Evaluating smart factory maturity for Chinese discrete manufacturing enterprises

A study submitted in partial fulfillment of the requirements for the degree of Master of Science in Information Management at THE UNIVERSITY OF SHEFFIELD

by

Fei Xing

September 2016
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Abstract

Background: Some Chinese discrete manufacturing companies are in a dilemma nowadays owing to different kinds of problems, as the appearance of the concept of German Industry 4.0, US Industrial Internet, Made in China 2025, building a smart factory to meet the requirements of dynamic production has been one of things they need to do. Therefore, it is quite meaningful to build a smart factory maturity model to evaluate their maturity level for their factory.

Aim: This study aimed to build a smart factory maturity model based on the academic literatures regarding German Industry 4.0, US Industrial Internet and Made in China 2025. Based on this model, one of Chinese discrete manufacturing companies named Xiamen Intretech Inc will be evaluated as a case study. Besides this, enablers and barriers in developing a smart factory will be explored.

Methods: Observation and semi-structured interviews are used to do data collection in this study. 12 participants at different departments in case company take part in the interview and all the interview questions are developed based on different dimensions in smart factory maturity model. Besides, thematic analysis approach with a priori coding is used to analyze the interview data.

Results: Generally speaking, a theoretical smart factory maturity model was developed based on the research knowledge of German Industry 4.0, US Industrial Internet and Made in China 2025. Besides this, enablers and barriers regarding technical and non-technical parts were presented in developing smart factory. Besides this, during the development of smart factory for Chinese discrete manufacturing companies, it is important for those companies to have a self-understanding on their factory and avoid investing in new machines and advanced technology blindly. In addition, it is helpful for discrete manufacturing companies have a reasonable plan in developing a smart factory that is suitable for them.

Conclusions: For this dissertation, all the research objectives were achieved successfully. Most importantly, a theoretical smart factory maturity model was built through the literature review study. However, it is necessary and important to know the establishment of a theoretical smart factory maturity model is just a beginning of the study in the field of smart factory. It will be important for manufacturing companies to develop further step and activity based upon the evaluation results. Further study consists of the improvements of the smart factory maturity model and learning in the field of smart factory.
Acknowledgment

First of all, I want to give the most precious thanks to my supervisor, Dr. Peng. He gave me a lot of support and helpful advice during the completion of the whole dissertation.

Secondly, I want to say thanks to all participants in my interview and some staffs in Xiamen Intretech Inc. With the help of them, I can collect the data in their company efficiently.

Finally, I want to say thanks to my friends at The University of Sheffield. They helped me a lot not only in study, but also in my daily life.
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Chapter 1: Introduction

1.1 Introduction and context

At present, manufacturing industry is one of the important signs to evaluate a country in the aspects of economic development and international competitiveness (Holz, 2008). However, due to fierce competition in manufacturing industry in the world nowadays, many manufacturing powerful nations have announced different plans to enhance their manufacturing industry in order to revitalize the economy (Li & Wang, 2015). In such these plans, German Industry 4.0 and US Industrial Internet can be viewed as two big themes in manufacturing industry (Li & Wang, 2015).

In November 2011, German Federal Government announced that Industry 4.0 as one of main initiatives for its ‘High-Tech Strategy 2020’, which is in order to make Germany stay a globally competitive high-wage economy around the world (Kagermann et al, 2013). Therefore, since that time, many articles, books and academic publications have concentrated on this topic (Bauernhansl, Hompel, & Vogelheuser, 2014).

However, what does ‘Industry 4.0’ mean? Although Industry 4.0 is the most discussed terminology for manufacturing industry, however, there are many different versions for Industry 4.0. Therefore, sometimes it is difficult to discuss Industry 4.0 on an academic level. Dr. Ralf C. Schalepfer & Markus Koch (2015) described that “The term industry 4.0 refers to a further developmental stage in the organization and management of the entire value chain process involved in manufacturing industry.” Another way to identify Industry 4.0 is that it represents the coming fourth industrial revolution (Kagermann et al, 2013).

As Kagermann et al (2013) pointed out that the core of German Industry 4.0 is to build a smart factory, which makes the manufacturing environment more dynamic, digital and smart. Germany is one of the countries in the world which has strong industrial foundation in terms of mechanical and equipments manufacturing. However, due to some great challenges like increasing cost, lack of employees, they also need to do some improvements in their factory (Russwurm, 2014). Meanwhile, US also face many problems in their manufacturing industry. Consequently, a development plan in US was announced, which is called ‘Advanced National Manufacturing Strategy’ that relies on ‘Industrial Internet’ (Evans & Annunziata, 2012).

At the same time, as Liu (2016) pointed out that since China’s reform and opening up, manufacturing industry in China has developed rapidly. The export of industrial products is also rising. However, Chinese manufacturing companies face a lot of problems like overproduction, increasing production cost, lack of self-innovation ability such these problems especially discrete manufacturing companies (Li & Wang, 2015). As a result, ‘Made in China 2015’ was announced by Chinese Government. Equally, it also focuses on the development of smart factory with Chinese environment (Liu, 2016).
However, there is not a standard about a real smart factory. This dissertation aims to build a smart factory maturity model, which can help those discrete manufacturing companies to evaluate their maturity level for their factory.

1.2 Research questions and objectives

Research questions: How to evaluate the performance and maturity of smart factories in China? And what are the enablers and barriers associated with smart factory development?

Research objectives:
1. To carry out a systematic review on relevant literatures of smart factory and build a theoretical smart factory maturity model for discrete manufacturing companies
2. To apply this established maturity model to evaluate the maturity level of smart factory development in a Chinese case study
3. To explore both technical and non-technical enablers for Chinese manufacturing companies to develop smart factories
4. To investigate the barriers and challenges for Chinese manufacturing companies building or turning into a smart factory

1.3 Research methodology

This study is an inductive study and two qualitative data collection methods were used in this study, they are observation and semi-structured interview. A case study approach was used and the thematic analysis approach with a priori coding was adopted to analyze the qualitative data.

1.4 Structure of dissertation

This dissertation will be divided into six chapters. The first chapter is the introduction part, which focus on the research background and the research question and objectives. The second chapter is the literature review part, which is in order to build a theoretical smart factory maturity model. The third chapter is the methodology part, which describes the methods used in this dissertation covers the data collection, data analysis, ethics consideration, etc. Chapter four discusses the findings of this dissertation. Chapter five is the discussion part. After the discussion chapter, chapter six describes the conclusion part, which covers the implications, limitations and future work.
Chapter 2: Literature Review

2.1 Introduction

As discussed above, due to various problems in manufacturing industry in the world. In order to solve these problems, many countries in the world draw their own plans to revitalize the manufacturing industry (Evans & Annunziata, 2012). This literature review part mainly focuses on the plan of German Industry 4.0, US Industrial Internet and Made in China 2025. Conducting the research on relevant materials regarding these three concepts, a smart factory maturity model was built, which can help manufacturing companies evaluate their maturity level of smart factory.

2.2 The concept of smart factory

2.2.1 German Industry 4.0

MacDougall (2014) described Industry 4.0 is the forthcoming the fourth industrial revolution that transforms the embedded system to cyber-physical system. At the same time, from the definition of Industry 4.0, it identifies a paradigm shift from ‘centralized control production’ to ‘decentralized enhanced control production’ with the intention of establishing a highly flexible production pattern for digital and personalized products and service (MacDougall, 2014). In fact, as Kagermann et al (2013) concluded that there are two major themes in Industry 4.0, which are called smart factory and smart manufacturing separately. Simply speaking, for the first theme, smart factory mainly focus on intelligent production system and process, besides this, achievement of networked distributed manufacturing can be made in smart factory. On the other hand, the second theme of Industry 4.0 is smart manufacturing, it mainly discusses the whole production process that involves logistics management, intelligent technologies, human-machine interaction, 3D printing and other technologies in the company (Kagermann et al, 2013). In this dissertation, the proposed maturity model is used for smart factory instead of intelligent manufacturing. “Smart factory constitute a key feature of Industrie 4.0” (Kagermann et al, 2013, p.19). However, for the definition of smart factory, as Radziwon, Bilberg, Bogers & Madsen (2014) pointed out that the terminology ‘smart factory’ was used by some scholars to describe their thoughts on the future of manufacturing. Smart factory is an innovative factory that combines different types of information and computer technologies to solve problems between machines, humans, materials, systems and others (Yoon et al, 2012; Radziwon, Bilberg, Bogers & Madsen, 2014).

Meanwhile, there is an official definition for smart factory from German Research Center, owing to combination of virtual and physical world, from traditional factory transforming to a smart
factory, machines will be equipped with the abilities of analyzing, inferring, diagnosing, thinking, communicating and determining independently (MacDougall, 2014). In many traditional factories nowadays, machines have been already used massively to manufacture products. However, most of them work independently and they are lack of communication. In a smart factory, based on internet of things (IoT) technology and monitoring technology, manufacturing equipments can communicate with each other like human-beings through the internet. At that time, controllability and quality of production process can be improved, similarly, manual interventions during production process can be reduced gradually (Liu et al, 2015). Additionally, as Liu et al (2015) concluded that mass production will be replaced by mass customization in future and the manufacturing process will become more agile and flexible.

Actually, as Kagermann et al (2013) described that one of the most important factors in a smart factory is cyber-physical system, which is called CPS by public. At the same time, MacDougall (2014) explained that one of the key elements to make smart factory successful is the configuration of cyber-physical system. Besides this, at present, the rising cyber-physical system represents an unprecedented opportunity to make smart factory be implemented well (Wang et al, 2016).

In addition to cyber-physical system in smart factory, the importance of three integrations can not be ignored in the concept of German Industry 4.0 (Kagermann et al, 2013). As mentioned above, interaction between physical world and cyber space is emphasized a lot in CPS. Besides this, as Kagermann et al (2013) pointed out three main integrations are also important in the development of smart factory.

### 2.2.2 US Industrial Internet

In America, the concept of ‘Industry 4.0’ is replaced by ‘Industrial Internet’, although the names are different, the main ideas of these two concepts are similar (Bruner, 2013). These two concepts all focus on the combination or connection between virtual network and physical world, which leads to a manufacturing system with high efficiency. In 2012, General Electric (GE), IBM, Cisco, Intel and AT&T these five big companies established Industrial Internet Consortium (IIC) in Boston and then the concept of Industrial Internet was put forward by them (Industrial Internet Consortium, 2015). Due to global fierce competition, they want to improve the efficiency of existing production patterns and create new industry fields through combining manufacturing equipments and information technology (Industrial Internet Consortium, 2015). However, as LaWell (2015) summarized that German Industry 4.0 specializes more in hardware components like manufacturing machines and technologies, in contrast, US Industrial Internet emphasizes on the software parts such as integration of communication, controlling, big data and cloud computing. Besides this, Industrial Internet aims to change original economic model into a new one, manufacturing companies can make profits from both products and its service based on the analysis of big data (LaWell, 2015). In fact, General Electrics Company thought that Industrial Internet is the combination of machines and information technology, which proposes to link people, data and machines seamlessly (Industrial Internet Consortium, 2015).
As mentioned above, German Industry 4.0 is considered as the fourth industrial revolution in the world. Compared with it, Industrial Internet is identified as the third wave in the past 200 years by GE Company (Evans & Annunziata, 2012). Evans & Annunziata (2012) described that the first wave is industrial revolution, which is a long process from 1750 to 1900. The innovative technology was applied in manufacturing field. Besides this, the second wave is called internet revolution, computing capabilities and distributed information network played an important role in internet revolution. Nowadays, in the twenty-first century, the Industrial Internet is viewed as the third wave by public, intelligent devices, intelligent systems and intelligent decisions are playing leading roles in Industrial Internet gradually (Evans & Annunziata, 2012). However, all these are based on the big data analytics (LaWell, 2015). As LaWell (2015) pointed out that system is collecting data duly during the manufacturing process, based on such a huge amount of data, which can improve the manufacturing efficiency.

In addition to this, Evans & Annunziata (2012) concluded that there are three core elements in Industrial Internet and they are intelligent equipments, advanced analysis and people at work respectively. For the first one, intelligent equipments, which means using advanced sensors, controllers or software systems to connect a large number of machines, facilities, fleets and networks in the factory (Evans & Annunziata, 2012). Actually, it has the similar function as cyber-physical system in German Industry 4.0. The second element is advanced analysis. The aim of it is to understand the operation process of machines and big network system based on the physical analysis, predictive algorithm and professional knowledge of other disciplines (Evans & Annunziata, 2012). The final key component is people who are at work. General Electrics Company highlighted that although some researchers mainly focus on the machines and data when they talk about Industrial Internet, people at work are equally important and can not be ignored (Evans & Annunziata, 2012). It means connecting people in different working places whether they are at home, in the office or on move, which can provide them more intelligent design, operation, maintenance, high-quality service and security (Evans & Annunziata, 2012). If these elements are combined together, it will bring new opportunities to enterprise (Evans & Annunziata, 2012). For example, historical data collection technology was used in the traditional statistical methods, in this method, data, analysis and decision-making are always separated (Evans & Annunziata, 2012), which is highly possible to result in information island. That is to say, information can not be flowed effectively in the enterprise. However, as the development of advanced monitoring system and information technology, the ability of processing real-time data has been improved. Different sensors and other advanced devices are embedded in various machines in order to make it convenient to collect massive data, which is helpful to improve the efficiency between the connection of machines’ system and network (Evans & Annunziata, 2012). When various data is produced by machines constantly, at that time, a large number of data will be collected every second and they all need to be analyzed to create value (Bruner, 2013). As a result, data analysis is the core task of industrial internet in improving the manufacturing performance (Industrial Internet Consortium, 2015).
2.2.3 Made in China 2025

Moreover, there is also a plan in China that has the same aim as German Industry 4.0 called Made in China 2025. Recent years, China’s manufacturing industry has been faced many problems such as rising labor costs, excessive consumption of resources, unattractive products, environmental problems, talent shortages, etc (Liu, 2016). In May 2015, a national plan named “Made in China 2025” was unveiled by Chinese State Council and it was authorized by Prime Minister Li Keqiang. As Liu (2016) explained that the aim of Made in China 2025 is to help Chinese manufacturing industry reach the advanced level in the world within one decade. Actually, appearance of Made in China 2025 is based on the concepts of US Industrial Internet and German Industry 4.0 and these two typical concepts are leading to the transformation of production pattern and products development (Yan & Kong, 2016). As Lee (2015) pointed out that there are ten priority sectors and five major projects identified in Made in China 2025. One of the major projects is called intelligent engineering project, which focus on the development of smart factory (Lee, 2015). Therefore, it is clear to see that both German Industry 4.0 and Made in China 2025 focus on the hardware development of smart factory. In order to consolidate and promote the position of Chinese manufacturing industry in the world, as Yan & Kong (2016) concluded that Chinese manufacturing industry must insist on the integration of information and industrialization, strengthen the foundation of intelligent manufacturing and enhance the international cooperation in manufacturing fields. From the perspective of Chinese manufacturing companies, with the support of cyber-physical system from Made in China 2025 and Industry 4.0, they need to build a smart factory based on industrial big data and internet plus. Information technology has penetrated into every link in the whole industry chain. From the point view of Chinese government, the important thing they need to do is to speed up the implementation of Made in China 2025 in manufacturing industry (Yan & Kong, 2016).

2.2.4 Identification of 6 dimensions of smart factory

As a result, based on the three concepts of German Industry 4.0, US Industrial Internet, Made in China 2025, there are mainly six dimensions in the smart factory maturity model. They are cyber-physical system (CPS), integrated management system (IMS), big data, cloud computing, information security and smart service.

