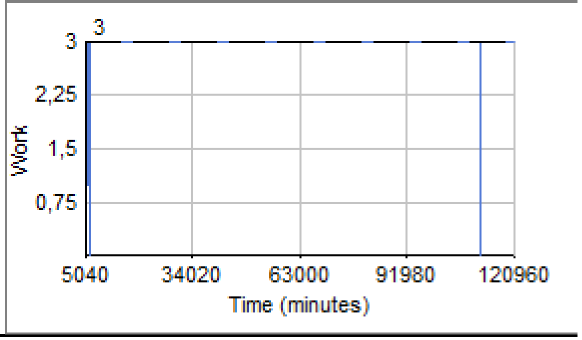




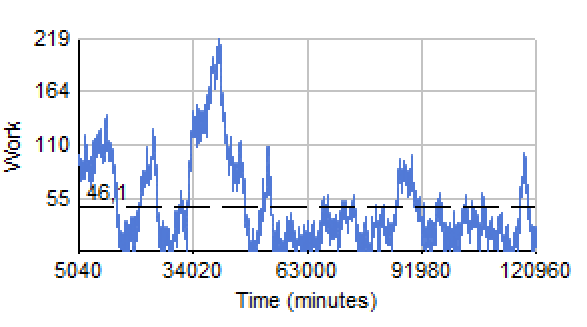
Retailer 5
working
91.76%

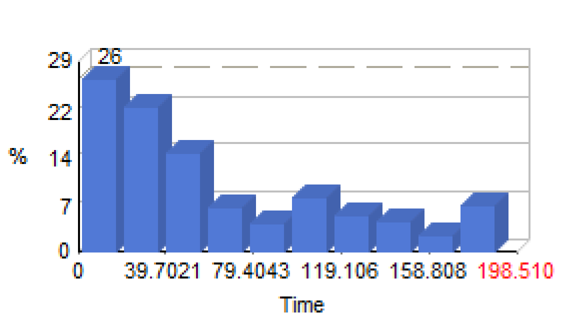


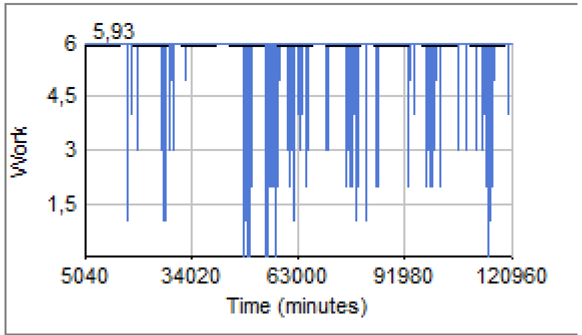




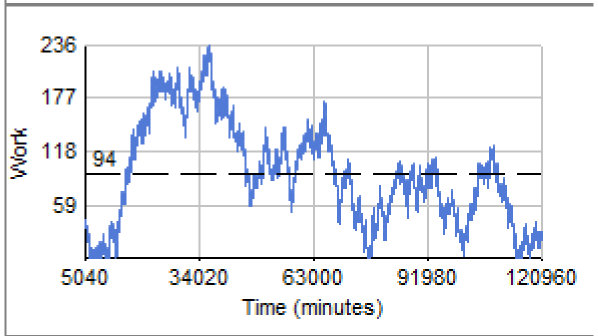
Retailer 6
working
99.86%

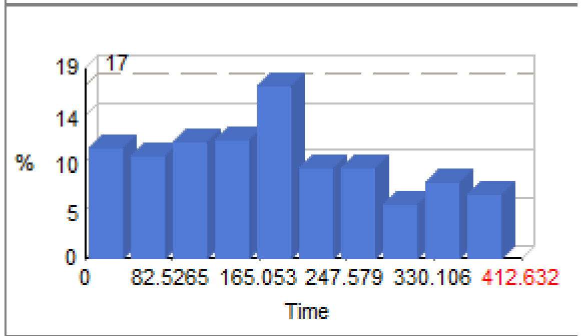


