Emerging Technologies for Supply Chain Management

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conference papers. She served as the reviewer for five indexed international journals. She has been involved in several research and consulting projects. She received research grants to the amount of US$30,000 between 2015 and 2017. She is a Monbukagakusho scholar. Prior to joining the academic, she has more than seventeen years of extensive experience in the government-linked corporation and Fortune 500 multinational companies managing information technology, supply chain logistics and corporate compliance. She held a managerial position at Sharp Asia Parts Centre, a regional distribution centre. She was the founding manager of the data analysis department and QESH management system department of technology companies.

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Foreword

The two-day roundtable entitled *Emerging Technologies for Supply Chain Management* bringing together academics and practising professionals in related fields, held in Wawasan Open University (WOU) on 12 – 13 January 2017, was most timely and appropriate indeed. I would like to congratulate WOU’s School of Business and Administration (SBA) for taking the initiative to organise this roundtable. I also commend Dr. Loo Saw Khuan in making the effort to be the project leader of this roundtable and for co-editing this publication, based on the papers and proceedings presented in the roundtable, for future reference and action.

Here is a quick historical flashback. In the early 1970s, Penang pioneered the export-oriented industrialisation for Malaysia, and indeed, the whole of South-East Asia, through the establishment of Free Industrial Zones (FIZs) to attract multinational corporations (MNCs) such as, Intel, Hewlett Packard, Motorola, Siemens, Osram, Hitachi, Sony, etc., to set up manufacturing plants here for the electronics and related industries. Besides incentives such as free duty and tax holiday granted by the federal government, the attractive factors then were hard-working and trainable labour, well-planned industrial land with utilities, adequate transportation infrastructure, efficient government services, etc., all at very competitive costs.

From the 1980s, local suppliers emerged to supply parts and components and to provide supporting services to MNCs. The MNCs and local Small Medium Enterprises (SMEs) also sourced from suppliers from other parts of the country, the region and the world. Starting in the 1990s, the industry moved towards high-tech and high value-added products. The technological level of products became more sophisticated with corresponding advancement in parts and components, again, sourced from all over the world. Hence, supply chain management (SCM) became more sophisticated, with increasing and more integrated involvement of I.T., robotics and artificial intelligence (A.I.). Meanwhile, many MNCs and even some SMEs operating here started to move into design and development (D & D) and even research. In fact, the pace of development has accelerated tremendously, at a dazzling speed, over the past decade.
Therefore, with the advent of Industry 4.0, the traditional supply chain model is being rapidly transformed into Supply Chain 4.0 with digitisation and integration of the entire process, from D & D, manufacturing, marketing, delivery, to customer service. The increasingly integrated supply chain eco-system has enhanced efficiency, transparency, communication, collaboration, flexibility and responsiveness among supply chain partners, to ensure accurate demand forecast, to reduce order lead time and save costs, to enhance product and service quality, and to increase customer satisfaction.

Hence, the main objective of the roundtable was to examine the emerging technologies for supply chain in the global market, to compare them to the present practices in the Malaysian context, so as to prepare the Malaysian supply chain management professionals to adopt, adapt and apply these new technologies, so as to further improve the SCM, especially for SMEs.

It is important and imperative for companies to be keenly aware that SCM has become the heart and the circulatory system of the company’s entire value chain processes which need to be fully digitised. Supply Chain 4.0 happens when supply chain is incorporated into and drives Industry 4.0. It also implies that supply chain partners, such as suppliers, customers, distributors, retailers and transporters must be connected to Supply Chain 4.0 which should include Procurement 4.0, Logistics 4.0, smart warehousing, prescriptive supply chain analytics, effective spare parts management and integrated planning and execution, etc.

However, it must be realised that, besides positive contributions as briefly described above, Supply Chain 4.0 comes with some challenges or even negative impacts. Supply Chain 4.0 requires substantial investment in hardware and software. The local SMEs may encounter a lot of barriers, costs and challenges to adopt and apply the emerging technologies. How can MNCs assist and support their SME suppliers to adopt the technologies? How can the government provide grants and incentives for the SMEs more effectively?
Supply chain professionals in the manufacturing sector who are used to the extensive use of MRP (material requirement planning) systems will have to figure out how to incorporate their current MRP system with the emerging technologies of Big Data and Internet of Things. How can we effectively encourage and equip supply chain professionals to be data and technology-savvy to stay relevant in their professional field?

This leads us to the educational question of how we can effectively train supply chain professionals to be technology-savvy in the first place. In the past, industry might prefer to hire procurement professionals with engineering or technical qualifications so that they can contribute to value engineering and quality improvement of materials and components purchased from suppliers. However, with emerging technologies of artificial intelligence, Big Data and 3D printing, they may now prefer procurement professionals with information technology qualifications. Hence, should we train the supply chain students to be technology-savvy or alternatively, provide our information technology students or data scientists knowledge on SCM?