2.3 Building of the smart factory maturity model

2.3.1 Cyber-physical system (CPS)

As one of most important parts in smart factory, cyber-physical system (CPS) can be viewed as one of dimensions in the maturity model. In fact, Lee, Bagheri & Kao (2015) described CPS as a transformation technology to connect physical factory floor with the cyber computing space. For
traditional embedded systems, majority of them are designed as stand-alone equipments, therefore, traditional embedded systems are considered as closed systems to some extent (Jazdi, 2014). In contrast, cyber-physical system is an open embedded system with the functionality of internet and control. A control unit is included in CPS. Generally, there are more than one microcontroller(s) in the unit control (Jazdi, 2014). In a smart factory, as Jazdi (2014) explained that all the sensors and actuators should be controlled through cyber-physical system and data will be stored and transformed with other embedded systems in the factory. As a consequence, data exchange can be considered as the most important characteristic for a cyber-physical system in a smart factory (Jazdi, 2014). Besides this, CPS will help today’s manufacturing factory transform into smart factory in Industry 4.0 times through integrating cyber-physical system with manufacturing, logistics and services currently (Lee, Bagheri & Kao, 2015). In order to make an adequate assessment of cyber-physical system (CPS), Lee, Bagheri & Kao (2015) created a ‘CPS 5C level architecture’, which can be considered as a guideline to develop the cyber-physical system in a smart factory.

For 5C architecture, in general, it is the steps from initial data collection to data analysis, and then to the value creation from the collected data, which can be considered as a sequential way (Lee, Bagheri & Kao, 2015). For the first stage, it is called smart connection level. Reliable and accurate data will be collected from machines and other equipments. For those data, parts of them can be acquired by sensors, controllers or other components directly or gained from enterprise manufacturing systems (ERP, SCM, MES, etc) (Lee, Bagheri & Kao, 2015). At this level, as Lee, Bagheri & Kao (2015) emphasized two factors need to be deliberated. Firstly, it is significant to think over the different types of collected data and the method of transferring data. Secondly, it is also important for manufacturing companies to choose proper sensors in this level. For the second stage, which can be called Data-to-information conversion level, it is mainly about the conversion from data to information. Lee, Bagheri & Kao (2015) explained that some tools are available nowadays to convert data into information. Besides this, several algorithms can be developed and used to do analysis on machine prognostics and health management. Through analyzing data regarding machines’ health and it will be easier for staffs in factory to know the fault and remaining life of the machines in advance. Therefore, for the second level of cyber-physical system, the major function here is to guarantee the self-awareness of machines in manufacturing factory (Lee, Bagheri & Kao, 2015). The third level in CPS is called cyber level. Simply speaking, as Lee, Bagheri & Kao (2015) concluded that the function of cyber level is acted as an information center. Once the collected data is converted into information, all the information will be stored in a cyber space and it can be combined to form a machinery network. Due to real-time collection from machines, an awesome amount of data is produced at that time (Lee, Bagheri & Kao, 2015; Jazdi, 2014). After gathering massive data, additional valuable data can be extracted and compared with historical data, that is to say, future performance of machines can be predicted through analysis (Lee, Bagheri & Kao, 2015). The fourth level of cyber-physical system in smart factory is called Cognition level. Lee, Bagheri & Kao (2015) summarized it as a decision support system (DSS), the main function of this level is to optimize the decision made based on the acquired knowledge. It seems difficult to know and see the acquired knowledge. Thus, it will be necessary to transfer the acquired knowledge to information graphics to help make decisions (Lee, Bagheri & Kao, 2015). The final level of CPS is known as
**Configuration** level, which is viewed as the highest level in CPS (Lee, Bagheri & Kao, 2015). In this level, feedback from cyber space will be generated to physical floor by analyzing massive collected information. Meanwhile, it can also be called resilient control system (RCS) to monitor the manufacturing system (Lee, Bagheri & Kao, 2015). At this time, machines in factory have the ability of self-configuration, self-regulation and self-optimization. These are the five levels for cyber-physical system in manufacturing field in the context of German Industry 4.0.

### 2.3.2 Integrated management system (three integrations)

There are three main integrations in Industry 4.0 (Kagermann et al, 2013). The first integration is called vertical integration of manufacturing system, which can be viewed to solve isolated information inside the company itself. As Kagermann et al (2013) concluded that vertical integration is the basis for realization of smart factory. For example, actuators, sensors, controllers, production management system, ERP system and other IT systems will be linked together to form a vertical integration and create a flexible and dynamic manufacturing environment in smart factory (Kagermann et al, 2013).

The second is end-to-end integration across the whole value chain. Simply speaking, the main aim of this integration is to realize the integration of physical world and digital world. Meanwhile, it can meet the customers’ requirements (Kagermann et al, 2013). Compared with traditional manufacturing patterns, customers do not have to select goods from pre-made products. Instead, manufacturing companies can satisfy different customers’ requirements through mixing or resetting components in future smart factory. However, from product design and development to production planning, and from manufacturing to service, these steps need to be equipped with proper IT systems. All the end sockets through the whole product lifecycle will be connected to cyber-physical system (Kagermann et al, 2013).

The third integration is horizontal integration through value networks. Generally speaking, according to Kagermann et al (2013), horizontal integration is the information resource integration among different companies, customers, suppliers, external partners or even the smart grid. Due to the fierce market competition, information integration inside the company is not enough nowadays. Therefore, horizontal integration can help enterprises collaborate together and supply real-time products and services (Kagermann et al, 2013). However, as Kagermann et al (2013) stressed there are also some issues need to be solved such as lack of standardization or protection of intellectual property. These three integrated management systems can also be viewed as one of dimensions to evaluate the smart factory.

### 2.3.3 Big data

As Lee, Bagheri & Kao (2015) pointed out that there will be a high volume data as a result of
continuous rise in use of sensors and networked machines in smart factory. For the high volume of data, it can be called big data (Lee, Lapira, Bagheri, & Kao, 2013). As Dijcks (2012) identified that the term big data has attracted lots of people’s attention. The data from sensors or machines in factory is just one of kinds of data that can be used to extract value in industry field. However, beside this, data from weblogs, social media platforms, networks, emails these can also be dug out valuable information (Dijcks, 2012). Consequently, nowadays more and more companies focus on big data and they are trying to extract valuable information and use them in their business intelligence analysis (Dijcks, 2012).

For manufacturing industry, as Dijcks (2012) concluded that there are hundreds of different data types in manufacturing factory such as call detail records (CDR), equipment operations data, human operator data and data from smart meters and manufacturing sensors. Facing with increasing amounts of diverse data, it will be extremely important to manage and analyze these data in order to provide competitive benefits to the company (Halper & Krishnan, 2013). As a consequence, as mentioned above, big data as one of dimensions for smart factory, Halper & Krishnan (2013) created a framework that helps the factory know their position in the deployment of big data. Besides this, companies can understand what they need to do and know the best practice in their big data implementation.

Actually, as Halper & Krishnan (2013) summarized that there are five stages in big data maturity model. Each stage is discussed in the aspects of organization, infrastructure, data management, analytics and governance separately (Halper & Krishnan, 2013). For the first stage, it is called nascent stage. In this stage, people in the company do not know the meaning of value of big data and even some employees have not heard of big data (Halper & Krishnan, 2013). However, in this stage, companies have the concept of data analytics and put it in implementation. For example, advanced analytics have not been used in these organizations but they are trying to explore it (Halper & Krishnan, 2013). Typically, as Halper & Krishnan (2013) suggested that those organizations do not know what to do with the collected data and the data utilization is low in nascent stage.

Pre-adopter stage can be perceived as the second level in this big data maturity model (Halper & Krishnan, 2013). In this level, the organizations try to make some investments in big data technology like Hadoop, NoSQL databases, which can support big data analysis. From the organization’s view, generally, CIO in the organizations will support this project but not everyone on the board sponsor it (Halper & Krishnan, 2013). As Halper & Krishnan (2013) suggested that big data analytics is only implemented in a single department as an experimentation process in a whole company. Although these companies are trying to collect some internal big data sources, the formats of collected files are different as well as naming standards basically. From the perspective of data governance, different departments manage their departmental data separately, which will be highly possible to lead to a mess in data integration (Halper & Krishnan, 2013).

For the third level in this maturity model, it is called early adoption stage, as Halper & Krishnan (2013) described that organizations need to spend a long time in this stage due to the difficulties
of implementing big data analytics from departmental level to corporatewide adoption. From the view of the whole organization, besides CIO, more executives have interest in big data and an IT team will be established in order to manage and analyze the data in the company (Halper & Krishnan, 2013). Importantly, as Halper & Krishnan (2013) concluded that an installed tier 2 production-class cluster can be seen a typical infrastructure in the third stage. From the point of view of analytics, some basic predictive analysis will be used in this stage to solve problems that the company faces. One typical thing in this stage is that the organizations use only one kind of data such as structured data, for example, if the volume of the structured data is quite large (i.e., 10TB) in a manufacturing company, some kind of predictive models will be run to do analysis on these data (Halper & Krishnan, 2013). However, facing with various types of data, organizations are strong in managing data but weak in analyzing in this stage (Halper & Krishnan, 2013).

In fact, a long time period needs to be spent at the third stage in this big data maturity model (Halper & Krishnan, 2013). Meanwhile, as Halper & Krishnan (2013) considered that organizations need to overcome a series of obstacles when they try to move from the third stage to the fourth stage, which covers data security, business funding, data management and governance, new technology skills, cultural and social issues etc. The fourth level in this model is named corporate adoption, as Halper & Krishnan (2013) explained that companies are involved in big data journey and they can get new business ideas from the results of data analysis.

In the fourth stage, from the organization’s perspective, top managers in company have realized that big data analytics can bring them competitiveness and the return on investment (ROI) of business project is calculated by big data analytics (Halper & Krishnan, 2013). One of signs in the aspects of infrastructure is that multiple workloads can be performed by the company on a cluster, besides this, big data analytics have been deployed in the whole company (Halper & Krishnan, 2013). Moreover, from view of data management, as Halper & Krishnan (2013) summarized, more mature this company is, the better it can manage the data. In this stage, many different kinds of data can be made good use of and there will be a good data lifecycle management or framework in the company. Apart from these, the collected real-time data can be analyzed quickly and some organizations’ decisions are supported by data analytics (Halper & Krishnan, 2013). In addition, there will be some mature guidance in company to govern the data and the company can know more details about the collected data including the source, purpose, duration. Meanwhile, at this stage, a steering committee can monitor the progress of data through a defined data strategy (Halper & Krishnan, 2013).

The final stage in this big data maturity model is called mature stage or visionary stage, as Halper & Krishnan (2013) pointed out that almost no company reaches this level in the way of big data or big data analytics. At this stage, from the organizations’ view, first of all, big data analytics is perceived as a strong weapon to make business decision. Besides, the main characteristic in this stage is to create more value based on continuous data analytics (Halper & Krishnan, 2013). As a mature company in terms of big data, a coherent analytics framework will be deployed and it can be used in business projects. Whether the data is from internal or external source, they can be integrated to do analysis (Halper & Krishnan, 2013). Moreover, as Halper & Krishnan (2013) concluded that data security, disaster recovery, backup & recovery are ensured and there will be appropriate staffs and technology skills in big data program. From the point of view of analytics at mature stage, visionary company can utilize various types of data, new
collected data and existing assets can be linked together. Additionally, parts of visionary companies will establish an innovation department that includes business and IT staffs, which can enhance the production and business through data analytics (Halper & Krishnan, 2013).

As discussed the deployment of big data in manufacturing companies, from the point view of technology, there is no doubt that it is impossible to implement big data analytics without cloud computing (Yen et al, 2014). Therefore, as Ali (2013) discussed that cloud computing has penetrated into many fields like banks, education, retail and automobile parts. Apart from this, cloud computing has been one of major components for manufacturing industry (Ali, 2013). Yen et al (2014) considered cloud computing ignites a new wave of IT development through cyber-physical system in industry 4.0 like flexible expansion. There are three kinds of cloud computing service and IaaS (Infrastructure as a Service) or SaaS (Software as a Service) is used in smart factory (Yen et al, 2014).

2.3.4 Cloud computing

Behrendt et al (2011) concluded that there are five stages for implementing IaaS (Infrastructure as a Service) in smart factory. For the first step, it is called virtualized. Actually, many companies are located at this stage currently. Simply speaking, resources are managed, calculated and stored through virtualization technology in the company, which can get higher utilization of resource (Behrendt et al, 2011). Besides this, as Behrendt et al (2011) indicated that the degree of automation is not high enough and the company has just achieved a certain degree of automation to support the resource virtualization in this level. For the second level, it can be called deployed stage and the use of virtualization technology has been strengthened (Behrendt et al, 2011). At this stage, basic management process has been built and the cost of IT is also tracked in the company (Behrendt et al, 2011). Additionally, some fundamental monitoring function should be equipped, which mainly monitor the usage of equipments in the factory (Behrendt et al, 2011). The third stage is the optimized level in IaaS, besides the features mentioned in former two stages, additional function of infrastructures management is added in order to reduce the cost of operation and maintenance (Behrendt et al, 2011). At this stage, as Behrendt et al (2011) pointed out that some mature management process is needed like infrastructure monitoring management, image management, patches management, backup & recovery management and others. However, some management processes are optional, for example, capacity planning & forecasting management and event management (Behrendt et al, 2011). Moreover, the fourth stage is named enhanced level. At this stage, high value service will be more focused on, for instance, pattern-based provisioning, disaster recovery for cloud platform and cloud-based backup service (Behrendt et al, 2011). Furthermore, as Behrendt et al (2011) concluded that the major difference between the third stage and the fourth stage is the service scheduling capability for data center, calculating ability from external public cloud can be used in order to reduce the business peak pressure during some special time periods. The final stage in IaaS is called monetized level, at this stage, service ability in former four stages is equipped (Behrendt et al, 2011). The platform should transfer from a cost center to a profit center through the cloud service provided by IaaS (Behrendt et al, 2011). Meanwhile, as Behrendt et al (2011) considered that all the process
management requires life cycle. Finally, the ability of good service storefront is equipped and integrated with CRM, Billing system (Behrendt et al, 2011).

As discussed above that another cloud service used in smart factory is SaaS (software as a service). However, as Noshpitz et al (2013) summarized that not all organizations will use SaaS. From their research, there are also five stages for the assessment of cloud adoption maturity to company’s needs. For the first stage, it is called initial level, the company starts to adopt external SaaS and departmental cloud strategies will be established (Noshpitz et al, 2013). The second stage is named repeatable level is this SaaS maturity model, business value can be obtained from using applications (Noshpitz et al, 2013). As Noshpitz et al (2013) pointed out that categorized business applications and appropriate data policies should be established, besides this, cloud strategy needs to be consolidated. The third stage is called defined level, Noshpitz et al (2013) concluded that SaaS is implemented for key business in the company. At this stage, private SaaS framework and defined cloud architecture will be built. Additionally, the company will have the service delivery management including cloud portal or interface (Noshpitz et al, 2013). The fourth stage can be called measured level, as Noshpitz et al (2013) highlighted that business value can be obtained from the integration among SaaS applications. Online risk and compliance management can be used at this stage, besides this, one typical feature is that there will be hybrid SaaS in the company (Noshpitz et al, 2013). Moreover, integrated security management will be equipped at measured level (Noshpitz et al, 2013). The final stage is called optimized level, as Noshpitz et al (2013) said “Integration across business partners is based on open and interoperable cloud environment”. At this level, all the service and applications deployment are automated according to business requirements and controls (Noshpitz et al, 2013). In addition to this, as Noshpitz et al (2013) concluded that the cloud is federated, interoperable and open, dynamic compliance and control can be achieved at this level.