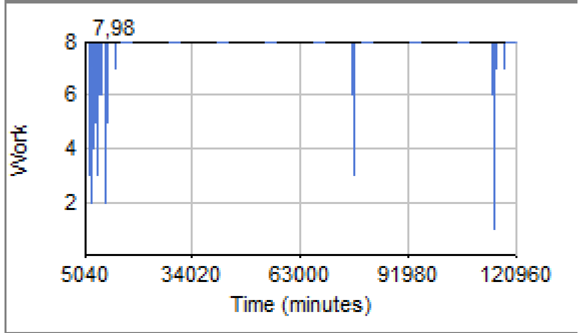




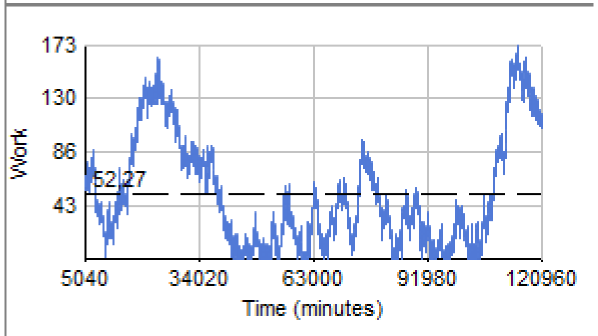
Retailer 7
working
99.15%

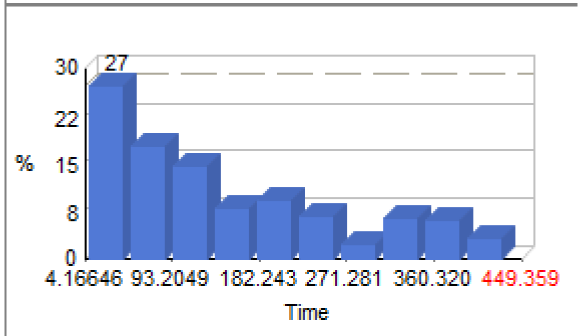


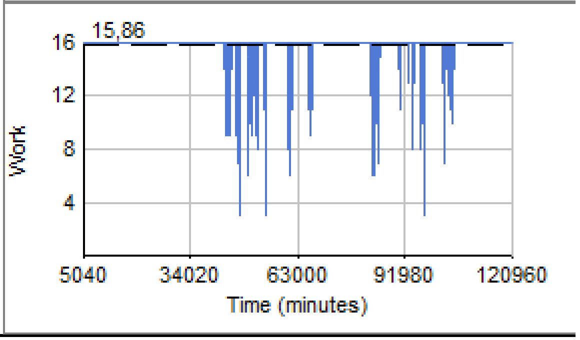


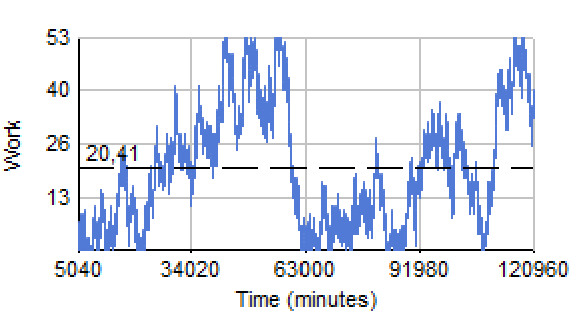
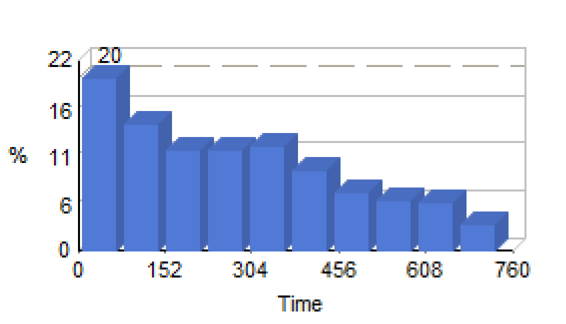