For supply chain academics, they need to equip themselves with the emerging technologies so that they could impart the required knowledge to the students, who may be more technology-savvy than their teachers! Should all the courses of supply chain programmes be incorporated with emerging technologies? Should universities offer programmes with double degrees in supply chain and information technology?

Moreover, the utilisation of robotics, artificial intelligence, self-driving vehicles and big data may result in unemployment to many white-collar and blue-collar employees. What are the social impacts due to job loss of the warehouse workforce? We need to consider whether investment in automation is more cost saving than human investment. How can the affected employees, such as clerical staff, be trained effectively to migrate to a higher level task which includes decision making? To what extent can all forms of automation reduce our dependence on foreign migrant workers?
The above are pressing issues and relevant questions, some of which were answered well in the roundtable. Others need further deliberation, exploration and experimentation. Hence, the roundtable was a good start. I believe that the participants would have learned a lot and forged friendship for future collaboration in more effectively applying emerging technologies to improve SCM in practice and SCM programmes in universities. I look forward to WOU continuing to play a leading role in this area.

Tan Sri Dr. Koh Tsu Koon
Pro-Chancellor of Wawasan Open University
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This collection of papers explores the research and practices on the broad theme of “Emerging Technologies for Supply Chain Management”. The papers were given at the roundtable entitled “Emerging Trends of Technologies in Supply Chain Management” that the School of Business and Administration organised in collaboration with Penang Skills Development Centre on 12th and 13th of January 2017. There were twenty-four academics and twenty-six industry practitioners who attended the two-day roundtable to exchange information pertaining to the emerging technologies for supply chain management. The emerging technologies discussed in the roundtable were Supply Chain 4.0, Internet of Things (IoT), big data, electronic procurement and robotics in warehouse.

Emerging technologies for supply chain management may include robotics, smart warehousing, 3D printings, big data, IoT and artificial intelligence. These technologies are now affecting every component of supply chain, namely customer fulfilsments, supplier sourcing, purchasing, distribution, transportation and warehousing. These emerging technologies potentially contribute to effectiveness, efficiency, shorter lead time and cost savings to supply chain. However, the emerging technologies may potentially cause job loss to lower level or clerical workforce. In order to stay relevant in the industry, supply chain professionals need to be well versed to utilise these emerging technologies.

The IoT is the network of physical devices, vehicles and other items embedded with electronics, software, sensors, actuators and connectivity which enables these objects to connect and exchange data. Machine to machine (M2M) connection is the new frontier of IoT, which refers to all technologies that allow systems to communicate with other devices of the same type. Apart from this, there are machine to person (M2P) and person to person connections. With all these connections of IoT, supply chain professionals could connect and exchange data very effectively with all their supply chain partners, namely suppliers, customers, transporters, distributors, retailers and warehouses. The related supply chain partners will have full visibility into the needs and changes of each other in real time.

Automated robotic applications such as self-driving trucks and automatic drones now become viable solutions for warehousing and transportation. The advantage of robotic applications is that
they are capable to work 24 hours every day. However, robots may not be able to perform high level decision makings for warehousing and shipping. Hence, savvy companies come out with synergistic scenarios where robots perform repetitive and routine tasks so that humans could focus on strategic tasks. Alternatively, a co-robot or cobot is a robot which could be physically interacting with humans to perform tasks. These cobots are potentially very useful for loading, unloading and picking of products in the warehouse.

The artificial intelligence could be utilised by purchasing professionals to source, identify and match the items with the suitable suppliers. It can also be used to alert purchasing professionals about the potential price increase and commodity shortage. In addition, the artificial intelligence can be used to alert supplier contract renewal and administration.

The technology of 3D printing is very useful for products with high mix/low volume. It can be used to print spare parts, sunset products or aftermarket products. It also contributes to inventory reduction and cost savings by eliminating tool and die fabrication.

The advent of technology and its application to the Supply Chain Management processes can either be viewed as a disruptive intrusion into the functioning of the processes or an opportunity to embrace the new digital approach. This will lead to enormous benefits to the Supply Chain Industry. This excellent collection of articles will be an invaluable resource material to students and practitioners of Supply Chain Management.