When evaluate the smart factory, maturity of big data and cloud computing has been discussed above in detail. Apart from this, when using big data and cloud computing, security of information can not be ignored during the development of smart factory.

2.3.5 Information security

As Ge, Yuan & Lu (2011) emphasized that information security is playing an important role in individual and organizational sectors. Due to real-time communications between PCs and equipments in smart factory, information security seems particularly important. According to the research conducted by Ge, Yuan & Lu in 2011, there is a defined 6-level for information related technology maturity model. The first level is called non-existent, at this level, the awareness of IT security in organizations is weak and there is no defined process for information system security (Ge, Yuan & Lu, 2011). The second level is named as initial or Ad hoc, Ge, Yuan & Lu (2011) concluded that the organizations start to realize the importance and need for IT security at this stage, but they think it is a small probability event and do not pay any attention on efficient policies or processes. For third level, which is known as developing, an IT security coordinator is assigned to take charge of IT security. The awareness of information security has been enhanced.
Besides this, some approached or policies are made in responding to risks, but the process is still in developing (Ge, Yuan & Lu, 2011). The fourth level is called defined level and staffs at the company all have the awareness of security (Ge, Yuan & Lu, 2011). As Ge, Yuan & Lu (2011) pointed out that an organization-wide policy regarding information risk management is defined to address the problems about IT risks. At the same time, some documents about risk assessment are available for all staffs training (Ge, Yuan & Lu, 2011). The fifth level is called managed, roles and responsibilities for IT security are assigned definitely. Moreover, there will be standard procedures in dealing with IT risks (Ge, Yuan & Lu, 2011). The final level for information security is optimized level, all staffs in organizations have known the importance of IT security and it has been integrated with the whole corporate security (Ge, Yuan & Lu, 2011). In addition, there will be a structured and organization-wide process for IT security and continuous improvements will be made on security policies (Ge, Yuan & Lu, 2011). These are the six different levels for information security in manufacturing company.

2.3.6 Smart services

The final dimension of smart factory maturity model is smart service. As Kagermann et al (2013) pointed out that smart service and products is a new economy in future manufacturing industry. Smart products can communicate with manufacturers and let them know their condition or situation, which can help the producers solve possible problems in advance. As a result, smart service can be considered a logical consequence of industry 4.0. At here, customer service and smart product can be listed as two sub-dimensions. According to the researches conducted by Leppik in 2013, there are five levels for customer service maturity model. The first level is called ignorance level and the organizations have little on products’ feedback from customers (Leppik, 2013). For the second level, it is tracking level. As Leppik (2013) concluded that some high-quality feedback from customers are collected and tracked in order to make improvement on products in the future. However, there is almost nothing about data analysis (Leppik, 2013). The third level is named accountability level, personal targets for feedback scores will be set by the company. Besides this, the company has a closed-loop service for those customers give negative feedback (Leppik, 2013). The fourth level is continuous improvement level, the company will link the customer feedback with database, which can let the staffs do analysis on the data and seek improvements to business (Leppik, 2013). The final level is called agile level, the company will analyze the customer feedback continuously. At the same time, staffs in the company need to update the feedback questions to reflect current business environment and some tools will be used to enhance interaction between customers and producers (Leppik, 2013).

Another sub-dimension of smart service is smart product, for this sub-dimension, as Kagermann et al (2013) considered that can be divided into three sectors to discuss, they are ‘integration of sensors or actuators’, ‘ability of communication’ and ‘ability of monitoring’. In addition, there are five levels in each sub-dimension. As Kagermann et al (2013) suggested, from the perspective of integration of sensors in product, level 1 represents there is no use of sensors in product, level 2 indicates the use of sensors in product, level 3 means that sensors readings can be processed by the product, level 4 shows that acquired data can be evaluated for analysis by the
product. Finally, level 5 represents that the product can respond independently based on the obtained data.

2.4 Enablers and barriers associated with smart factory development

Actually, as Kagermann et al (2013) highlighted it is not easy to build a real smart factory. Despite this, manufacturing companies also should make great efforts in developing the smart factory. As Zuehlke (2008) concluded that there are several factors contribute to the development of smart factory. First of all, from the technical dimension, M2M communication that using embedded sensors in machines can help company do data collection and information exchange, because some communication technology has been deployed among the components in the machines like Bluetooth, Zigbee and RFID systems (Zuehlke, 2008). Use of some automatic controllers improve the production efficiency and reduce human errors (Zuehlke, 2008). Secondly, from the organizational dimensions, as Zuehlke (2008) summarized that adoption of information systems improves the efficiency of whole company such as ERP, MES, SCM etc. Moreover, from the cloud service perspective, mature and secure cloud can help company store, balance and manage data effectively (Noshpitz et al, 2013). However, during the development of smart factory, there are also some challenges. Primarily, from the organizational level, as Lee (2015) suggested that manufacturing companies must have a strategic planning when they try to implement smart factory, because some companies have not got a holistic understanding of their position, it will waste lots of time and money. Besides this, lack of standards and regulations are also serious problems particularly in the aspects of machines and data sharing (Lee, 2015). Moreover, as Babiceanu & Seker (2016) pointed out that data security will be another challenge in future. As data sharing grows in future, hackers or data theft may become a risk for companies. They will steal commercial secrets or technological achievements through attacking the company. Therefore, secure network environment is quite important (Babiceanu & Seker, 2016).

2.5 Conclusion

In conclusion, a smart factory maturity model (Table 1) which has six dimensions is established based on the knowledge about German Industry 4.0, US Industrial Internet and Made in China 2025. Besides this, some exploration about enablers and barriers of developing a smart factory have also been discussed in literature review part. For this dissertation, this maturity model was used to evaluate smart factory development in one case company, which is one of Chinese discrete manufacturing companies, namely Xiamen Intretech Inc (as discussed in the next chapter).

<table>
<thead>
<tr>
<th>Level</th>
<th>Definition</th>
<th>Supported Literature</th>
</tr>
</thead>
<tbody>
<tr>
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</table>

20
### Dimension 1: Cyber-physical System (CPS), including 5 levels

<table>
<thead>
<tr>
<th>Level 1: Smart Connection Level</th>
<th>1. Plug &amp; Play</th>
<th>Lee, Bagheri &amp; Kao, 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2. Non-contact and real time communication</td>
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<td></td>
<td>3. Wireless or wired sensor network</td>
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<td></td>
<td>4. Collect accurate basic parameter from machines, components and manufacturing devices</td>
<td></td>
</tr>
<tr>
<td>Level 2: Data to Information Conversion Level</td>
<td>1. Data is transformed to meaningful information</td>
<td>Lee, Bagheri &amp; Kao, 2015</td>
</tr>
<tr>
<td></td>
<td>2. Smart analysis for machines’ prognostics and health management</td>
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<tr>
<td></td>
<td>3. Have the ability of smart analysis for multi-dimensional data correlation</td>
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<td></td>
<td>4. Performance prediction for machines and sensors</td>
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<td></td>
<td>5. Have the ability of estimating remaining useful life (self-consciousness)</td>
<td></td>
</tr>
<tr>
<td>Level 3: Cyber Level</td>
<td>1. Cyber level has the similar function as central information hub</td>
<td>Lee, Bagheri &amp; Kao, 2015</td>
</tr>
<tr>
<td></td>
<td>2. Machines’ performance can be compared with fleet and historical information to predict the future behavior of machines</td>
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<td></td>
<td>3. Dual-model for machines and components</td>
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<td></td>
<td>4. Collect the similarities from data mining (self-comparison)</td>
<td></td>
</tr>
<tr>
<td>Level 4: Cognition level</td>
<td>1. Use appropriate info-graphics to help prioritize and optimize decision based on comparative information</td>
<td>Lee, Bagheri &amp; Kao, 2015</td>
</tr>
<tr>
<td></td>
<td>2. The whole operation process can be realized in virtual reality remotely</td>
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</tr>
<tr>
<td></td>
<td>3. Planned product can be simulated and synthesized</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. Have the ability of collaborative diagnostics and work</td>
<td></td>
</tr>
<tr>
<td>Level 5: Configuration Level</td>
<td>1. It acts as a monitoring system that can make machines become self-configuration and self-adaptive</td>
<td>Lee, Bagheri &amp; Kao, 2015</td>
</tr>
<tr>
<td></td>
<td>2. Have the ability of achieving self-aware, self-predict, self-compare, self-configure, self-maintain and self-organize</td>
<td></td>
</tr>
</tbody>
</table>

### Dimension 2: Integrated Management System, including 3 levels

<table>
<thead>
<tr>
<th>Level 1: Vertical Integration and Networked Manufacturing Systems</th>
<th>1. At different levels in the company, integrated IT system should be used particularly in production development</th>
<th>Kagermann et al, 2013</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2. Sensors, actuators, production control system, manufacturing systems, performance management, ERP, R&amp;D, other information system need be linked together</td>
<td></td>
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<td></td>
<td>3. Integration in production process (e.g. internal integration in R&amp;D)</td>
<td>Liu et al,</td>
</tr>
</tbody>
</table>
4. Integration in different department (e.g. information integration between R&D department and manufacturing department)  

### Level 2: End-to-end Integration Across the Entire Value Chain

<table>
<thead>
<tr>
<th>1. Make the manufacturing process full digitization, which can be seen as a virtual portrayal of the real world</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Customers can design their desired products from combining independent components instead of choosing from what manufacturers have produced already</td>
</tr>
<tr>
<td>3. Integration of product and production lifecycle, from product design to future service</td>
</tr>
</tbody>
</table>

### Level 3: Horizontal Integration through Value Networks

<table>
<thead>
<tr>
<th>1. Information Integration inside the company (e.g. inbound logistics, warehousing, production, outbound logistics, downstream services)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Besides the information integration inside the company, suppliers, customers and other external partners should also be linked together to form a value network</td>
</tr>
</tbody>
</table>

### Dimension 3: Big Data (from five angles), including 5 levels

#### Level 1: Nascent Level

**Organization**

1. Organizations have some concepts of data analysis and it may have a data warehouse, but employees in organizations have a low awareness of big data
2. Organization has not started the advanced data analysis

**Infrastructure**

1. Misunderstand the requirements to distinguish between infrastructures and data

**Data Management**

1. Have some data warehouses
2. Collect data as files in different formats and do not have naming standards
3. Do not have the real data management strategy
4. Data lifecycle management strategy is weak
5. Bring out some immediate results and silos of information rather than a whole plan

**Analytics**

1. May not use advanced analytics
2. Do not have an independent analytics group
3. Organization uses some analytics such as predictive analytics, but only the structured data is analyzed in general

**Governance**

1. Data governance strategy is more based on IT rather than business and IT

#### Level 2: Organization

<p>| | |</p>
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<tbody>
<tr>
<td></td>
<td>2015</td>
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<tr>
<td></td>
<td>Kagermann et al, 2013</td>
</tr>
<tr>
<td></td>
<td>Kagermann et al, 2013</td>
</tr>
<tr>
<td></td>
<td>Halper &amp; Krishnan, 2013</td>
</tr>
<tr>
<td></td>
<td>Halper &amp;</td>
</tr>
</tbody>
</table>
| Pre-adoption Level | 1. Usually the supporter is in the CIO team  
2. Attitude to big data in organization is around experimentation  
3. Use big data analysis to make some decisions in some departments, the whole company is not driven by data analysis | Krishnan, 2013 |
|---|---|---|
| Infrastructure | 1. Some companies potentially try to use Hadoop or other big data tools as experiments  
2. Installation, configuration and maintenance of infrastructure can meet the standards of enterprise  
3. Some companies may develop Hadoop clusters and it will be only used in one single department as experimentation | |
| Data Management | 1. Company will collect some big data source to do experimentation, these data are internal basically  
2. There is no defined lifecycle data management  
3. Data is not audited and lined | |
| Analytics | 1. To some extent, companies have explored and used some advanced data analytics  
2. Statisticians from internal or external organizations set the analytics strategy | |
| Governance | 1. A steering committee is might established by the company to oversee the program  
2. Representatives from different departments prepare their own reports on data governance progress | |
| Level 3: Early Adoption Level | **Organization**  
1. At least one executive sponsor support big data & big data analytics  
2. More executives have interest in big data due to some success in proof of concept  
3. Organizations plan to establish a team for planning a wider scope of big data  
4. Goal of big data analytics is cost control | Halper & Krishnan, 2013 |
| Infrastructure | 1. There are potentially many different types of big data technologies like Hadoop clusters, NoSQL databases  
2. A unified ecosystem is not shaped  
3. Company will install and maintain a tier 2 production-class cluster in data center or in cloud | |
| Data Management | 1. There are departmental or organizational standards for naming and storing data  
2. Data will not be discarded by organizations unless there are some special purposes | |
3. There is not a solid big data management strategy at the company level

<table>
<thead>
<tr>
<th>Analytics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Descriptive and predictive analysis will be used in this level</td>
</tr>
<tr>
<td>2. Organizations are still using one kind of data (e.g. structured data)</td>
</tr>
<tr>
<td>3. Organizations are strong in managing data but weak in analytics</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Governance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Some preliminary data governance is set up in the company</td>
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</tbody>
</table>

**Level 4: Corporate Adoption Level**

<table>
<thead>
<tr>
<th>Organization</th>
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</thead>
<tbody>
<tr>
<td>1. Company realizes the importance of data analytics as a competitive component, data innovation and data analysis are key</td>
</tr>
<tr>
<td>2. Data infrastructure support a top-down and bottom up business strategy</td>
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<tr>
<td>3. Funding is fixed, ROI (return on investment) is produced by big data analytics</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Infrastructure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Company will install and maintain a tier 1 production-class cluster in data center</td>
</tr>
<tr>
<td>2. Number of Hadoop cluster is around between 50 to 100 nodes in this level</td>
</tr>
<tr>
<td>3. Multiple workloads can be performed by the company on a cluster</td>
</tr>
<tr>
<td>4. Big data analytics will be deployed in the whole organization and IT department and business stakeholders support it</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Data Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Organization can utilize many different types of data</td>
</tr>
<tr>
<td>2. Organization can see the value from all components in data infrastructure</td>
</tr>
<tr>
<td>3. Data lifecycle management is identified, and data is audited and lined</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Analytics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Data can be analyzed quickly and the organization will be supported by data analytics</td>
</tr>
<tr>
<td>2. There is a special department that serves different department, data science team members are included in this special department</td>
</tr>
<tr>
<td>3. Data analytics is used to support business behavior</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Governance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Company has guidance to govern data</td>
</tr>
<tr>
<td>2. A well-identified data strategy and management will be used and a steering committee can monitor the progress of data</td>
</tr>
</tbody>
</table>

**Level 5: Mature Level**

<table>
<thead>
<tr>
<th>Organization</th>
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</thead>
<tbody>
<tr>
<td>1. Company has owned big data and big data analytics, from executives’ view, big data is quite important. Big data analytics is used to support business process</td>
</tr>
<tr>
<td>2. Company can find new business chance and create new value from</td>
</tr>
</tbody>
</table>

Halper & Krishnan, 2013
big data analysis
3. Collaboration can be considered as a big part of organizations’ culture

**Infrastructure**
1. Coherent data analysis is fully operated through the whole company
2. Have the ability to integrate internal or external sources to do data analysis

**Data Management**
1. Make sure the ability of security, disaster recovery, backup & recovery, performance management
2. Adequate staffs and technology skills can be used in big data program