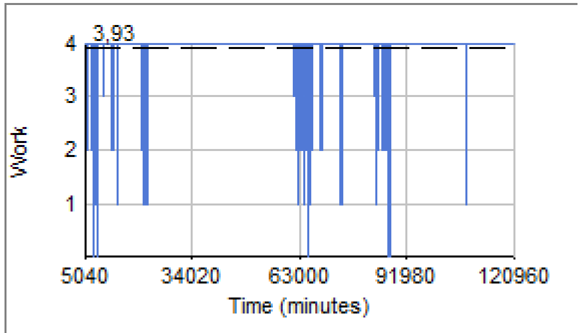
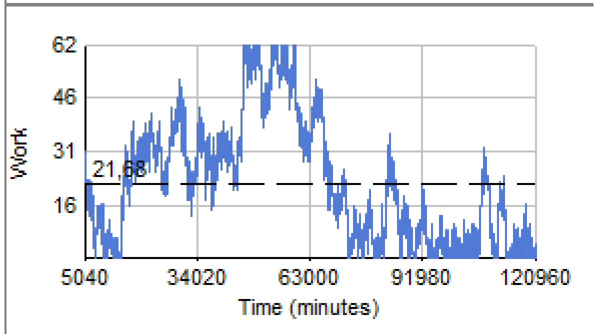
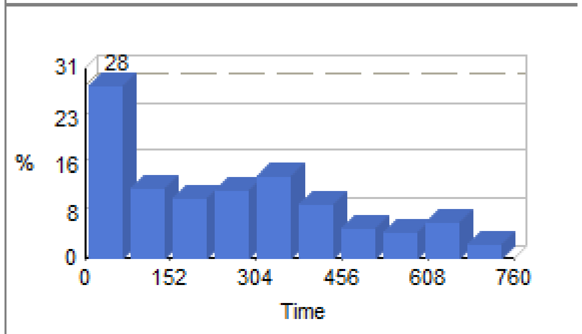
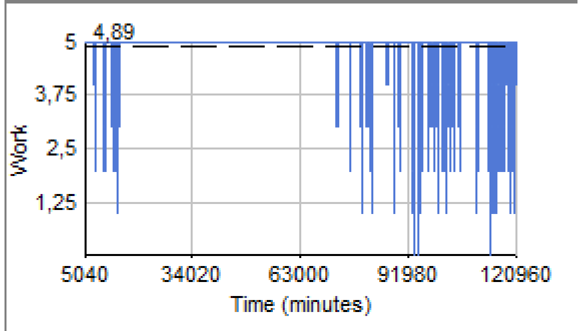
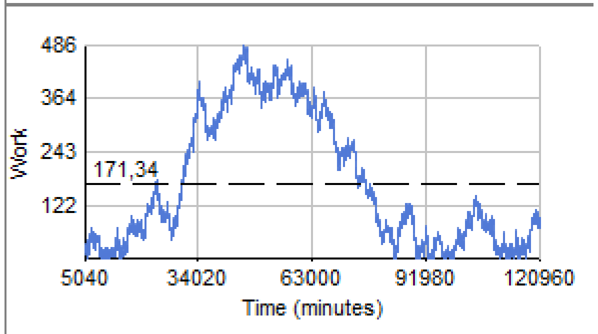
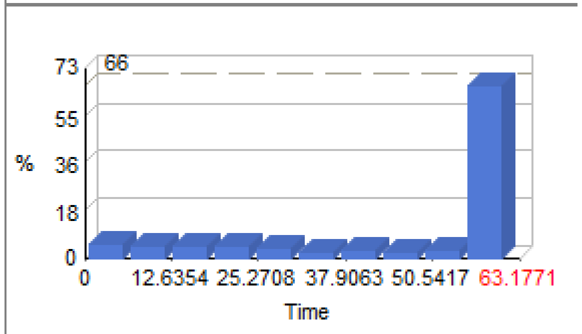
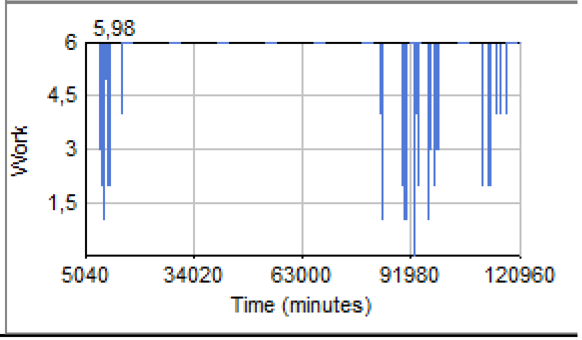


