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Enablers for embedding big data solutions in smart factories: an empirical investigation

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Abstract

This study provides insight into the enablers that assist organizations in implementing big data solutions in their smart factory development, as well as the interrelationships between these enablers from an information system (IS) perspective. The research followed an inductive qualitative approach. Twenty-two in-depth semi-structured interviews were conducted with experienced consultants and IT managers from SAP Consultancy Company, and general managers and engineers from Xiamen Intretech Inc., a leading manufacturing company in adopting big data solutions in smart factory. Following thematic analysis approach, three sets of enablers including organization, technology and external environment were identified together with the interrelationships between them. This paper extends the current understanding of smart factory and big data solutions in information system research through offering an empirical investigation of different enablers in this context. The findings also provide recommendations for practitioners to increase the possibilities of success when implementing big data solutions in smart factory context.

Keywords: smart factory, big data, enablers, SAP, Intretech Inc.

Introduction

The appearance and application of big data have led to enormous changes and improvements, for example, from environmental research to complex physics simulations and from finance and business to healthcare (Yin & Kaynak, 2015). From an industry perspective, with the wide discussions on big data, there have been increasing focuses on the concept and development of smart factory. The smart factory is defined as a factory within in which the context-aware assists workers and machines executing their tasks (Hermann, Pentek & Otto, 2016). A smart factory utilizes big data through physical cyber systems so that machines and resources can communicate in the 'social network' that is being created (Yin & Kaynak, 2015). It adopts and combines physical technology and cyber technology as well as deeply integrates previous independent systems (Chen et al., 2018), which makes the production machine and pattern more accurate, efficient and dynamic. Therefore, smart factory fills the idea of connecting people such as organization employees and customers, things including machines and products, and data so that there can be new ways of organizing (Hermann et al., 2016). Compared to traditional manufacturing, a smart factory extensively integrates customers, companies, partners and the public, and is highly flexible in production and customization (Shrouf, Ordieres & Miragliotta, 2014). Such a smart factory is more efficient due to the combination and integration of production technologies and devices, information systems, data and services in network infrastructures (Strozzi et al., 2017).

Big data plays a primarily important role in smart factory development. In a mature smart factory context, there are a large number of smart or intelligent machines working simultaneously and autonomously in order to assist in the production. Within such context, a huge amount of data is constanly generated via the usage of IoT-based sensors, actuators, controllers embedded in the machines throughout the manufacturing processes (Lee et al, 2014). According to a research conducted by McKinsey, through the use of big data in smart factory, manufacturers could decrease up to 50% of their efforts in product development and decision-making; the analysis results of data processing sent by smart devices could assist the factories to identify the preferences of customers and thus improve and shape their future products (Yin & Kaynak, 2015). This allows the organizations to cope with challenges such as short product life cycles and rapid reaction to market changes in a timely manner. Another research result shows that up to the end of the year of 2016, 90% of the data existing in the world was created throughout the year of 2015 (Mabkhot et al., 2018), which provides significant potential to store and retrieve data for companies to meet different requirements and goals. Companies would also be able to produce small batch sizes of products or even cost-effective single items as big data analysis results enable them to have sufficient functionality and connectivity with customers and suppliers (Mabkhot et al., 2018).

Despite enormous opportunities that are brought by embedding big data solutions, challenges remain with regard to how to enable its application in the smart factory context effectively. Particularly, with the emergence of smart factory concept and big data, the traditional philosophy of information systems will change in this context. Up to this date, researchers have studied specific topics related to the application of big data to the smart factory context, our review of the literature revealed that the current studies mainly focus on security aspects (Sadeghi, Wachsmann, & Waidner, 2015), smart operators and enhanced supply chains (Kolberg & Zühlke, 2015), development and application of CPS in Industry 4.0 environments from engineering perspectives (Jazdi, 2014) or the relationship between Big Data and IoT (Shah, 2016). More importantly, current studies in the big data and smart factory field are primarily driven by technical perspectives. Indeed, the success of big data usage in smart factory context highly depends on advanced technologies; however, its success still relies on how to utilize and manage the big data in smart factory more efficiently and effectively from a socio-technical and information system (IS) perspective, especially with considerations of the application environment.