**Analytics**
1. Link new data to the existing assets
2. Data, analytics and infrastructure are combined well with each other
3. Potentially, an innovation team that covers IT and business staffs is established to innovate technology and put them into use in business process

**Governance**
1. A well-established guidance and data governance strategy can be used in the company, data transparency is very high

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### Dimension 4: Cloud Computing (IaaS, SaaS), each includes 5 levels

<table>
<thead>
<tr>
<th><strong>IaaS</strong></th>
<th><strong>Level 1: Virtualized</strong></th>
<th><strong>Level 2: Deployed</strong></th>
<th><strong>Level 3: Optimized</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1. Company manages and calculates the information resource, store them mainly based on virtualization technology, which can be able to simplify the resource management and obtain a higher utilization of resource</td>
<td>1. Use of virtualization technology is strengthened through the automated deployment of virtual machines</td>
<td>1. In this level, all functions in level 2 can be achieved here. Besides this, function of managing infrastructures is added, which can reduce the cost of operation and maintenance, and improve the SLA &amp; QoS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Basic management process is established and it has achieved the tracking management for IT cost</td>
<td>2. Some mature management process is needed to improve the cloud service infrastructure platforms, for example, infrastructure monitoring management image lifecycle management, safety &amp; compliance management, patches management, backup &amp; recovery management,</td>
</tr>
</tbody>
</table>
**Level 4: Enhanced**  
1. Beside the functions in level 2 and level 3, company needs to focus on high value service, like pattern-based provisioning, disaster recovery for cloud platform, cloud-based backup service  
2. The biggest difference is that it can use the computing power from external public cloud, which can reduce the business peak pressure during some special time period

**Level 5: Monetized**  
1. Transfer a cost center to a profit center through the cloud service  
2. Management of various processes requires life cycle and pay more attention on ease of service and customization of service interface  
3. Have a good service storefront, integrated with CRM and billing system, based on Federated Service

### SaaS

<table>
<thead>
<tr>
<th>Level 1: Initial Level</th>
<th>1. Organizations utilize SaaS for some special needs and the service-oriented architecture is basic and developing using external SaaS and there will be information pool in the company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 2: Repeatable Level</td>
<td>1. Using of SaaS increases and further business value can be obtained from using applications, cloud strategy is consolidated and there is a defined cloud service catalog</td>
</tr>
<tr>
<td>Level 3: Defined Level</td>
<td>1. Company deploys SaaS for some key business, functional value chain through internal needs, customer-facing business use cases and there is a defined cloud architecture, besides this, SaaS framework is private</td>
</tr>
<tr>
<td>Level 4: Measured Level</td>
<td>1. Integration between SaaS application can create value and end-to-end business processes, which is able to create value through SaaS applications and functions, integrated security management should be achieved</td>
</tr>
<tr>
<td>Level 5: Optimized Level</td>
<td>1. Cloud environment is open and interoperable, all service and applications deployment are automatic. Applications in the cloud can be migrated based on business requirements. The SaaS environment is managed by lifecycle of choosing, deploying, integrating and operating</td>
</tr>
</tbody>
</table>

### Dimension 5: Information Security, including 6 levels

<table>
<thead>
<tr>
<th>Level</th>
<th>1: Non-existent Level</th>
<th>1. The importance of IT security has not been sensed and recognized by the organization. Besides, there is no defined process for information system security</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 2: Initial/Ad hoc Level</td>
<td>The importance of IT security in factory has been sensed by organization, but they think it is a small probability event and there is no specific process and policies to handle</td>
<td></td>
</tr>
<tr>
<td>Level 3: Developing Level</td>
<td>1. There will be a position like an IT security coordinator, who is responsible for IT security in the company. People in company realize the importance of IT risks. It will be important to do IT risk assessment, some approaches are being operated, but they are still developing</td>
<td></td>
</tr>
<tr>
<td>Level 4: Defined Level</td>
<td>1. Awareness of security in factory is being spread by executive levels. Some policies and rules are produced as well as some roles for</td>
<td></td>
</tr>
</tbody>
</table>
information security have been established. However, IT department still take most responsibility on this. Staffs in company will be trained to improve their information security awareness, document for IT security are printed out.

| Level 5: Managed Level | 1. Roles and responsibilities for IT security are defined clearly. Potentially, there will be a formal information security committee that is led by CISO. There will be standard procedures dealing with IT risks |
| Level 6: Optimized Level | 1. All staffs in organization have known the importance of IT security. IT security is a joint responsibility of business and IT management. All staffs need to be responsible for their behaviors. IT security has been embedded into the organization culture. Continuous improvements are needed on security policies |

**Dimension 6: Smart Service (four angles), each has five levels**

| Customer Service |  |
| Level 1: Ignorance Level | 1. Company do not collect or just collect a little customers’ feedback for product improvements in future business |
| Level 2: Tracking Level | 1. Some high-level customer feedback are collected and acquired by the company and the company will track its performance. However, there is almost nothing about data use |
| Level 3: Accountability Level | 1. Some personal targets regarding customer feedback scores will be set by the company and the company has a closed-loop service for those customer who gave negative feedback |
| Level 4: Continuous Improvement Level | 1. Company puts those data about customer feedback in original assets, these data is about customer experience on products. Then, company will use these data to make improvements on future products as well as their business plan |
| Level 5: Agile Level | 1. Company will update the customer feedback continuously and make some new business ideas at some areas. Updating survey questions of products, which is in order to reflect the new business needs and provide interactive reporting tools throughout the whole company |

| Integration of Sensors in Product |  |
| Level 1 | 1. No use of sensors or actuators in product |
| Level 2 | 1. Sensors or actuators are integrated in product |
| Level 3 | 1. Sensors readings are processed by the product |
| Level 4 | 1. Acquired data is evaluated for analysis by the product |
| Level 5 | 1. Product can respond independently based on the gained data |

<p>| Ability of Communication for Product |  |
| Level 1 | 1. Product has no interfaces |
| Level 2 | 1. Product can send and receive I/O signals |
| Level 3 | 1. Product has field bus interfaces |
| Level 4 | 1. Product has industrial Ethernet interfaces |</p>
<table>
<thead>
<tr>
<th>Level 5</th>
<th>1. Product has access to the internet</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ability of Monitoring</strong></td>
<td></td>
</tr>
<tr>
<td>Level 1</td>
<td>1. Product does not have ability of monitoring</td>
</tr>
<tr>
<td>Level 2</td>
<td>1. Product can detect the failure</td>
</tr>
<tr>
<td>Level 3</td>
<td>1. Product can record the running status in order to diagnose the fault</td>
</tr>
<tr>
<td>Level 4</td>
<td>1. Product prognosticates its own functional condition</td>
</tr>
<tr>
<td>Level 5</td>
<td>1. Product adopts control measures independently</td>
</tr>
</tbody>
</table>

Table 1: smart factory maturity model
Chapter 3: Research methodology

3.1 Introduction

This chapter introduces the research methodology used in this dissertation. In this dissertation, an inductive and qualitative approach was adopted. Besides, observation and semi-structured interview were used to do data collection. Moreover, the thematic analysis with priori coding was selected to do data analysis.

3.2 Research approach

Actually, there are two kinds of research approaches, namely inductive and deductive. As Shaffer (1989) stated that a deductive approach can be sometimes called “top-down” approach. Researcher needs to think up a theory about his topic and narrow down into specific hypothesis, after that, using the data to check the accuracy of the theory (Shaffer, 1989). In contrast, inductive approach starts from specific observations and ends up with a conclusion or theory, which can be called “bottom-up” approach (Shaffer, 1989). Consequently, this study is an inductive study, because the smart factory maturity model is build based on the literatures and this model was used to evaluate the maturity level of one smart factory instead of proving the model.

Moreover, as Merriam (2009) concluded that a qualitative research handles the problem of “how people make sense of their world and the experience they have in the world” (p.13). However, quantitative research is used to generate results from huge amounts of data, which defines people’s attitudes, ideas and behaviors (Abawi, 2008). Therefore, exploring the maturity level for current smart factory in case company and investigate the enablers and barriers in building the smart factory can be viewed as a qualitative research.

3.3 Case study approach

3.3.1 what is a case study

As Eisenhardt (1989) explained that case study is one of qualitative research approaches and it is used in order to generate a depth understanding for one specific question under the realistic background.
3.3.2 why use case study approach

Case study approach was adopted to use because as Eisenhardt (1989) explained that case study approach is used to investigate a specific problem or question. In this dissertation, case study was used in order to evaluate its maturity level and explore the enablers and barriers in the development of a smart factory built by one Chinese discrete manufacturing company.

3.3.3 introduction of case company

The choosing case company is called Xiamen Intretech Inc and it was introduced by my friend and they had a partnership before.

Xiamen Intretech Inc. was founded in May 2011 and located in the Fujian region, which is a subsidiary company of Malata. Intretech Inc. has around 1300 employees and more than 560 engineers and managers. Intretech is a leading manufacturer in the field of information system and industrial automation which focuses on Internet of Things Technology. Intretech has formed industrial robot, smart home, smart manufacturing, internet of vehicles and UMS (united management system) as a completed industrial chain. At the same time, Intretech has cooperated with some global enterprises like Logitech, Nestle and PMI for several years, with annual revenue about 100 million RMB. Nowadays, they are trying to build up a real smart factory to improve their industrial efficiency and build a model for other discrete manufacturing companies.

3.4 Data collection

3.4.1 Selection of data collection method

As mentioned above, qualitative data collection method was used. There are three common types of qualitative data collection methods in general and they are observation, interview and focus group (Patton, 1990). In this dissertation, observation and semi-structured interview were adopted as data collection methods. As Marshall & Rossman (1989) identified that observation as “the systematic description of events, behaviors and artifacts in the social setting chosen for study” (p.79). There are several advantages for adopting observation as one of data collection methods. Primarily, observation approach enables researchers have a general overview of the activities that they want to know (Marshall & Rossman, 1989), which can help researchers have a good holistic understanding of the company. Secondly, it can help researchers to know the participants’ daily work (Kawulich, 2005). That is to say, it is helpful to know the routine work of the factory in company. Moreover, as DeWalt & DeWalt (2002) considered that a holistic understanding of the phenomena can be developed through observation, which improves the quality of data collection and facilitates the new research question. However, as one of
limitations pointed out by Kawulich in 2005, it is highly possible for researcher’s not being participated in the activities due to lack of trust and company’s inconvenience. In order to solve the problems like distrust and inconvenience, it is necessary to arrange time in advance and sign confidentiality agreement with the case company if possible.

As Newton (2010) considered that semi-structured interview can be placed between ‘unstructured’ and ‘structured’ interview. Besides, ‘unstructured’ is close to observation while ‘structured’ use of closed questions is quite similar to questionnaire (Newton, 2010). From the point view of semi-structured interview, both interviewer and participants are engaged in a formal interview together (Cohen & Crabtree, 2006), which can increase interaction and lead to a deep discussion compared with ‘structured’ use of closed questions. Moreover, as Cohen & Crabtree (2006) concluded that there is a list of interview questions in semi-structured interview and they are prepared in advance by researcher, which will be easier to collect high-quality data than using unstructured interview. As a result, it is quite suitable for this research project to choose semi-structured interview as major data collection method. However, there are also some weaknesses when choosing interview as one of data collection approaches. Primarily, it is time consuming when do interview with participants (Smith, 1995). It took almost one hour on each participant for this research project. Moreover, some participants were not available due to their personal reasons, which will cause some inconvenience (Smith, 1995). Finally, it is a little difficult to know the validity of the results from interview, because the researcher does not know if the participant is lying (Smith, 1995).

3.4.2 Development of observation list and interview questions

Before conducting the observation, here listed the content that needs be observed in the case company.

◆ CPS (production process in factory)
◆ Integrated Management System (Information flow in internal company)
◆ Big data (whether have special department to take charge of)
◆ Security (Information security guidance)

There are six dimensions in smart factory maturity model and it is difficult for researchers to conduct observation on smart service and cloud computing these two dimensions. Consequently, except the two dimensions, others four dimensions were observed to some extent. For CPS part, the production process of machines in factory was observed mainly. Besides this, the automation level, degree of human machine interaction, the defective rate of production line was observed too. Moreover, whether there is early warning before machines failure was also observed in factory, but for machines failure, it is a probability event actually. Therefore, it is difficult to know the early warning of their machines in factory. Finally, a self-tracing system and whether staffs in factory still use paper to transfer information were observed.

For integrated management system this dimension, communication and data exchange between different departments, tasks arrangement, whether there is still paper using inside the company, such these phenomenon were observed. It is helpful for researcher to have a holistic
understanding of company operation. The third observation part is about big data. Whether the company has a separate department to do data analysis or conduct big data project was viewed. The final observation part is about security, which can only focus on the security guidance. Whether there is any guidance for information security in the company was observed.

Those mentioned above are the content that needs to be observed in case company. However, as Johnson & Sackett (1998) discussed that observation as an approach to do data collection is not enough and it is lack of representative for the research topic. Moreover, according to the research conducted by Ratner (2002), some qualitative researchers will use more than one method to do data collection to make sure a high quality of the collected data. Consequently, semi-structured interview was selected as the major data collection method in this dissertation. For any types of interview, as Clough & Nutbrown (2007) emphasized that listen attentively is important, as writing speed can not keep up with the speech speed, sound recording was chosen to record conversation temporarily and researcher did transcription after finishing interview.

As semi-structured interview was selected to use in this dissertation, 20 questions about the following topics are involved in the interview scripts. These 20 questions are emerged from literature review and almost each question has follow-up question and trigger question, which is helpful for researcher to collect efficient data.

◆ **Open questions** (participant position, daily work, their understanding of smart factory)
◆ **Cyber-physical system questions** (machine operation, data collection, data usage, data storage, production process, machine performance, etc)
◆ **Integrated management system questions** (information flow, communication mode, information system tools, information sharing, information interaction, cooperative partner)
◆ **Big data questions** (understanding of big data, support for big data, big data analytics, big data tools, data usage, data storage, data management strategy, data governance strategy, etc)
◆ **Cloud computing questions** (deployment model, cloud applications, cloud service, cloud computing technology, cloud data processing, etc)
◆ **Information security questions** (actions to information security, security awareness, specific security department, data protection, etc)
◆ **Smart service questions** (sensors in product, customer service, smart product, product failure warning, data collection from product, etc)

These seven parts mentioned above were included in the interview scripts and the detailed interview questions are presented in appendix 6.

### 3.4.3 Interview administration

All the interviews were recorded through the mobile phone after participants’ agreement and those participants have authority to stop the recording and interview at any time. After finishing the interview, interview transcripts were done based on the recoding. All the interview transcripts are stored at University storage.
3.4.4 Participants

Subsequently, in order to make the data extensive, 12 semi-structured interviews were conducted with Co-general Manager, IT manager, hardware engineers, software engineers, smart home director, and several the-roots workers, which is shown in figure 2 for the position and time-cost of each interviewee.

