Interaction between international manufacturing networks and international R&D networks

Developing an Integrated Framework

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June 2017

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Abstract

Purpose – The purpose of this study is to develop an integrated framework to investigate how international R&D networks and international manufacturing networks interact with each other and compare this integrated framework with practices in one company.

Method – A deductive research method is adopted and this study mainly aims at theory building. First, an integrated framework is developed after reviewing the existing literature to understand the interactions between international R&D networks and international manufacturing networks. Then, a case study is conducted to verify the integrated framework.

Findings – This study identifies three competitive strategies that can be adopted to integrate international R&D networks and international manufacturing networks: efficiency, learning and responsiveness. Under each strategy, capacities at individual site level and network level are properly designed and arranged to contribute to fulfil the strategy. Different types of configurations of international R&D networks and international manufacturing networks are found under each strategy to best support the capabilities. Research and development can be treated differently when interacting with manufacturing. Compared with research, development has closer interaction with manufacturing. And when R&D is technology-driven, international R&D networks and international manufacturing networks have minimum interactions.

Keywords – Manufacturing, R&D, International manufacturing networks, International R&D networks, Interaction, Globalization, Networks

Preface

This thesis concludes the authors' Masters of Science at Faculty of Engineering(LTH) at Lund University. Both authors are from International Master's Program, logistics & supply chain management. The thesis is mainly built on previous literature review, with a case study performed at Alfa Laval in Sweden.

First, we would like to thank our supervisor at Lund university Jan Olhager for your patience, support, guide, experience sharing, model check and so on. You guided us to the objectives of this research step by step through great discussions and logical explanations. There are so many things that we could not list all of them. We really appreciate your help and it is a great honor to have you as our supervisor.

Second, we want to thank the company Alfa Laval, especially the two managers that we interviewed. We would like to thank Jens Richter and Carina Resare for your time and interest in our study. And we highly appreciate your friendly and patient explanations during the interviews. The report would not have been completed without your contributions.

Next, we would like to thank our opponents at the half-time seminar and the final defense presentation. They provided useful suggestions for us. Also, we want to thank our examiner Dag Näslund, for his time, presence and valuable advice on our defense presentation.

Finally, we want to thank our families and friends here, too. Without their support, we could not have the chance to study and do research abroad at Lund University.

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Glossary

R&D: research & development

IMN: international manufacturing network

FDI: foreign direct investment

GATT: general agreement on tariffs and trade

MNC: multinational company or multinational corporation

IMF: international Monetary Fund

OECD: organization for Economic Co-operation and Development

PHE: Plate heat exchanger

1 Introduction

This chapter as the beginning of the paper, aims at introducing the background, problem description, research purpose, focus and delimitations, contribution to related stakeholders, and the structure of the paper.

1.1. Background

Research on international manufacturing networks has been around for some time. More recently, the related R&D networks are gaining recognition. Some companies have international networks of factories as well as of design facilities; these can in many instances be regarded as two different networks, even though some facilities can be co-located. The two networks are typically designed independently of each other - even though a product is developed in one place which “owns” the product design, manufacturing may be distributed among a number of factories.

It has been recognized that in today’s world of global competition and high-speed product development, the linkages and interactions between R&D and manufacturing is more vital to successful business than ever before (Cheng et al. 2015).

1.2. Problem Description

Currently, literature on international networks typically only focuses on one of the aspects: either about international manufacturing networks or about international R&D networks. The connections and linkages between international R&D networks and international manufacturing networks (IMNs) are important to the success of a company that competes on the world basis in today’s global competition and short product life cycle. Since there is very little literature studying the interaction between international manufacturing and R&D networks, it is important to know how these two networks interact with each other in a global context. Therefore, it is necessary to research international manufacturing and R&D networks as a whole and develop an integrated model of the two networks.

1.3. Research Purpose

The idea with the thesis is to make a structured review of the literature on IMNs and on international R&D networks, develop models or frameworks that can describe how these networks can be integrated, and compare with practice in one manufacturing company (Alfa Laval).

Research questions 1:

How do the international R&D networks and IMNs within a company interact with each other?

Research questions 2:

How can companies manage and optimize their international R&D networks and IMNs to meet their strategic objectives?

1.4. Focus and Delimitations

Because of the time constrain, the study focuses on the intra-company networks, which means a multinational company or corporation (MNC) has a direct investment of the manufacturing network and the R&D network. The reason is that the company has direct management control of these activities and furthermore, a company should first optimize or better manage its own resources. The manufacturing and R&D activities that are co-managed by the focal company and other organizations, for example, some companies involve their suppliers in the R&D and manufacturing activities, are excluded from the consideration. Because these activities are managed across more than one organization and will make the discussion and analysis much more complex.

1.5. Contribution

1.5.1. Contribution to Companies

The conceptual integrated model could be applied in multi-plants manufacturing and R&D companies, and help them organize and manage their IMNs and international R&D networks in global perspective, which could help them gain real benefits.

1.5.2. Contribution to Research

Although there are some endeavors to address the connections and interactions between IMNs and international R&D networks, the existing studies generally do not offer a comprehensive and integrated framework for investigating the interactions between international manufacturing and R&D networks. This research could fill that gap to some extent.

1.5.3. Contribution to Individuals

This master thesis project could train and sharpen skills of students in managing a complex project covering both theoretical and practical parts.

1.6. Target group

The target group are researchers and multi-plants manufacturing and R&D companies. Even though some researchers could understand the mentioned terms or abbreviations, it is still difficult for all the companies to take them in. To be more comprehensive, a glossary table is listed before the Introduction Part, for those who would like to look up the explanations and gain deeper understanding to use.

1.7. The structure of the paper

Before introducing the structure of the paper, a funnel model, should be explained first. “The funnel model illustrates the gradual narrowing down of the subject” (Björklund and Paulsson, 2014), which is present in ***Figure 1. 1***.

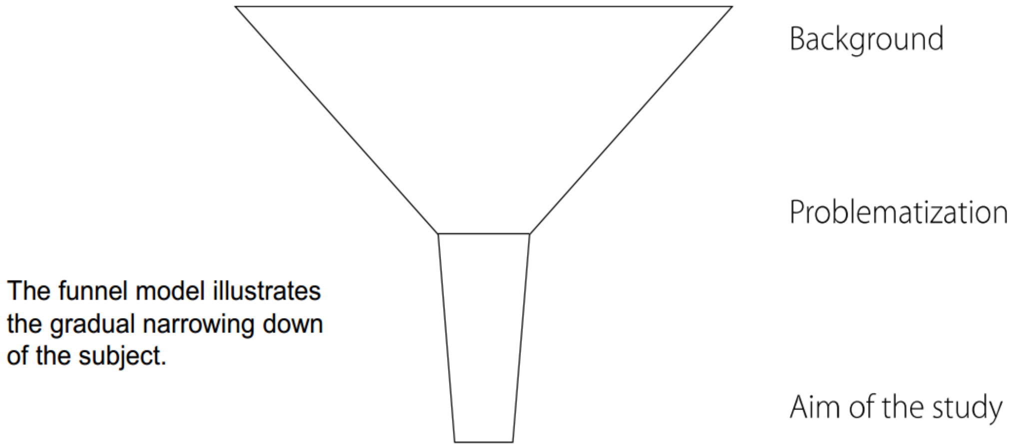

Figure 1. 1 - Funnel model (Björklund and Paulsson, 2014)

And similarly, both ***Theory and Frame of Reference Part*** as well as ***Case Study at Alfa Laval Part***, apply this funnel model (seen in ***Figure 1. 1***), narrowing down from wide topic to the focused subject. The structure of the paper is illustrated below in ***Figure 1. 2***.

- The first two chapters are ***Introduction Part***, consist of introduction and methodology.
- Next, for the structure of the ***Theory and Frame of Reference Part***, it is organized based on the mentioned funnel model in ***Figure 1. 1***. More specifically, it consists of “Globalization”, “Networks related theory”, “international R&D Networks” and “IMNs”. Furthermore, the connections and interactions between them are discussed, and a new integrated framework, integrating IMNs and international R&D networks, is given.

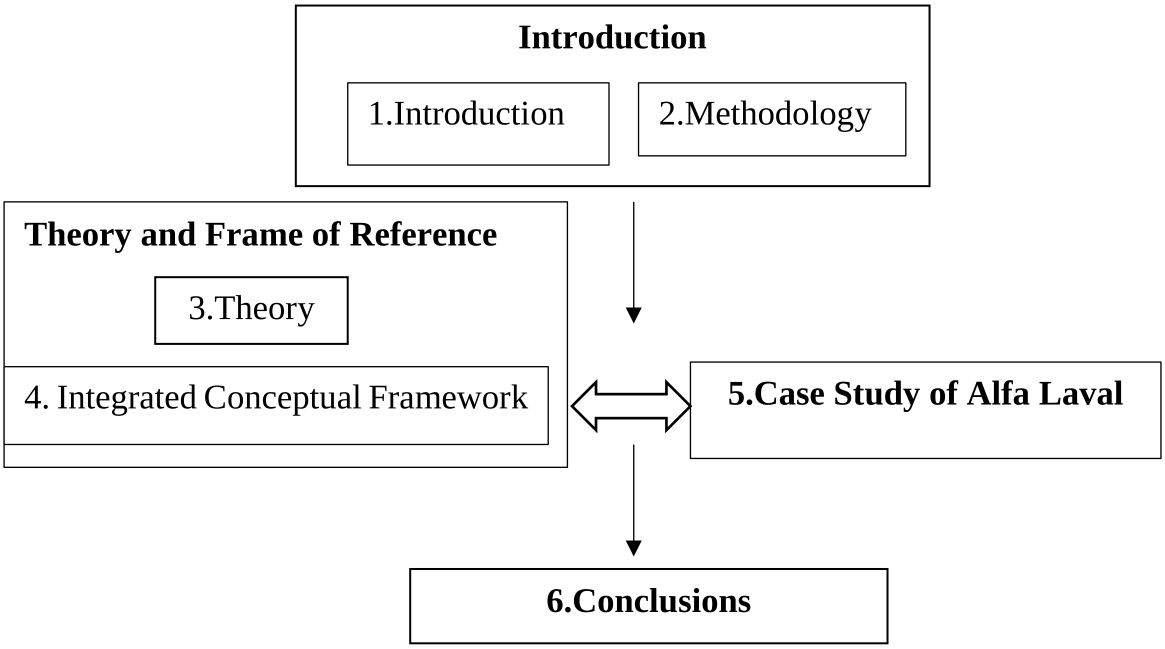

Figure 1. 2 – The structure of the paper

- And the ***Case Study at Alfa Laval Part*** follows the similar pattern as the “***Theory and Frame of Reference***” Part. It starts with general information of the company, which is the wide topic. Then it narrows down to the specific details, about their current state and planning of International R&D Networks and IMNs. Then, the interactions between them are discussed later. Finally, comparisons between the integrated framework and this practical example are made and analyzed.
- Finally, there are ***Conclusions Part*** in the end.

2 Methodology

This chapter consist of five sections, which are research strategy, data collection method, literature finding method, analysis method, and trustworthiness and credibility. And in each section, common method would be discussed first, and then the appropriate one that is suitable for this paper would be selected.

2.1. Research Strategy

This section introduces several general research approaches and methods, and then the appropriate research strategy is selected to use.

2.1.1. Descriptive, Explanatory, and Prescriptive-driven studies

Generally, there are two basic research questions that social researchers would ask, which are listed below in ***Table 2. 1***.

Table 2. 1 - Two fundamental studies in social research (De Vaus, 2001)

Questions	Forms of study
what is going on	Descriptive study
why is it going on	Explanatory study

Descriptive studies describe what things are, while explanatory studies explain the reasons why they happened.

Aken (2004) compares two research programmes. The main differences between description-driven and prescription-driven research program are illustrated in ***Figure 2. 1*** (Aken, 2004). According to Aken (2004), description-driven research program is like descriptive study. However, prescription-driven research program, aims at giving complete solutions to solve problems.

Due to time limitation, in our study, one global manufacturing company is chosen as an example of case study. And this case study could only test one perspective of the integrated framework. This test could not provide enough evidences to complete a whole pack of solutions covering all industries. So description-driven research program is selected instead of prescription-driven research program.

Characteristic	*Description-driven research programmes*	*Prescription-driven research programmes*
Dominant paradigm	Explanatory sciences	Design sciences
Focus	Problem focused	Solution focused
Perspective	Observer	Player
Logic	Hindsight	Intervention-outcome
Typical research question	Explanation	Alternative solutions for a class of problems
Typical research product	Causal model; quantitative law	Tested and grounded technological rule
Nature of research product	Algorithm	Heuristic
Justification	Proof	Saturated evidence
Type of resulting theory	Organization Theory	Management Theory

Figure 2. 1 - The main differences between description-driven and prescription-driven research program (Aken, 2004)

The corresponding relation between chapters and selected research methods are listed below:

1) **Theory and Frame of Reference Part**
Theory and Frame of Reference Part is descriptive research, summarizing the previous research findings and bridging gaps between the two networks.
2) **Case Study at Alfa Laval Part**
Case Study at Alfa Laval Part, as descriptive and explanatory study, would describe the current situations and explain the reasons behind company decisions or behaviors.

Overall, our article is mainly **descriptive** study, Also, explanatory method is mentioned in case study, to make a complete research.

2.1.2. Inductive, Deductive, Abduction, and a Balanced Approach

There are three classes of approach. They are inductive approach, deductive approach, and abductive approach (Björklund and Paulsson, 2014). ***Figure 2. 2*** shows the differences among the three approaches.

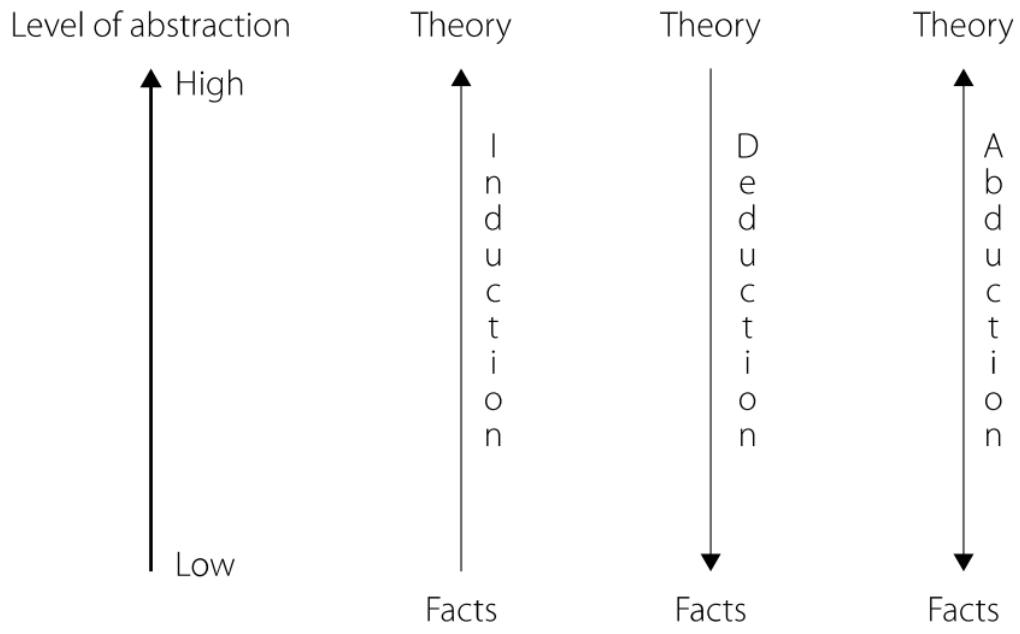

Figure 2. 2 - Inductive approach, deductive approach, and abduction approach (Björklund and Paulsson, 2014)

The main difference among them is the various positions of start points in ***Figure 2. 2***. The explanations of three approaches are listed as follows (Björklund and Paulsson, 2014):

1) **Deductive approach** begins with theory to predict the empirical material.
2) **Inductive approach** starts from reality to form a pattern.
3) **Abductive approach** takes place between the different level of abstraction, then follows one of the double-side arrow's directions (seen in ***Figure 2. 2***). In other words, it starts from somewhere between the theory and facts, heads to either facts or theory.

Besides these three, Woodruff (2003) brings up another approach, called a balanced approach. That could use both deductive approach and inductive approach in one model. This balanced model is shown below in ***Figure 2. 3***.

Generally, a deductive approach follows the right-side circles in number order from 5 to 8 in ***Figure 2. 3***. Then, how our article fit in this deductive approach will be explained.

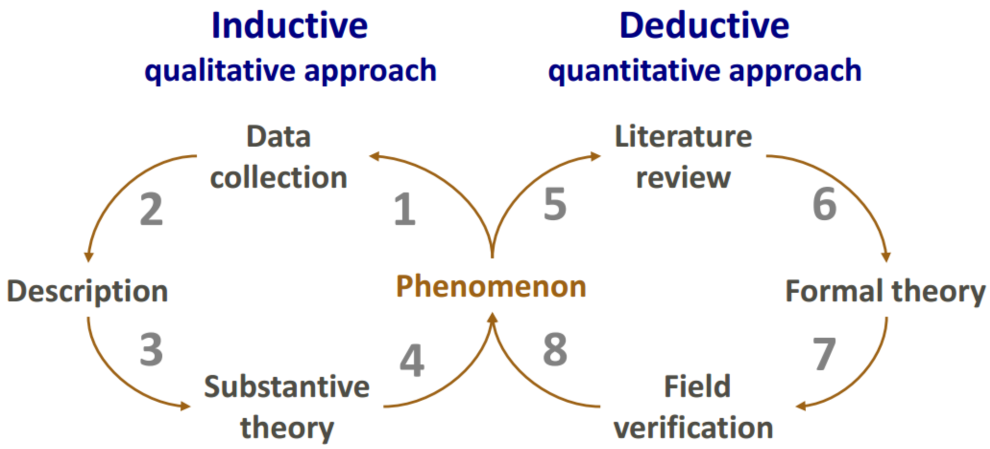

Figure 2. 3 - A balanced approach [(Woodruff, 2003) referred to in (Olhager, 2016)]

5) Literature review

First, the phenomenon that there is a lack of integrated consideration of international R&D and manufacturing networks is identified. Then, this study reviews the existing literature and studies. Obviously, ***Theory and Frame of Reference Part*** is corresponding to literature review, which is the first step.

6) Formal Theory

The ***Integrated Framework*** summarizes the previous literature review into the formal theory, which might be applied in practice. Verification would be done in the following step.

7) Field verification

Next step, ***Case Study at Alfa Laval Part***, it starts with data collection. And this collected practical information from the company would be used, to verify one perspective of the integrated framework. This step is called field verification.

8) Phenomenon

Questions concerning the phenomenon are analyzed and solved.

Considering that the study fully follows this circle path on the right side, the selected method is a **deductive** approach.

2.1.3. Qualitative and Quantitative studies

Qualitative and quantitative studies are two common methods that researchers would use. Qualitative studies are using descriptive sentences to explain problems and models. Quantitative studies rely on mathematical tools to prove ideas.

The research purpose of this study aims at finding the interactions between international R&D and manufacturing networks. And usually, it is hard to quantify interactions with accurate numbers. So, **qualitative** study is more appropriate here.

2.1.4. The Overall Selected Research Strategy

Table 2. 2 illustrates each sections and corresponding research strategy, including a summary of whole article's research strategy.

Table 2. 2 – The overall selected research strategy

Different parts in this Paper	**Research methods (section 2.1.1）**	**Research approach (section 2.1.2)**	**Study methods (section 2.1.3)**
Theory and Frame of Reference	Descriptive	Literature review	Qualitative
Integrated Framework	Descriptive	Formal theory	
Case Study	Descriptive and explanatory	Field verification	
Entire article	**Mainly descriptive**	**Deductive**	**Qualitative**

Based on the three sections discussed above, overall, the selected Research Strategy are mainly **descriptive**, **qualitative** research, with a fully process of **deductive** approach.