Smart factory undoubtedly brings changes to elements in the traditional IS whilst incorporate new requirements to the systems so that the company operating smart factory can better compete in the future market (Mabkhot et al., 2018). As smart factory is considered to be one of the key components driving the next industrial paradigm, these initiatives will require sufficient IS that supports all the data that will be generated and effective IS Consultancy teams to implement these solutions when a manufacturing company decides to make the shift. Meanwhile, in a recent literature review on the IS requirements in developing smart factory, Mabkhot et al (2018) suggested that there is very few research focusing on system enablers or factors in the smart factory context. They further pointed out that researchers tend to place little emphasis on the current state of industry in terms of facilitating smart factory from IS perspectives (Mabkhot et al., 2018).

In light of the above literature gap, studies on how to utilize big data in smart factory context especially from an IS perspective are important and currently neglected. Therefore, the aim of this research is to empirically investigate and present different types of enablers that are perceived important, not only by experienced IS project managers, consultants but also from the perspective of a user company to realize the successful big data usage in smart factory. The primary research question of this study is:

What are the enablers from not only IS consultants but also a user perspective in order to successfully facilitate the implementation of Big Data solutions in the smart factory context?

This paper contributes to the literature through providing an empirical investigation and identification of a variety of enablers that facilitate the big data application in the smart factory context. The research also provide recommendations for practitioners in order to increase the possibilities of success when implementing Big Data solutions in Industry 4.0 initiatives.

Methodology

This section provides detailed justification of the adopted research methodology together with explanation about how it was implemented. In order to explore the enablers associated in applying big data solutions in smart factories, this study followed an inductive qualitative approach with the use of semi-structured interview as the data collection method. Twenty-two semi-structured interviews were conducted with 5+ years experienced SAP Consultants, IT Managers from the SAP consultancy company, and general managers and engineers from the Xiamen Intretech Inc. company. The purpose of collecting data from two distinct organizations is to gain insights from the perspectives of both consultants and users, and thus obtaining a relatively more comprehensive understanding of the enablers under investigation. The research data was analyzed via the thematic analysis approach.

Inductive qualitative approach

It is widely acknowledged that inductive research approach aims to build theory based on collected data, and is so suitable for studies focusing on new topics which do not have many existing literature (Saunders, 2011). In contrast, deductive research aims to test existing theory or verify hypotheses derived from current literature on a specific topic (Soiferman, 2010). As revealed in the introduction section, the existing studies have not yet investigated enablers of implementing big data solutions in the smart factory context. Due to this lack of existing theory and literature to conduct a deductive study, this research followed an inductive approach. Moreover, considering the complexity of different enablers for big data in a smart factory, this study required the collection of in-depth human opinions, insights and perceptions (rather than just numerical data) in order to explore related phenomena in details. Consequently, this inductive study also adopted a qualitative approach.

Data collection

Semi-structured interview strategy was adopted for data collection. Semi-structured interview can increase interaction and lead to a deep discussion compared with 'structured' use of closed questions (Cohen & Crabtree, 2006). Moreover, as Cohen & Crabtree (2006) concluded that researchers need to prepare in advance a list of interview questions in semi-structured interview, which will be easier to collect high-quality data than using unstructured interview.