<table>
<thead>
<tr>
<th>Position</th>
<th>Interview time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Co-general Manager</td>
<td>1h 48min</td>
</tr>
<tr>
<td>2. IT Manager</td>
<td>1h 11min</td>
</tr>
<tr>
<td>3. Chief Engineer</td>
<td>56min</td>
</tr>
<tr>
<td>4. Electrical Control Director</td>
<td>1h 24min</td>
</tr>
<tr>
<td>5. Structural Engineer</td>
<td>48min</td>
</tr>
<tr>
<td>6. Electrical Engineer</td>
<td>58min</td>
</tr>
<tr>
<td>7. Software Engineer</td>
<td>47min</td>
</tr>
<tr>
<td>8. UMS Engineer</td>
<td>1h 18min</td>
</tr>
<tr>
<td>9. Smart Home Director</td>
<td>1h 04min</td>
</tr>
<tr>
<td>10. Office Staff</td>
<td>41min</td>
</tr>
<tr>
<td>11. Warehouse Keeper</td>
<td>39min</td>
</tr>
<tr>
<td>12. Factory Operator (SMT Line)</td>
<td>36min</td>
</tr>
</tbody>
</table>

Figure 2: Position and time of interviewees

These interviewees include the management level, technical level and the-roots workers level, which helps the researcher to have a deep understanding about current smart factory they built. As discussed above, all the interviews were recorded through the mobile phone and it lasted around one hour on average. Before doing the interview, each participant was told that he or she has the authority to stop the interview at any time and they need to sign a contract that proves all work are voluntary. Moreover, as Saunders (2011) pointed out that it will be better to write the interview transcriptions on the same day in order to improve the reliability of collected data.

3.5 Data analysis

After finishing the data collection, next work needs to do is data analysis. For this dissertation, a thematic analysis approach with a priori coding was used to analyze the interview data. According to the research conducted by Christofi, Nunes & Peng in 2009, thematic analysis can be viewed as one of predominant techniques that in order to analyze qualitative data. Moreover, as Bruan & Clarke (2006) described thematic analysis is “a method for identifying, analyzing and reporting patterns (themes) within data”. At the same time, this data-driven inductive approach can be adopted combing with a deductive priori coding (Fereday & Muir-Cochrane, 2006). In this dissertation, smart factory maturity level for case company, enablers and barriers
of building a smart factory can be seen three main findings. Therefore, based on the smart factory maturity model that has been built from literature review, one concept map and table will be built to show the smart factory maturity level. Besides this, enablers and barriers were also built as concept map.

Braun & Clarke (2006) concluded that there is a guideline that covers five stages of conducting thematic analysis to do data analysis. For the first stage, it is called “Getting familiar with the data”, which means researcher needs to understand the collected data through interview, doing transcription and reading the transcription. Researcher needs to spend a lot of time on this stage (Braun & Clarke, 2006). The second stage is called “Coding the data”. As Braun & Clarke (2006) explained that researcher should develop a coding way that makes all textual data into relevant codes after having a good understanding of the collected data. For this step, Allan (2003) suggested that it was time-consuming if the researcher conducts coding word by word or line by line. Therefore, it is helpful to decide the objects of analysis at first (Allan, 2003) (e.g. the enablers and barriers of building a smart factory within the context of Chinese discrete manufacturing companies in this dissertation). The third stage is named “Connecting codes and identifying themes”. As all data has been initially coded, the next thing that researcher needs to do is sort all the different codes into the potential themes (Braun & Clarke, 2006). If one main theme has several sub-themes, researcher should classify those codes in detail. For example, through researching and analyzing the defined codes, one main theme is called enablers of building a smart factory, which contains five sub-themes, namely CPS enablers, IMS enablers, cloud computing enablers, security enablers and organization level enablers. On the other hand, another theme is called barriers of building a smart factory, which contains four sub-themes, namely CPS barriers, big data barriers, organization level barriers and smart service barriers. Subsequently, all defined codes were classified into corresponding themes and sub-themes. Moreover, if some codes can be viewed as cause or consequence of the smart factory barriers, they can be linked together. The following is an example for this situation.

![Diagram of relation among theme, sub-theme and codes](image)

Figure 3: Relation among theme, sub-theme and codes
The initial coding scheme is presented in appendix 1 and the maturity level can be defined based on its concept map. Appendix 2 describes the codes about enablers and barriers, the concept maps are built based on them.
The fourth stage is called “Reviewing themes and developing concept maps”, for this step, as Braun & Clarke (2006) concluded that the researcher will review all codes again and make sure an accurate match for each code and theme. After reviewing all codes, a concept map is built, which can represent the relationship between all codes and themes or sub-themes. As Nunes et al (2004) argued that concept map can be seen as a useful tool to discuss and represent the qualitative data. In this dissertation, three concept maps were developed, namely smart factory maturity level, smart factory enablers and smart factory barriers.

The final stage is called Reporting findings, as Braun & Clarke (2006) emphasized that the procedures of reporting findings step are quite similar to doing analysis of interview data, because the researcher will compare the interview data with literature review and report the results at findings chapter.

In conclusion, those are the five stages for analyzing the interview data in detail, which is called thematic analysis with a priori coding. However, it needs to be noted that all the semi-structured interviews were conducted in Chinese. As Peng & Nunes (2010) explained that inaccurate expression and errors can often happen in process of translation. As a result, interview data was analyzed in Chinese at first. In addition, some parts quotations were translated into English if they are required to be presented in findings chapter, which can reduce the workload and improve the quality of data.

### 3.6 Ethics considerations

For this dissertation, it has been ethically approved by ethical procedures at Information School, The University of Sheffield before going to case company to conduct the interview and observation. This research project was defined as a low-risk one, some human participants in case company are involved in the interview and parts of personal data are collected but there are no vulnerable participants or sensitive topics like salary, race, faith, etc. Moreover, all the collected data will be only used in this dissertation and they are kept safely.

### 3.7 Summary

To sum up, this is the research methodology part. Inductive and qualitative approach was used in this dissertation. Observation and semi-structured were used to do data collection, data is mainly derived from semi-structure interview. Besides, thematic analysis with a priori coding was adopted to do data analysis.
Chapter 4: Findings

4.1 Introduction

For the finding chapter in this dissertation, table and concept map were used to present and discuss the results. This chapter is divided into three main parts, namely smart factory maturity level for Intretech, enablers of building a smart factory and the barriers they face in building a smart factory.

4.2 Smart Factory Maturity Level for Intretech

In this sub chapter, smart factory maturity for Intretech was discussed in detail based on the established smart factory maturity model and the data collected from the interview. The interview data was sorted into codes and a concept map regarding smart factory level was built.

4.2.1 CPS Level

As Kagermann et al (2013) pointed out that CPS can be considered as one of most important components in the development of smart factory, there are five different levels in the smart factory maturity model for cyber-physical system. For the case company, its achievement in the aspect of CPS is at the second level, which is called data to information conversion level. For this level, the collected data from machines will be transformed into meaningful information, which in order to do data analysis on machines to improve their machines’ efficiency. Besides this, staffs will do some improvements based on the collected data. As the Co-general Manager talked that:

*I am the Co-general Manager in this company. In the aspect of building the smart factory, we hope to establish a smart factory with Chinese characteristics and other manufacturing companies can imitate. In our production factory, most of our machines in our factory are designed and fabricated by ourselves. Majority of machines in factory are connected with our united management system (UMS), we will collect some data through the UMS in order to calculate the power of the machines, boot time and off time of machines, abnormal time of devices, etc. All the collected data from machines are some basic parameters instead of detailed data. Then, engineers will try to improve the machines’ efficiency based on the collected data. (Co-general Manager)*

Moreover, the remaining useful life can be estimated at this level as Lee, Bagher & Kao (2015) concluded. In this company, for the standards machines, most of them can be estimate the remaining life through the system. As the chief engineer discussed that:

*The UMS can collect some basic data from the machines during the process of production. We will use these data to improve our machines in the future. Based on the data, remaining life of parts machines can be
estimated, which can help us to change some components duly. Let me give you an example of our machines, one of our machines is called automatic polishing machines, which is in order to improve the finish of work’s surface. There are some polishing papers in automatic polishing machines, if the ideal number of polishing times for one paper is 8000, we will set a parameter like 6000, when the polishing time reached 6000, at that time, automatic polishing machines will warn. Therefore, staffs will know it is time to replace the polishing papers. This is one of our examples of self-consciousness (Chief Engineer).

As a result, according to the interview transcriptions from Co-general Manager and Chief Engineer, it is clear to see that the company located at the second level of the smart factory maturity model.

4.2.2 IMS Level

Besides the cyber-physical system, as Kagermann et al (2013) considered that the importance of three main integrations can not be ignored in the concept of German Industry 4.0. Generally speaking, the case company has achieved the second level. From the smart factory maturity model (Table 1), Kagermann et al (2013) concluded that information in internal company can flow without any barriers. Meanwhile, company can supply customization modules when selling their UMS and machines. The fact was pointed out clearly by the UMS engineers:

Communication among different departments are smooth in our company, there is not any information island with the use of UMS. From the perspective of whole company, UMS is designed by ourselves and we have used it for around 5 years. The full name of UMS is united management system, like our company, there are many external third party software applications like ERP, OA, HR and PLM after we becoming larger. For example, we use Kingdee ERP software and Weaver OA. However, after the number of third party software applications is becoming large, at that time, one management staff or one operator needs to open several software applications at the same time, which is easy to cause confusion to users. Actually, with the support of UMS, we do not use paper basically in office and factory. On the other hand, there are many disadvantages for third party software applications. For example, the third party applications can only be used in local area network. In this way, if the managers are on a business trip or going abroad, they can not see the information they want. However, our united management system can solve this problem and integrate all the third party software applications together (UMS Engineer).

Besides this, now we sell the UMS to our partnership or other manufacturing companies. Because some modules in UMS are unhelpful to them, we can design the new UMS for them to use. Our customers are all proud of our UMS (UMS Engineer).

Not only this, our UMS can help our company do a MRP (manufacturing resource plan) analysis before implementing production, which make sure the sufficient materials in advance. Moreover, during the production, our self-tracing system can trace the whole lifecycle of each product (UMS Engineer).

Intretech has reached a successful vertical integration inside the company and end-to-end integration from UMS engineer’s opinion. Consequently, they have made a good achievement in IMS level.
4.2.3 Big Data Level

Big data, as Lee, Bagheri & Kao (2015) concluded that it is a new field through using various sensors, machines, systems in smart factory. For manufacturing industry, according to the research conducted by Dijcks, due to hundreds kinds of data in manufacturing factory like equipment operation data, human operator data, sensors data, etc, therefore, the function of big data analytics is immeasurable, which is used in analyzing and forecasting working condition of machines in factory and improve production efficiency. However, level of big data use in the case company is the first level, which is called nascent level. As Co-General Manger stated that:

Regarding big data, First of all, we also think big data is useful in manufacturing industry, however, at the moment, staffs in the company do not know what is big data and some operators even do not hear about big data before. Secondly, our data is not sufficient and we only do some data collection currently. We do not have any data analytics tools to do analysis, in fact, we have started big data project. However, from the leadership perspective, we all support the big data project (Co-general Manager).

Clearly, top management level in company has the concept of big data and they realize the importance of big data analytics. However, employees in organizations have a low awareness of big data.

Moreover, during the production in factory, lots of machines work at the same time, a large number of data is collected through UMS. When asked whether they have database to store data and their data management strategy, the IT manager responded:

Actually, when production process happens in factory, various sensors, machines are working at the same time. These data are collected through UMS. All the collected data will be stored in our data centre. We also take some measures to manage the data (IT Manager).

However, we have not started to classify and analyze them due to two main reasons. Firstly, we are lack of data at moment. Secondly, we do not have specialized analytics team and tools to do data analysis (IT Manager).

As a result, the big data maturity in the case company is the first level. As Halper & Krishnan (2013) pointed out that the organization does not have an independent analytics group to take charge of data analysis at nascent level.

4.2.4 Cloud Computing Level

As Duarte & da Silva (2013) pointed out that the organizations are trying to move their IT service and resource to the cloud. Managers hope to reduce the cost of managing IT resource. Therefore, they will choose outsourcing companies to manage their IT service. As the UMS engineer expressed:

From the point view of cloud computing, we adopt the Ali private cloud, which is one of mature cloud service companies in China. As we do not have any good cloud technology and there are many mature cloud
service companies, they outsource the cloud to us. It will save a lot of time and cost for us, which will be convenient to us. The private cloud is deployed in the firewall of the enterprise data center (UMS Engineer).

What’s more, some virtualization technology is used to manage the IT resource or storage resource, which can simplify the resource management. Besides, some infrastructures monitoring management, backup and recovery management are also moved into the cloud platforms (UMS Engineer).

According to the smart factory maturity model (table 1), it is clear to see the maturity level of cloud computing is level 3 (IaaS). At level 1, Behrendt et al (2011) summarized that company manages and stores the resource based on the virtualization technology. At level 2, some basic management process is established and some basic monitoring functions are provided to monitor the utilization of infrastructures (Behrendt et al, 2011). As Behrendt et al (2011) concluded that functions in level 3 consisted of functions in level 1 and 2. Moreover, some infrastructures monitoring management, patch management, backup and recovery management are also included in this level.

4.2.5 Information Security Level

As discussed in the literature part, due to using of big data technology and cloud computing technology, information security in organizations can not be ignored in a smart factory (Ge, Yuan & Lu, 2011). The information security level of case company is developing level. As the IT manager stated:

From the whole enterprise perspective, we adopted some actions to make sure the security of information system. Firstly, we use the in-house network inside the company. Besides this, we also have a secure firewall to against hackers. In our IT department, there will be some staff responsible for the IT security. For UMS, we have set the different permission for different level (IT Manager)

However, I do not think we have a specialized IT security coordinator because our company is not a very big or well-known enterprise in China currently. Temporarily, I think we do not need a specific staff to take charge of IT security because some IT engineers can do these as extra work and the workload is not big I think. However, each staff in our company has a login account, our system will record everything when the staff login his account (Smart Home Director)

I have never considered the issue about information security, I just do my own work in the company and nobody tell me problems about information security (Office Staff).

Obviously, company has taken some measures in information security, however, the awareness of information security for staffs is low. Some IT risk assessment is important for the company.

4.2.6 Smart Service Level

Smart service is considered as a new economy field in future manufacturing industry
(Kagermann et al, 2013). In this smart factory maturity model, there are two parts in smart service. From the customer service perspective, the case company stays at level 4 named continuous improvement level. From the point view of smart product, this company stays at level 3. As Co-general Manager concluded:

*I am also responsible for the equipments in smart factory. When we design and assemble some machines and sell to our customers, we will set some early warnings in the machines. We can use the remote monitoring technology to see which components in machines need to be replaced. Besides, we will not sell our machines separately, instead, we sell our machines together with the UMS. This system will be customized. After using several months, we will collect some customer feedback and then we can give them advice and do some improvements in future (Co-general Manager).*

Our company also designs and produces some interesting items such as Gugu Bird, which is a small printer actually. It can be seen as a smart product, we have integrated sensor in this item, during using this printer, we collect data regarding users’ behavior, which can help us improve the product and explore other business idea (Co-general Manager).

*When it talks to the smart products, currently, we mainly accept orders from big customers like Logitech, Nestlé. For some small products like remote controller, we will not integrate sensors in it because the cost of remote controller will be high if we do this. If the remote controller is broken, most people choose to buy a new one. However, for some big products like Nestlé coffee machines, we can analyze users’ preference through integrated sensor to collect data in coffee machine (Smart Home director).*

In conclusion, the customer service stays at level 4 as Leppik (2013) concluded that organizations will collect data and then using these data to make improvements on future products at the continuous improvement level. When it talks to smart product, there are embedded sensors in partial product and it can collect the data.
Figure 4: concept map for smart factory maturity level

Figure 4 presents the concept map for smart factory maturity level based on interview data after coding. In order to identify the maturity level easily, one table (table 5) shows its level in different dimensions clearly.