2.2. Data Collection Method

There are several data collection methods that could be applied in a research project. Below are some of the common methods. Also, the appropriate one would be selected to use in this project.

2.2.1. General Classification

Some of the data collection method would be introduced, which are literature studies, observations, presentations, interviews, and surveys.

1) **Literature studies**

Literature studies use information and data from previous study. These information and data are easy to attain, however, some of them maybe outdated or too theoretical (Björklund and Paulsson, 2014).

2) **Observations**

Participant observation is a method, when observer is part of the activities, so that he or she could feel and touch the real-life and first-handed experience and data. This data collection method is deep investigation (Jorgensen, 1989). But it is so time-consuming and costly that only few observers are willing to participate the whole research. And it is even harder to record the information detailly in such a long time. Privacy is not the only issue when recording. For example, video recording is a useful way to save the entire process for future analysis. However, this may cause the participant too nervous, so they would behave in an unnatural way, even opposite way in some cases. And that not only affects the results, but also destroys the whole research. If the participants forget what they see and only provide a little information, researchers cannot continue to analyze with limited input. And all the time is wasteful in this way. In conclusion, it is crucial for a research to select appropriate recording method, during or just after the observation.

3) **Presentations**

Some figures or data could be found on slides of company’s presentation. They are usually used to introduce the background or basic information of company to customers or public society(Björklund and Paulsson, 2014). On the one hand, the information and data are reliable because they are given by the company directly. On the other hand, these numbers maybe too subjective to use in some circumstance, since the original providers are stakeholders of the enterprise. (Björklund and Paulsson, 2014).

4) **Interviews**

There are three types of interviews, structured, semi-structured, unstructured. And the difference among them are listed below in ***Table 2. 3***.

Table 2. 3 – Comparisons among three types of interviews (Brewerton and Millward, 2001)

Interview types	Before interview	During interview
Structured interview	Prepare questions	Follow strictly to ask those questions
Semi-structured interview	Prepare questions	Some of questions are from preparedness, and the others are come up by interviewer during conversation based on the answer and response of interviewee
Unstructured interview	Not prepare questions	All the questions are generated then and there during the interview.

Kvale (2007) brings up several interview examples to show some rules that an interviewer needs to take care.

- The question should follow the sequence, from experience, to reasons and strength of belief.
- Researchers do not speak their own views out, neither show positive or negative attitudes about the answers from interviewees, during the conversation.
- Interviewers should encourage interviewees to speak broader or more detailed, by guiding them with different questions related to previous answers.

5) **Surveys and questionnaires**

Surveys and questionnaires are common research method to collect data. It is a convenient way to apply, especially online survey with internet connection. The cost of this method is low, and analysis of results is given fast with graph. But this method is usually with limited option and standard opinion. (Vaux and Briggs, 2005).

2.2.2. The Selected Data Collection Method

This study chooses two data collection methods, literature studies and interview.

- **Literature study** is the input of the integrated framework. Literature finding method will be explained later in section 2.5.
- Answers from **semi-structured interview** is the input of case study. Broad questions will be asked to all the representatives on the stage. Then, specific questions related to R&D department or Manufacturing department will be focused separately. During each interview, the voice will be recorded. And after this session, researchers will dictate them into text. The dictation results will be sent back to the interviewees to check. And any confidential information will be removed**.**

2.3. Analysis Method

There are three methods to cover in this section, which are analysis models, statistical processing, and simulation. All of them could be a choice to process the data.

2.3.1. General Classification

There are three methods to process the data, which are analysis models, statistical processing, and simulation. The corresponding explanations for them are listed below: (Björklund and Paulsson, 2014)

- **Analysis model**

For Analysis model, there could be many ways, or to say layouts of graphs, to show your logic of how you process the information. And these further results will be arranged into one or several frameworks or models.

- **Statistical processing**

Statistical processing could be used to do some calculations or find the relations between variables. This analysis method could be done with your own brain, or with the help of mathematical tools, which are usually in the form of coding programs on efficient computers. Writing entire program by yourself is not worthwhile, if you are doing a small project.

- **Simulation**

Simulation could show the visualized process and results of different experimental scenarios. And all these take place in specialized simulation programs. To run the simulation, some initial values and assumptions are necessary.

2.3.2. The Selected Analysis Method

Because this study is qualitative, the collected data from the interviewees are mainly descriptive, **analysis models** will be more suitable to use.

2.4. Trustworthiness and Credibility

It is reliability, validity, objectivity that are three important criteria to measure the credibility of research. Lindroth (2001) comes up with a model in a dart board to illustrate the differences between validity and reliability, which is present in ***Figure 2. 4***.

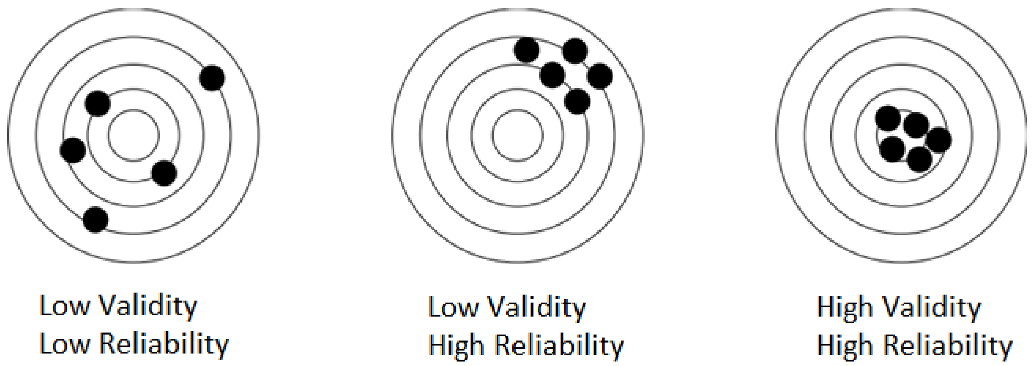

Figure 2. 4 – A dart board to explain validity and reliability (Lindroth, 2001)

- **Validity:**
  After you shoot, if the holes on dart board are far away from the central target, the validity is low. If they distribute in the middle area, the validity is high. In terms of research, high validity means researchers highly fulfill the main purpose of study.
- **Reliability:**
  If you shoot several times, these holes on dart board are close to each other, then you could say the reliability is high. Otherwise, the reliability is comparatively lower. As for a research, if researchers do the same study

for several times, the results are still similar or close no matter who did the experiment.

- **Objectivity:**
  Objectivity is contrary to subjectivity. It requires the researchers to obey the observation data without affecting the analysis or results by subjective opinions. The key point here is to get rid of prejudice.

2.5. Research Design

There are three phase of this study, literature review, model building, test model with case study.

Phase one: Literature review on international R&D and manufacturing networks

When searching the related literature, some sey words used are listed below:

Network, globalization, internationalization, manufacturing strategy, manufacturing network, production network, R&D strategy, R&D sites, R&D network, engineering network, manufacturing network and R&D network, production network and R&D network, manufacturing network and engineering network.

Several Search Engine we use are: Web of science, Google scholar and Lund library search

Key words search is useful, but it could not always find the target articles. Another way is to trace back and forward of the important literature. So highly related articles could be found in this way. Sometimes, some terms are not elaborated in articles, but they are explained detailly in books of the same author. However, not all the books offer online version. To understand these concepts well, it is helpful to borrow books from library.

Phase two: Integrated Conceptual Framework building

Analyze the existing research and look for the interactions between the two networks. Then, an integrated framework is built to investigate the interactions.

Phase three: Test one perspective of the integrated framework with the case study

Interview the company and test one perspective of the integrated framework. Then analyze and draw some conclusions.

3 Theory and Frame of Reference

We divide all the theories and literature related to our research into four parts, globalization, networks, IMNs and international R&D networks. The first two subsections introduce the theories and studies concerning globalization and networks, which are the fundamental research of the two networks. This chapter is structured by logical order, rather than chronological order of usage in the report. And in this way, the related knowledge can be built up gradually and more importantly, and it will help to develop the theoretical integrated framework for evaluating the interactions between IMNs and international R&D networks.

3.1. Globalization theories

Business today is becoming more and more international. Over the last decades, both global trade and foreign direct investment (FDI) have increased explosively. Many markets are truly global now (Rudberg and Olhager, 2003). The International Monetary Fund (IMF) (2000) identified four basic aspects of globalization: trade and transactions, capital and investment movements, migration and movement of people, and the dissemination of knowledge.

Ferdows (1997) gives some tangible and intangible reasons why companies choose to manufacture abroad. Tangible benefits include such as reduction of direct and indirect cost, reduction of capital costs, reduction of taxes and logistics costs. Intangible reasons include such as attraction of talent globally, learning from foreign research centers and foreign customers.

Abele et al. (2008) identify three phases of globalization, from cross-border trading to globalization in its current form. ***Figure 3. 1*** shows the development of globalization in three phases.

1) Before 1930: mainly sales offices abroad

Stock corporations expanded their customer and supply markets by setting up sales offices abroad. Because the telecommunications technology was in its infancy, information transfer was highly limited. Manufacturing in foreign countries was rarely economically viable.

2) 1930 to 1980: largely independent production abroad

After World War I and the world economic crisis, large companies grew fast. Coca-Cola, Mercedes, and IBM became famous around the world. Effective and low-cost telecommunications made it possible for large scale companies to tap economies of synergy and scale. Companies opened foreign markets by their dominance on the home market and the foreign facilities mainly operated independently.

3) Since 1980: globally networked production and cross-functional collaboration

The era after 1980 featured deregulation, rapid technical progress and declining transaction costs. Trade barriers fell, GATT (general agreement on tariffs and trade) rounds led to reductions in tariffs, and customs unions were founded. The concept of globalization drew a worldwide attention. Basic components were manufactured centrally to pursue economies of scale and also products were tailored to local requirements. A business unit's functions such as manufacturing, R&D and marketing may be spread around the world. The challenge is to manage corporate functions as a network.

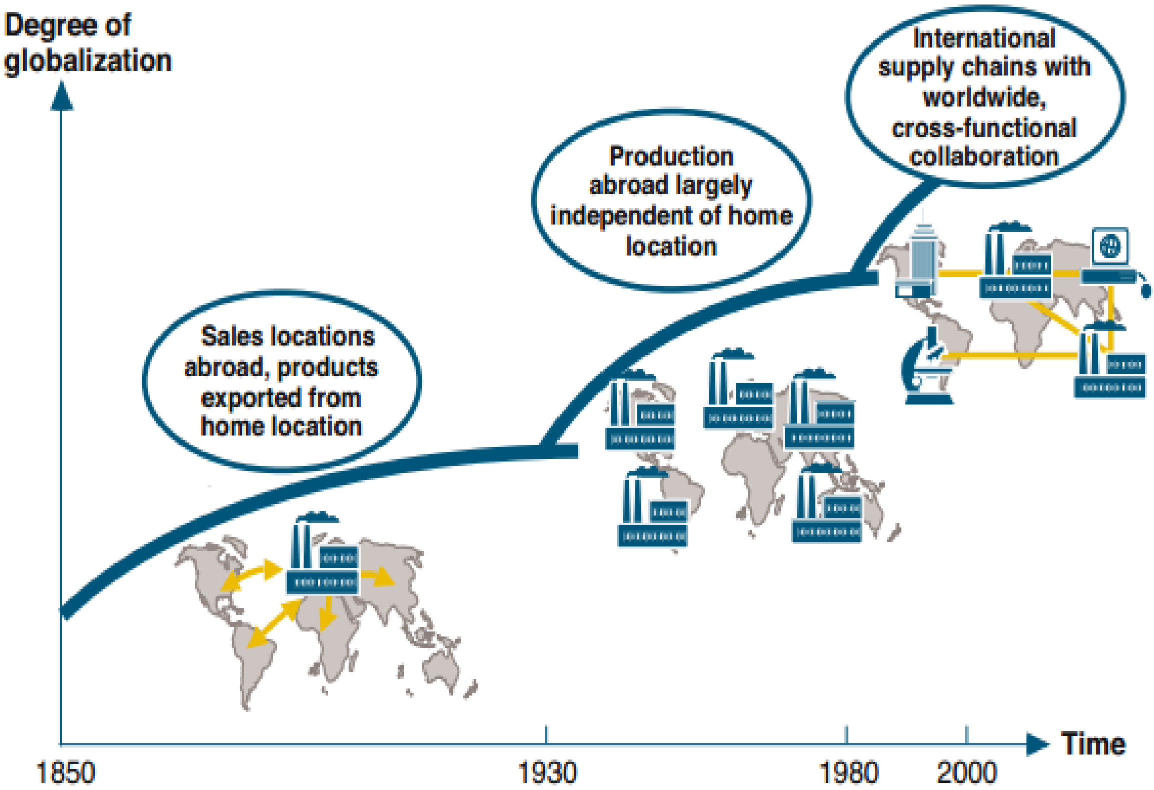

Figure 3. 1 - The development of globalization phases (Abele et al., 2008, p.4)

Bartlett and Ghoshal (1998) classify the worldwide corporations into three typical types: multinational companies, global companies and international companies, and each type competes on a competitive advantage. Below, the ***Table 3. 1*** explains organizational characteristics of distinct types of companies.

Table 3. 1 - Organizational characteristics of different types of companies (Bartlett and Ghoshal, 1998, p.67)

Organizational characteristics	**Multinational**	**Global**	**International**
Configuration of assets and capabilities	Decentralized nationally self-sufficient	Centralized and globally scaled	Sources of core competencies centralized, others decentralized
Role of overseas operations	Exploiting local opportunities	Implementing parent company strategies	Adapting and leveraging parent company competencies
Development and diffusion of knowledge	Knowledge developed and retained within each unit	Knowledge developed and retained at the center	Knowledge developed at the center and transferred to overseas units

1) Global companies: global efficiency strategy

Global companies develop their international operations by the need for global efficiency, and centralize their strategic decisions and competences. These companies treat the world market as an integrated one. For these companies, the global environment and worldwide customer demand are the dominant units of analysis instead of local market.

2) Multinational companies: national responsiveness strategy

Even though there is a trend toward standardized products, in many industries, many customers reject homogenized products and keep their traditional preferences. In this case, there are opportunities for companies that meet this need for locally tailored products and services. To be successful, multinational companies should be sensitive and responsive to local differences around the world.

3) International companies: worldwide learning strategy

The force driving companies to compete on this strategy derive from the global efficiency and local responsiveness forces described above. The increasing cost of R&D, together with short life cycles for new products and technologies require companies to seek global volume in order to amortize the heavy investment. Center's knowledge and expertise is transferred and adapted to foreign markets. The center of an international company has considerable control, but less than in a global company; foreign units can adapt products coming from the center, but have less autonomy and independence than the foreign units in multinational companies.

To summarize, the three types of companies develop their own competitive strategies: global companies develop strategies dominated by global-scale efficiency; multinational companies develop strategies dominated by national responsiveness; international companies develop strategy dominated by worldwide learning and innovation. And worldwide learning and innovation strategy is a strategy combining both global-scale efficiency and national responsiveness.

On the one hand, globalization has its positive effects, which are shown in the middle side of ***Figure 3. 2***. These effects include increased innovative capacity and appropriability of innovation (Kafouros et al., 2008).

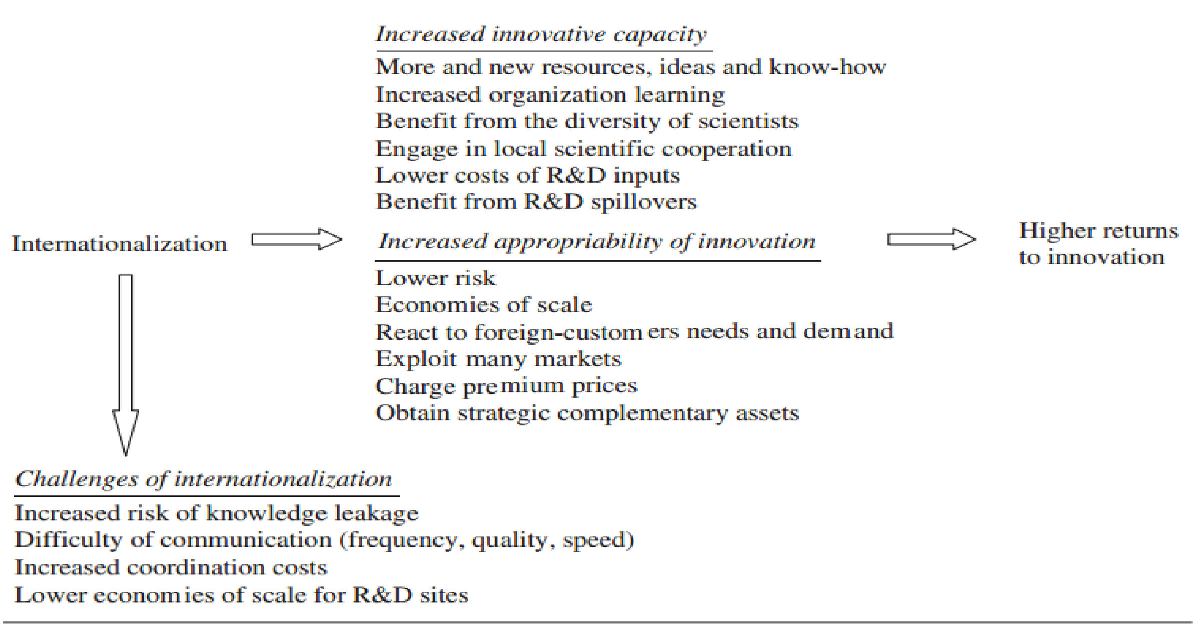

Figure 3. 2 - The main implications of globalization (Kafouros et al., 2008)

On the other hand, the cost and risk are always here and there, and globalization is of no exception. For example, the more globalized an enterprise is, the more people from various culture could reach the research document, and the more dangerous it is at the risk of exposition of innovative technology. In the conclusion of the article from Kafouros et al., (2008), the benefit of globalization outweighs disadvantages.

3.2. Networks related theories

There are two prominent definitions of "network" when researchers discuss the network-related topics. First, network is "an abstract notion referring to a set of nodes and relationships that connect them" (Fombrun, 1982). Second, Podolny and Page (1998) define a network form of organization as "any collection of actors ($N \geq 2$) that pursue repeated, enduring exchange relations with one another and, at the same time, lack a legitimate organizational authority to arbitrate and resolve disputes that may arise during the exchange" (p.59). But the problem with these definitions is that they focus mainly on interorganizational relationships and involve the external partners which cooperate with the focal company. As described in the introduction part, this thesis project only considers intra-firm or intra-organization networks in which all the facilities are owned by the focal company instead of shared with external partners. To better understand what kind of network is studied in this thesis project, other network-related research is described as follows.

Snow et al. (1992) identify three types of network organizations, each suited to a particular competitive environment.

1) Internal network:

An internal-network firm owns most or all of the assets associated with a particular business. The logic behind the internal network is that internal units should operate with prices decided by the market instead of artificial transfer prices. A well-designed internal network can reduce redundancy and response to markets more quickly. This type of network organizations achieves high resource utilization.

2) Stable network

In a stable network, assets are owned by several firms. A large "flagship" company outsources some activities to some other firms, these firms either providing inputs to the flagship or distributing its outputs. In this way, flexibility can be to some degree pursued. A stable network spreads asset ownership and risk across independent firms.