The interview questions were elaborated with the objective of allowing the researcher to obtain in-depth insights regarding the experience and knowledge of the interviewees related to the research scope (Qu & Dumay, 2011). Therefore, the interview was structured into three parts, all of them consisting on four types of questions: initiating, follow-up, trigger and closed questions. The first part of the interview is composed by two core questions that looks to open up the conversation and understand the current interviewee role, background and experience regarding big data and smart factory. As suggested by Yates (2003), the interview starts with an initiating question that looks to open up the topic, direct the conversation and encourage the interviewee to provide extensive answers during the process. After obtaining some general background of the interviewee's experience, the second part of the interview is focused on asking specific questions about the requirements for client and consultancy companies to implement a big data solution in the smart factory context, situations where the implementation was successful, as well as, different enablers that facilitate the implementation. Lastly, the third part of the interview is focused on obtaining demographic information about the interviewees.

The first round of data collection took place with the SAP, a software company offering assistance in managing business operations and customer relations. This was followed by a second round of data collection with the Xiamen Intretech Inc., a leading manufacturer in the field of information system and industrial automation, located in Xiamen city, Fujian Province, China. The table below presents the interviewees, their working roles and years of experience.

Table 1. Table of interview participants

Role	Pseudonym	Years of working experience	Big data experience
SAP Project Manager	SAP PM A	18	4 years
	SAP PM B	19	4 years
SAP Consultant	SAP Consultant A	9	1 year
	SAP Consultant B	12	2 years
	SAP Consultant C	15	4 years
	SAP Consultant D	11	3 years
	SAP Consultant E	8	2 years
	SAP Consultant F	11	3 years
Intretech Manager	Co-general Manager	24	3 years
	IT Manager	20	3 years
Intretech Engineer	Technical Director	21	2 years
	Engineer A	14	3 years
	Engineer B	13	2 years
	Engineer C	9	2 years
	Engineer D	11	2 years
	Engineer E	12	1 year

Data analysis

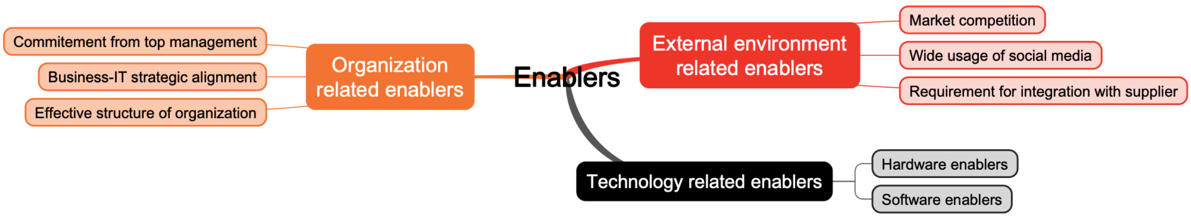
The research data was analyzed through a thematic analysis approach, which typically contains five steps as illustrated in the following table. To start with, the interview data was transcribed into word text and meanwhile familiarity with data was obtained. In the second stage of coding, a wide range of codes were generated together with relevant quotations. The following stages were focused on identifying interrelationships between the codes and developing themes simultaneously. Following the steps, a set of three themes emerged from the analysis as revealed in Figure 1 . The themes, codes and selected quotations are discussed in detail in the next section of this paper.

Table 2. Steps of thematic analysis approach (Peng & Nunes, 2010)

Stage	Description of the process
1. Familiarizing with the data	Getting known the data through the process of transcription, reading and re-reading the data.
2. Coding the data	Developing coding scheme - all codes emerged from the data, coding textual data in a systematic fashion across the entire data set.
3. Connecting codes and identifying themes	Collating codes into potential themes, gathering all data relevant to each potential theme.
4. Reviewing themes	Checking if the themes work in relation to the coded quotes and the entire data set.

5. Reporting findings	Final analysis of selected quotes, relating back of the analysis to the research question, questionnaire findings & literature, producing a chapter of findings.

Figure 1. Concept map of data analysis



Findings

This section presents the findings from this study i.e. different enablers that contribute to embed big data solutions in the smart factory development. Overall, the enablers fall into three main dimensions: the organization level enablers such as organization development, management and cultural issues; technology related enablers covering hardware, software and big data analytic techniques; and external environment related enablers which is regarded to factors outside the smart factories or external to big data solutions such as market competition and usage of social media.