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Chapter 1

Internet of Things and Supply Chains: A Framework for Identifying Opportunities for Improvement and its Application

Dr. Shardul Phadnis

Abstract

Management and technology experts believe that Internet of Things (IoT) has the potential to radically transform today's supply chains. Several practice-focused publications describe various ways in which IoT capabilities can affect the supply chains in positive and negative ways. However, no generic framework describing the peculiar effects of IoT on supply chains has yet emerged. This paper presents a theoretical framework to articulate the distinct ways in which the IoT can influence the management of supply chains. The use of this framework is illustrated by applying it to identify opportunities for improving two supply chains: the supply chain described in the famed “Beer Distribution Game” and a revised version of that supply chain. This framework, grounded in the foundation of organisational information processing theory, can be of practical use in guiding organisations to envision novel ways in improving the performance of their supply chains by deploying the IoT capabilities.

Introduction

Internet of Things (henceforth, “IoT”) is defined as “a network of physical objects that contain embedded technology to communicate and sense, or interact with their internal states or the external environment” (World Economic Forum 2015). It is considered a key technological development that will contribute to the emergence of the Fourth Industrial Revolution (i.e., Industry 4.0), and is counted among the nine component technologies in the Industry 4.0 platform (Rose, Lukic, Milon and Cappuzzo 2016). Despite its argued revolutionary potential, the implications of IoT remain unclear to a vast majority of firms (The MPI Group 2016). The World Economic Forum (2015) equates this state of ambiguousness with the state of understanding of the potential applications of the Internet in 1990s; it predicts that the IoT will dramatically transform the world just as the Internet did.
The juxtaposition of IoT’s revolutionary potential and the lack of understanding of its implications are troublesome for the firms seeking to harness the technology’s capabilities to seek competitive advantage. Given the technology’s newness, a few cases of success or failures of firms using IoT have been documented. Therefore, it remains unclear what a firm needs to do to improve the performance of its supply chain using the IoT capabilities. This paper seeks to shed some light on this matter by making three contributions. One, the paper highlights the salient features of the IoT that distinguish it from the present-day solutions commonly used for managing the supply chains. This distills the unique features of IoT as a technology that provides an information ecosystem for managing supply chains. Two, this paper presents a framework that can be used to envision the applications of IoT to improve performance of supply chains. Finally, the paper applies this framework to explore the ways in which IoT capabilities can be used to improve the supply chain in the “Beer Distribution Game” — one of the most widely-played management simulation games in the world (Sterman 1989), and a related version of that supply chain.

The rest of this paper is organised as follows. The Literature Review section provides a brief review of the pertinent literature. I summarised a few fundamental publications of IoT, and highlighted that IoT is an information technology revolution. I reviewed a few seminal works in the management literature that explore the role of information on the operational performance of supply chains. Building on this foundation, I propose a generic framework to explore novel opportunities for improving the performance of supply chains using IoT capabilities. The next section examines a Framework envisioning the effects of IoT on supply chains, and illustrates the application of this framework to use the IoT capabilities to improve the supply chain in the “Beer Distribution Game” (Sterman 1989) and a variation of the supply chain. The reason for choosing this supply chain is threefold: the “Beer Distribution Game” is one of the best-known management simulation games and has been played by thousands of people worldwide. The supply chain in this game is simple and representative of real-world supply chains, and the game is designed to demonstrate the effect of information availability (local vs. global) on the performance of supply chains. The last section concludes the paper by commenting on the efficacy of IoT for improving supply chain performance.

**Literature Review**

The IoT has been called “a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies” (Rose, Eldridge and Chapin 2015). It has also been described as “the point in time when more “things or objects” were connected to the Internet than people” (Evans 2011), which is estimated to have been reached between 2008 and 2009. The same report predicts that by year 2020, 50 billion devices will be connected to the Internet; another report predicts that the number will reach 100 billion by 2025 (Rose, Eldridge and Chapin 2015). The explosive growth of connected devices is no longer limited to smartphones and tablet computers, which provided the impetus for the trend. A recent definition of IoT by Rose et al. (2015) highlighted the increasing variety of “things” being connected to the Internet: “consumer products, durable
goods, cars and trucks, industrial and utility components, sensors, and other everyday objects are being combined with Internet connectivity and powerful data analytic capabilities that promise to transform the way we work, live and play”. Rose et al. (2015) identified five technological advances as the enablers of the IoT revolution: ubiquitous connectivity, widespread adoption of the IP-based networking, cloud computing, miniaturisation of computing devices, and advances in data analytics.

The different definitions of the IoT have one thing in common: they all project the IoT as a revolution of the information and communications technology. It is important to recognise this aspect when exploring the implications of IoT for supply chains. The important role of information in the management of supply chains has been examined in the scholarly and practitioner-focused literature. Deficient information sharing is one of the primary causes of emergence of the “Bullwhip effect,” a term used to describe the phenomenon in which a manufacturer of a product experiences high variability in the orders for that product compared to the retailer selling it, even when the market demand for the product had no variation (Sterman 1989). Lee et al. (1997) attribute this effect to the distortion of information about the market demand as the information travels from the retailer to the manufacturer through the parties involved in the supply chain. Due to the negative effect of variability on the efficient functioning of a supply chain, the bullwhip effect and the potential remedies to eliminate it have been extensively studied. Some of today’s widely-used industry practices, such as sharing point-of-sales data with the manufacturer, vendor managed inventory (VMI), etc., are intended to alleviate the deleterious consequences of the bullwhip effect.