3) Dynamic network

In highly discontinuous competitive circumstances, the lead company assembles assets owned largely or entirely by other companies. The lead firms rely on a core skill such as R&D/engineering, production, or in some cases, pure brokering. Dynamic networks can achieve both flexibility and specialization. However, dynamic networks risk quality variation across firms, temporarily unavailability of expertise, and possible exploitation of proprietary knowledge.

Within these three types of networks, this study focuses on internal networks and the other two types of networks can be used for further research.

Rudberg and Olhager (2003) distinguish between internal networks and external networks, which is illustrated in ***Figure 3. 3***. Internal networks and external networks can be considered as value networks, and the difference between these two kinds of networks is whether the assets are owned by one organization or different organizations. A manufacturing network is an internal network focusing on the nodes, while a supply chain is an external network focusing on the links.

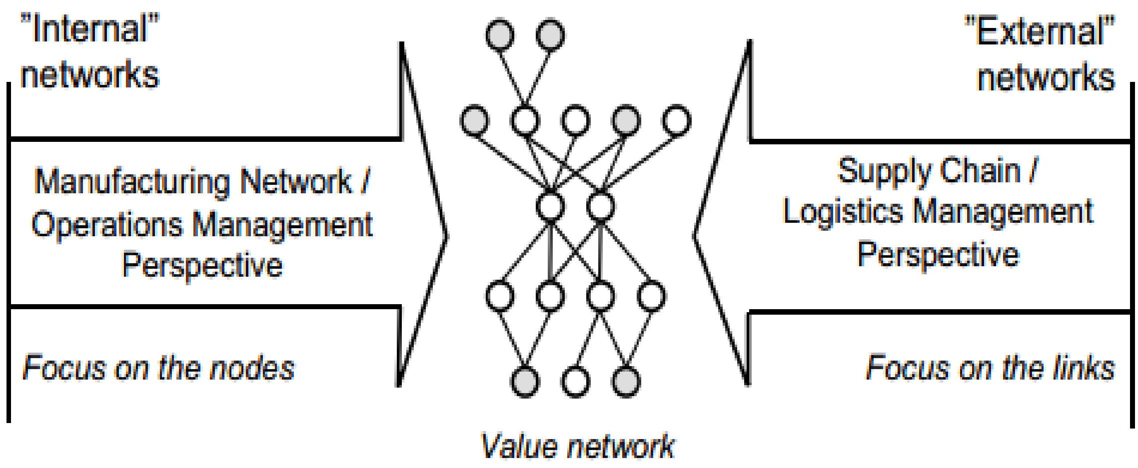

Figure 3. 3 - Internal networks and external networks (Rudberg and Olhager, 2003, p.30)

Furthermore, Rudberg and Olhager (2003) categorize value networks based on two dimensions: the number of organizations within the system analyzed, and the number of sites within each organization in the system. As a result, four different types of networks are defined: plant, intra-firm network, supply chain and inter-firm network, as shown below in ***Figure 3. 4***.

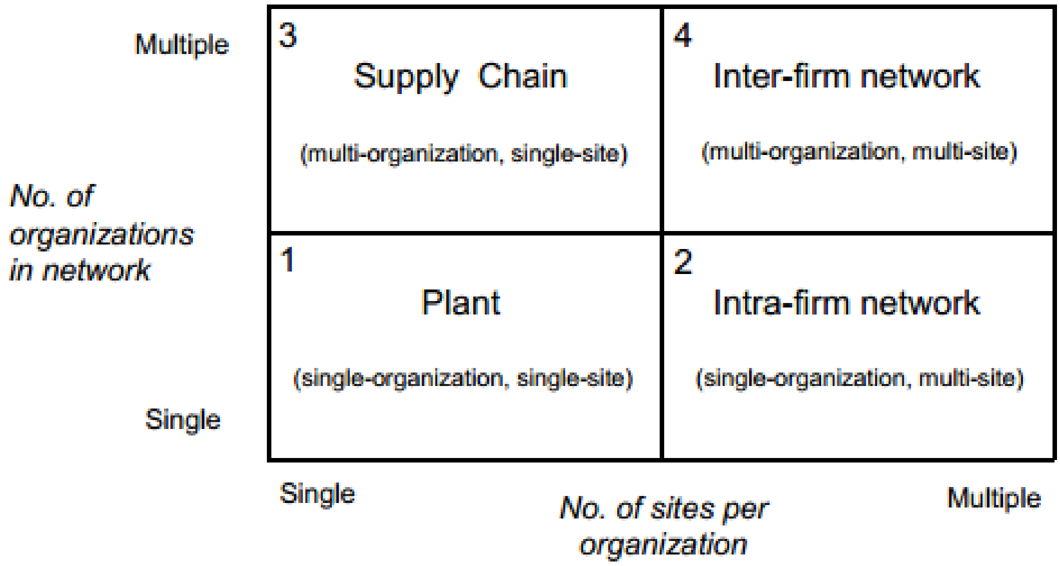

Figure 3. 4 - Different types of networks (Rudberg and Olhager, 2003, p.35)

The focused network in this thesis study is internal network and intra-firm network, given the studies of Rudberg and Olhager (2003).

Besides understanding the characteristics of a network, it is necessary to know the driving forces of the formation of networks. According to Snow et al. (1992), there are many factors affecting the formation of networks. Globalization and technological change, as well as deregulation and changing work force demographics create a new competitive environment. These factors demand companies to be simultaneously efficient and flexible. Global competition and deregulation require fully employed and flexible resources, driving out slack actors. Furthermore, computer-aided communications and other manufacturing advances facilitate the progress towards networks.

3.3. Lack of integration and interaction between IMNs and international R&D networks

Several studies give some clues about how to manage and organize such intra-firm R&D and manufacturing networks. Bartlett and Ghoshal (1989) indicate that subsidiaries differ in their tasks and capabilities and they classify three structures of companies operating globally: multinational companies, international companies and global companies. With reference to ***Figure 3.1***, each type of companies has its own characteristics and a comparison can be made between different ways of development and diffusion of knowledge. It can be found that the higher autonomy the subsidiaries have, the more decentralized the innovation activities. In the model of Ferdows (1997), a lead factory creates new processes, products, and technologies for the entire company. Deflorin et al. (2012) identify two general models of intra-firm networks, characterized by the knowledge transfer within the networks. (1) The first model is the lead factory concept: the lead factory is strategically important and serves as the intermediary of the network and it supports the R&D in the development of new products and processes and produces the prototype. Then, after the production of new products is stable, other production plants implement the processes developed by the lead factory and the R&D. (2) Archetype network structure: each plant works and interacts directly with R&D and is responsible for the products and production development. There is no intermediary between R&D and production plants.

Although there are some endeavors to address the connection and interaction between IMNs and international R&D networks, the existing studies generally do not offer a comprehensive and integrated framework for investigating the interactions between international manufacturing and R&D networks. In the following sections, research on IMNs and intentional R&D networks will be reviewed separately.

3.4. Current Research on IMNs

3.4.1. The emergence and evolution of the research on IMNs

The research on manufacturing networks stems from the operations management of a single plant (Rudberg and Olhager, 2003). Skinner (1969) discusses the configuration and organization of manufacturing operations within a well-defined factory. During the 1970s, the research on operations management continued Skinner's ideas and was dominated by issues such as "the focused factory" and "economies of scale" (Rudberg and Olhager, 2003). As the globalization of markets increased, the idea of economies of scale prevailed and products were manufactured at the home country and exported to international markets.

During the late 1970s and the early 1980s, more researchers found the need to manage not only the single facility but also multi-plant organizations. However, within the multi-plant structure, each plant was treated as a separate facility and there was no focus on networks (Rudberg and Olhager, 2003). In addition, manufacturing was still geographically concentrated while markets had become global.

Since the late 1980s, manufacturing has become more international because it is the single largest type of foreign direct investment (FDI) in most countries (Yip, 1989; Ferdows, 1997). Over the last 20 years, multinational corporations (MNCs) have attempted to build their geographically dispersed plants and coordinate them with a synergetic network (Ferdows, 1997; Shi and Gregory, 1998; Cheng et al., 2011). Research on operations management was extended from multi-plant to network.

As discussed above, single plant evolves to multi-plant and finally to IMN. The plant is viewed as the basic construct in a manufacturing network (Cheng, et al., 2011), so it is reasonable to review the literature on manufacturing networks from different level: plant level and network level. In this case, an in-depth understanding of IMNs can be gained.

3.4.2. Literature on Manufacturing Plant Level

3.4.2.1. Plant location decision

During the late 1970s and the early 1980s, research on manufacturing networks was mainly concerned with location decisions (Meijboom and Voordijk, 2003). For some plants, the choice was straightforward, selecting a cheapest site (Yang et al., 2011). More recent research indicated that making site selection decision only based on cost evaluation is not enough. Besides the cost element, the intangible and qualitative characteristics of a location should be examined and considered and therefore the strategic contribution of a location to the company can be identified (Cheng et al, 2015).

Following this logic, some research has focused on the factors influencing the location of a manufacturing facility (Ferdows, 1989,1997; Vereecke and Van Dierdonck, 2002). In Ferdows's model (1989, 1997), there are three strategic reasons for the site location: access to low cost production, access to skills and knowledge and proximity to market. Vereecke and Van Dierdonck (2002) basically use the same strategic reasons for plant location as Ferdows (1989,1997) and make some extension. And the location drivers identified are proximity to suppliers, availability of labor, availability of skills and know how, proximity to market, socio-political, competition, energy and other.

Feldmann and Olhager (2013) conclude that although there are other factors affecting site location decisions, it is commonly agreed that the three major factors are access to low-cost, access to skill and knowledge, and proximity to market that are introduced by Ferdows (1989, 1997).

3.4.2.2. Strategic plant roles

Plants are expected to play different roles in addition to low costs (Ferdows, 1989, 1997). Research on plant roles can be traced back to the focused factory concept proposed by Skinner (1974). Skinner (1974) defines a focused factory as a factory focusing on one strategic role and arranges its activities accordingly. Barlett and Ghoshal (1989) classify four different strategic roles of subsidiaries of MNCs based on two dimensions: importance of the local environment and capabilities of the subsidiaries itself. And the four roles are: the strategic leader, contributor, black hole and implementer.

Ferdows (1997) classifies six strategic roles of factories based on site competence and strategic reason for the site as shown in ***Figure 3. 5***. The three strategic reasons for locating a site are: access to low-cost production, access to skills and knowledge and proximity to market. Site competences evolve along a continuum from “assume responsibility for production (lowest competence)” to “become global hub for product or process knowledge (highest competence)”.

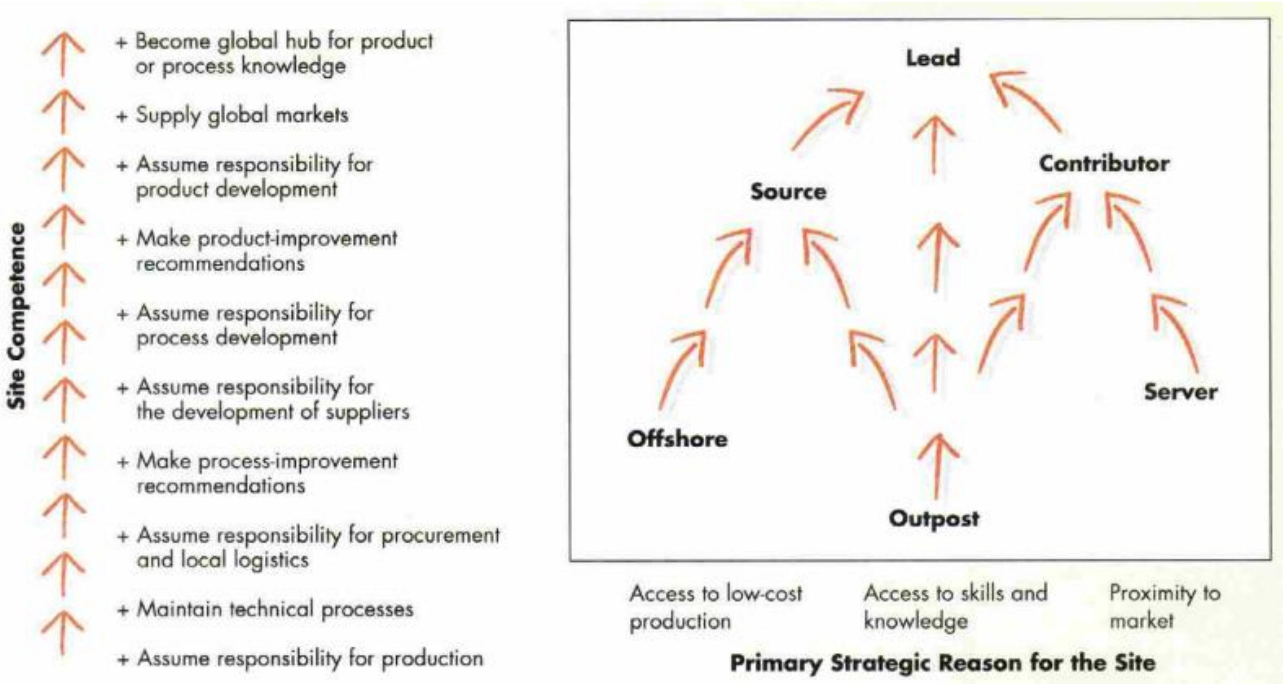

Figure 3. 5 – The strategic roles of plants (Ferdows, 1997b, p.79)

- An offshore plant is built to get access to low cost and its responsibilities are limited to the low-cost manufacturing of specific items. No innovation happens and such a factory depends on others to provide the knowledge in new products and processes.

- A source plant is also set to gain access to low-cost production. But it has the resources and the expertise to develop and produce a part or a product for the company's global markets.
- A server supplies specific national or regional markets.
- A contributor factory serves a local market and has the ability to product customization, product development or process improvement.
- An outpost is built mainly to sense the knowledge.
- A lead factory has the ability to innovate new products, processes and technologies for the company.

Ferdows (1997) also indicates that with the changing markets and competition, a factory's role is not static. Basically, the role of foreign factories should be upgraded following the path marked in ***Figure 3. 5***. Sometimes, a factory can also keep its current role, move horizontally across the matrix (from source to contributor, for example), move down the matrix, or if a factory is already at the bottom of the matrix, be closed.

Many other scholars use Ferdows's model as the basis and do some extended research (Vereecke and Van Dierdonck, 2002; Meijboom and Voordijk, 2003; Meijboom and Vos, 2004; Feldmann and Olhager, 2013).

Vereecke and Van Dierdonck (2002) discuss and test Ferdows's model on a sample of plants that disperse globally and they find that their empirical data supports Ferdows's model in most of its aspects. However, they also find that Ferdows's typology is only useful for describing the role of the plants in the existing manufacturing network and it cannot be used to describe the plants that may be added to the network. Also, not only the plants with the location advantage of skills and knowledge but also the plants with the advantage of proximity to market can play the role of the "center of excellence". Finally, the research indicates that the headquarter and the plant management may perceive the plants' strategic role in a different way.

Meijboom and Voordijk (2003) use Ferdows's strategic role model to assess internal motives for certain production and distribution staying in Western Europe. Also, they introduce external location factors including stage in the product life-cycle, technology integrated in the firm's product, responsiveness within the region of the market and transportation considerations. Both internal motives and external factors affect the location decision. Meijboom and Vos (2004) upgrade Ferdows's model of strategic plant roles and make a clear definition and more precise operationalization of "site competence". This work results in an instrument that can be used to measure the dynamics in the role of plants in international manufacturing networks. In their four case studies, they find that two of these plants have low cost as the primary location advantage and the other two factories have proximity to market as the primary location advantage. They also find that low cost plants show a slow rate of progression with respect to site competence while the plants close to market stay more or less the same.

Feldmann and Olhager (2013) group the site competences introduced by Ferdows (1997) into three bundles based on three themes: production (production, maintenance and process improvement), supply chain (logistics, supplier development and purchasing), and development (product development and the introduction of new product and new process technologies). Furthermore, plants are classified into three types: those with only production responsibilities, those with production and supply chain responsibilities and those with all the responsibilities within the three themes. The authors suggest site competences should be managed according to theme and each theme includes several competences. The research finds no clear relationship between site competence and site location factors. Finally, the level of site competence affects three of eight performance indicators which are cost efficiency, quality and the rate of new product introduction. The higher of the site competence, the better of the performance.

Besides the research that treats Ferdows' model as a springboard, other typologies of factories are also introduced from other perspectives. Vokurka and Davis (2004) conduct a survey to investigate the major dimensions that firms use to differentiate manufacturing plants and these dimensions' information can be used to allocate products, processes and customers/markets to individual manufacturing plants. Then, they identify three clusters of strategic manufacturing facility types: standardizers, customizers and automators. The authors find that there is no clear relationship between the strategic type of a facility and its performance. Vereecke et al. (2006) propose a new typology of plants in the international manufacturing network. This typology is based on the knowledge flows between the plants. Four types plants are identified: the isolated plants, the receivers, the hosting network players and the active network players. Different types of plants have a different strategic role, have a different focus, age, autonomy and level of resources and investments.

3.4.3. Literature on IMN level

Shi and Gregory (1998) define manufacturing networks as “a factory network with matrix connections, where each node affects the other nodes and hence cannot be managed in isolation”. The structural elements of such an IMN consist of factory's characteristics, geographic dispersion, horizontal coordination and vertical coordination. And the infrastructure elements include dynamic response mechanism, product life cycle and knowledge transfer in international manufacturing networks, operational mechanisms and dynamic capability building and network evolution (Shi and Gregory, 1998). Configuration can be considered as the structure of manufacturing networks, and coordination as infrastructure of manufacturing networks.

Hence, the literature concerning manufacturing network level issues can be typically categorized into two types: those concerning configuration, which addresses the globally dispersed manufacturing network design, and those related to coordination, which addresses infrastructural links between factories (Colotla et al., 2003; Rudberg and Olhager, 2003; Cheng et al., 2015). Besides these two dimensions, our literature review also includes the literature concerning manufacturing strategy and IMN capability.

3.4.3.1. IMN Competitive Strategy

Shi and Gregory (1998) state that lack of global vision and appropriate strategies during the globalization is the major barrier to the international operations management. Setting up a correct manufacturing network strategy is important for the success for an international manufacturing company. Manufacturing strategy is one of the functional strategies in a hierarchy of industrial, corporate, business, and functional strategies (Miltenburg, 2009). Friedli et al (2014) differentiate between manufacturing strategy and network strategy.

1) Manufacturing strategy

Manufacturing strategy determines in which aspects a company can differ from its competitors, and provides the manufacturing objectives. There are mainly four differentiating factors in the manufacturing strategy: cost, quality, ability to supply and flexibility. A company should make trade-offs between these differentiating factors by evaluating them in terms of its importance to the company. According to Hill (2009), these factors can be categorized into three groups: unimportant, order qualifiers and order winners.

2) Network strategy

Besides the differentiating factors in the manufacturing strategy, network competencies resulting from the global dispersed activities can be summarized under the term network strategy. Friedli et al (2014) summarize five differentiating factors of network strategy. They are access to markets, access to resources, efficiency, mobility and learning. And each factor can be further subdivided into several factors as shown in ***Table 3. 2***.

As discussed above, Bartlett and Ghoshal (1998) identify three strategies of globally operating companies: global efficiency (global companies), national responsiveness (multinational companies), and worldwide learning (international companies). Friedli et al. (2014)[1] show four ideal network strategies in practice: market-based network strategy, competence & resources-based network strategy and efficiency-based network strategy.