Organization related enablers

The research data was analyzed through a thematic analysis approach, which typically contains five steps as illustrated in the following table. To start with, the interview data was transcribed into word text and meanwhile familiarity with data was obtained. In the second stage of coding, a wide range of codes were generated together with relevant quotations. The following stages were focused on identifying interrelationships between the codes and developing themes simultaneously. Following the steps, a set of three themes emerged from the analysis. The themes, codes and selected quotations are discussed in detail in the next section of this paper.

Commitment from top management

Commitment from top management in the context of applying big data solutions in smart factory development refers to organizational managers being not only dedicated to the big data implementation but also supportive in relevant staff allocation, sufficient funding and innovation encouragement (Lee et al, 2016). Illustrated by both IT managers and several consultants in the SAP company, having committed top managers is regarded as a key requirement and enabler for a successful big data implementation project. The findings from this study also indicate that with effective communication and support from the top positions to all stakeholders in an organization, key change management and implementation issues can be addressed in a smooth manner; therefore, problems such as user resistance and unawareness of big data solutions can be avoided or solved.

> *"The support from our boss is also quite important, which means we will have sufficient funding and time to do this project." (Co-general Manager, Xiamen)*

The top management team can also provide the right guidelines to ensure all relevant areas being aligned towards the same objectives through the implementation of big data analytics in smart factories. With commitment from top management, the teamwork inside an organization can also be more efficient, which contributes to embed and apply big data analytics in the smart factory development (Müller et al, 2017). Exemplified by the quotation below, a team consist of experts from diverse background and with effective coordination among them can facilitate the application of new technologies and techniques i.e. big data solutions.

> *"In our company, we have a strong team and each member in our team is in charge of his own work. For example, structural engineer is responsible for designing the machine contour, electrical engineer is responsible for electrical and automation design, etc. A strong team can usually perform better in terms of using big data analytics and in building smart factory."(Co-general Manager, Xiamen)"*

Business-IT strategic alignment

Strategic alignment between organizational business and IT department is another critical enabler that facilitates big data solution adoption. When an organization develops or evolves, the complexity level of its business process and the demand for higher-value solution increases accordingly (Gemünden et al, 2018). This requires strategic move towards new lines of its business (Davies & Brady, 2000). In this sense, the working areas where require big data analytics and solutions are larger in numbers and more integrated with each other. As mentioned by a co-general manager from Xiamen Intretech Inc., most organizations are pragmatic that they adopt new technologies or facilities because of their business development needs rather than 'blindly' pursuing advanced technology.

> *"We are a pragmatic company, we will do those aspects that are useful to our instead of pursuing some advanced technology blindly." (Co-general Manager, Xiamen)"*

Furthermore, the development of an organization usually means sufficient funding available. To embed big data solutions, a number of facilities need to be invested in advance including a large amount of sensors and new equipment as well as efficient information systems and relevant workers. Therefore, sufficient funding is an important factor that guarantees the possibility of this type of implementation.

Effective structure of organization

Effective structure of an organization in the context of smart factory is mostly reflected on the perspective of its scale and maturity level in adopting new technologies and in meeting customers' expectations (Lu, 2017). Research indicates that enterprises with higher level of formalization tend to be more effective in their management processes and more experienced in implementing different projects and products (Maduenyi et al., 2015). As exemplified and explained by the SAP consultant, high level of enterprise formalization can assist the organization in their adoption and application of big data analytics. Greater degree of horizontal connectivity and interoperability helps to increase the big data application and smart manufacturing (Kusiak, 2018). Findings from the study also illustrate that effective organizational structure can contribute to the facilitation of big data solutions especially due to the reasonable arrangement for staff and paperless office promotion.