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Level</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyber-Physical System</td>
<td>level 2</td>
<td>It has achieved the real-time data collection and wireless or wired communication in factory, some parts data can be transformed to useful information to do basic analysis. Besides, remaining life of parts machines can be estimated. However, information transfer is unidirectional.</td>
</tr>
<tr>
<td>Integrated Management System</td>
<td>level 2</td>
<td>Information exchange is smooth in internal company, almost all information systems are integrated in UMS. Staffs can use UMS to communicate with each other and managers can see the manufacturing process in detail through UMS. Product lifecycle can be monitored through UMS. Besides, data in factory are collected in UMS too. Moreover, when company sells UMS and machines, UMS and machines can be customized.</td>
</tr>
<tr>
<td>Big Data</td>
<td>level 1</td>
<td>Top management level supports the big data project, but staffs have a</td>
</tr>
</tbody>
</table>
low awareness of big data. Actually, they have some data warehouse. But, the amount of data is insufficient. Company has not started to do big data project.

Cloud Computing level 3
Company uses Ali private cloud to store their information resources. Some infrastructures monitoring management system, patch management, backup & recovery management are moved into cloud.

Information Security level 3
Organization has a low awareness of importance, they think it is a small probability event. However, they also take some actions in information security such as data encryption, permission setting, secure firewall, etc.

Smart Service (customer service) level 4
Customer feedback is collected by the company and they will use these feedbacks to make improvements on their products, however, there are not interactive reporting tools.

Smart Service (smart product) level 3
Sensors in parts products can do data collection and some products like Gugu Bird, some standard machines can connect to internet in real time. Parts of products can record their using status like automatic polishing machine.

Table 5: Smart Factory Maturity for Intretech

4.3 Enablers of building the smart factory for Intretech

Figure 6 demonstrates the enablers for Intretech in the development of the smart factory based on the codes. The smart factory enablers is divided into five categories, they will be discussed part by part next.
In the aspect of CPS enablers, as stated by chief engineer and electrical control director:

All machines in factory will be equipped with a module called AIO-First, which is designed by our group. AIO-First can be viewed as a converter and it connects basic layer with system layer. Nowadays, we adopt many different brands PLC, microcontrollers, and they have different interfaces. We need to do monitoring control in each device, as a result, AIO-First module can help us to identify and collect data from different machines easily. We collect the real-time data and store these data in our UMS and we adopted wired connection between AIO-First modules (Chief Engineer).

When it talks to self-tracing system, we have an ITTS checking platform, we will use this platform to check some items and then it will collect the data and transform to UMS (Chief Engineer).

We add spare sensors that the machines can continue to work if partial sensors go wrong during production. Based on some parts of collected data, we can do some early warnings in some machines. For example, the life span of one component in a machine is 5000 times, when it reaches this working times and it will sent out an alarm signal (Electrical Control Director).

From the point view of IMS, as the UMS engineer stated:

The UMS is designed by their group, it has integrated many information systems in it like OA, WIKI, JIER, SCM, PLM, EMS etc. Information exchange in internal company is smooth, even our customers can use partial functions for UMS, they can track their product output at home without going to factory. Moreover, there is one system called IPQC, which is used to check the stock materials. Additionally, we have KPI analysis in UMS, staffs in the company can give anonymous comments on other staffs (UMS Engineer).

Besides, as mentioned that our customers and suppliers can also use the UMS for partial functions, they can check the product output at their home or company without going to factory (UMS Engineer).

In the aspect of cloud computing and information security, as the IT manager pointed out:

Due to lack of cloud technology, we rent the Ali private cloud to store resource. I am happy we have sufficient IT staffs in our company, they are full of knowledge and young, which leads to a successful UMS. However, we are also improving this system gradually (IT Manager).

We use in-house network in internal company, and we will do some encryption during the data transformation. Besides this, we also adopt the secure firewall to prevent hackers from attacking (IT Manager).

Inside the company, each staff has his login account, when he logins his account, what you have done are recorded in the system. It can prevent staffs from stealing company secrets (Smart Home Director).

However, apart from those, there are also some enablers in organization level in the development of smart factory,

Due to fierce competition in current manufacturing industry, we must do some changes in manufacturing for better development in future. In our company, we have a strong team and each member in our team is in charge of his own work. Fro example, structural engineer is responsible for designing the machine contour, electrical engineer is responsible for electrical and automation design, etc. Besides this, the support from our
boss is also quite important, which means we will have sufficient funding and time to do this project. We are a pragmatic company, we will do those aspects that are useful to our development instead of pursuing some advanced technology blindly (Co-general Manager).

These are the five categories enablers in building a smart factory for Intretech.

4.4 Barriers of building the smart factory for Intretech

Besides the enablers for the development of smart factory, they also face a lot of challenges during the process of building the smart factory. Figure 7 presents a general concept map for barriers in building the smart factory.

![Figure 7: Barriers for building the smart factory](image)

From figure 7, barriers for building the smart factory can be divided into four parts. Firstly, the CPS barriers, as electrical control director stated:

*Our collected data is lack of quantity and quality due to weak communication between systems and*
machines. During the production, our collected data are some parameters like production, boot time, downtime, etc, therefore, it is difficult for us to do predictive maintenance. Secondly, data collection can be done from partial machines and we are trying to make improvements (Electrical Control Director).

Data transmission is unidirectional, UMS can collect data from machines, however, it can not give instructions to machines (Chief Engineer).

Secondly, from point view of big data, as Co-general Manager explained:

We know the importance of big data and it will be useful in our future manufacturing. However, we are lack of knowledge about big data currently. Actually, we have not started the big data project in our company. But, from the top management level, we all support this project (Co-general Manager).

Our self-tracing system is about the logistics tracking instead of the machines parameters, because our technology can not reach this level (Chief-Engineer).

In our company, we do not have specialized team to do data analytics and amount of data is insufficient, besides this, the data usage is not efficient I think (Electrical Control Director).

Moreover, there are also some organizational level barriers.

As a whole, the scope of our company is not large enough, some of our staffs are lack of skills and knowledge. Unlike Germany, some German workers are full of knowledge and skills, we need to study their spirit (Co-general Manager).

We will negotiate with the external suppliers to open interface to do data collection, because some devices are not designed by ourselves. It will be difficult for us to do data collection if suppliers do not provide the interface (Electrical Engineer).

Actually, some old technical staffs trust in their experience when they do decision instead of trusting system data, it is also a problem in some fields (Software Engineer).

Additionally, in the aspect of smart service, as smart home director expressed:

If some products are equipped with embedded sensors, the production cost will be high. At that time, we will sell higher than before, customers will not buy them. Beside this, we are also lack of technical support on the smart service. Because all the products need be connected to the internet, it will cause a lot of problems (Smart Home Director).

4.5 Summary

In conclusion, three main findings were obtained in this chapter, the smart factory maturity level for the case company as well as the enablers and barriers of building the smart factory.
Chapter 5: Further discussion

As discussed in the literature part, the aim of these three concepts is to build a smart factory. As a result, through the deep research and systematic study, a theoretical smart factory maturity model was build based on the six dimensions, namely cyber-physical system (CPS), integrated management system (IMS), Big data, Cloud computing, Information security and Smart service. In this smart factory maturity model, each dimension has several levels. In addition to this, each level has its corresponding characteristics.

For Chinese discrete manufacturing companies, the process of developing a smart factory is a comprehensive system project, as Liu (2016) concluded that transformation for some traditional companies and the innovation ability of the whole industry need to be taken into account. When a company tries to build or turn into a smart factory, they need to analyze the key factors at first. This smart factory maturity model can give a broad view in the development of smart factory. For example, the interconnection of smart devices, make decision and give support based on the big data analytics, management and control during the production process, the integration of the whole value chain and system, etc.

During the evaluation of the smart factory, there are some enablers and barriers that influence the development of smart factory. For the enablers in the development of the smart factory, it can be divided into two parts from the evaluation results. One is the technical part and another part is non-technical part. For technical part, automatic and networked machines are the basic condition in a smart factory. As Liu (2016) pointed out that the machines in smart factory need to be intelligent. Besides, real-time data collection is also essential in a smart factory. Therefore, choosing suitable and efficient sensors for machines is important. Moreover, big data analytics can not be ignored in smart factory. As LaWell (2015) highlighted that big data analytics can bring manufacturing industry huge treasure in future. Based on the big data analytics, company can do health management on machines and products, and it is highly possible to find new business chance through big data. For the products, self-tracing system is helpful because it can monitor and trace the product from raw material to final product step by step, which can make the whole production transparent. Additionally, with the use of big data, cloud computing will become more and more important particularly in data storage, data mining, data sharing, etc. Actually, apart from these technical enablers, some non-technical parts are also important. For example, top management support, sufficient funding, reasonable plan, long-term plan, talents, IT experts, etc are necessary for developing the smart factory. As Lee (2015) suggested that financial support is essential for one company to upgrade. Actually, it is correct, if the company has enough money and it means they can purchase machines, technology, building a strong team. As a result, for small Chinese manufacturing companies with low profits, it will be difficult for them to transform and upgrade without any help.

Meanwhile, there are also some challenges that Chinese manufacturing companies will face in the development of smart factory. Similarly, it can also be divided into two parts. One is technical barriers and another is non-technical factors. For technical challenges, there is no doubt
that lack of technology can be seen one of major reasons, which consists of hardware technology, software technology, etc. For the hardware technology, it covers machines, sensors, embedded systems, microcontrollers, etc. In the aspects of software technology, it consists of big data technology, cloud computing technology, information systems technology, etc. In contrast, some non-technical challenges also need to be paid attention. For example, lack of top management support, insufficient financial support, lack of good teams (talents), lack of good relationship with partners, lack of knowledge, etc can be viewed as some main challenges for developing the smart factory.

As a result, for most Chinese manufacturing companies, it is quite important for them to set up an effective and reasonable plan in developing smart factory step by step. In fact, many Chinese manufacturing companies stay at the level of industry 3.0 or even industry 2.0 (Liu, 2016). Therefore, a long-term plan is quite meaningful for them. Besides this, some rich Chinese manufacturing companies should avoid following the trend blindly, for example, purchasing many advanced machines that are unhelpful to them. Consequently, have a clear and accurate self-understanding of their factory and make a reasonable plan seem realistic and meaningful to them.

In fact, this dissertation not only illustrates how this smart factory maturity model can be used in manufacturing companies, but also resulted in some important conclusions.

First of all, it is important and necessary to know that smart factory evaluation can not be viewed as a simple assessment on one manufacturing company. Actually, as Markus & Tanis (2000) pointed out that a successful measurement on system can provide a deep understanding of its implementation. During this evaluation of the smart factory built by one Chinese manufacturing company, it can provide a deep insight in how to build a real and reasonable smart factory in six dimensions. Consequently, it is important for each manufacturing company to have an accurate and holistic self understanding of their location in the development of the smart factory. In this way, they can develop their smart factory step by step and avoid investing in new equipments and technology blindly.

Additionally, it is necessary and significant to know the establishment of a theoretical smart factory maturity model is just a beginning of the study in the field of smart factory. It will be important for manufacturing companies to develop further step and activity based upon the evaluation results. From the point view of IS change management, due to new business process and advanced technology, it will never be easy to develop a smart factory based on current knowledge and theory. As a result, manufacturing companies need be always prepared the inevitable barriers or challenges in their future.

In conclusion, a theoretical maturity model for smart factory based on six dimensions has been built under the concepts of German Industry 4.0, US Industrial Internet and Made in China 2025. However, different manufacturing companies stay at different levels in industry field. Therefore, it will be important for Chinese manufacturing companies have a self-understanding and have a reasonable plan for the development of their smart factory.
Chapter 6: Conclusion

The conclusion chapter is divided into four parts totally. Inside this chapter, section 6.1 describes the research objective achievements. Besides this, section 6.2 discusses the implications of this study. Moreover, limitation of this study was discussed in section 6.3. Finally, future work will be presented in section 6.4.

6.1 Research objective achievement

To sum up, as discussed above, there are four research objectives in this dissertation. These four objectives have been achieved finally. For the first objective, a smart factory maturity model (table 1) was built based on the concepts of German Industry 4.0, US Industrial Internet and Made in China 2025, which can be viewed as a major one. The second objective is to evaluate the smart factory maturity level built by one Chinese discrete manufacturing company based on this theoretical model. The third objective is to explore the enablers (technical & non-technical) in developing the smart factory for discrete manufacturing companies. In the final, the fourth objective is to investigate the barriers (technical & non-technical) that Chinese manufacturing companies will face during the development of smart factory.

However, as a consequence, for most Chinese manufacturing companies, it will be meaningful and reasonable to have a clear and accurate self-understanding on their own company and make a development plan for them.

6.2 Implications

This research study has important practical and theoretical implications. In practical terms, this smart factory maturity model built and proposed in this dissertation can be used as a tool by Chinese discrete manufacturing companies to evaluate the maturity level of their smart factory. Moreover, this smart factory is easily to be applied by discrete manufacturing companies or some consultants. Furthermore, the experience of using smart factory maturity model based on the case company above can give a platform for manufacturing companies to understand their problems in building the smart factory. Meanwhile, it can be viewed as a good opportunity to improve their knowledge and skills regarding smart factory in the company.

On the other hand, as this research is one of the first studies contributes to the smart factory maturity model, which can extend our understanding of smart factory related to those six dimensions. As presented in figure 4 and figure 5, which will be helpful during the development of smart factory for other manufacturing companies.
6.3 Limitations

For this dissertation, there are several limitations. First of all, when doing the evaluation in the case company, the number of participants seems not sufficient, especially the staffs who takes charge of UMS. Secondly, the results about enablers and barriers are lack of representation to some extent and parts of them are too general to some extent.

6.3 Future work

As discussed above, establishment of the theoretical smart factory maturity model is just the beginning of the study in the field of smart factory, what needs to do in the future is to improve this maturity model in manufacturing industry continuously based on more literature and practical experience.

Moreover, based on the improved smart factory maturity model and practical experience, try to make my own contribution to manufacturing companies in the word.

Word count:
13915 (except abstract, acknowledge, table, reference, appendix)
Reference


Bruner, J. (2013). Industrial Internet. " O'Reilly Media, Inc.".