Table 3. 2 - Differentiating factors of network strategy (Friedli et al., 2014, p. 73)

Access to markets	Access to resources	Efficiency	Mobility	Learning
Access to markets and customers (e.g. local product adaptation)	Access to suppliers/raw material (e.g. cheap suppliers)	Economies of scale (e.g. by bundling of production volumes of identical products)	Mobility of products, process and personnel	External learning (e.g. markets, customers etc.)
Access to competitors (e.g. diminishing local competition)	Access to specialists (e.g. engineers)	Economies of scope (e.g. by bundling of production volumes of different products)	Mobility of production volumes	Internal learning (e.g. products, processes, best practices etc.)
Access to socio-political factors (e.g. taxes etc.)	Access to cheap labor (e.g. low-wage countries)	Avoiding redundancies (e.g. by concentrating of business process)		
Access to image factors (e.g. made in …)	Access to external sources of knowledge (e.g. universities)			

[1] The original source is Thomas, Stefan. Produktionsnetzwerksysteme. Ein Weg zu effizienten Produktionsnetzwerken. Diss. Dissertation, University of St. Gallen, 2013.

1) Market-based network strategy

The strategic aim of this network is to be active in every relevant market. Companies using this strategy gain competitive advantage via proximity to markets, and adapting their products to suit local requirements.

2) Competence & resources-based network strategy

This strategy aims at making the best use of the worldwide resources such as labor costs, knowledge (e.g. universities or research institutions), suppliers and raw materials. And these resources are fully exploited through economies of scope and scale.

3) Efficiency-based network strategy

This strategy can be further subdivided into two strategies: local efficiency and global efficiency. Local efficiency strategy focuses on taking advantage of the economies of scope and scale. Redundancy in the network can be minimized by aggregating the worldwide activities in a selected number of sites. Global efficiency strategy focuses on the mobility of production and resources. Flexible resources allocation lets a company react quickly to the changing business environment, as well as make full use of global network resources.

Miltenburg (2009) classifies seven generic strategies for international manufacturing based on two dimensions: pressure for globalization and pressure for local responsiveness. The seven strategies are shown in ***Figure 3. 6.*** Pressure for globalization is the necessity for a company to operate on a worldwide basis. When the pressure is low, a company may operate only in its home country. When the pressure is medium, a company may partner, acquire or build operations in some countries. When the pressure is high, a company need to operate a worldwide network of manufacturing. Pressure for local responsiveness is the necessity for a company to adapt to local customers' requirements, employees and governments. When the pressure is low, a company can produce standard products. When the pressure is high, a company should disperse its activities and give its facilities autonomy in order to be responsive to the local requirements.

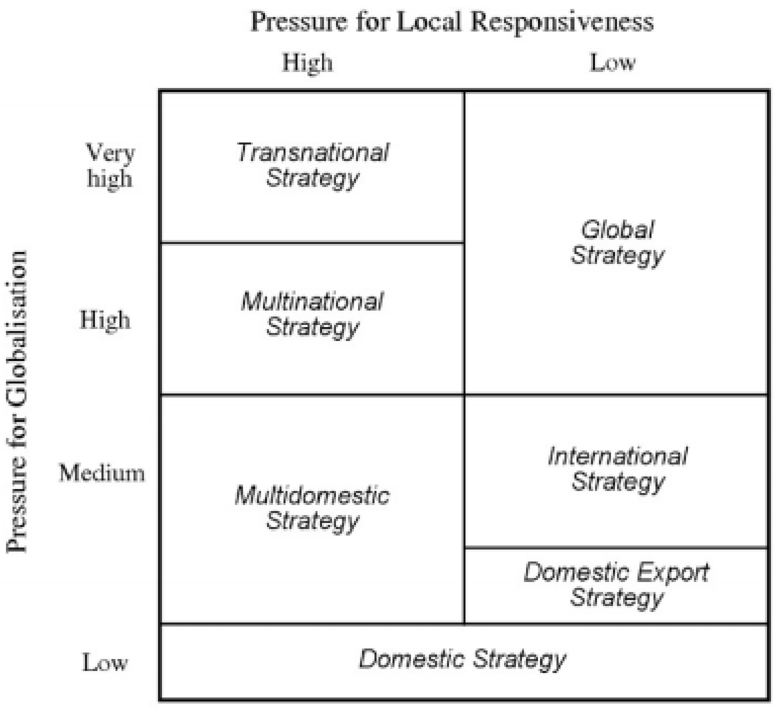

Figure 3. 6 – generic strategies for international manufacturing (Miltenburg, 2009, p.6184)

3.4.3.2. IMN Configuration

Configuration shows the location of plants and the inter-facility allocation of resources along the value chain (Meijboom and Vos, 1997). Geographic dispersion of the manufacturing network is driven by external forces and they include market opportunities and global competition (Shi and Gregory, 1998).

At the beginning, much research focused on identifying the drivers for allocating manufacturing facilities in specific locations (Ferdows, 1997; Meijboom and Vos, 1997). Recently, more researchers have recognized the importance of managing the manufacturing network as a whole, so study has been extended from plant location decisions to IMN configurations.

Shi and Gregory (1998) say that "configuration provides a better way of concisely representing a complex organization and an approach forming an integrated view". They propose seven configurations of IMNs based on two dimensions: degree of plants dispersion and coordination conditions within the networks. Plants dispersion evolves along the range of options from domestic manufacture to worldwide manufacture. **Domestic** means that all manufacture is concentrated in the home country and serves both home country and foreign markets. **Regional** means that all manufacture is carried out in geographic region which sharing similar culture value. **Multinational** approaches set up plants in several countries where there are social and cultural differences. **Worldwide** is the maximum of multinational approaches, and manufacturing operates around the world. As for coordination approaches, there are two types. One is the multidomestic-oriented approach characterized by manufacturing system adapted to the local market and having autonomy. In this approach, factories are independent with each other and therefore coordination is weak. Another approach is global-oriented which means integration and coordination is high. The seven configurations of IMNs are listed in ***Table 3. 3.***

Furthermore, Shi and Gregory (1998) group these seven configurations into four blocks, in terms of Regional Focus Networks, Global Export Networks, Multi-domestic Autonomy Networks, and Global Coordination Networks, and ***Figure 3. 7*** shows this IMN configurations map. This configurations map indicates the relationship between the configurations and the transformation of the networks. It is clear that many companies evolve towards more global configurations.

Kulkarni et al. (2004) describe two IMN configurations: product plant network and process plant network. They find that process plant networks offer risk pooling advantages under a wide range of conditions and conclude that firms may prefer the process plant network configuration because of the risk pooling benefits.

Table 3. 3 - Classification of IMNs configurations (Shi and Gregory, 1998, p.203)

The degree of plants dispersion	Coordination conditions	
	Multidomestic-oriented approaches	Global-oriented approaches
Worldwide	MMC3: Glocalised Manufacturing Configuration. Glocalisation means global localization, which is the maximum of multinationalization. This strategy is strong market and local management resource oriented and autonomy focused. The competitive advantage could be generated from taking full advantage of local resources, especially national characteristics to have real adaptability in terms of quick responsiveness and special service, and network synergy, in terms of product R&D, capability and culture fusion from the autonomy.	GMC4: Global-Coordinated Manufacturing Configuration. It manufacturing is dispersed worldwide with homogeneous strategy-separated facilities and shared products, technology and operation mechanism. The configuration includes global product and standardized process and managerial mechanisms. The network disperses its nodes globally to access the markets. McDonald and KFC could be examples. When companies focus more on its core competence and adopts advances manufacturing technology, the factory could be more integrated and easier to be distributed in this kind of configuration.
Multinational	MMC2: Multidomestic Manufacturing Configuration. Its plants disperse in some or lots of countries with no or weak linkage. The network is designed for accessing corporate strategic points including markets and/or production factors. Basically, the plants have more autonomy in product, process and management. In many cases of merge and acquisition, the companies have this type of configuration if they don't adopt a coordinated strategy to transform the network.	GMC3: Global-Integrated Manufacturing Configuration. The corporate value adding chains (VACs) or supply chains are dispersed in many countries to access to the most optimized resources, markets and strategic capabilities according to the corporate strategic intentions. Contrast to GMC4 integrating its VAC in a factory, this configuration distributes VAC vertically and centralizes each stages of process to reduce the duplication of manufacturing facilities. Coke Cola production network can be an example
Regional	MMC1: Regional Uncoordinated Manufacturing Configuration. Its international manufacturing disperses centrally in only one region (Europe, Far East…) and the plants are tailored to the local markets. There is no coordination between the plants. As the culture is very similar in the region, there is no big problem for manufacturing transfer.	GMC2: Regional Exporting Manufacturing Configuration. Its international manufacturing is focused in a region but its products could reach the global market based on its regional coordinated manufacturing network in the region and global product development.
Domestic	It does not belong to the international manufacturing networks since it has no transnational manufacturing operations	GMC1: Home Exporting Manufacturing configuration. It centralizes manufacturing in home country but has a global logistics system. Its products lines could cover the global market.

Hayes et al. (2005) suggest four network configurations: horizontal network (product-focused network), vertical network (process-focused network), mixed network, and "orchestrated" network (collaborative network with one major hub), and indicate that different structures have different strengths and weaknesses, and these types of networks cannot do everything equally well.

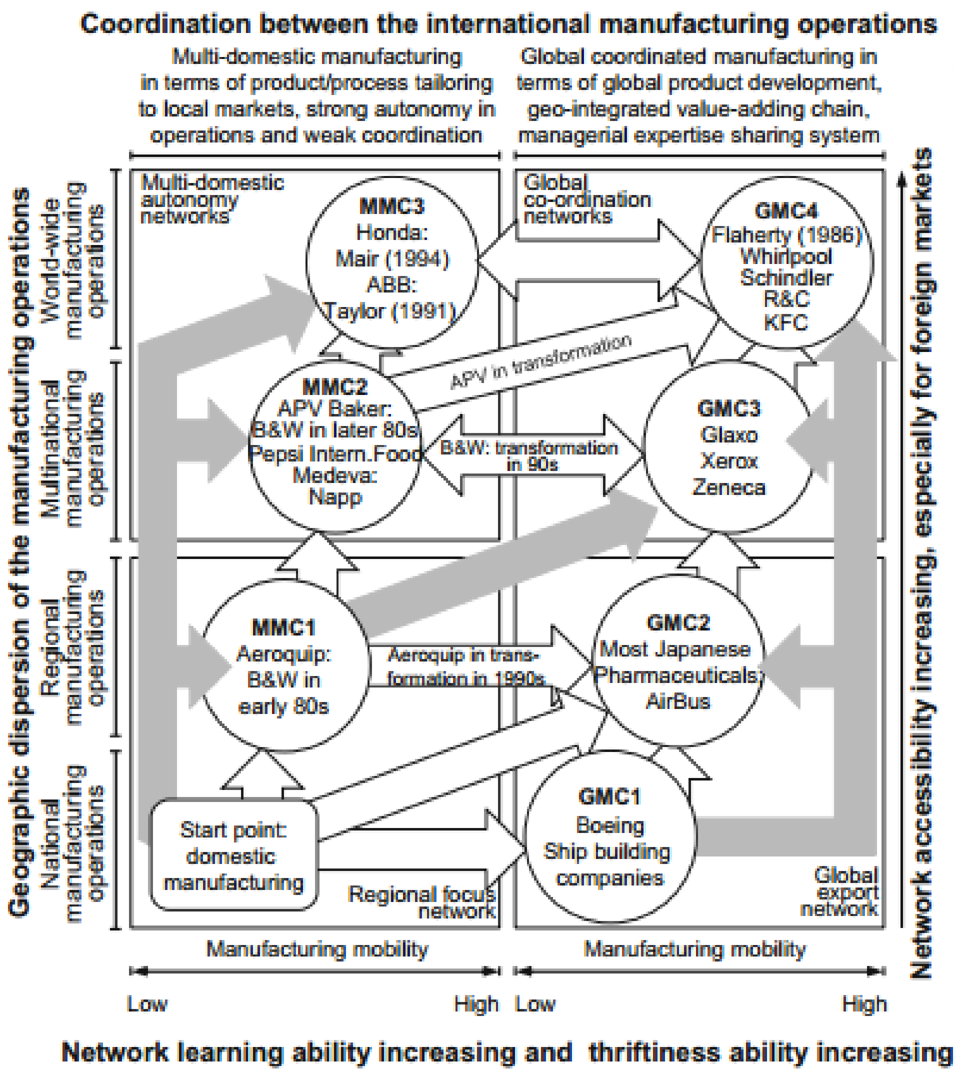

Figure 3. 7 - Map of IMNs configurations (Shi and Gregory, 1998, p.211)

Ferdows (2008) propose two types of manufacturing networks, one is footloose manufacturing network which is continuing looking for a better factory and moving production there as soon as the factory is found; another is rooted manufacturing network, which is making long term commitment to each production site and giving it the resource to reach its full potential. Ferdows also suggests a simple framework to help decide how to choose the right long term strategy. And this framework shows a footloose model is suitable only when the product is turning into a commodity and the processes used for its production and delivery are becoming more standardized and widely available.

Miltenburg (2009) extends the study of Shi and Gregory (1998) and proposes a framework to design the configuration of an IMN. The author identifies seven generic strategies for international manufacturing as discussed above. Based on these strategies, nine manufacturing networks configurations are proposed and each strategy has its corresponding manufacturing network configuration, except global strategy where three networks configurations are used. There networks configurations are domestic, domestic export, international, multidomestic, multinational, global product, global function, global mixed, and transnational. Within these networks configurations, domestic, domestic export, international, and multidomestic are simple networks; multinational, global product, global function, global mixed and transnational are complex networks.

Friedli et al (2014) conclude four decision dimensions of international manufacturing networks configuration: the network structure, the specialization of the network and sites, the distribution of resources in terms of technology and investment and the internal supply chain.

1) The network structure

This dimension decides the geographic distribution of sites and the distribution of capabilities within the network. Geographic distribution of sites addresses how many sites does a network need and where should these sites be located. Following this decision dimension, the decision about the distribution of capabilities within the network should be made.

2) Specialization

This decision dimension addresses the questions concerning which products should be produced at each site, which market should be served. And specialization can be further divided into network specialization and site specialization.

***Network specialization*:** Schmenner (1982) develops four multiplant manufacturing strategies: product oriented strategy, the market-oriented strategy, the process-oriented strategy and the flexible-oriented strategy.

***Site specialization*:** This dimension level decides site roles defining further specialization in the network. Site roles have already been discussed in section 3.4.2.2.

3) Resources

This decision dimension covers two elements: the sites' manufacturing facilities (technology) and the allocation of finances (investments).

Technology**:** Manufacturing technologies concern the product mixture and the level of manufacturing automation. The product mixture can be evaluated by: (1) low volume, individual production; (2) low volume, high variety; (3) high volume, few products and (4) high volume, standard products. The level of automation is based on the product mixture and on the wage levels at the site.

Investments**:** The decision dimension investments determine which technology the network invests in. There are two basic investment strategies: the copy/paste strategy and the localization strategy. The cost/copy strategy requires that identical technologies and manufacturing facilities are installed at all sites. The localization strategy requires that each site has suitable technologies and facilities.

4) The internal supply chain

This decision dimension is related to internal links between sites. And there are two types of structures: horizontal structure and vertical structure. The choice of structure for the internal supply chain has considerable influence on the interactions between sites. In horizontal structure, a site produces the complete products, while in vertical structure, the production process is spread across a number of sites.

3.4.3.3. IMN Coordination

Coordination between dispersed factories is another key feature of manufacturing networks. Rudberg and Olhager (2003) indicate that coordination issues in manufacturing networks is mainly concerned with technology transfer and diffusion as well as within network learning.

Shi and Gregory (1998) identify two different coordination conditions in IMNs. One is multi-domestic oriented strategy, with weak coordination. Another is global-oriented strategy, involving closely coordination of dispersed manufacturing facilities and integration of product and process development.

Rudberg and West (2008) indicate that to facilitate the smooth coordination, companies typically develop common policies regarding manufacturing structure and infrastructure. The authors study a model factory for concept that describes how companies can manage their international operations so as to facilitate the coordination of their manufacturing networks. The concept is based on a model that was developed at Ericsson in the mid-1990s and focuses on the blending of cost competitive, flexibility and innovations.

Deflorin et al. (2012) research on the transfer and diffusion of production technologies and knowledge among plants. The authors indicate that the lead factory concept benefits from an efficient knowledge transfer and also describe the conditions under which the lead factory concept is more profitable than the archetype network.

3.4.3.4. IMN Capability

The capability of a firm is to renew, augment, and adapt its for competencies over time (Shi and Gregory, 1998). Colotla et al. (2003) define capabilities as a result of complex patterns of interactions and coordination between resources. Furthermore, core capabilities are thought of as those linked to the firm's competitive strategy.

Bartlett and Ghoshal (1998) study the strategic capabilities in global, multinational and international companies. For global companies, the strategic capability is building cost advantages through centralized global-scale operations; for multinational companies, the strategic capability is building strong local presence through sensitivity and responsiveness to local differences; for international companies, the strategic capability is exploiting parent company knowledge through worldwide diffusion and adaptation.

Shi and Gregory (1998) present the strategic capabilities of the IMNs and they are accessibility, thriftiness, learning and mobility. Accessibility and thriftiness are more derived from configurations of IMN while learning and mobility are more related to coordination.

1) Strategic targets accessibility: mainly derived from dispersion of the network

- Strategic markets: beating trade barriers, closing to the customers
- Production factors: labor, material, product and process technology
- Managerial skills
- More sensitive to global changes

2) Thriftiness ability: mainly derived from coordination of the network

- Economy of scale
- Economy of scope
- Reducing duplication of activities

3) Manufacturing mobility

- Product/process mobility
- Managerial skill mobility
- Factory manufacturing flexibility
- Network manufacturing flexibility

4) Learning ability

- Special learning opportunities: wider internal and external comparison, exchange
- National capability integration: culture fusion, learning and tapping the special national strengths
- Global product integration: learn from the worldwide market demands and abstract core requirements for development of world product

Colotla et al. (2003) study capabilities from both factory level and network level and the authors propose a framework to explore the interdependencies between factory and network capabilities. They conclude that the interdependencies may be established if factory and network capabilities affect the same dimensions of performance such as cost, quality, speed, flexibility, innovation and etc. And competitive advantage of companies can be achieved through well aligned factory and network capabilities.

Miltenburg (2009) classify four levels of capability of an IMN: infant level, industry average level, adult level and world class level. A company can assess the capability level of the IMN by benchmarking against the network levers and the networks of other companies.

3.5. Current Research on International R&D Networks

This chapter introduces the current research on international R&D networks. And these research is divided into R&D site level and international R&D networks level.

3.5.1. Introduction of R&D

There are several definitions about R&D. Some people defines R&D as a whole. For example, according to OECD (1996), “R&D is generally defined as comprising creative work undertaking systematically to increase the stock of knowledge and the use of this knowledge in order to devise new and improved products, processes, applications and services that fill market needs.”

While, Medcof (1997) makes a different definition system. He defines “R” and “D” separately. “Research is the discovery of new scientific knowledge which has the potential to act as a platform for the subsequent development of commercially viable products and manufacturing processes.” And he explains that “Development is the creation of new products and processes which have commercial value, through the application of currently available platforms of scientific knowledge.”

Figure 3. 8 is structured from Medcof (1997), which shows the connection among Research, Development and Support.