Retailer 8
working
99.64%

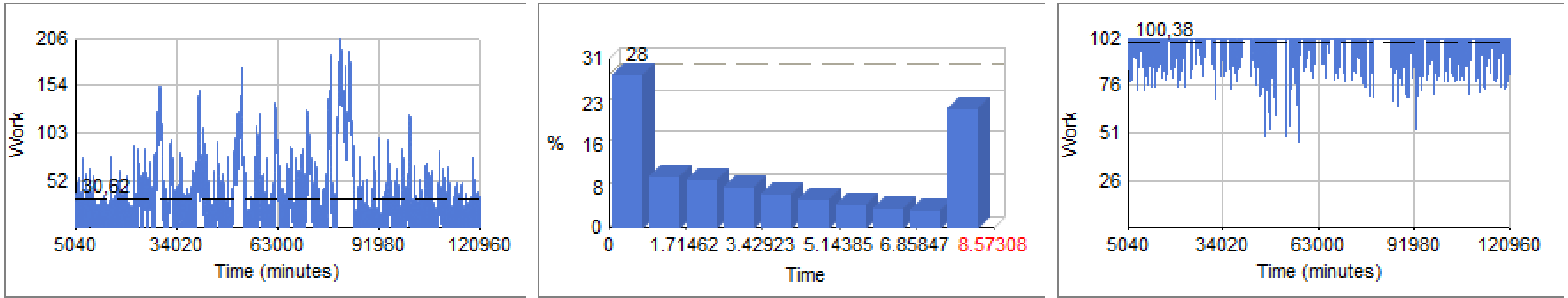




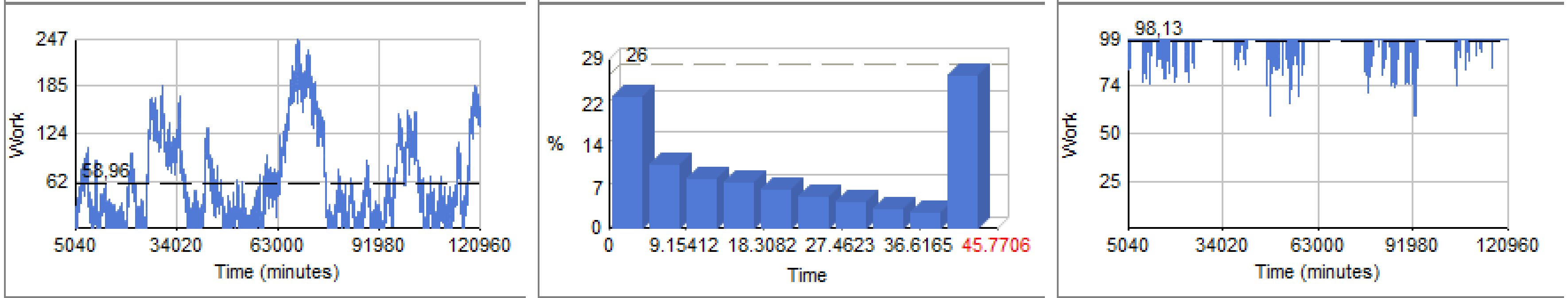


Retailer 9 working 98.61%			
Retailer 10 working 98.61%			
Retailer 11 working 99.93%			

Retailer 12 working 98.97%



Retailer 13 working 99.94%



Retailer 14 working 99.23%