## Appendix

### Appendix 1: Initial Coding Scheme

<table>
<thead>
<tr>
<th>Code</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Own development need</td>
<td>Texts about development need for the company</td>
</tr>
<tr>
<td>Data exchange</td>
<td>Texts about data exchange in manufacturing equipments</td>
</tr>
<tr>
<td>Build a model factory</td>
<td>Texts about building a model factory for other companies</td>
</tr>
<tr>
<td>Efficient system control</td>
<td>Texts describe systems can control the operations in factory like PLC, microcomputer</td>
</tr>
<tr>
<td>Do not have big data analysis tools</td>
<td>Texts about they are lack of big data tools to do data analysis</td>
</tr>
<tr>
<td>Human machine interaction</td>
<td>Texts describe barrier free communication between human and machine</td>
</tr>
<tr>
<td>Equipment management system</td>
<td>Texts about equipments management in UMS</td>
</tr>
<tr>
<td>AIO-First module</td>
<td>Texts about connecting manufacturing equipments through Modbus communication protocol</td>
</tr>
<tr>
<td>Wired communication</td>
<td>Texts describe communication among equipments is wired</td>
</tr>
<tr>
<td>Equipment basic parameters</td>
<td>Texts about some parameters like boot time, abnormal time</td>
</tr>
<tr>
<td>Machine failure remind</td>
<td>Texts about machines failure remind in factory</td>
</tr>
<tr>
<td>Collecting data from machines</td>
<td>Texts about collecting data from machines in factory</td>
</tr>
<tr>
<td>ITTS</td>
<td>Texts about a system to monitor the quality of product step by step</td>
</tr>
<tr>
<td>Paperless office</td>
<td>Texts about most reports at office, production line are paperless</td>
</tr>
<tr>
<td>Self-tracing system</td>
<td>Texts about a system that can trace the product from raw material to final product</td>
</tr>
<tr>
<td>B2B business</td>
<td>Texts about the business pattern in Xiamen Intretech Inc</td>
</tr>
<tr>
<td>B2C business</td>
<td>Texts about the business for smart home and smart manufacturing</td>
</tr>
<tr>
<td>Enterprise internal integration</td>
<td>Texts about the internal integration in company</td>
</tr>
<tr>
<td>Lack of scope</td>
<td>Texts describe the scope of the company is not large enough now</td>
</tr>
<tr>
<td>Insufficient data</td>
<td>Texts describe the amount of data is insufficient</td>
</tr>
<tr>
<td>Top management support</td>
<td>Texts describe top managers support the project of smart factory</td>
</tr>
<tr>
<td>Sufficient funding</td>
<td>Texts describe the funding for smart factory is sufficient</td>
</tr>
<tr>
<td>Lack of knowledge of basic staffs</td>
<td>Texts describe the basic staffs in factory are lack of knowledge</td>
</tr>
<tr>
<td>Do not have a big data team</td>
<td>Texts about the big data in the company</td>
</tr>
<tr>
<td>Do not have a security officer in factory</td>
<td>Texts about the security in factory</td>
</tr>
<tr>
<td>Set different access permission</td>
<td>Texts about the permission for the UMS in company</td>
</tr>
<tr>
<td>Bundle sales (machines &amp; UMS)</td>
<td>Texts describe the company will not sell machines separately</td>
</tr>
<tr>
<td>Trust in subjective experience</td>
<td>Texts describe that whether staffs trust in experience than system data</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>---------------------------------------------------------------------</td>
</tr>
<tr>
<td>Low-skilled staffs</td>
<td>Texts describe the staffs in factory is lack of skills</td>
</tr>
<tr>
<td>Low data quality</td>
<td>Texts about the quality of collected data from machines</td>
</tr>
<tr>
<td>Early warning</td>
<td>Texts about the early warning in machines or products</td>
</tr>
<tr>
<td>Reasonable plan</td>
<td>Texts about the plan for future development</td>
</tr>
<tr>
<td>Good relationship with partners</td>
<td>Texts about building up partnership with other companies</td>
</tr>
<tr>
<td>A strong team</td>
<td>Texts about people working together</td>
</tr>
<tr>
<td>Willpower of boss</td>
<td>Texts about the willpower of boss in investing to build a smart factory</td>
</tr>
<tr>
<td>Willingness of team</td>
<td>Texts about the willingness of team to build a smart factory</td>
</tr>
<tr>
<td>Sufficient IT experts in company</td>
<td>Texts about whether the IT experts in company is sufficient</td>
</tr>
<tr>
<td>Regular system check</td>
<td>Texts about the regular system check in company</td>
</tr>
<tr>
<td>Do not have vendor support</td>
<td>Texts about vendor support is insufficient in improving machines that are bought</td>
</tr>
<tr>
<td>Production transparency</td>
<td>Texts describe all the production process can be seen clearly</td>
</tr>
<tr>
<td>High efficient enterprise resource integration</td>
<td>Texts describe all the information systems in company are integrated in UMS such as OA, ERP, CRM, WIKI and others</td>
</tr>
<tr>
<td>Project management plan</td>
<td>Texts about the project plan during the production in factory</td>
</tr>
<tr>
<td>IPQC check</td>
<td>Texts about checking the quality of raw materials after purchasing</td>
</tr>
<tr>
<td>Simulation of materials</td>
<td>Texts about simulating whether materials that will be used tomorrow are sufficient</td>
</tr>
<tr>
<td>KPI analysis</td>
<td>Texts about key performance indicators analysis in factory</td>
</tr>
<tr>
<td>Independent technical architecture</td>
<td>Texts about using independent technical architecture in UMS</td>
</tr>
<tr>
<td>Platform sharing with suppliers and customers</td>
<td>Texts describe the suppliers and customers can use the UMS for free to interact with company</td>
</tr>
<tr>
<td>Collaborate with competitors</td>
<td>Texts describe the company collaborates with competitors</td>
</tr>
<tr>
<td>Rejection rate analysis</td>
<td>Texts about analysis for rejection rate during production in factory</td>
</tr>
<tr>
<td>Private cloud</td>
<td>Texts describe the cloud the company use is private</td>
</tr>
<tr>
<td>Cloud disaster recovery</td>
<td>Texts describe data in cloud can recover and will not leak out if something happens</td>
</tr>
<tr>
<td>Pragmatism</td>
<td>Texts describe the company adopts useful and beneficial ideas and they are really suitable for the company</td>
</tr>
<tr>
<td>Reasonable arrangement for staffs</td>
<td>Texts describe the managers arrange staffs in a reasonable way</td>
</tr>
<tr>
<td>Do not have scanner in warehouse</td>
<td>Texts describe there are lack of scanners for inbound and outbound operations in warehouse</td>
</tr>
<tr>
<td>Lack of big database</td>
<td>Texts describe there is not big database for company to use to do analysis</td>
</tr>
<tr>
<td>Do data collection at parts of machines</td>
<td>Texts describe that data are collected from parts of machines in factory</td>
</tr>
<tr>
<td>Feature</td>
<td>Description</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Real-time data collection</td>
<td>Texts about data collection is real-time</td>
</tr>
<tr>
<td>Add spare sensors</td>
<td>Texts about spare sensors are added to prevent error in machines during production</td>
</tr>
<tr>
<td>Reliability design</td>
<td>Texts about the design is reliable for machines</td>
</tr>
<tr>
<td>Simulation of machine operation</td>
<td>Texts about the simulation of machine operation before using in factory</td>
</tr>
<tr>
<td>User involvement</td>
<td>Texts about user involvement in using and maintaining the machines</td>
</tr>
<tr>
<td>Increasing cost</td>
<td>Texts about cost of smart service will increase</td>
</tr>
<tr>
<td>Insufficient data usage</td>
<td>Texts about data usage is not sufficient</td>
</tr>
<tr>
<td>Technical team support</td>
<td>Texts about technical team support in building smart factory</td>
</tr>
<tr>
<td>Data transmission is unidirectional</td>
<td>Texts describe the data transmission is unidirectional</td>
</tr>
<tr>
<td>Weak communication between machines and system</td>
<td>Texts about the communication between machines and system is weak</td>
</tr>
<tr>
<td>In-house network</td>
<td>Texts about the network is in-house in company</td>
</tr>
<tr>
<td>Data encryption</td>
<td>Texts about the data encryption during transmission in factory</td>
</tr>
<tr>
<td>Automatic machines</td>
<td>Texts about the most machines in factory are automatic</td>
</tr>
<tr>
<td>Data archiving</td>
<td>Texts about the data archiving in company</td>
</tr>
<tr>
<td>Remote monitoring</td>
<td>Texts about remote monitoring through UMS in company</td>
</tr>
<tr>
<td>Secure firewall</td>
<td>Texts describe there is a secure firewall in company</td>
</tr>
<tr>
<td>Lack of knowledge about big data</td>
<td>Texts describe the knowledge about big data in company is insufficient</td>
</tr>
</tbody>
</table>

**Appendix 2: Second Coding Scheme with themes**

**Enablers (5 sub-themes)**

<table>
<thead>
<tr>
<th>Theme</th>
<th>ID</th>
<th>Code of Enabler</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPS Enablers</td>
<td>E1</td>
<td>Human machine interaction</td>
<td>Texts describe barrier free communication between human and machine</td>
</tr>
<tr>
<td>E2</td>
<td>AIO-First module</td>
<td>Texts about connecting manufacturing equipments through Modbus communication protocol</td>
<td></td>
</tr>
<tr>
<td>E3</td>
<td>Efficient system control</td>
<td>Texts describe systems can control the operations in factory efficiently like PLC, microcomputer</td>
<td></td>
</tr>
<tr>
<td>E4</td>
<td>Early warning</td>
<td>Texts about the early warning in machines or products</td>
<td></td>
</tr>
<tr>
<td>E5</td>
<td>ITTS</td>
<td>Texts about a system to monitor the quality of product that are produced step by step</td>
<td></td>
</tr>
<tr>
<td>E6</td>
<td>Rejection rate analysis</td>
<td>Texts about analysis for rejection rate during production in factory</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td></td>
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<tr>
<td>E7</td>
<td>Real-time data collection</td>
<td>Texts about data collection is real-time</td>
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</tr>
<tr>
<td>E8</td>
<td>Production transparency</td>
<td>Texts describe all the production process can be seen clearly</td>
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<tr>
<td>E9</td>
<td>Add spare sensors</td>
<td>Texts about spare sensors are added to prevent error in machines during production</td>
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<td>E10</td>
<td>Reliability design</td>
<td>Texts about the design is reliable for machines</td>
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<td>E11</td>
<td>Simulation of machine operation</td>
<td>Texts about the simulation of machine operation before using in factory</td>
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<td>E12</td>
<td>Automatic machines</td>
<td>Texts about the most machines in factory are automatic</td>
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<td>E13</td>
<td>Effective remote monitoring</td>
<td>Texts about remote monitoring through UMS in company is effective</td>
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<tr>
<td>IMS Enablers</td>
<td>E14</td>
<td>Useful equipment management system</td>
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<td></td>
<td></td>
<td>Texts about equipments management in UMS is easy-use</td>
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<tr>
<td>E15</td>
<td>Self-tracing system</td>
<td>Texts about a system that can trace the product from raw material to final product</td>
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<td>E16</td>
<td>Efficient enterprise internal resource integration</td>
<td>Texts describe all the information systems in company are integrated in UMS such as OA, ERP, CRM, WIKI and others</td>
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<td>E17</td>
<td>Regular system check</td>
<td>Texts about the regular system check in company</td>
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<td>E18</td>
<td>IPQC check</td>
<td>Texts about checking the quality of raw materials after purchasing</td>
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<tr>
<td>E19</td>
<td>Simulation of materials</td>
<td>Texts about simulating whether materials that will be used tomorrow are sufficient</td>
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<tr>
<td>E20</td>
<td>KPI analysis</td>
<td>Texts about key performance indicators analysis in factory</td>
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<tr>
<td>E21</td>
<td>Platform sharing with suppliers and customers</td>
<td>Texts describe the suppliers and customers can use the UMS for free to interact with company</td>
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<tr>
<td>Cloud Computing Enablers</td>
<td>E22</td>
<td>Sufficient IT experts in company</td>
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<td></td>
<td></td>
<td>Texts about whether the IT experts in company is sufficient</td>
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<td>E23</td>
<td>Independent technical architecture</td>
<td>Texts about using independent technical architecture in UMS</td>
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<tr>
<td>E24</td>
<td>Private cloud support (Ali cloud)</td>
<td>Texts describe the cloud the company use is private</td>
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<tr>
<td>E25</td>
<td>Cloud disaster recovery support</td>
<td>Texts describe data in cloud can recover and will not leak out if something happens</td>
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<tr>
<td>Security Enablers</td>
<td>E26</td>
<td>Wired communication use</td>
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<td></td>
<td></td>
<td>Texts describe communication among equipments is wired</td>
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<tr>
<td>E27</td>
<td>Set different access permission</td>
<td>Texts about the permission for the UMS in company</td>
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<td>E28</td>
<td>In-house network</td>
<td>Texts about the network is in-house in company</td>
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</tr>
<tr>
<td>E29</td>
<td>Data encryption</td>
<td>Texts about the data encryption during</td>
<td></td>
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</table>
transmission in factory

E30 Data archiving  
Texts about the data archiving in company

E31 Secure firewall  
Texts describe there is a secure firewall in company

**Organization level Enablers**

E32 Own development need  
Texts about development need for the company

E33 Paperless office  
Texts about most reports at office, production line are paperless

E34 Top management support  
Texts describe top managers support the project of smart factory

E35 Sufficient funding  
Texts describe the funding for smart factory is sufficient

E36 Reasonable plan  
Texts about the plan for future development

E37 Good relationship with partners  
Texts about building up partnership with other companies

E38 A strong team  
Texts about people working together

E39 Willpower of boss  
Texts about the willpower of boss in investing to build a smart factory

E40 Willingness of team members  
Texts about the willingness of team to build a smart factory

E41 Collaborate with competitors  
Texts describe the company collaborates with competitors

E42 Pragmatism  
Texts describe the company adopts useful and beneficial ideas and they are really suitable for the company

E43 Reasonable arrangement for staffs  
Texts describe the managers arrange staffs in a reasonable way

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**Barriers (4 sub-themes)**

<table>
<thead>
<tr>
<th>Theme</th>
<th>ID</th>
<th>Code of Barriers</th>
<th>Definition</th>
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<tr>
<td><strong>CPS Barriers</strong></td>
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<tr>
<td>B1</td>
<td></td>
<td>Low data quality</td>
<td>Texts about the quality of collected data from machines</td>
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<tr>
<td>B2</td>
<td></td>
<td>Do data collection at parts of machines</td>
<td>Texts describe that data are collected from parts of machines in factory</td>
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<tr>
<td>B3</td>
<td></td>
<td>Insufficient data usage</td>
<td>Texts about data usage is not sufficient</td>
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<tr>
<td>B4</td>
<td></td>
<td>Data transmission is unidirectional</td>
<td>Texts describe the data transmission is unidirectional</td>
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<td>B5</td>
<td></td>
<td>Weak communication between machines and system</td>
<td>Texts about the communication between machines and system is weak</td>
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<td><strong>Big Data Barriers</strong></td>
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<td>B6</td>
<td></td>
<td>Do not have big data analysis tool</td>
<td>Texts about they are lack of big data tools to do data analysis</td>
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<td>B7</td>
<td></td>
<td>Insufficient data</td>
<td>Texts describe the amount of data is</td>
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<td>Organizational Level Barriers</td>
<td>B8</td>
<td>Do not have a big data team</td>
<td>Texts about the big data in the company</td>
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<tr>
<td>B9</td>
<td>Do not have data scientist</td>
<td>Texts about one position for data analysis</td>
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<tr>
<td>B10</td>
<td>Lack of big databases</td>
<td>Texts describe there is not big database for company to use to do analysis</td>
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<tr>
<td>B11</td>
<td>Lack of knowledge about big data</td>
<td>Texts describe the knowledge about big data in company is insufficient</td>
<td></td>
</tr>
<tr>
<td><strong>B12</strong></td>
<td>Lack of scope</td>
<td>Texts describe the scope of the company is not large enough now</td>
<td></td>
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<tr>
<td>B13</td>
<td>Lack of knowledge of basic staffs</td>
<td>Texts describe the basic staffs in factory are lack of knowledge</td>
<td></td>
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<tr>
<td>B14</td>
<td>Trust in subjective experience</td>
<td>Texts describe that whether staffs trust in experience than system data</td>
<td></td>
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<tr>
<td>B15</td>
<td>Low-skilled staffs</td>
<td>Texts describe the staffs in factory is lack of skills</td>
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<tr>
<td>B16</td>
<td>Lack of vendor support</td>
<td>Texts about vendor support is insufficient in improving machines that are bought</td>
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<tr>
<td>B17</td>
<td>Inadequate understanding of smart factory</td>
<td>Texts about staffs in company have inadequate understanding of smart factory</td>
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<tr>
<td>Smart Service Barriers</td>
<td>B18</td>
<td>Increasing cost</td>
<td>Texts about cost of smart service will increase</td>
</tr>
<tr>
<td>B19</td>
<td>Lack of technical support</td>
<td>Texts about technical team support in building smart factory</td>
<td></td>
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</tbody>
</table>
Appendix 3: Ethics Approval Letter (screenshot)

Dear Fei

PROJECT TITLE: How the German vision of Industry 4.0 can be viewed in Chinese discrete company?
APPLICATION: Reference Number 009254

On behalf of the University ethics reviewers who reviewed your project, I am pleased to inform you that on 28/06/2016 the above-named project was approved on ethics grounds, on the basis that you will adhere to the following documentation that you submitted for ethics review:

- University research ethics application form 009254 (dated 18/06/2016).
- Participant information sheet 1019003 version 1 (19/06/2016).
- Participant consent form 1018860 version 1 (27/05/2016).