Various types of information pass through the supply chains and influence their operations. Lee and Whang (2000) described five types of information shared in a supply chain: inventory levels, sales, demand forecasts, order status, and production schedule. The information transfer takes place via different modes such as direct information transfer (through electronic data interchange, vendor manager inventory, etc.), transfer through a third party, or through an information hub. The information shared influences the behaviours of the parties using it. As a result, any distortion of the information can cause unintended disturbances in the supply chain. Lee et al. (1997) suggested four potential causes of information distortion that create the bullwhip effect.

1. Demand signal processing, in which the retailer’s orders to the wholesaler (who would then order from a distributor or the manufacturer) are based on the updated demand forecast, instead of the actual demand.

2. Rationing game, in which the retailer orders more than what is needed if he/she anticipates that the wholesaler would allocate less than what was ordered.

3. Order batching, in which the retailer orders periodically from the wholesaler and, as a result, the finite demand information is lumped into one order.

4. Price variations, in which retailer orders different order quantities in response to the actual and anticipated changes in price.
The net result of each of these four is that the orders placed by the retailer to the wholesaler exhibit a pattern different from that of the market demand.

Human biases also influence the information shared in the supply chain. Croson and Donohue’s (2006) examination of the behavioral causes of bullwhip effect showed that the decision makers’ under-weighing of the supply line — i.e., not considering fully the amount of goods ordered but not received yet, as partly responsible for the phenomenon. Furthermore, their study showed that the tendency to underweigh the supply line persisted even when information on inventory levels was shared with the decision makers. Thus, it is not just the distortion of information shared in the supply chain that leads to the bullwhip effect; natural biases present in human decision making are also partly responsible. Adverse effects of human involvement in the making of operational decisions are also observed in other decisions made in supply chains. For instance, Schweitzer and Cachon (2000) showed through experiments that human decision makers order suboptimal quantities when making one-time purchase decisions, such as ordering goods to fulfil a season’s demand. These deviations from the optimal quantity are systematic, and can result in potential loss of revenue, especially more for high-margin products (Ho, Lim and Cui 2010). Some fundamental human biases, such as overconfidence, are shown to be the root causes of this effect (Ren and Croson 2013).

Such supply chain maladies related to information exchange and human decision-making biases may be cured by using a different information and decision-making ecosystem such as the IoT. Some of the emerging researches on implications of IoT for supply chain management suggest that the IoT capabilities can help companies improve the efficiency of their supply chain operations and facilitate innovation (Rong, Hu, Lin, Shi and Guo 2015). In addition, IoT capabilities can also be used to track goods geographically and over time (as well as people; however, ethical ramifications of tracking people need to be considered), provide improved situational awareness, facilitate sensor-driven decision making, automate production processes, optimise resource use, and allow real-time sensing of unpredictable conditions (Chui, Löffler and Roberts 2010).

A study of the IoT in logistics (Macaulay, Buckalew and Chung 2015) jointly published by the leaders in the domains of IoT (CISCO) and logistics (DHL), notes that IoT can enhance an organisation’s capabilities for measuring, controlling, automatising, optimising, learning, and monitoring various activities in the supply chain. The paper provides examples to illustrate how IoT could improve the outcomes of logistics processes. These examples include improvement of operational efficiency (fleet and traffic management, resource and energy monitoring, and connected production floor), improvement of safety and security (equipment and employee monitoring, health monitoring, physical security), enhancement of customer experience (connected retail, context-aware offers to customers), and creation of new business models (firms become service providers, usage-based insurance). The report concludes by providing three use-cases of IoT in logistics: warehouse operations, freight transportation, and last-mile delivery.
A few studies have explored the effects of IoT in specific industries. A graduate thesis and a subsequent article by researchers at the Malaysia Institute for Supply Chain Innovation explored the implications of IoT on the chemical industry (Phadnis 2015; Ravi and Wu 2015). The researchers mapped the existing flows of goods and information at a construction chemicals business, documented the state-of-the-art of the IoT capabilities, and then conjectured various ways in which IoT capabilities could realistically be employed to enhance various activities in the supply chain (such as process control, production planning, procurement, order fulfilment, etc.). They noted several potential benefits from the application of IoT: lower variability in ordered and shipped quantities, higher revenue with the same or lower finished goods inventory levels, lower work-in-progress and raw material inventories, fewer lost sales, automated procurement and production planning, improved process quality and safety, and so on.