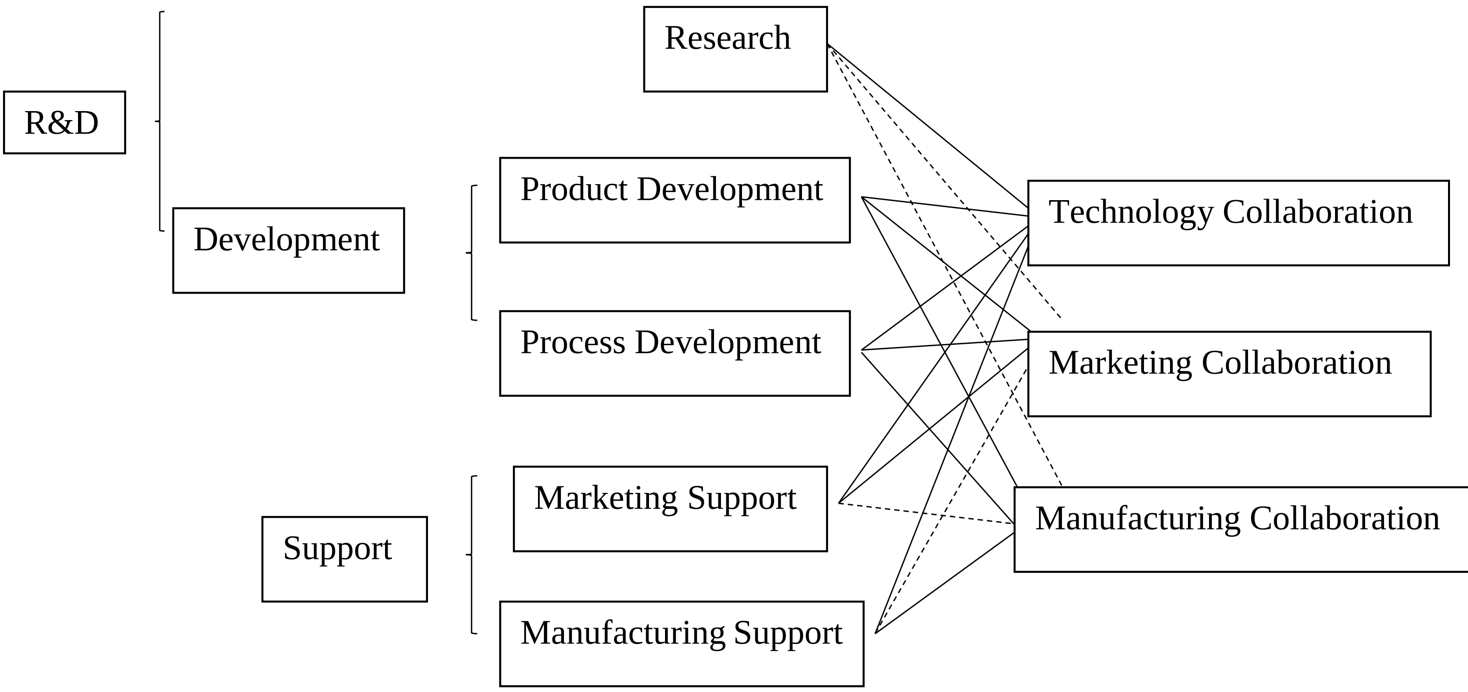

Figure 3. 8 – Connection among Research, Development, and Support (adapted from (Medcof, 1997))

Support is divided into Market support and Manufacturing support. Marketing support here is “The adaptation of already established product technology to the needs of particular customers and/or the helping of customers to use those applications (Medcof, 1997).” And Manufacturing support here is “The adaptation of already established process technology to some particular condition (Medcof, 1997).” Solid lines represent strong collaboration between them, while dash lines mean that there is short of significant collaboration between them (Medcof, 1997).

As for the relation between engineering and R&D, plenty of the researchers use the terms engineering and R&D interchangeably, but some of them believe engineering refers to ‘D’ (development) rather than ‘R’ (pure research) (Von

Zedtwitz and Gassmann, 2002; Zhang, 2007). In other words, a small group of researchers clarify that engineering is not the same as R&D, but a part of it. On the contrary, lots of authors use two terms without differentiating them. And our thesis includes the large groups view, when writing the literature review, because some articles are helpful, even though they use R&D and engineering interchangeably.

3.5.2. Literature on R&D Site Level

This section focus on the individual sites level, summarizing the key factors when choose a new R&D site, also showing several types of strategic roles of R&D sites.

3.5.2.1. Site location decisions

Kuemmerle (1997) brings up two groups of R&D sites. They are Home-Base-Augmenting Laboratory site, and Home-Base-Exploiting Laboratory Site. Home-Base-Augmenting Laboratory site is for taking in the local knowledge, while Home-Base-Exploiting Laboratory Site is for spreading out that to local (in ***Figure 3. 9***). Generally, for knowledge immigrant, taking in requires more effort than spreading out. Apart from knowledge information, there are also market and production information flows in the network. However, they are transferred in opposite direction of knowledge information.

The choice of location is based on distinct purpose. More specifically, the choice Home-Base-Augmenting Laboratory site is out of scientific convenience purpose, while the choice of Home-Base-Exploiting Laboratory Site is because its location near the company's production facilities and foreign markets (Kuemmerle, 1997).

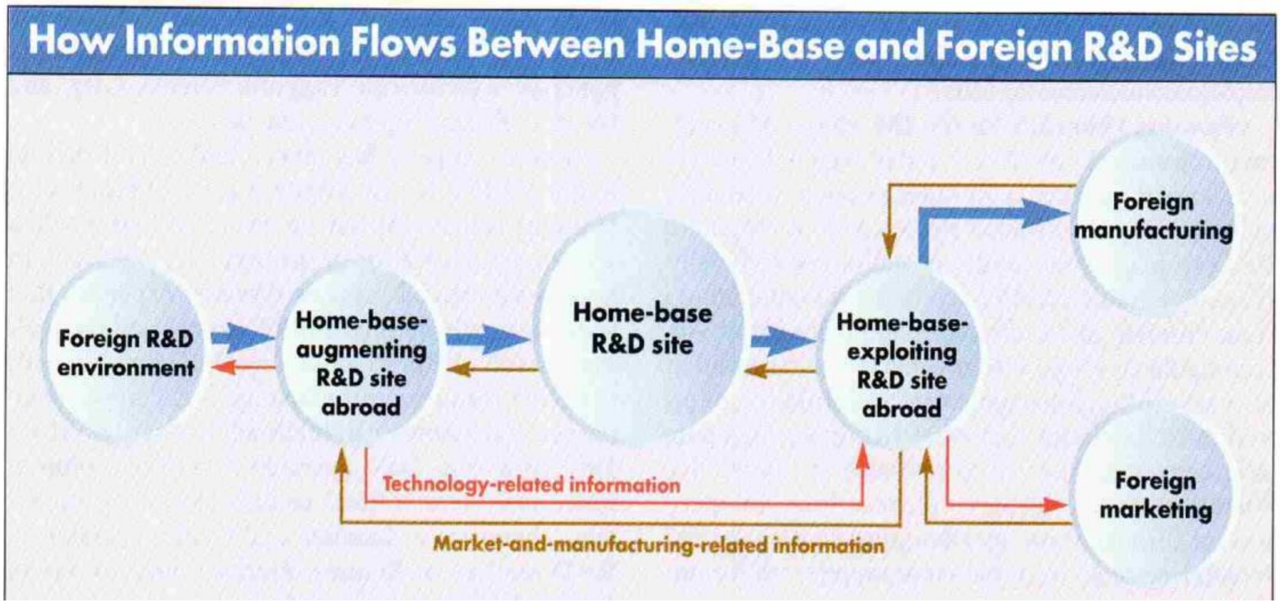

Figure 3. 9 - How Information Flows between home-base and foreign R&D Sites (Kuemmerle, 1997, p.64)

Besides that, Sachwald (2008) clarifies main determinant factors of the foreign R&D location choice. First, he divides R&D units into three types, which are shown below in ***Table 3. 4***.

Table 3. 4 - Determinants of the location of foreign R&D units, by type (adapted from Sachwald (2008))

Type of R&D units	**Another classification of R&D units**	**Determinant factors of location choices**
Local development center	Home-Base-Exploiting R&D sites	Market driven
Global research laboratory	Home-Base-Augmenting R&D sites	Technology driven
Global development center	/	Cost driven

This table is summarized from Sachwald (2008). The left column are three types of R&D units, and the right column are the main determinant factors of the location choice of corresponding type of R&D units. The middle column is the classification from Kuemmerle (1997), which in mention above in ***Figure 3. 9***.

1) Local development center

Local development centers are home-Base-Exploiting R&D sites, which provides scientific environment to train the related employers. And the main reason of its location decision is accessing to large local market.

2) Global research lab

Global research labs are home-Base-Augmenting R&D sites, which is technology and industrial relationship driven.

3) Global development center

Global development centers are neither home-Base-Exploiting R&D sites nor home-Base-Augmenting R&D sites. Development center are dispersed abroad, which benefits from low cost R&D activities and high efficiency in local sites.

Besides above Sachwald's (2008) classification of R&D sites, there are another classification from Chiesa (1996) introduced below. And they are support labs, exploitation labs, and experimentation labs. The strategic role of them are explained in the next section.

3.5.2.2. Strategic Roles of R&D sites

Chiesa (1996) comes up with three groups of foreign R&D units at different corporate levels, shown in ***Table 3. 5***.

Table 3. 5 – Three categories of foreign R&D units (adapted from (Chiesa, 1996))

Labs	**Support Labs**	**Exploitation Labs**	**Experimentation Labs**
Level	Operation	Business unit	Strategic
Project length	Short	1-3 years	>3 years
Task	Technical support, and Adapt to domestic market	Strong focus on one thing about innovation	Exploring a wide range of technologies
Range	Views on local	Cross national	Views on global

The three categories of foreign R&D units are Support Labs, Exploitation labs, Experimentation labs. ***Table 3. 5*** illustrates their level and range in a company's global R&D strategy. They are arranged from lower level to higher level, from short project length to long project length, and from local view to global view.

Besides that, the table also suggests that the tasks of each labs are its strategic roles. Two tasks of Support Labs are explained respectively. "Technical support" is offered to other foreign companies, and "adapt to domestic market" is localization. (Chiesa, 1996) Exploitation Labs is to concentrate on certain innovation. While experimentation Labs is to explore global technologies.

3.5.3. Literature on International R&D Networks level

This section introduces literature related to competitive strategy, configuration, capability and evolution of international R&D Network.

3.5.3.1. International R&D networks competitive strategy

International R&D networks have been proposed as the strategy to support markets or to access technologies on a global scale (Zhang et al., 2007). According to Zhang et al. (2007), there are three key patterns of the current international R&D networks and each pattern has its own orientation and competitive advantage.

1) **Efficient international R&D networks**
   The aim is to make R&D operations more efficient. So, it is necessary to be better in integration and synergizing. The interdependent and integrated centers are generally centralized.
2) **Flexible international R&D networks**
   The main objective is strategic flexibility. And that mainly develops on market adaptation. The autonomous and independent centers are globally dispersed, with specific help for various markets.
3) **Innovative international R&D networks**
   The main task is effective product development, which focus on innovation and learning. The configurations of these networks are neither absolutely centralized nor dispersed.

3.5.3.2. International R&D networks Configuration

The section consists of two parts:

I. Comparisons between decentralization and centralization of R&D Networks
II. Organizational structure of internationalized R&D Networks

Comparisons between decentralization and centralization of R&D Networks

Generally, the structure of R&D network could be divided into two groups, which are decentralization and centralization.

Gassmann and Von Zedtwitz (1998) summarize several reasons to centralize the R&D, from Behrmann and Fischer (1980), De Meyer and Mizushima (1989), Coombs and Richards (1993), Carnegie Bosch Institute (1994). von Boehmer et al. (1992). Bedmann and Fischer (1994). Gassmann and von Zedtwitz (1996).

- Economies of scale
- Synergy effects
- Optimal career planning
- Minimal R&D costs and development time
- No case of 'not-invented-here' Syndrome
- Allocation of technological competence to SBU is simple
- Better control over basic research results
- Common R&D culture

Pearce (1999) compares decentralized labs and centralized labs of multinational organization in several perspectives. Below are a ***Table 3. 6*** to demonstrate some distinctions between them. The decentralized networks are lack of strong connections, while the connection among the centralized networks are so strong that constrain independent creativity of each labs. The conclusion of Pearce’s article (1999) emphasizes the importance of decentralized networks to build strategic competitiveness. And in terms of the ideal relationships among R&D networks, it is interdependent and specialized that could reach a balance between weak and strong connections.

Reger (2004) believes the global decentralized structure of R&D networks is one of the reasons that Philips’s success. He also believes decentralization is much better than centralization, which might be true in certain industry.

However, Dunning and Lundan (2009) said "There are powerful reasons favoring both the centralization and decentralization of R&D."

Table 3. 6 – Summary of Decentralized R&D and strategic competitiveness (adapted from (Pearce, 1999))

Overseas R&D	**Decentralized Networks**	**Centralized Networks**
Type of enterprise	Multinational	
Structure of organization	Parallel hierarchy	Hierarchical
Strategic competitiveness	Product development	Core technology
Strategic term	Medium term	Long term
Force orientation	Centrifugal force	Centripetal force
Emerge Time	Nowadays	Traditional
Individual Position	Independent	Dependent
Distribution	Dispersed	Aggregated
Relationships among R&D networks	Connected	Instructive
Disadvantage	Lack strong connections	Restrain independent creativity
Ideal relationships among R&D networks	Interdependent, specialized	

Based on above discussions, which structure is better to use is still debatable. Decision makers should make the choices, according to their company's current situation and future planning. Both decentralized or centralized have its own pros and cons. Also, could make an impact on financial performance if use properly.

Organizational structure of internationalized R&D Networks

Nohria & Ghoshal (1997) divides R&D networks into four classes, according to various contributions to the company.

1) ***Local for Local Networks***
   Within a country, a subsidiary company puts innovation into head office.
2) ***Local for Global Networks***
   Transfer the local innovative findings to several foreign markets.
   Another name for these networks is “locally-leveraged networks”.
3) ***Center for Global Networks***
   Research Center invents new method (process, product) that could be used in the markets all over the world. These networks are traditional view of R&D networks.
4) ***Global for Global Networks***
   Buffer from dispersed R&D sites to work out the problem that happens globally. These networks also called “globally-linked networks”

Also, in Von Zedtwitz and Gassmann (2002)'s model, R&D networks are grouped into four types. Generally, Research and development are often integrated together when discussing them in R&D networks. Below in ***Figure 3. 10***, "R" and "D" are treated separately. This model not only includes all the situaitons in Nohria & Ghoshal's (1997) classification of R&D networks mentioned above, but add a new category, which is called a technology-driven R&D network.

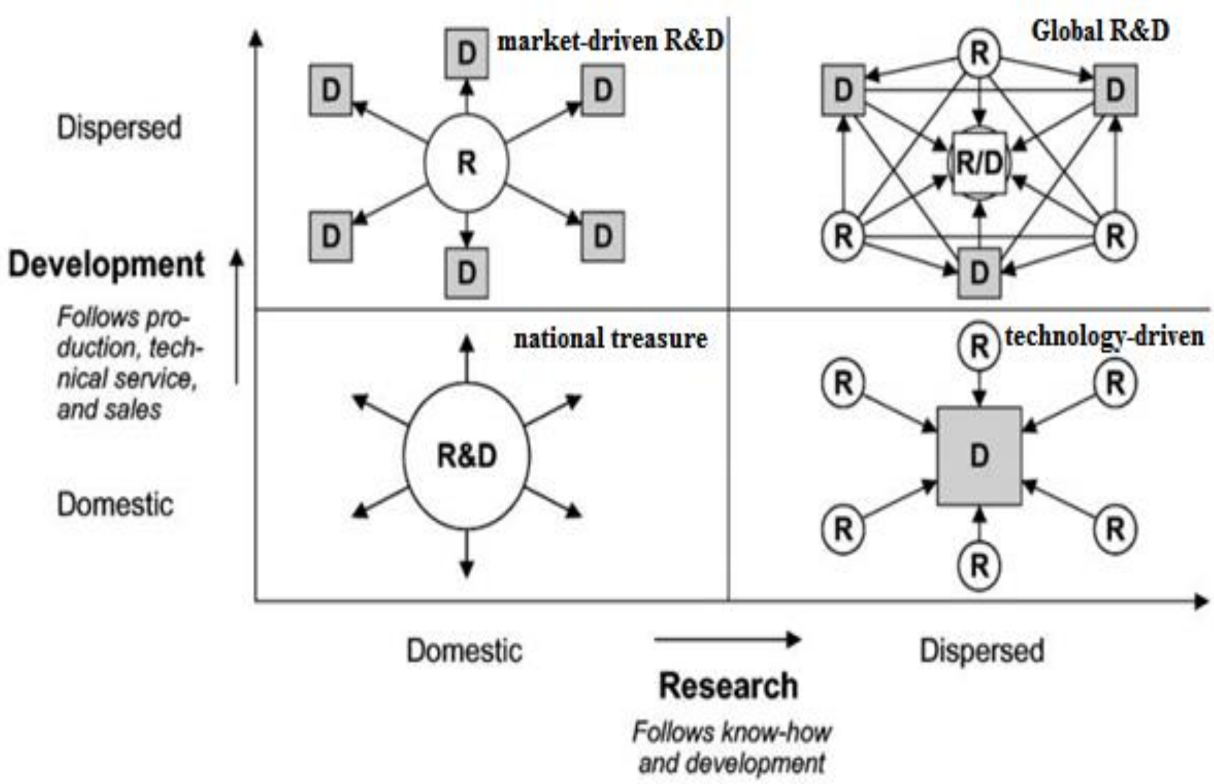

Figure 3. 10 - Organizational structures of internationalized R&D (adapted from (Von Zedtwitz and Gassmann, 2002, p.575))

The horizontal dimensions are distribution density of research, and vertical dimensions are that of development. Four types of R&D networks are explained respectively below:

1) **National treasure R&D Networks**
   - National treasure R&D Networks chases for local resources in both research and development. And all are integrated together into a big party.
   - National treasure R&D Networks are corresponding to ***Local for Local Networks*** and ***Local for Global Networks***.

2) **Market-driven R&D Networks**

- Market-driven R&D Networks looks for opportunity in local research and foreign development. The research is in the center, and development sites are dispersed outside around a strong local research center.
- Market-driven R&D Networks are similar to ***Center for Global Networks***.

3) **Technology-driven R&D Networks**
   - Technology-driven R&D Networks aims at research abroad and development locally. The determinant development function is in the center with a group of small dispersed research sites around it, which is on the contrary to the shape of Market-driven R&D.
   - Technology-driven R&D Networks are not in four classes of R&D networks of Nohria & Ghoshal (1997).

4) **Global R&D Networks**
   - Global R&D Networks goes outside of country not only in dispersed research but also in dispersed development. And this structure makes it into a complex and interdependent R&D Networks.
   - Global R&D Networks are corresponding to ***Global for Global Networks***.

3.5.3.3. International R&D Networks Coordination

Reger (1999) summarizes four forms of international R&D coordination mechanisms: Among them, structure mechanism and Informal mechanism are contrary to each other.

1) **Structural or formal mechanism**
   - Centralization and decentralization
   - Structural coordinating bodies
   - Programming and standard
   - Planning
   - Control.
2) **Informal mechanism**
   - Regular contacts
3) **Hybrid/overlaying mechanism**
   "Some of structure are neither above two mechanism, or a part of each, so they are put into a third group called, hybrid mechanism." Reger (1999) state "Hybrid mechanisms include task forces, interdisciplinary or

multifunctional project groups, cross-company strategic projects, core programmes and core projects, technology platforms, and promoters."

4) **Internal market**
   - Intercompany prices
   - Research about contract

And Reger (2004) also brings up a model of coordinating global research competence, which is shown in ***Figure 3. 11***. This model is built for case study of Philips's research competence, including the discussion of structure of decentralization configuration.