If during the course of the project you need to deviate significantly from the above-approved documentation please inform me since written approval will be required.

Yours sincerely

Daniel Rose
Ethics Administrator
Information School

Appendix 4: Participant Information Sheet

1. Research Project Title
Evaluation of smart factory maturity based on Chinese discrete manufacturing enterprise

2. Invitation paragraph
You are being invited to take part in a research project. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part in. Thank you for reading this.
3. What is the project purpose?
Due to different kinds of problems in Chinese manufacturing companies nowadays, Chinese government releases the policy named ‘Made in China 2025’, which has the similar function like German Industry 4.0. Therefore, during the transformation from traditional factory to smart factory, whether the factory is a real smart factory or not need to be evaluated. Through interviewing staffs in case company, the data can be collected and it will be helpful for evaluating. The project will be lasted for around 5 working days.

4. Why have I been chosen?
The smart factory maturity model will be used in the case company, Xiamen Intretech Inc. All prospective participants are from Xiamen Intretech Inc. Participants from manufacturing departments, IT departments and line production are in the majority. It is estimated that there will be about 20 participants taking the interview.

5. Do I have to take part?
It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep (and be asked to sign a consent form) and you can still withdraw it at any time without affecting any benefits that you are entitled to in any way. You do not have to give a reason.

6. What will happen to me if I take part?
Each participant will be involved in the research for about 45 minutes. There are around 15 questions will be asked but it really depends on circumstances. The type of interview will be semi-structured interview.

7. What do I have to do?
No lifestyle restrictions will be happened as a result of participating.

8. What are the possible disadvantages and risks of taking part?
The biggest disadvantage for your participation will be inconvenient. It will potentially cause some inconveniences for participants. There are not any other disadvantages and risks for the participation.

9. What are the possible benefits of taking part?
Whist there are no immediate benefits for those people participating in the project, it is hope that this work will be helpful for the case company to be developed into smart factory further.

10. What happens if the research study stops earlier than expected?
If this is the case, the reasons for this situation will be explained to the participants.

11. What if something goes wrong?
Participants have authority to complain about the problems they encountered. For example, participants can contact my supervisor to raise a complaint. However, if they are not satisfied with the results, they can contact the Head of Department, who will then escalate the complaint through the appropriate channels.

12. Will my taking part in this project be kept confidential?
All the information that we collect about you during the course of the research will be kept strictly confidential. You will not be able to be identified in any reports or publications.

13. What type of information will be sought from me and why is the collection of this information relevant for achieving the research project’s objectives?
Information regards the manufacturing process, infrastructures, IT system, manufacturing equipments, technologies and other information in case company factory will be collected.

14. What will happen to the results of the research project?
We promise that the data collected will be deleted after finishing the master dissertation, if possible, the publications will not cover the individual information for each participant. In addition, the data will not be used by any other people or organizations.

15. Who is organizing and funding the research?
Xiamen Intretech Inc will organize this research and nobody will fund the research.

16. Who has ethically reviewed the project?
My supervisor will review the project.

Question to insert into an information sheet if the research involves producing recorded media:
The audio recordings of your activities made during this research will be used only for analysis in the researcher’s dissertation. No other use will be made of them without your written permission, and on one outside the project will be allowed access the original recordings.

12th July, 2016
Appendix 5: Participant Consent Form

Participant Consent Form

Title of Research Project: **Evaluation of smart factory maturity based on Chinese discrete manufacturing enterprise**

Name of Researcher: Fei Xing

**Participant Identification Number for this project:**

1. I confirm that I have read and understand the information sheet dated [12th July, 2016] explaining the above research project and I have had the opportunity to ask questions about the project.

2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason and without there being any negative consequences. In addition, should I not wish to answer any particular question or questions, I am free to decline. *Contact number is 0044 1142222658*

3. I understand that my responses will be kept strictly confidential. I give permission for members of the research team to have access to my anonymised responses. I understand that my name will not be linked with the research materials, and I will not be identified or identifiable in the report or reports that result from the research.

4. I agree for the data collected from me to be used in future research

5. I agree to take part in the above research project.
Appendix 6: Interview questions

Introduction: Hello! My name is Fei Xing, I am the master student studying at Information School, The University of Sheffield. Thank you so much that you can participate in this interview during your busy work. The content of this interview is about evaluation of the smart factory maturity in your company.

Before conducting the interview, I want to ask if you mind me using the electronic equipment to record the conversation during the interview, which is order to collect data conveniently. At here, I need to explain all the interview data will be kept confidentially and will not reveal to others
without your permission. It is only for the research dissertation and will not use it as commercial use. In addition, you have the authority to stop the recording at any time.

Open questions
1. Hi, what is your position in your company?
2. Besides this, what is your daily work in the company?
3. Would you mind telling me your idea about smart factory? Another way to say, what kind of factory can be viewed as a smart factory?

CPS (cyber-physical system) questions
4. Let us talk about the facilities in factory, how can the IT system control the machines or sensors in the factory? Can the machines or sensors collect the real-time data during the manufacturing?
   Follow-up question: if the data is collected, what kind of the data does the sensors or machines collect? (e.g. stock data, manufacturing time, machines usage, residual materials, position data, overall equipment efficiency, etc)
   Trigger question: what are the functions of the collected data? (machine predictive maintenance, optimize the production process, create the transparency of whole production, quality management, control production through real-time data usage, Utilize resource efficiently, etc)

5. How to collect data from machines by using data or machines? (manually, automatically)
   Trigger question: when the sensors or machines are collecting data, where are these data stored?
   Do you have some tools to classify the collected data into different databases?

6. During the production in the company, how to avoid or reduce the probability of error?
   Whether the factory is paperless? Do you adopt some methods to simulate the production?
   Follow-up question: Does the machines have the ability of self-diagnose, self-prediction, self-tracing, self-maintenance? If so, how to achieve this? Is there any technology?

IMS (integrated management system) questions
7. From the point view of the whole company, are all the information systems (OA, ERP, WIKI, SCM, etc) integrated in one system? How to integrate these information systems?
   Follow-up question: Do you use any information technology to do integration?

8. During the production in the factory, does the IT system can control the manufacturing process or change the production approach at any time?
   Trigger question: Whether it is full digitalized during the manufacturing process? Whether the real production mode can be combined with actual situation?
   Follow-up question: Can customers design their product by themselves? Whether the process is transparent from materials to final product?

9. Can information be shared between internal company and external company?
   Follow-up question: Does the information flow smoothly inside the company? What about the efficiency and effectiveness of information exchange?
Follow-up question: Besides the information flow in internal company, does the information can be shared or exchanged among customers, suppliers, partners, competitors?

**Big data questions**

10. What is the opinion of big data for the staffs in the company? Is there any support from the aspects of leadership, funding, culture, organization strategy?

Follow-up question: Does the CIO of the company support the project of big data? What is opinion of big data from the staffs in IT department?

Trigger question: By the way, can you tell me how to do the business analysis when you design or produce the products? What things are you based to do the business analysis? Will you use the big data analysis? If it is, how to do this and what are the steps?

11. From the perspective of infrastructures, does the company be equipped with some data big tools such as Hadoop cluster, NoSQL database, etc?

Trigger question: If not, where are the company data stored? (manufacturing data, customer data, supplier data, material data, staffs information data etc). Besides this, how often does the company update the data warehouse? Whether the data warehouse is enough?

12. From the perspective of data management, what does the strategy of data management?

Follow-up question: whether there is a standard or process copied with organizational data management strategy? How to deal with the amounts of data? What is the method? Updating database regularly?

13. From the perspective of data analysis, how to do data analysis in company?

Follow-up question: Do you have the specialized data analyst? Or do you have the separate department be responsible for data analytics?

Trigger question: If the company does the data analysis, how to divide those data into different categories? What are the standards?

14. From the perspective of data governance, which department takes charge of these data?

Follow-up question: Is there any data governance strategy in the company?

**Cloud computing questions**

15. Does the company adopt any cloud computing service? What kind of cloud service does the company adopt? (private cloud, public cloud and Hybrid cloud)?

Follow-up question: what kinds of applications does the company move them into the cloud? What kinds of data are stored in the cloud? How to make sure the security of these data?

Trigger question: Is there any standard to manage the data? Is there any measure to make sure the cloud disaster recovery, cloud backup service?

Trigger question: what is the aim of using cloud computing?

**Security question**

16. Have you thought about the information security of the smart factory? What is your opinion of information security in your company?

Follow-up question: What kinds of action does the company take to make sure the security of
information? Who is responsible for information security in the company?
Trigger question: In the daily guide of the company, does it include the information technology security?
Trigger question: How to ensure the security of data in data warehouse or database? How to make sure the security during data exchange?

**Smart service**

17. For the products manufactured in company, whether there are some sensors in the products that can collect the real-time data? (user data, remaining life, etc)
Follow-up question: If the company can collect these data, what they will do to deal with these data?

18. Does the company do some improvements based on the customers’ feedback? How to do this?
Trigger question: For the bulky product, whether the company can monitor their working process and remaining life and give advice to customers based on the collected data?

19. Further question, what are the enablers for your company during the establishment of smart factory
Follow-up question: which factors will influence the development of smart factory?
Trigger question: From your experience, what will be the most important factor?

20. During the development of smart factory, what kinds of barriers do you face now? What about in the future?
Follow-up question: What are the specific problems you encounter?
Trigger question: When you face these problems, how to deal with them?
Appendix 7: Ethics Application Form

Application 009254

Section A: Applicant details

Created:
Fri 27 May 2016 at 20:41

First name:
Fei

Last name:
Xing

Email:
fxing1@sheffield.ac.uk

Programme name:
Information Management

Module name:
INF6000

Last updated:
28/06/2016

Department:
Information School

Date application started:
Fri 27 May 2016 at 20:41

Applying as:
Undergraduate / Postgraduate taught

Research project title:
How the German vision of Industry 4.0 can be viewed in Chinese discrete company?

Section B: Basic information

| 1. Supervisor(s) | | |
|------------------|------------------|
| Name             | Email            |
| Alex Peng        | g.c.peng@sheffield.ac.uk |
2: Proposed project duration

Proposed start date:
Mon 27 June 2016

Proposed end date:
Thu 25 August 2016

3: URMS number (where applicable)

URMS number
- not entered -

4: Suitability

Takes place outside UK?
Yes

Involves NHS?
No

Healthcare research?
No

ESRC funded?
No

Involves adults who lack the capacity to consent?
No

Led by another UK institution?
No

Involves human tissue?
No

Clinical trial?
No

Social care research?
No

5: Vulnerabilities

Involves potentially vulnerable participants?
No

Involves potentially highly sensitive topics?
No

Section C: Summary of research
1. Aims & Objectives

Aim: How the German concept of industry 4.0 be used in Chinese discrete company

Objectives:
1. explore the problems that Chinese discrete company face
2. explore the benefits for Chinese discrete company adopting the concept
3. explore the enablers for this transformation
4. investigate the challenges or barriers those companies face during the transformation
5. build a Chinese model with the view of Industry 4.0
6. discover the future situation and development for Chinese discrete company

2. Methodology

Data collection: Interview and observation
I will make a plan ahead and list some questions that I want to know. Face-to-face interview can help me know more details about the company including their current situation and future plan. For observation, I will list a plan and do observation based on specific points, which includes visit their factory, working process.
Data analysis: Inductive Thematic Analysis
Through literature review and case study, build a Chinese model and then implement this model in case company.

3. Personal Safety

Raising personal safety issues? No

Personal safety management
- not entered -

Section D: About the participants

1. Potential Participants

Top managers, R&D center manager, Operations center manager, QA center manager and other potential staffs at Xiamen Intretech Company

2. Recruiting Potential Participants

First of all, all the potential participants are from case company called Xiamen Intretech Inc. Besides, they have agreed to accept the interviews conducted by me. They know the data will be used in my master dissertation and I will keep the collected data for about three months. The time for collecting data is around the mid of July and it will last for about 7 working days I think. Majority of participants are from IT department and some manufacturing departments, and some basic staffs work in the factory will also be included.

2.1 Advertising methods
Will the study be advertised using the volunteer lists for staff or students maintained by CiCS? No

- not entered -

3. Consent

Will informed consent be obtained from the participants? (i.e. the proposed process) Yes

I will write it clearly that all the data collected will be just used in this project. I will not leak these data to other company for business value.

4. Payment

Will financial/in kind payments be offered to participants? No

- not entered -

5. Potential Harm to Participants

What is the potential for physical and/or psychological harm/distress to the participants?

Inconvenience will become a harm to the participants, therefore, i will arrange each participant and make sure it will not cause inconvenien for them.

How will this be managed to ensure appropriate protection and well-being of the participants?

Make an appointment and arrange time in advance

Section E: About the data

1. Data Confidentiality Measures

No individual names will be collected or recorded at any point of the interview, and no individual names will be mentioned in the final dissertation and its related publications.

2. Data Storage

The data collected will be analysed for my master dissertation. It will be stored on the Information School's research data drive which can be accessed by only by me, my supervisor and the School's Examinations Officer and ICT staff operating the facility. The data will be deleted 3 months after the dissertation has been completed. I will also store a password protected backup copy my personal USB stick, and will delete this data once the dissertation has been completed and marked.

Section F: Supporting documentation

Information & Consent
Participant information sheets relevant to project?
Yes

**Participant Information Sheets**
- Participant Information Sheet.pdf
  (Document 023744)

Consent forms relevant to project?
Yes

**Consent Forms**
- Consent-Form.doc
  (Document 022539)

**Additional Documentation**
None

**External Documentation**
- not entered -

Offical notes
- not entered -

**Section G: Declaration**

Signed by:
Fei Xing
Date signed:
Sat 18 June 2016 at 17:41
Appendix 8: Access to Dissertation

A Dissertation submitted to the University may be held by the Department (or School) within which the Dissertation was undertaken and made available for borrowing or consultation in accordance with University Regulations.

Requests for the loan of dissertations may be received from libraries in the UK and overseas. The Department may also receive requests from other organisations, as well as individuals. The conservation of the original dissertation is better assured if the Department and/or Library can fulfill such requests by sending a copy. The Department may also make your dissertation available via its web pages.

In certain cases where confidentiality of information is concerned, if either the author or the supervisor so requests, the Department will withhold the dissertation from loan or consultation for the period specified below. Where no such restriction is in force, the Department may also deposit the Dissertation in the University of Sheffield Library.

To be completed by the Author – Select (a) or (b) by placing a tick in the appropriate box

If you are willing to give permission for the Information School to make your dissertation available in these ways, please complete the following:

√ (a) Subject to the General Regulation on Intellectual Property, I, the author, agree to this dissertation being made immediately available through the Department and/or University Library for consultation, and for the Department and/or Library to reproduce this dissertation in whole or part in order to supply single copies for the purpose of research or private study

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Name  Fei Xing
Department  Information School
Signed  Fei Xing  Date  30/8/2016

To be completed by the Supervisor – Select (a) or (b) by placing a tick in the appropriate box

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