> *"To plan the production, to plan sales, to find scenarios, determine the markets, determine the scopes, ... And that will be way easier with the use of big data and predictive analysis… Maybe currently this is not very critical because, in general, these modern concepts of smart factory and big data are just being incorporated. But in long term, this will be critical (SAP Consultant G)".*

Furthermore, effective structure can also contribute to efficient planning and resource management in big data solutions. To succeed in smart factory development, an organization should plan and manage all resources and activities especially its big data resource, management and analysis. As illustrated by the interviewee, planning with regard to smart factory involves planning the research and design, production, sales, finding scenarios, determining the markets and determining scopes; and these require big data analysis to provide predictive information for decision makers. For example, effective organizational structure and planning towards big data solutions reflects by the four areas of research, production, sales and service, i.e. to answer the questions of what information the decision maker requires and what data should be collected in order to obtain these information. On the other hand, the application of such analytics will benefit and maximize the value and outcome of planning, especially in the long term with the wider application of such technologies and techniques.

"If you handle your stock correctly and use optimized procedures to predict it,or predict when are you going to need them, evidently you will lower your cost from supplies that got expired, or supplies you don't move. You can optimize the use of raw materials. Leverage supplies, reduce scrap produced throughoutthe production process and hence optimize resources. (SAP Consultant G)"

The structure of an organisation, to some extent, can also influence its culture which indirectly drives the innovation and technology development within a firm (Büschgens et al, 2013). The innovative and communitive enterprise culture can encourage the application of new technologies such as big data solutions and smart factories, as well as the positive communication among employees towards these new technologies.

Technology related enablers

Smart engineering and technology is the most critical enabler for the smart factory development (Abramovici et al., 2015). Findings from this research illustrate that the latest ICT developments in hardware areas especially in terms of communication and embedded micro-devices, as well as software technologies has entered and facilitated the big data applications and smart factory developments.

Hardware enablers

Hardware enablers are with regard to different facilities and equipment that contribute to the application of big data analytics in smart factories. The hardware that enables the application of big data analytics is mostly reflected on three perspectives. Firstly, recent development in sensor technology enables the automation of production line in smart factory, which is regarded as the requisite in development of smart factory. The sensors nowadays become smaller and more sensitive so that they can be better embedded into the traditional equipment. Particularly, the improvement in sensitivity of sensors can assist in collecting richer and more accurate data from equipment, which can later be used to facilitate better analysis of the big data.

Secondly, embedded technology performs the role of 'control' the sensors, which also contributes to facilitate the application of big data analytics (Magdaleno et al, 2013). Typical examples of embedded technology include single trip microcomputer (used to control single equipment) and programmable logic controller i.e. can be used in controlling multiple equipment. The embedded technology can be placed into sensors and other devices, and thus control the sensors and assist relevant devices in operations. It is the placement of sensor that enables the data from equipment to be detected and stored whilst the equipment is working. These data acts as the foundation for big data analytics.

"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 machines 5000 times, when it reaches this working times and it will sent out an alarm signal."(Electrical Control Director, Xiamen)"

Communication technology is one of the most critical elements in developing smart factories and in facilitating big data analytics (Wan et al, 2015). It enables to communicate the data that are collected from sensors. More importantly, both the analysis of data and coordination and corporation among the equipment highly replies on the support from communication technology. As mentioned by a manager from Xiamen Intretech Inc., the communication technology plays a key role in enabling other devices to deliver data, which is a fundamental step in applying big data analytics.

"At Xiamen Intretech Inc., we adopt the Modbus communication protocol. It supports the traditional RS-232 port, RS-485 port, as well as other industrial facilities including PLC, DCS, Variable-frequency Drive and intelligent instrument. These devices can use Modbus communication protocol as the standard to communicate with each other." (Intretech Manager)

Software enablers

Apart from hardware, smart factory requires autonomous software and systems in order to cope with different demands and challenges. Efficient systems and software packages can contribute to big data analysis and its application in smart factories (Lee et al, 2014). For smart factory and future market, systems will be more complex, flexible and difficult to control (Mabkhot et al., 2018). Results from this study indicate that software and information systems play a critical role in the big data analytics and its application in smart factories.