Another study explores the impact and the applications of IoT on the high-tech industry (Biswas, Ramamurthy, Edward and Dixit 2015). This whitepaper describes how IoT can increase sales and improve operations for four types of firms in the high-tech industry: semiconductor firms, contract manufacturers, distributors, and original equipment manufacturers (OEMs). The potential improvements in supply chain operations resulting from the application of IoT cited in the study include increase in the yield of semiconductor fabrication facilities, improvement of asset utilisation, predictive maintenance, facilitation of anti-counterfeiting measures, improvement of product quality through more effective collaboration between the OEM and its supplier for product design and development, and so on.

The extant studies exploring the potential effects of using IoT to manage supply chains typically identify specific benefits (and threats). Some of these studies list the implications of IoT in more generic terms (e.g., Chui et al. 2015; Macaulay et al. 2015; Phadnis 2015; Rong et al. 2015; etc.), while others discuss them in the context of particular industries (e.g., Biswas et al. 2015; Macaulay et al. 2015; Ravi and Wu 2015). However, no comprehensive framework for exploring the implications of IoT for the management of supply chains has yet emerged in the literature. The present study seeks to fill this gap by providing a generic framework that can be used to explore novel opportunities for enhancing the performance of supply chains in a chosen industry.

**Framework for Envisioning Effects of IoT on Supply Chains**

Given that IoT provides a new way of gathering and sharing information to make operational decisions for managing the supply chain, the proposed framework is based on the theoretical foundation of information processing and decision making in management. In the theoretical discourse on the association between information processing and decision making in organisations, Tushman and Nadler (1978, 614) noted that “information processing refers to the gathering, interpreting, and synthesis of information in the context of organisational decision making.” They elaborated the distinction between data and information by noting that information refers to the data that are “relevant, accurate, timely and concise” that can “effect a change in knowledge.” In another influential
Early work on information processing in organisations, Kiesler and Sproull (1982) called “managerial problem sensing” a precondition for managerial decision making and action, and suggested that problem sensing consists of three processes: noticing (i.e., gathering data), interpreting the data to assign it actionable meaning, and incorporating the information with other information. These three processes parallel the three steps in organisational information processing identified by Tushman and Nadler (1978). The gathering data, interpreting it into information, and the change in knowledge effected by incorporation of new information, also called sense making, is central to the functioning of organisations because “it is the primary site where meanings materialise” and “inform and constrain (organisational) identity and action” (Weick, Sutcliffe and Obstfeld 2005). Thus, data gathering, data sharing, data interpretation and decision making are the fundamental processes in the information processing model of organisations.

Building on this theoretical foundation, I propose a framework for exploring the effects of IoT capabilities on the performance of supply chains. The framework consists of three components: data gathering, data sharing, and interpretation and decision making. For each component, the framework describes the salient ways in which IoT differs from the information technology solutions used for managing supply chains at present. The framework is presented in Figure 1 as described below.

**Figure 1** Framework for exploring opportunities to improve supply chain performance using Internet of Things (IoT)
Data Gathering

One of the fundamental drivers of the growth of IoT is the increasing variety of objects connected to the Internet. As Macaulay et al. (2015) pointed out, “with the advent of IoT, Internet connections now extend to physical objects that are not computers in the classic sense and, in fact, serve a multiplicity of other purposes.” Such objects may include “consumer products, durable goods, cars and trucks, industrial and utility components, sensors, and other everyday objects” (Rose et al. 2015). Different objects will collect and share different types of data, such as heart rate from a fitness tracker, driving speed of a car, or level of ink remaining in a printer cartridge. Thus, a natural consequence of the variety of objects connected to the Internet is that an IoT information ecosystem will gather more types of data.

The number of objects connected to the Internet is projected to reach 50 billion by 2020 (Evans 2011) and 100 billion by 2025 (Rose et al. 2015). This equates to an average of more than six connected objects per living human being by 2020 and over twelve by 2025. Thus, the same kind of data may be available from multiple sources. One example of this is the driving speed data from multiple connected cars in one geographic area. This information can be used to compute the average and variance of driving speed at a particular location at a given time. Thus, the IoT information ecosystem will also have more sources contributing the data of a given kind. More data points enable computation of reliable statistics.

Finally, due to their automated nature, data collection and transmission can both be performed more frequently than what may be plausible with the human involvement in either collection and/or transmission of data. Therefore, the third distinguishing feature of the IoT information ecosystem is that it allows more frequent data collection.