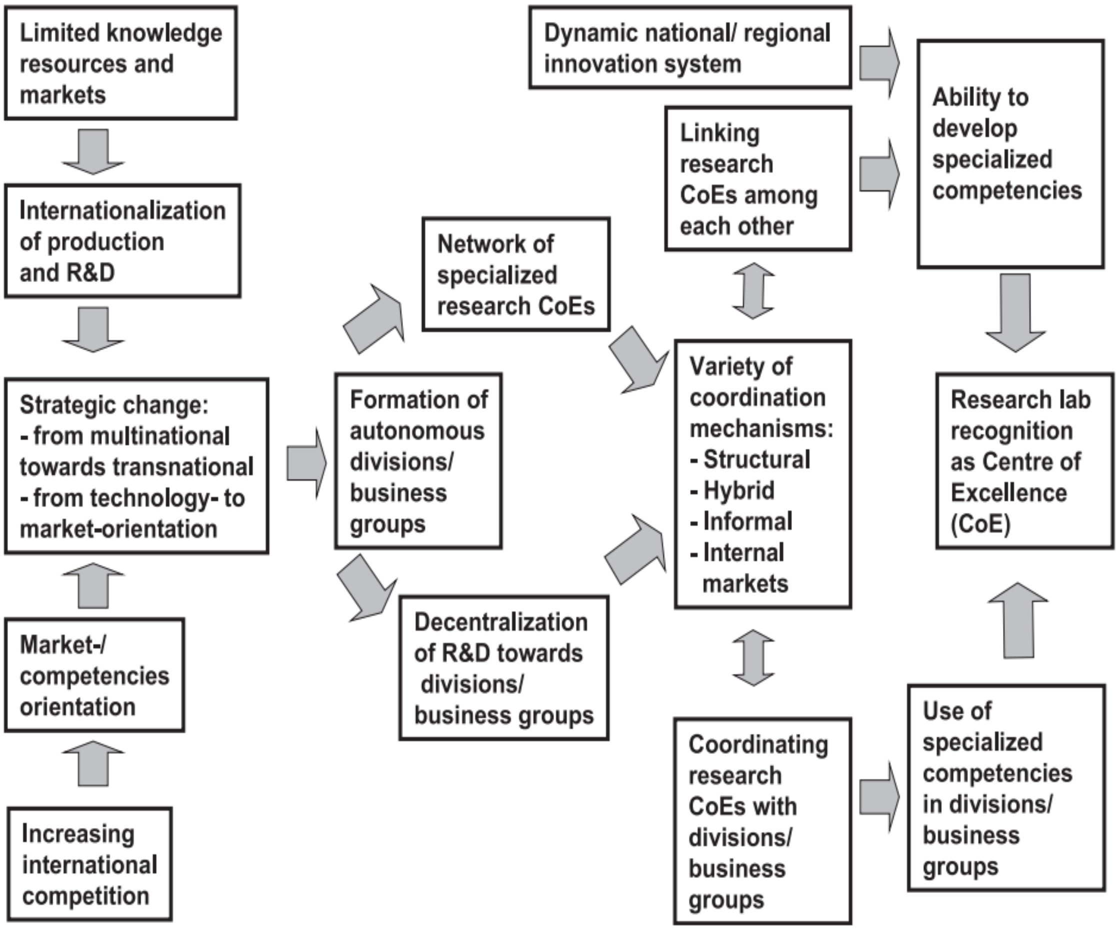

Figure 3. 11 - Coordinating global research competence (Reger, 2004, p.72)

And in this coordinating model, all the steps are based on the Philips' global decentralization structure of R&D network. And there are three sorts of coordination according to their geographic range, which are coordination within several worldwide R&D centers owned by Philips, coordination within outsourced autonomous divisions all over the world, and coordination between global centers and divisions. New findings will transfer to global centers first to be recognized or certificated. If approved, then spread out to each related division to learn. (Reger, 2004)

3.5.3.4. International R&D Networks Capability

Bartlett and Ghoshal (1989) do a research about international organizations, saying that there exits three kind of capabilities in worldwide learning, and multinational flexibility global efficiency. Shi and Gregory (1998) clarify network capabilities are the its functions or potentials where some helpful activities could be developed. The key dimensions, which they introduced here for network capability, are strategic accessibility, thriftiness, manufacturing mobility, and learning ability.

Subsequently, Zhang et al. (2007) group the international R&D capabilities into four dimensions:

1) **Communication and sharing**
   Communication and sharing is to gain access to dispersed R&D resources. Key issues are "accessing dispersed resources; effective communication across locations, languages, cultures, time zones, and organizations; collaboration with internal/external partners; social networks of engineers; knowledge sharing and reuse; and identifying and transferring best practice."

2) **Integration and synergizing**
   Integration and synergizing is to coordinate R&D activities for global efficiency. Key issues are "common working procedures; joint problem solving; integration along product lifecycle; international operations synergies; and well-developed standards; quality focus."

3) **Innovation and learning**
   Innovation and learning is to hold and spread technology or knowledge.
   Key issues are "leaving room for creativity/differentiation; learning across disciplines/businesses; capturing the knowledge of key individuals; customer-focus and market/technology intimacy; systematic IP protection; continuous improvement."

4) **Adaptation and restructuring**
   Adaptation and restructuring is to reconfigure R&D resource for local demand.
   Key issues are "strategic off-shoring/out-sourcing; flexible operating approaches; full range of global leading competencies; working with

customers and human centric; working around the clock and the globe; rigorous risk management."

Zhang et al. (2007) also bring up a capability maturity matrix framework (seen in ***Figure 3. 12***), including four dimensions above, and each of dimension has four levels of maturity, from initial capability (Level I), repeatable capability (Level II), managed capability (III), to optimizing capability (Level IV).

	Level I	Level II	Level III	Level IV
Communication and sharing: accessing and linking dispersed engineering resources	Isolated resources	Separating when projects complete	Exchanging resources regularly	Interdependent centres
Integration and synergizing: coordinating engineering operations for global efficiency	Standalone centres	Initiatives of global project	Regional or divisional coordination	International operations synergies
Innovation and learning: capturing and transferring internal and external knowledge	Re-inventing the wheel	Modularized solutions	Institutional learning	Innovation as a culture
Adaptation and restructuring: reconfiguring engineering resource for changes	Arbitrary decisions of key individuals	Established processes, but for reference	Effective processes across company	Self-optimizing

Figure 3. 12 - Capability maturity matrix for global engineering networks (Zhang et al. ,2007, p.1275)

Zhang et al. (2016) further classify the capabilities of international R&D networks into three areas: network resource, network coordination, and network learning.

4 Integrated Conceptual Framework

This chapter will present our three-layer integrated framework to describe the interactions between international R&D networks and IMNs.

4.1. Towards the three-layer integrated framework

After reviewing the current research on international R&D networks and IMNs as well as the globalization and networks related theories, a three-layer integrated framework is developed to study the interactions between international R&D networks and IMNs, as shown in ***Figure 4. 1***.

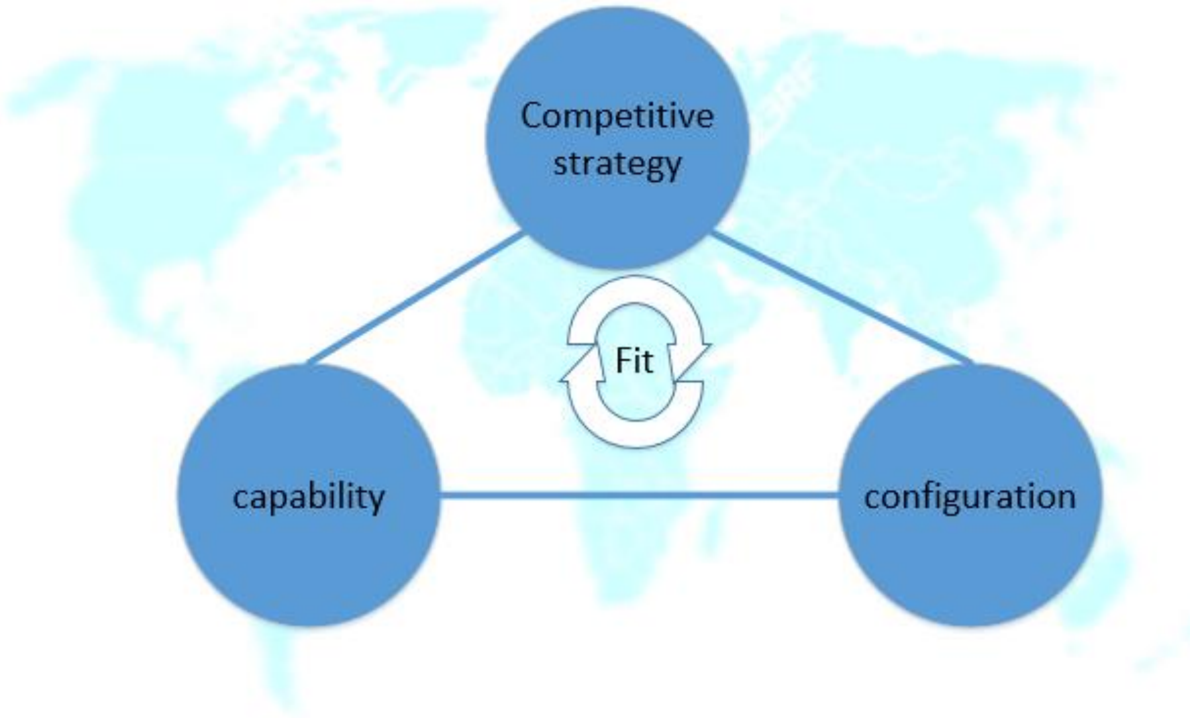

Figure 4. 1 - The three-layer integrated framework for international R&D networks and IMNs

First, competitive strategy determines in which aspects a company can differ from its competitors (Miltenburg, 2005), and provides objectives for different functions. Setting up a correct strategy is important for the success of an international companies. Second, Colotla et al. (2003) present that the firm's internal resources and capabilities are the basis for the firm's strategy. Compared with the external environment which is often dynamic and unpredictable, the internal resources and capabilities provide a more stable basis for defining a firm's identity. Then, the configurations of intra-firm networks can be well designed to support the network capabilities (Zhang et al., 2007). Finally, a proper intra-firm networks design in terms of international R&D networks and IMNs requires fit between these three layers: competitive strategy, capability and configuration, resulting in a superior network performance. This three-layer integrated framework can provide a holistic perspective on international R&D networks and IMNs. In the following sections, this integrated framework will be presented step by step.

4.2. Competitive strategy

The first step is to decide competitive strategy. The three strategies identified by Bartlett and Ghoshal (1998) are used in the integrated framework. Because these three strategies gained widely recognition and other strategy classifications presented in the frame of reference are similar and related to these three strategies.

1) Efficiency competitive strategy:

Companies using this strategy are seeking highly centralization of their strategic decisions and competences to achieve greater cost efficiency. Standard products and processes are provided under this strategy.

2) Local responsiveness strategy:

Companies using this strategy should be sensitive and responsive to local differences around the world, which means products should be tailored and adapted to the local markets. In this way, customized products and flexible processes are available.

3) Learning competitive strategy:

The scope of this strategy is not exactly the same as it defined by Bartlett and Ghoshal (1998) and it is extended combined with the study of Zhang et al. (2007) about innovative R&D networks. Companies using this strategy aim to create value by effectively satisfying business and customer needs through innovative new product/process development. This strategy can be thought of as a strategy combining both efficiency and responsiveness. It comprises of two elements: learning and innovation. Learning includes external learning such as learning from markets, customers, and centers of excellence, and internal learning such as branch factories learning from lead factories. Innovation means companies should make the best use of the learned knowledge to create innovative products and processes to better satisfy customers and create values. In general, learning strategy is about effective innovation and fast knowledge diffusion.

4.3. Capability

The second step is to integrate capability layer to the competitive layer. Each individual site has to contribute to fulfil the overall network strategy (Friedli et al., 2014). When choosing the strategy, the strategic competences of each individual site and the strategic capabilities at the network level should be considered and aligned to best serve the overall strategy. Capabilities used in the three-layer integrated framework are abstracted mainly from the studies of Bartlett and Ghoshal (1998) and Zhang et al. (2007) and other research concerning network capability discussed in the frame of reference chapter are also combined. Each capability should be well designed and therefore match the corresponding strategy as shown in ***Table 4. 1.***

Table 4. 1 – The Three-layer integrated framework (appending capability part)

competitive strategy	efficiency	learning	responsiveness
⇩ capability	Integration and synergizing, building cost advantages through centralized global scale operations	Innovation and learning, exploiting parent company knowledge and capabilities through worldwide diffusion and adaptation	Adaptation and restructuring, building strong local presence through sensitivity and responsiviness to local differences

4.4. Configuration

The final step is to integrate configuration layer to the framework and then this three-layer framework is completed. And this step includes two sub-steps, firstly integrating international R&D networks and secondly integrating IMNs. The configuration classification of international R&D networks is from Von Zedtwitz and Gassmann (2002) and the configuration classification of IMNs is from Shi and Gregory (1998). And the reason is that the two networks configuration classifications cover both networks structure issues and coordination issues. When describing the configuration layer, in addition to the physical structures of networks, single site location drivers and competences as well as coordination issues within the networks are also covered.

The first sub-step is to integrate international R&D networks configurations into the three-layer integrated framework as shown in ***Table 4. 2***. Before describing which international R&D networks configurations are appropriate for supporting the capabilities under each competitive strategy, one concept *complexity level* should be firstly explained.

Table 4. 2 – The three-layer integrated framework (appending international R&D networks configuration part)

competitive strategy		efficiency		learning			responsiveness	
capability		Integration and synergizing, building cost advantages through centralized global scale operations		Innovation and learning, exploiting parent company knowledge and capabilities through worldwide diffusion and adaptation			Adaptation and restructuring, building strong local presence through sensitivity and responsiviness to local differences	
configuration	*complexity level*	*high*	*low*	*high*		*low*	*high*	*low*
	R&D network	*market driven R&D*	*national treasure R&D*	*global R&D*	*technology driven R&D*	*market driven R&D*	*global R&D*	*market driven R&D*

4.4.1. Complexity level

Complexity level consists of process complexity level and product complexity level. Process complexity is shown in three perspective, process volume, process variety, and maturity of technology. High process volume and variety could lead to the high complexity level. Clark and Fujimoto (1991) define product complexity with the number of parts and components during the production. Lamming et al., (2000) point out that "The distinction between complex and simple products is frequently used to distinguish products in terms of not only the number of components, but also the range and intensity of technologies and the way in which they interact." In a word, product complexity is related to component number, product volume, product variety, product maturity, technology maturity, technology range and technology intensity.

Hartley et al., (1997a) claims that products simplicity has big effect on effectiveness of supplier involvement in product design. One of Hong et al., (2009)'s findings is that "The effectiveness of a manufacturer's coordination strategies is influenced by the extent of product complexity, component modularity, technology uncertainty, and the technical capability of suppliers." Besides, it is high product complexity that could makes the centralized-programming strategy less efficient, and reduces the effectiveness (Hong et al., 2009). As for information processing requirements, product complexity plays a significant role in developing an assembly product (Hong et al., 2009).

Manuj and Mentzer (2008)'s framework indicates that product complexity is one of the sources of supply risk. Lamming et al., (2000) illustrates that the supply of the product could be more complicated in the complex market, where customers are various in order requirement and difficult to understand. Subsequently, Lamming et al., (2000) classify supply networks into four sorts, based on products complexity and product uniqueness, which are simple product networks, complex product networks, neutral product networks, unique product networks.

Kotha and Orne (1989) brings up a manufacturing structure framework that uses three dimensions, which are product line complexity, process structure complexity, and organizational scope, to describe generic manufacturing strategy. Marley (2006) states complexity has significant effect on both R&D and manufacturing. He says, "When there is a high degree of complexity, even small seemingly independent failures can interact in unexpected ways that cannot be anticipated by process designers nor understood by operators."

Based on the above discussions, it is reasonable to use complexity level, as a crucial factor, to divide R&D networks and classify manufacturing networks. Clearly, within the same strategy category, the high or low complexity level in the three-layer integrated framework is easily comparable. As for comparisons of complexity level between different strategy categories, it is not easy to draw a certain conclusion. However, in general, the complexity level under the learning and responsiveness strategy is higher than that under the efficiency strategy. For instance, functional products usually apply the efficiency strategy, while innovative products often adopt the learning or responsiveness strategy.

4.4.2. International R&D Network structures

A reminder of international R&D networks structures is shown in ***Figure 4. 2***, which has shown in ***Figure 3. 10***.

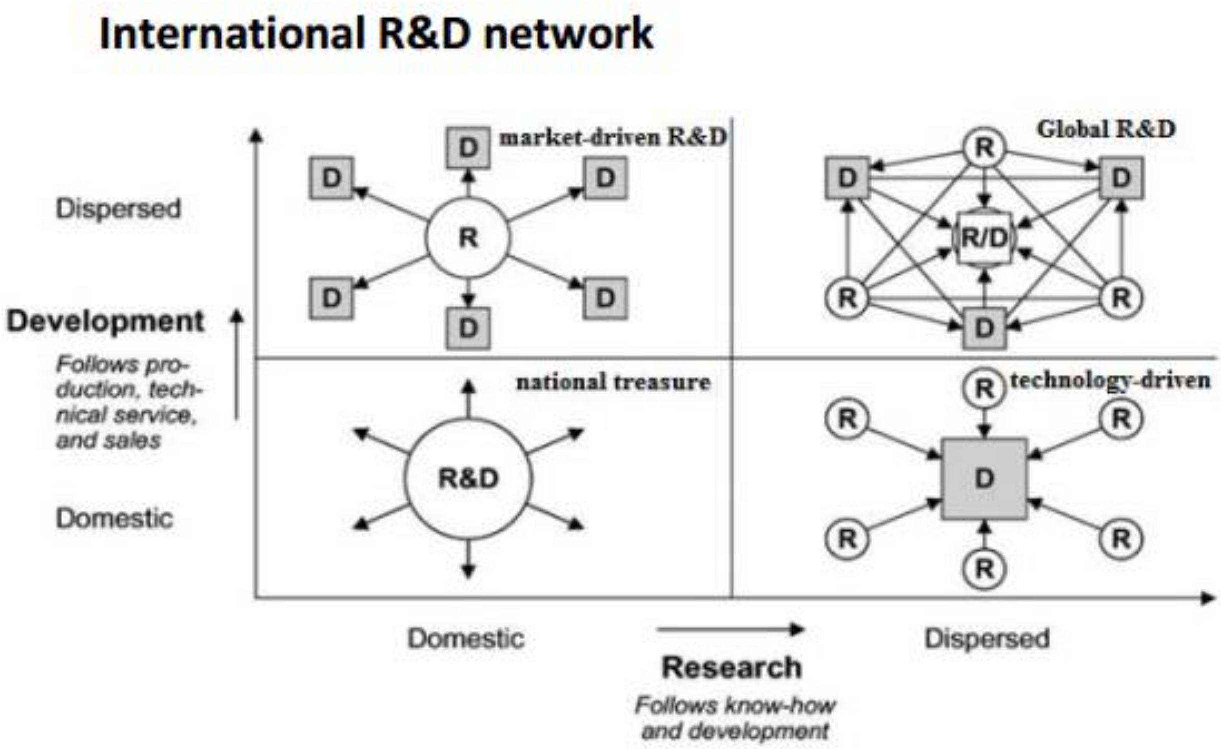

Figure 4. 2 – A reminder of international R&D networks structures (adapted from (Von Zedtwitz and Gassmann, 2002, p.575))

1) Efficiency strategy:

Low complexity level: When complexity level is low, it is not necessary to spread out the research labs and development sites abroad. Because integration and cost are two main goals that go for the efficiency strategy, it is suggested to apply national treasure R&D Networks. The highly-centralized research and development centers usually have high competences and strong coordination.