Integrated management system (IMS), referred as UMS in the Xiamen Intretech organization, is a typical example that enables the application of smart factory. As illustrated by the chief engineer in Xiamen Intretech Inc., an IMS not only assists them in communicating with colleagues and different departments; more importantly, the company needs to collect real-time data and store the data in their integrated management system. In this sense, the IMS acts as a basic factor or element that enables the storage and distribution of big data within the organization. Apart from IMS that is internally developed and used by the organization, third party software application such as ERP, PLM, MES and CAD also plays an important role in the application of big data solutions and the development of smart factories. As discussed in the introduction section of this article, smart factory assists people and machines in the execution of their tasks; and this is achieved by information systems working in the background (Hermann et al., 2016). More specifically, the systems conduct analysis and tasks based on the data coming from both the physical (for example position and condition of a particular tool and equipment) world and the virtual (such as electronic documents and simulation models) world (Hermann et al., 2016). The interview participants also emphasized that high-speed networks technology also assists in delivering the data in a more stable, high spaced manner so that the data can be better protected.

> *"Communication among different departments are smooth in our company, there is not any information island with the use of UMS (United Management System). From the perspective of whole company, UMS is designed by ourselves and we have used it for around 5 years… We need to do monitoring control in each device, as a result, AIO-First module can help us to identify and collect data from differentmachines 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, Xiamen)*

Cloud computing is another software related enabler for big data solutions and it is the essential place where big data is stored and where the analysis takes place in a smart factory. As identified from the interview, in general, enterprises adopts a mixed method in the could computing that some basic data can be placed as for public whilst the private and important data such as business secrets can be stored in private platforms which is managed and maintained by IT departments in the organization. Furthermore, confirmed by the manager from Xiamen Intretech Inc., systems and platforms from the third party obtain more advanced and mature technology. This can assist the organization in saving time and cost and in dedicating more energy in their own big data solutions and smart factory development.

> *"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 andthere are many mature cloud service companies, they outsource the cloud to us. It will save a lot of time and cost for us, whichwill be convenient to us. The private cloud is deployed in the firewall of the enterprise data center"(UMS Engineer, Xiamen)*

With the involvement of smart factory and big data solutions, more data is being created and gathered. Data security becomes one of the concerns and therefore secure data policies and technology, on the other hand, can promote the application of big data solutions. As mentioned in the quotation above, The IT manager in the Xiamen Intretech Inc. emphasized that apart from technologies, organizations should also address security concerns from perspectives of human resources allocation and organisational structure. The research results indicate that reliable data security technology and strategies are considered very important and can be an effective enabler to facilitate big data analysis.

> *"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, Xiamen).*

External environment related enablers

Market competition

Fierce market competition has always been a catalyst for the adoption of new technology. The availability of smart, connected products provide opportunities for new functionality and greater reliability, which forces the organizations to rethink and retool the tasks they operate internally (Porter & Heppelmann, 2014). Furthermore, the expanded capabilities of these smart, connected products as well as the data they generate lead to a new era of market competition (Porter & Heppelmann, 2014). Results from this study indicate that the market competition can encourage or even force the organization to adopt big data analytics and develop smart factories in order to obtain their competitive advantages. The findings also illustrate there are three main elements in the market competition that usher the organizational adoption of big data analytics.

Competition for improved customer service and experience is one of the most important dimensions for big data implementation in smart factories. As exemplified by consultants from the SAP company, improved customer experience is a key motivation in adopting big data analytics, because the analysis results can help the organization to better understand customer's needs and thus be at a better position in market competition.

> *"Because if I can identify my costumers' needs, for example, then the value offer that I am sending to the client will be enhanced and benefitted. From a quality's point of view, if I can extend (the improvements) towards the customers' needs, then their experience will be significantly better. Eventually I will have capacity to sign new agreements or to gain new clients through the year" (SAP Consultant C)"*

Improved product quality is another result of the new market competition. Adopting big data analytics in smart factory development is a key method to improve the product quality. Findings indicate that the improved product quality is another driver that motivates organizations in their big data techniques development and implementation.