Data Sharing

A second fundamental driver of the growth of IoT is the widespread ability to connect computational devices to the Internet (Rose et al. 2015). In IoT, communication among devices is enabled not only by the commonly-used information technologies such as wired connections, local wireless networks (e.g., Bluetooth, Wi-Fi, RFID), and wide-area telecommunication networks (e.g., EDGE, 3G, LTE), but also by “operational technologies” such as the “more specialised, and historically proprietary, industrial network protocols and applications that are common in settings such as plant floors, energy grids, and the like” (Macaulay et al. 2015, 4). The “always-on” connectivity allows the devices to share the collected data instantaneously.

The automated nature of data sharing also obviates the need for human operators to collect, process, or analyse the data before it is shared. Sharing data in the raw form is advantageous because the data get shared without getting subjected to human biases that are known to influence selective collection and processing of data (Ditto and Lopez 1992; Edwards and Smith 1996; Kunda 1987). One of the
robust findings in psychology informs that people “are likely to examine relevant empirical evidence in a biased manner” when they hold strong opinions about the issue (Lord, Ross and Lepper 1979). Automated data sharing can circumvent this problem. Therefore, the second key feature of an IoT information ecosystem is that data are shared without distortion.

Finally, connectivity over the Internet allows the connected devices to exchange data with each other or a common cloud-based platform directly (with the appropriate communications protocol), regardless of their place in the supply chain. Thus, a firm can exchange relevant data with another firm in its supply chain even if the firms are not direct suppliers or customers of each other. For example, the point-of-sales data at a retail store does not have to reach the product’s manufacturer from the retailer, through a distributor and a wholesaler; the point-of-sales data at a store can be sent either directly to the manufacturer or uploaded to a cloud-based platform where the manufacturer can access it. Thus, the third distinguishing feature of the IoT information ecosystem is that it allows data to be shared in a non-serial fashion with the supply chain partners.

**Interpretation and Decision Making**

Another fundamental driver of the growth of the IoT is the advances in data analytics (Rose et al. 2015). Macaulay et al. (2015, 6) noted that “the use of analytics and complementary business applications (e.g., data visualisation) is crucial if organisations are to capture and make sense of the data generated from connected devices”. The automated processing of data ensures that the analysis is not influenced by human biases (e.g., Kunda 1987; Lord et al. 1979). It also ensures that data are analysed consistently using the predefined algorithms. Of course, the use of algorithms is not a panacea: the design and selection of algorithms themselves are not immune to human biases and can arguably have monumental consequences, such as the 2008 Global Financial Crisis (O’Neil 2016). Firms need to be aware of these dangers. However, well-designed algorithms can make data processing consistent and free it from the vagaries of biased human decision making. Thus, one salient feature of the IoT information ecosystem is its algorithmic decision making.

The second important feature of IoT-based decision making is the ability to get *quick and frequent feedback*. Due to the automated collection and instantaneous sharing of data, an IoT-controlled system can take several small actions, measure outcomes, obtain feedback, and make corrections based on the feedback. This rapid action-correction loop could be prohibitively expensive with human involvement in data collection, sharing or decision making. Management research has long established that “if the action-outcome-feedback links are short and frequent, the individual (or, firm) is in a good position to learn about, and thus comprehend, the probable effects of actions on outcomes: short links enhance the ability to improve decision making by taking corrective actions” (Hogarth and Makridakis 1981, 120). Thus, the second key feature of the IoT information ecosystem is the *feedback-based nature of decision making*. 
Finally, the vast amount of data collected through IoT devices can enable predictive decision making. More accurate forecasts, enabled by larger volume of relevant data, can help optimise a particular system with fewer resources. For example, more data about sales or online searches can help predict demand with smaller variance, and as a result, a supply chain can provide the same level of product availability with smaller inventory. Thus, the third distinguishing feature of the IoT information ecosystem is the \textit{predictive decision making}.

\textbf{Application of the Framework}

In this section, I demonstrate the use of the above framework by applying it to envision opportunities for improving the performance of an existing supply chain using IoT capabilities. I use the supply chain depicted in the “Beer Distribution Game” (Sterman 1989) and one variation of it for the demonstration. I choose this supply chain because of its simple structure and its familiarity to a large number of management scholars and practitioners. I begin with a brief description of the supply chain in the \textit{Beer Distribution Game} and follow it up with a depiction of the modified supply chain designed by deploying IoT capabilities.