High complexity level: There are motivations to set up development sites dispersedly. Because the foreign factories need local development support and also the dispersed development sites can sense the markets. Research sites cannot be distributed dispersedly, due to the integration requirement of efficiency strategy. Consequently, it is suggested to set up market-driven R&D Networks. Since standard products and processes are developed by the center and implemented by the foreign sites, the dispersed development sites are usually technical support labs and usually do not have high competences. And coordination between research and development sites is high.

2) Learning strategy:

Low complexity level: There is little need to learn state-of-the-art technology and learning and innovation is mainly driven by the market requirements. So, companies do not have to set up research centers globally. To keep up with various requirements of customers, it is helpful to disperse development sites to learn culture difference, and therefore establish market-driven R&D Networks.

High complexity level: If the learning and innovation is mainly driven by technology. Research centers are spread to gain access to centers of scientific excellence. And the aim is to create high-tech products effectively and therefore gain competitive advantages over the competitors. If factors including scale effects in the development process, proximity to central control and decision making, protection of commercial results or the high information and coordination costs matter, development should be centralized, and therefore the international R&D networks form technology-driven configurations.

If the learning and innovation is driven from both technology and markets requirements, in addition to research centers, development centers should also be spread to gain access to markets and be proximal to production sites to help adapting products according to the local requirements. In this case, a complex global R&D networks will be formed

When the competitive strategy is learning, research and development centers within international R&D networks normally have high competences and coordination between these site is strong as the aim is to effective product innovation and faster knowledge transfer.

3) Responsiveness strategy:

Low complexity level: Technology requirement is not very high and therefore usually centralized within centers. Development sites are dispersed worldwide to be proximal to markets and production sites, which resulting in market-driven R&D configuration.

High complexity level: Technology requirement is relatively high and research is dispersed to gain access to technology knowledge while at the same time development sites are located close to markets and production to develop and adapt products and processes. In this case, a complex global R&D network will be formed.

Under responsiveness competitive strategy, research and development sites have high autonomy and are capable of the full range of competences. Coordination between these sites is quite weak.

4.4.3. IMN structures

The second sub-step is to integrate IMNs configurations into the three-layer integrated framework. Although the international manufacturing networks configurations model we use in our integrated framework is from Shi and Gregory (1998), other studies of manufacturing networks configurations described in the theory and frame of reference chapter will be also combined when analyzing the framework. After integrating IMNs configurations, the three-layer integrated framework is completed as presented in ***Table 4. 3.***

Table 4. 3 – The three-layer integrated framework (appending IMNs Configuration part)

<table>
<tr><td colspan="2">competitive strategy</td><td colspan="2">efficiency</td><td colspan="3">learning</td><td colspan="2">responsiveness</td></tr>
<tr><td colspan="2">capability</td><td colspan="2">Integration and synergizing, building cost advantages through centralized global scale operations</td><td colspan="3">Innovation and learning, exploiting parent company knowledge and capabilities through worldwide diffusion and adaptation</td><td colspan="2">Adaptation and restructuring, building strong local presence through sensitivity and responsiveness to local differences</td></tr>
<tr><td rowspan="5">configuration</td><td>complexity level</td><td>high</td><td>low</td><td colspan="2">high</td><td>low</td><td>high</td><td>low</td></tr>
<tr><td>R&D network</td><td>market driven R&D</td><td>national treasure R&D</td><td>global R&D</td><td>technology driven R&D</td><td>market driven R&D</td><td>global R&D</td><td>market driven R&D</td></tr>
<tr><td rowspan="3">Manufacturing network</td><td rowspan="2">global-integrated manufacturing</td><td rowspan="2">home exporting manufacturing</td><td rowspan="3">global-coordinated manufacturing</td><td>home exporting manufacturing</td><td rowspan="3">global-coordinated manufacturing</td><td>regional uncoordinated manufacturing</td><td>regional uncoordinated manufacturing</td></tr>
<tr><td>regional exporting manufacturing</td><td>multidomestic manufacturing</td><td>multidomestic manufacturing</td></tr>
<tr><td>global-coordinated manufacturing</td><td>regional exporting manufacturing</td><td>global-coordinated manufacturing</td><td>glocalised manufacturing</td><td>glocalised manufacturing</td></tr>
</table>

1) Efficiency strategy

Low complexity level: Companies have both low complexity level products and processes. Pressure for globalization is low, so companies mainly concentrate their production in the home country or a region and export to the foreign markets. In this case, competences and resources are highly concentrated and economies of scales can be achieved. Plants are usually fully fledged and therefore they are mainly lead factories. There is a great possibility that the manufacturing, research and development will be set up close to the headquarter within the home exporting manufacturing. And development sites may be located close to the factories in regional exporting manufacturing.

***High complexity level*:** While the complexity level is relatively high, concentrating the manufacturing in the home country or a region is not enough. And the first aim for companies using this strategy is still global integration and cost efficiency while at the same time pressure for globalization is high. As a result, the manufacturing operations should be dispersed widely to acquire more competitive resources and at the same time to sense the markets requirements. One possible IMN configuration is global coordinated manufacturing, within this configuration the markets are assigned to each site largely without any overlap. Each site is responsible for producing the products demanded by its markets, and the products and processes as well as the managerial mechanisms in each site are quite standard and similar. Efficiency is achieved by highly standard production and management. Products that will incur high transportation cost is suitable to use global coordinated manufacturing.

In global coordinated manufacturing network, lead factory concept (Deflorin et al., 2012) is prominent. Development sites work closely with the lead factory to carry out the central development of production technologies. After the production processes are stable and reliable, the lead factory will transfer the knowledge to the branch factories. Small technical support labs may be located close to these branch factories to support the production.

Another alternative IMN configuration is global integrated manufacturing. In this situation, Economies of scale are gained by pooling standard component manufacturing at a few sites. The vertically integrated structures usually take the form of hub and spoke networks. The manufacturing of high-volume standard products or components is concentrated in a small number of regional or global hubs which supply the spokes concentrating on the manufacturing of smaller numbers of customized products. Spokes are located close to markets while the hubs are located in regions with competitive wages. And the hubs are mainly offshore and source plants while the spokes can be servers, contributors or lead factories. Some technical support labs and development centers are located proximal to high-volume components hubs to support production; some development centers are co-located to customized products assembly spokes to help adapt the products and processes; other technical support labs and development centers are located proximal to the markets to gain access to customer needs. By using this vertically integrated manufacturing configuration, both cost efficiency and some degree of customization can be achieved.

2) Learning strategy

***Low complexity level*:** learning and innovation is mainly driven by the market requirements. Since development sites are spread around the world to gain access to the markets, pressure for globalization is high. Manufacturing should also be dispersed to be proximal to markets and customers. As learning strategy is seeking both responsiveness and efficiency and avoid any extreme configurations. Global coordinated manufacturing is suitable in this situation. And the lead factory concept is also applied to this configuration. Development sites and the lead factory work tightly with each other to develop products and processes and after the production is stable, the process knowledge and technologies will be transferred to other plants which are dispersed to gain access to different markets. In addition to producing the products, these plants sense the market requirements and analyze whether adaptation of the products to local requirements should be made or not. If changes are required, these plants should report them back to the lead factory, which, in turn, makes the changes together with the development centers and then transfer the solution back to all the plants where the changes are needed. In this way, innovation is achieved through learning from the markets and learning between the lead factory, development centers and other production plants. And at the same time, some degree of efficiency is gained via effective communication and fast knowledge transfer. Furthermore, small technical support labs may be co-located with the production plants to support the production. And the production plants are usually servers or contributors.

***High complexity level*:** When the innovation is technology oriented, the research centers are spread to gain access to centers of scientific excellence. And the aim is to create high-tech products effectively and therefore gain competitive advantages over the competitors. As for the manufacturing, pressure for globalization and pressure for local responsiveness is low, so the manufacturing can be concentrated to gain economies of scale and therefore the IMN configurations can be either home exporting manufacturing or regional exporting manufacturing. As discussed above, in such manufacturing configurations, the production sites are usually lead factories and they work closely with the development centers. When the transportation cost of the products is high, the suitable manufacturing configuration is global coordinated manufacturing. The detailed analysis of this configuration is similar as that under the situation where the competitive strategy is efficiency and the complexity level is high.

When the innovation is driven from both technology and markets requirements, which means the international R&D network configuration is global R&D, the most suitable configuration for IMN is global coordinated manufacturing. The interaction between international R&D networks and IMNs is also characterized by the lead factory concept as discussed when the complexity level is low.

3) Responsiveness strategy

***Low complexity level & High complexity level*:** Each manufacturing site operates as discrete units, thus capable of full range of competencies in the manufacture, development of products and processes, which means each site is normally a lead factory. And they are completely responsible for their markets. Site resources (capacity, technology, level of automation) are aligned to their specific markets and customer requirements. A suitable IMN configuration can be chosen according to the pressure for globalization for companies adopting this strategy, be it regional uncoordinated manufacturing, multidomestic manufacturing or glocalised manufacturing. Development centers interact closely with manufacturing to develop products and processes.

4.4.4. Industry and Product Examples

Product examples of the three strategies within different industries are presented in ***Table 4. 4.***

Table 4. 4 – Product examples of complexity level in three-layer integrated framework

	Efficiency		**Learning**		**Responsiveness**	
Complexity level	High	Low	High	Low	High	Low
Product Example	Automotive	Bicycle	Medicine for cancer or HIV	Medicine for common disease	Clothes for extreme sports	Clothes for daily use

1) Efficiency strategy:

Complexity level of automotive is comparably higher than bicycles. The main activity of automotive manufacturing is assembling. Cars usually need assemblers worldwide. And factories often integrate with development sites. While manufacturing process of bikes are simple and only need to develop domestically.

2) Learning strategy

Lamming et al., (2000) examples "pharmaceutical products represented an interesting case as their supply networks seemed to be fairly small due to the relatively small number of components, yet the environment in terms of regulations and product standards, and also the level of technology (high-tech) made supply important but complex to control."

Generally, medicine for common disease, with low complexity level, has already highly developed. As for some special diseases, like cancer and HIV, which have higher death risk, it is urgent and beneficial to develop the cure solution. And the complexity level is higher for the medicines used for these high-risk diseases.

3) Responsiveness strategy

Nowadays, the fashion style has a considerable influence on daily clothes choice, which are easily to change and hard to measure. Close to customers and reacting to markets variation are highest priority in clothes industry.

A special type of clothes, extreme sports clothes, which are used in special circumstance, has higher requirement in the performance and quality of material and production process. Extreme sports clothes need global R&D to develop both high-technology material, comfortable wearing and beautiful style, while daily clothes are much simpler, which only needs common material and looks good.

4.4.5. Discussions of the three-layer integrated framework

Research and development can be treated separately when discussing interactions between international R&D and manufacturing networks. Compared with research centers, development centers have more intense interactions with manufacturing since development centers should work with manufacturing sites to develop and adapt products and processes. And when R&D is technology driven, IMNs and international R&D networks have minimum interaction, because the aim of R&D networks is to seek state-of-the-art technology while the orientation of manufacturing networks can be either markets or costs. Different industries tend to follow different competitive strategies and therefore have different configurations of international R&D and manufacturing networks. companies can use this three-layer integrated framework to better design and evaluate their IMNs and international R&D networks

5 Case Study at Alfa Laval

This chapter introduces the case study in Alfa Laval. The set-up of the IMN and international R&D network of business unit PHE in Alfa Laval is presented and then analyzed using our integrated framework. The interview questions are listed in ***Appendix 1.***

5.1. Introduction

Alfa Laval is a world leader within the key technology areas of heat transfer, separation and fluid handling. Its key products include heat exchangers, separators, pumps and valves. The company has over 17 000 employers, the majority of whom are located in Sweden, Denmark, India, China, the US and France. And the headquarter of Alfa Laval is in Lund, Sweden. Manufacturing and R&D are two important functions in the company. The company has 42 major production units around the world (22 in Europe, 10 in Asia, 8 in the US and 2 in Latin America). Currently, Alfa Laval holds more than 2500 patents, and invests about 2.5 percent of its sales in R&D launching between 35 and 40 products every year (Alfa Laval AB, 2017). The organization structure of Alfa Laval is illustrated in ***Figure 5. 1***. The company is made up of three business divisions: food & water, energy, and marine. Each division has several business units and there are in total 12 business units.

The corporate mission is to optimize the performance of their customers' processes. This means Alfa Laval is a customer-focused company and it defines the challenges faced by its customers and offers them solutions that respond to their true needs.

Our case study is focused on Alfa Laval's Plate Heat Exchanger (PHE) business unit ("***the company***" in the following text is used to refer to PHE business unit) which is under Energy business division. PHEs are used to heat or cool down one liquid with another liquid without liquids contacting with each other. There are a range of PHEs such as gasketed plate heat exchangers, brazed plate heat exchangers. Some examples of PHE are shown in ***Appendix 2.***

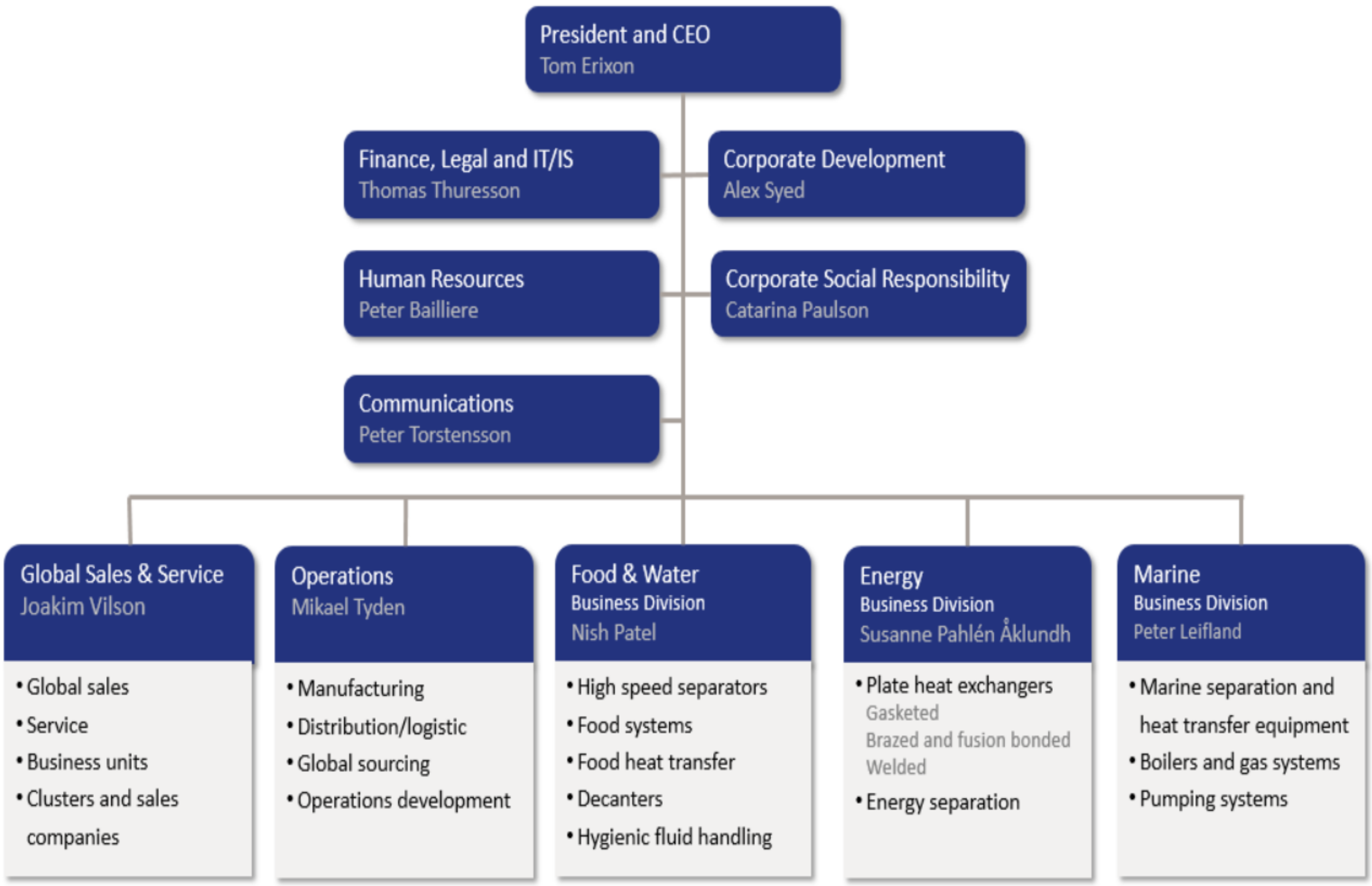

Figure 5. 1 – The organization structure of Alfa Laval (from Alfa Laval AB, 2017)

5.2. IMN of PHE at Alfa Laval

The structure of PHE influences the manufacturing process and IMN of PHE. The structure of PHE is shown below in ***Figure 5. 2***.

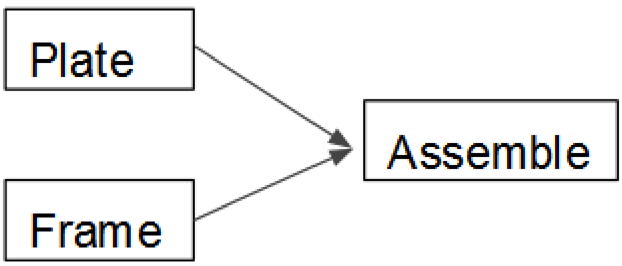

Figure 5. 2 – The manufacturing process of PHE

PHE consists of two parts, plate and frame components. Plate is used to transfer heat and frame is used to hold plates together. Final products are assembled according to customers’ requirements. The manufacturing of plates requires high competence and heavy investment. The core competence of the company is within plates and therefore the plate manufacturing is kept in house. Frame components manufacturing is not capital intensive and they are either produced in the own factories or purchased from external suppliers.

Nowadays, Alfa Laval owns several factories producing PHE around the world. The rough locations of the factories are drawn in ***Figure 5. 3***. And there are some differences among these factories.

Figure 5. 3 – The locations of factories owned by Alfa Laval (hide picture due to privacy requirement)

In order to understand the IMN of PHE better, ***Figure 5. 4*** is created to show the operations and connections in those factories.

Figure 5. 4 – International manufacturing network of the company (hide picture due to privacy requirement)

As mentioned before, the final products of PHE is made up of plates and frame components. In order to produce plates and frames, raw materials and components are sourced from external suppliers and sourcing accounts for a big part of total cost. As for plates, the raw materials are purchased in shape of sheets or coils and the majority of the materials are stainless steel and also titanium. Suppliers are located in Europe, China, India and Japan. The frame consists of several components and the main components are frame and pressure plate, tightening bolts, carrying and guiding bar and supporting Coolum. These frame components are either purchased from local or regional suppliers that are close to the factories or produced at the factories.

The manufacturing of plates is highly coordinated and controlled by the center. And the volume can be moved from one factory to another if needed and therefore the mobility and flexibility is high. Then the produced plates can be exported between the factories. As for frame components, factories have higher autonomy. Only a small part of the total frame volume is exported from one of the factories to another.

The final products are assembled according to customers' orders and in each factory, there is engineering site to help adapt products. When locating these factories, the main reason is to be close to end customers and therefore understand the market needs. Basically, each factory serves the corresponding local or regional markets and there are very few overlaps. The market dispersion for each factory is shown in ***Figure 5. 4*** (hide picture due to privacy requirement). Not all the factories can produce full scope of products, and customers can buy products from the factory in Sweden if these products are not available in the local factory. The factory in Sweden has a global role and is the center of excellence.