> *"You can further reduce costs because you are improving your performance. In general, you have less errors to pay… Evidently, if you have these options the quality of your product will be better […] You would have an earlier availability of high quality products. (SAP Consultant G)"*

Requirement for integration with supplier

The development of smart factory also puts pressure on organizations to better integrate and obtain positive relationships with their business partners. This requires improvements in the maturity of big data solutions and therefore can be considered as one of the drivers for applying big data solutions in the smart factory development. As illustrated by the quotation below, good relationship with partners, especially suppliers, assist the organization in obtaining more data from the partners as well as gaining more help from others. This is beneficial in the smart factory development.

> *"The idea is to integrate the supplier in order to see what is happening with him, and that he knows what is happening to me as well… then it comes a concept that is called "Supply orchestration". Make constant revision of the actual state versus the forecast. To have a detailed schedule instead of an aggregate schedule, make re planning (IT Manager A)."*

Wide usage of social media

Usage of social media enables the big data analytics application in the sense that enormous amount of data becomes available to be collected. Digital life on the Internet are built by individuals using smart phones, mobile devices and computers; this supplies dynamic online information of social media messages, websites, forum discussions, photos and experience sharing etc. which has become an important category of big data and has valuable potential use for organisations (Tsou, 2015).

> *"And the third element we consider are external events. And what are those external events? It's social media ... We also look our competitors. In the local market we have them easily identified." (SAP IT Manager A)*

Illustrated by the findings from this study, social media data can be useful in analysing current market trend and customer's preference. The availability of this type of data encourages the organisations to employ and apply big data analysis in order to pursue better market performance. The IT manager from SAP also mentioned that further to customer's style and preference, social media also assists them in identifying their competitors' strategies and activities.

Further discussion and conclusion

This paper reported a qualitative study which aims to fill the current literature gap of enablers that contribute to facilitate the implication of big dat asolutions. The current studies on facilitating big data solutions in smart factory development tend to focus on single aspects and placing particular importance on the hardware and technology issues such as IoT and CPS (e.g. Wang et al., 2016; Kang et al., 2016). This study extends beyond the boundary of technology or hardware issues and has identified three sets of enablers including the organization, technology and external environment related enablers. Furthermore, our finding illustrates that these three sets of enablers do not function isolated. Instead, the enablers are related and can affect each other. For example, the technology related enablers act as the fundamental conditions for big data solutions to be implemented; without technology related enabler, the organization and external environment related enablers cannot perform their roles. Organizational related enablers are the 'soft' support from the management and strategy side of the big data solutions. External environment related enablers perform as the 'catalysis' for organizations implementing big data solutions.

The list of enablers produced from this study can serve as a base for research in this area to further explore the application big data analytics and the development of smart factory from socio technical perspectives. The result of this study also has strong practical implications by presenting insights from both consultants and organization perspectives in embedding big data solutions. For practitioners, the list of enablers need to be considered and paied attention to when they adopt big data solutions in their daily work and in the development of smart factories. Particularly, the study confirms that the enablers extends far beyond the technical aspects of sensors or technology development. Therefore, practitioners should consider the organizational factors and the wide external context of the market and use of social media from customers.

There are several limitations that are associated with this study. The research data is collected via interviews in the exploration of the phenomenon. Therefore, further investigation method such as quantitative survey or qualitative study within another setting is recommended so that the findings can be transferrable to a broader context of the smart factory development. In addition, as the focus of this research is the IS perspective of big data solution adoption, the enablers in this study are identified from the insights of organizations rather than customer, supplier or other key participants in the smart factory development. Future research can extend the findings from this study by focusing on perspectives such as customer requirements or market competition.

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