\textbf{The “Beer Distribution Game”}

The “Beer Distribution Game” is a “role-playing simulation of an industrial production and distribution system” (Sterman 1989, 326). It was developed in the 1960s at the Massachusetts Institute of Technology to demonstrate some key dynamics in the supply chain. It has been played all over the world by thousands of people “ranging from high school students to chief executive officers and government officials” (Sterman 1989). The supply chain in the game delivers one product (i.e., cases of beer) through four stages or echelons — retailer, wholesaler, distributor and factory, with only one firm at each echelon. The retailer orders the product from the wholesaler to meet the market demand; the wholesaler fulfils the demand from its inventory, and orders the product from the distributor, who in turn, fulfils the demand from its inventory and orders the product from the factory, which produces (i.e., brews) the necessary quantity to meet the demand. There is a lag of two weeks between the placement of an order and receipt of the goods between each pair of consecutive stages. The game is played over several “periods,” with each period equivalent to one week. The objective of the game is to minimise the total cost for the supply chain over the duration of the play. Each case of beer carried in the inventory costs $0.50 per week, and each lost sale due to not having any inventory at the retailer costs $1 per week.

Each firm, manned in the game by a player, has to make only one decision in each period: determine the quantity to order in the next period. The only exception is the factory, which decides the quantity of beer to produce (i.e., place an order on itself). The key feature of this game is that each player (i.e., firm) “has good local information but severely limited global information” (Sterman 1989, 328). The players are told not to communicate with each other; thus, no player except the retailer...
Emerging Technologies for Supply Chain Management

has any knowledge of the consumer demand in the market. Furthermore, the market demand is not known in advance; the retailer discovers the market demand as the game progresses. The players are told of the two types of costs incurred in the game and the game’s objective of minimising the total cost. However, they are not given specific guidelines for determining their order quantities. Thus, each player may decide the quantity to order based on the quantity of the product ordered by his/her customer, his/her interpreted pattern of customer’s orders, his/her anticipated future orders, and any other metrics he/she considers relevant for determining the order quantity.

The customer demand is set at four cases per week for each of the first four weeks of the game. The demand experiences one unannounced one-time increase to eight cases per week in week five; after that, the demand remains stable at eight cases per week for the rest of the game. This one small change creates major fluctuations in the supply chain. Sterman (1989) noted that almost all runs of the Beer Distribution Game exhibit the same three qualities: oscillation, amplification, and phase lag. Order quantities and inventory levels of all four firms oscillate over time. The inventory levels of the retailer decline first, followed by the decline in inventory levels of wholesaler, distributor, and the factory in that order. The declines generally cause severe shortages throughout the supply chain. To compensate for this, the players increase their order quantities. This swings the inventory levels in the opposite direction, and the “inventory in many cases substantially overshoots its initial levels” (p. 330). The magnitude of orders is amplified from the retailer to the factory; the peak order rate at the factory can be about twice as high as that at the retailer. Finally, because of the time lags between the stages, the order quantities exhibit a phase lag, such that the peak orders at the factory occur, on average about four weeks after the peak orders at the retailer.

These phenomena are also observed in the real world. Sterman (1989, 3) noted that the “production-distribution networks in the real economy exhibit the three aggregate behaviours generated in the experiment, i.e., oscillation, amplification from retail sales to primary production, and phase lag.” The oscillations are caused by the failure to account for the goods in the pipeline (i.e., the products ordered but not received yet) when placing orders, as well as incorrect assumptions about market demand. The amplifications are the result of lack of visibility to the true demand for the parties’ upstream in the supply chain and their over-adjustments to the disturbances observed in their own demand. Another result of the lack of visibility is that the players representing the firms’ upstream in the supply chain have incorrect assumptions about the true demand. Sterman (1989, 335) showed that “the majority of subjects (playing the wholesaler, distributor, or factory roles in the game) judge that customer demand was oscillatory,” when in reality, it is stable throughout the game barring one fluctuation in week five. Finally, the phase lag is a natural result of the time lags in the placement of orders by the parties in the supply chain.

Overall, three aspects of this supply chain engender this phenomenon: lack of visibility of market demand to all parties except the retailer, the time lag between placing and receiving the orders, and the failure to keep track of the inventory in transit. The decision makers in the game use an anchoring-and-adjustment heuristic (Tversky and Kahneman 1974) to determine the order quantity:
they anchor on the expected demand from their customers and then adjust the order quantity to “reduce the discrepancy between the desired and actual stock” and “maintain an adequate supply line of unfilled orders” (Sterman 1989, 324).

“Beer Distribution Game” with IoT Ecosystem

In this section, I describe how the framework presented earlier can be used to think of ways in which the potential causes of the undesirable dynamics in the Beer Distribution Game’s supply chain can be mitigated by deploying IoT capabilities. To do this, I present a list of initiatives, envisioned with the help of the framework, to improve the supply chain performance using IoT capabilities. The initiatives are presented in Table 1 below. I first present three initiatives targeted to improve the performance of the supply chain described in the Beer Distribution Game (Section I of Table 1), which is a rather simplified version of a real-world supply chain. Following this, I present four initiatives to improve the performance of a modified version of the supply chain based on the game (Section II of Table 1).