Three types of quality regulations of pressure vessel are applied and they are PED (European pressure vessel directive), ASME (American society of mechanical engineers) and ALS (Alfa Laval standards). PED and ASME are used in the corresponding markets and if there is not a special requirement, ALS is used. It is very important to assure the quality of products since it will be dangerous if products are not well manufactured.

5.3. International R&D Network of PHE at Alfa Laval

The international R&D network of PHE at Alfa Laval is simpler than the IMN of PHE. International R&D strategy adopted in PHE is focusing on cost and performance and the aim is to reduce waste and increase performance towards better adapting products for customers' current and future needs. The international R&D activities in terms of PHE are summarized in ***Figure 5. 5***.

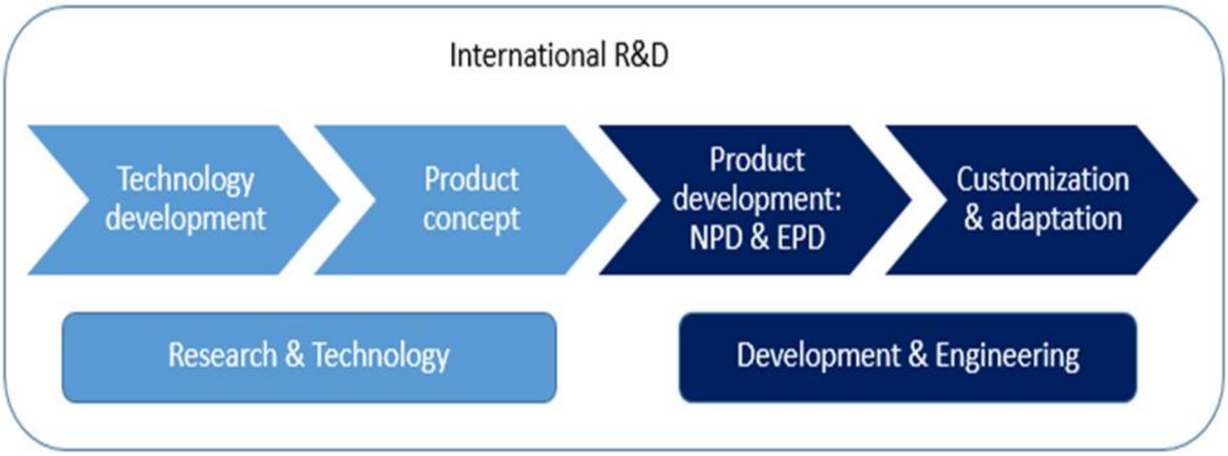

Figure 5. 5 – International R&D activities in the company

Technology development is the process of establishing technologies that can be applied into products and processes and has long term focus. Based on these technologies, possible product concepts are built and if the product concepts are accepted by the company, these concepts are transferred into product development stage.

Product development consists of two types: NPD and EPD projects. NPD means new product development while EPD means existing product development. NPD and EPD follow similar processes while NPD is more expensive than EPD. After products are launched and produced in these factories, some customization and adaptation can be made according to customer orders. These different R&D activities are located in different places. Technology development, product concept development, NPD and EPD centers are shown in ***Figure 5. 3*** (hide picture due to privacy requirement).

Adaptation engineering sites can be found in every factory. Although adaptation engineering is to some degree a part of manufacturing, it is reasonable to consider engineering as the last stage of R&D, since it is related to the design of products. It should be noted that the customization and adaptation is order unique and very limited. Only minor changes, such as painting colors or painting layers that required by customer orders, are included in customization and adaptation stage. If changes are product level, which means components or products should be changed, product development is responsible for these changes. The adaptation engineering activities in each factory are to some degree different, and the differences are based on the engineering capabilities one factory has and how complicated the orders are. For example, factories which involve nuclear, can conduct more complicated engineering adaptation according to customer orders.

Innovation for PHE is driven by both technologies and markets. People work internationally and have close cooperation with universities and other projects, although technology development is concentrated in the headquarter in Lund. The company tries to keep up with technologies and understand them, in order to apply these technologies into products and processes. Also, the company tries to understand different market needs when developing products. PHEs seem quite standard and simple when looking at their appearance. But the truth is that the complexity level of these products is not low, especially when the products involve nuclear technologies. PHEs should be designed appropriately for manufacturing and reducing cost, while at the same time transfer heat efficiently and satisfy customers' requirements.

5.4. Interactions between the international R&D network and IMN of PHE

In order to understand how the international R&D network and the IMN interact with each other, an extended organizational structure is drawn, and it is shown in ***Figure 5. 6***.

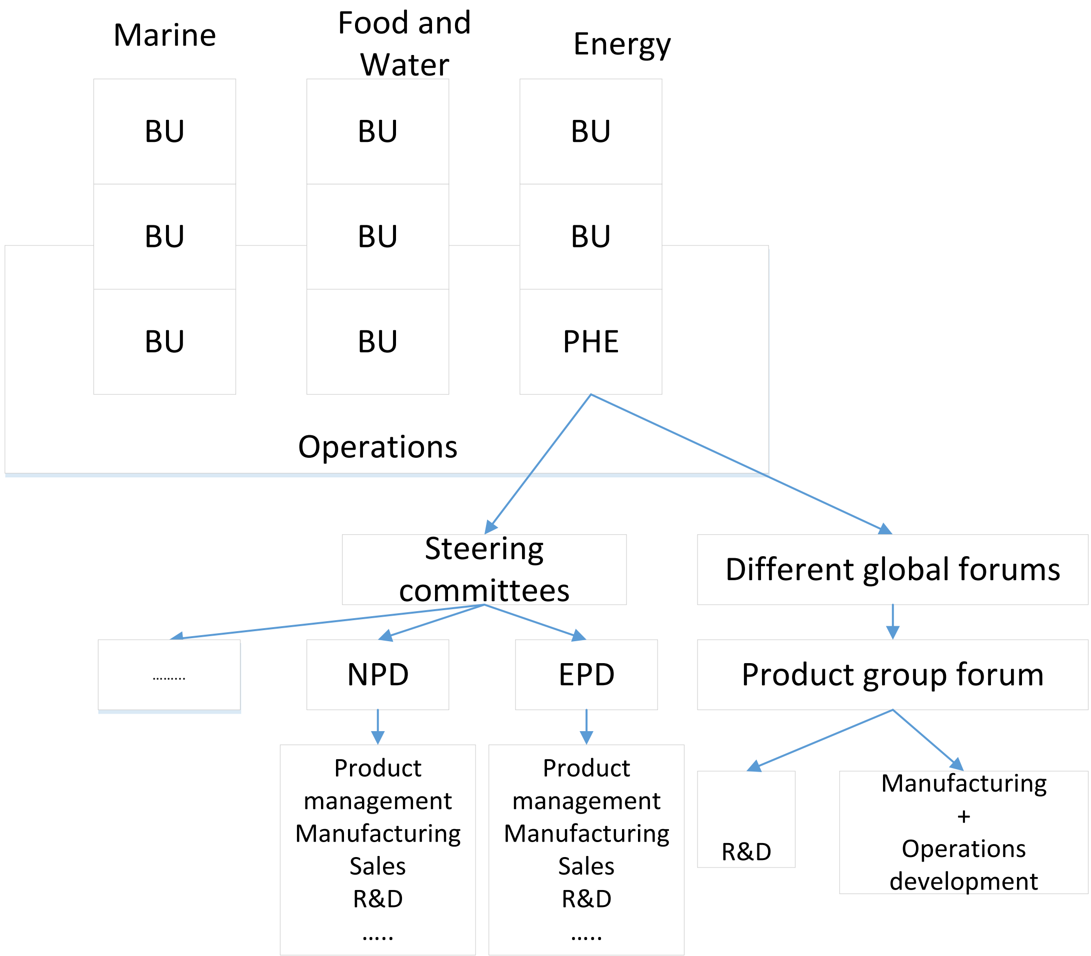

Figure 5. 6 – Alfa Laval organizational structure

Operations are independently organized across all the business units. There are three parts within operations development for the company: projects & technology, NPD/EPD projects and supply chain management. The manufacturing in these factories are coordinated by these three parts working together. There are many different global forums where all functions such as manufacturing, sales and R&D work together. One forum is product group forum which involves R&D and manufacturing within these factories as well as operations development. R&D team and operations development team meet regularly to work together. Also, there are steering committees where there are projects such as NPD and EPD. Each project will involve all the functions like product management, manufacturing, sales and R&D.

R&D works closely with manufacturing when launching products mainly through operations development team to find best solutions. And sometimes R&D can also work directly with factories. For example, if R&D need to do product testing in factories. As a result, how R&D works with manufacturing depends on what is doing.

Manufacturing is located close to customers and needs source material from local suppliers. This will influence products development since development should adapt to local material. Also, Development works with manufacturing to find components available to satisfy local variations. Besides local markets, all the markets should be considered when developing products.

Factories cannot make any changes without consulting R&D. For small adjustments for unique order like painting colors, the engineering groups within factories can take full responsibility; for a change on all the products, it should be done by R&D centers.

In general, the international R&D network and IMN of PHE have strong connections. They should understand each other; manufacturing should understand why products look like this and R&D should understand the local requirements for manufactuirng.

5.5. Plans for international R&D network and IMN of PHE

The company is going to consolidate sub-suppliers of raw material and components, to reduce cost and delivery time and spread risks. Since the three regulations on pressure vessels (PED, ALS, ASME) influence the frame design, R&D is going to have global design of three versions and therefore conduct global processes. And the company is trying to develop new processes in Lund, and then copy and implement the processes in other factories.

5.6. Analysis and Comparison

After presenting the current and future organization of the international R&D network and the IMN of PHE, their positions are fitted into the three-layer integrated framework.

5.6.1. Strategy and capability adopted by the company

We conclude that the company is under efficiency competitive strategy. But it doesn't mean that the company is only focusing on cost, other objectives including safety, quality, lead time, customer response are also important. The company is facing fierce competition especially at local markets today. As a result, safety, quality, short lead time are the order qualifiers for the company. If these order qualifiers are not fulfilled, it will lose customers. Cost and customization are the order winners for the company. Under efficiency strategy, both cost efficiency and customization can be achieved through the well-organized international R&D network and IMN. Although the company has strong local presence and response to customer needs, the overall autonomy within each factory is limited. That is the main reason why the company is not under responsiveness strategy.

5.6.2. Complexity level

The complexity level of PHE products is high especially plate parts, although the products seem standard and simple, as mentioned above. In order to deliver safe, high quality and customized products to end customers quickly, the international R&D network and IMN of PHE work closely and the interaction and connection between the two networks are strong.

5.6.3. The international R&D network configuration

The R&D activities conducted in the company are distinguished between research and development; research consists of technology development and product concept development; development includes product development (NPD/EPD) and adaptation engineering. The R&D center including technology development, NPD and EPD in Lund is fully fledged and has very high competence. Adaptation engineering in every factory can help adapt products and sense market needs. As a result, the international R&D network of PHE is market driven according to the framework. But it is should be noted that research in Lund works internationally to get access to advanced technology and the innovation is driven by both technology and markets.

5.6.4. The IMN configuration

The core competence is within plates and the plates manufacturing is concentrated mainly in Lund, although there are some other factories can also produce plates. The manufacturing of plates is highly coordinated and controlled by the center, and in this way economies of scale can be achieved. As for frame components, they are not capital intensive and each factory has higher autonomy for them. And these factories are located close to customers around the world to understand customers' needs and therefore to do customization. In this case, the IMN of PHE is a hub-and-spoke structure, hubs are the factories that can produce plates and all the factories are spokes. The factories in Lund are lead factories and other factories are contributors. As a result, the IMN of PHE is global integrated manufacturing according to the three-layer integrated framework.

As discussed above, the positions of the international R&D network and the IMN of PHE are marked in the three-layer integrated framework, as shown in ***Figure 5. 7***.

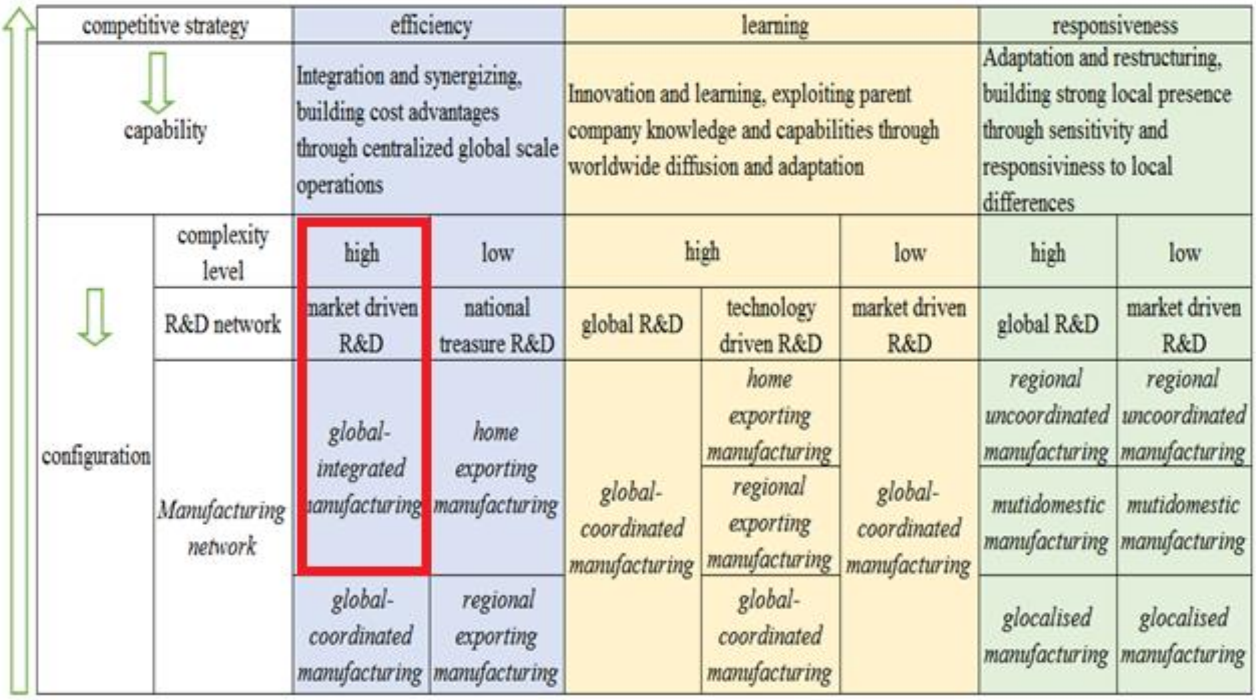

Figure 5. 7 - The positions of the networks of PHE within the three-layer integrated framework

The organization and set up of the international R&D network and IMN of PHE is well aligned under the efficiency strategy. In the future, the international R&D and manufacturing network configurations will move further towards market driven R&D and global integrated manufacturing respectively, and then the efficiency strategy will be more pronounced and obvious.

The case study about PHE at Alfa Laval proves that part of the three-layer integrated framework works well and can be applicable to industries to help companies well design and configure their international R&D and manufacturing networks.

6 Conclusions

This chapter aims to conclude the study by discussing the theoretical contributions, managerial implications and answers to the research questions. Also, limitations and recommendations for future research are presented.

6.1. Discussion of the research questions

This study applies a deductive research method, mainly aiming at theory building. After reviewing the current existing literature on international R&D networks and IMNs as well as studies on globalization and networks, a three-layer integrated framework is created to describe and evaluate the interactions between international R&D networks and IMNs. Alfa Laval case only concerns 1 out of 7 positions in the three-layer integrated framework. And this case study could confirm that one of the positions in the three-layer integrated framework works well in practice.

Research questions 1:

How do the international R&D networks and IMNs within a company interact with each other?

International R&D networks and IMNs within a company have different structures and relationships under different competitive strategies. Compared with research centers, development centers have closer interactions with manufacturing plants since they should work closely to develop and adapt products and processes. And when R&D is technology driven, IMNs and international R&D networks have minimum interaction, because the aim of R&D networks is to seek state-of-the-art technology while the orientation of manufacturing networks can be either markets or costs.

Research questions 2:

How can companies manage and optimize their international R&D networks and IMNs to meet their strategic objectives?

First, a suitable competitive strategy should be decided to guide companies compete successfully in their industries. Then, capabilities at both individual site level and overall network level should be well designed and arranged to contribute to fulfil the competitive strategy. Finally, international R&D networks and IMNs are configured differently to support the capabilities under each strategy.

6.2. Theoretical contributions

Compared with the research on manufacturing, the research on R&D is quite new especially the globalization of R&D activities. After reviewing the current studies on international R&D networks and IMNs, the theoretical gap in the existing literature between international R&D networks and IMNs is identified. This study bridges this gap by developing a three-layer integrated framework to clarify the interactions between international R&D and manufacturing networks.

6.3. Managerial implications

In order to manage international R&D networks and IMNs efficiently, managers have to fully understand their industry and company characteristics and choose a best suitable competitive strategy for their companies. Appropriate capabilities should be well designed and assigned based on the corresponding strategies. Finally, international R&D and manufacturing networks should be configured properly to support the capabilities. When making these relevant decisions, management must consider all related factors such as characteristics of products, processes and site locations and competences and integrated them as a whole.

6.4. Limitations and future research

This study conducts one case study which only tests one part of the three-layer integrated framework. In order to fully test the integrated framework, more case studies from different companies and different industries should be conducted. Since this study only considers intra-company networks, inter-company R&D and manufacturing networks that involve companies across the whole supply chain can be studied.

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8 Appendices

Appendix 1. Interview questions

Part 1. IMN of PHE at Alfa Laval

1. How has your international manufacturing network evolved over time – from the initial setup to the current network?
2. What is your manufacturing strategy?
3. What are the strategic reasons for locating a plant in your international manufacturing network: low-cost manufacturing, proximity to market and/or access to skills and knowledge, or other? (There may be different reasons for different plants).
4. Are plants similar or do they have different roles and responsibilities? How do you assign roles and responsibilities to plants?
5. How can the international manufacturing network be characterized? Are there different network types for different product families? If so, what are the key drivers for selecting a network type for a product family?
6. How do you coordinate operations in your international manufacturing network?
7. Is it possible to assess the capabilities or performances of your international manufacturing network (at the network level and not at the plant level), and if so, how do you assess them?
8. What else do you think is important in your international manufacturing network?

Part 2. International R&D networks of PHE at Alfa Laval

1. What is your R&D strategy?
2. How has your international R&D network evolved over time – from the initial setup to the current network?
3. What are the strategic reasons for locating an R&D site in your international R&D network?
4. Are there differences between each R&D site's roles? If so, how do you assign roles and responsibilities of each R&D site?
5. How can the international R&D network be characterized? Do you treat "Research" and "Development" differently, when discussing the R&D activities in your company? Are there different network types for different product families? If so, what are the key drivers for selecting a network type for a product family?
6. How do you coordinate R&D activities in your international R&D operations?
7. Is it possible to assess the capabilities or performances of your international R&D network and/or for R&D sites, and if so, how do you assess them?
8. What else do you think is important in your international R&D network?

Part 3. Interaction between the IMN and international R&D network of PHE at Alfa Laval

1. How does the globalization of your manufacturing network influence the globalization of your R&D network and vice versa?
2. How does your international manufacturing network cooperate with and interact with your international R&D network?
3. How many of your R&D sites or more specifically, how many of your research sites and development sites are <u>co-located</u> with your manufacturing plants?
4. In your co-located R&D sites and manufacturing plants, how do they <u>cooperate</u> with each other?
5. What else do you think is important in terms of the interaction between your international manufacturing networks and international R&D networks?

Appendix 2. Examples of PHE products