<table>
<thead>
<tr>
<th>Initiatives to improve supply chain performance using IoT capabilities</th>
<th>Data gathering</th>
<th>Data sharing</th>
<th>Decision making</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>More data types</td>
<td>More data sources</td>
<td>Higher frequency</td>
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<tr>
<td>Data gathering</td>
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<td>Data sharing</td>
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<td>Decision making</td>
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Section I: Supply chain in “Beer Distribution Game”

1. Sharing retailer’s point-of-sales data with other firms in the supply chain
   - ✓
   - ✓
   - ✓
   - ✓

2. Forecasting customer demand based on point-of-sales data and share within the supply chain
   - ✓
   - ✓
   - ✓
   - ✓

3. Multi-echelon inventory optimisation, with real-time visibility of inventory in the supply chain
   - ✓
   - ✓
   - ✓
   - ✓
   - ✓
   - ✓
   - ✓
Table 1 Initiative to improve performance of supply chain in the “Beer Distribution Game” using IoT capabilities

<table>
<thead>
<tr>
<th>Initiative to improve performance of supply chain in the “Beer Distribution Game” using IoT capabilities</th>
<th>✓</th>
<th>✓</th>
<th>✓</th>
<th>✓</th>
<th>✓</th>
<th>✓</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Predicting sales of different products at different retail stores based on consumers’ electronic footprint, listing of local events, weather conditions, etc.</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>2. Unscheduled expedited deliveries based on real-time product availability at retail stores using centralised storage</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>3. Customised product packaging for individuals and events</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>4. Product promotions customised to individual consumers, for specific time of the day and offered at specific retail stores</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Initiatives for Supply Chain in “Beer Distribution Game”

The first initiative is to share point-of-sales data from the retailer with the wholesaler, distributor and the factory. This involves collecting new type of data (i.e., retail sales), and sharing it without distortion (i.e., sharing raw sales data, instead of order data from retailer and other firms) in non-serial manner (i.e., the sales data is sent directly from the retailer to the wholesaler, distributor, and factory, instead of having to traverse serially through the supply chain). This provides complete visibility to all the players about the nature of market demand, and can help make correct assumptions about market demand by three firms that do not see the market demand directly. This can result in lowering the total cost by reducing the overall inventory carried in the supply chain, while simultaneously increasing product availability by reducing the stock-out situations.
The second initiative is to forecast customer demand based on point-of-sales data and share it with all firms in the supply chain. This initiative is enabled by the first one. Besides the features of the framework used to enable the first initiative, this initiative involves the use of *algorithmic* and *predictive decision making* (i.e., a forecasting heuristic to predict demand, although a very simple forecasting algorithm can suffice in the *Beer Distribution Game*) instead of relying on manual judgment to determine order quantities, as done in the game. It also involves the use of *more types of data*: the firms can develop one forecast of the market demand and share it among all four parties in the supply chain. The benefit of this initiative is that it allows all parties in the supply chain to work to meet one common goal. The outcome of this initiative is the same as the first: it can lower cost by reducing inventory in the supply chain and, simultaneously, *increase product availability*.

The third initiative is to provide real-time visibility of inventory in the supply chain and use multi-echelon inventory optimisation. Inventory visibility in the supply chain described in the *Beer Distribution Game* can be enabled by attaching RFID tags or similar sensors to the cases of product shipped, which can be scanned and geotagged as they move from one facility to another. This initiative involves the use of *more types of data* (i.e., product location) collected from *more sources* (i.e., the location data is collected from several cases of beer from a single batch) and shared *instantaneously, without distortion* (i.e., raw location data, instead of a summary report about the amount of product at a location) in a *non-serial manner* (i.e., shared with all parties in the supply chain through a common platform), so that the inventory in the supply chain could be optimised using sophisticated *algorithms* (i.e., using multi-echelon inventory management algorithms, instead of manually determining the optimal inventory levels at each echelon). The benefit of this initiative may be particularly evident when the consumer demand experience a small change — which disturbs the equilibrium in the game and causes severe oscillations of inventory levels and order quantities in the supply chain — as the adjustments to the inventory levels are based on a multi-echelon inventory optimisation algorithm, instead of the overcorrection of a human decision maker typically observed in the game. Thus, the result is a more *cost-effective response to unexpected changes in demand*.

**Initiative for Revised “Beer Distribution Game” Supply Chain**

The following describes a more realistic version of the supply chain based on the game, without deviating too far from the original design, to demonstrate the benefit of the proposed framework for identifying opportunities for improving performance of the supply chain. Assume that the supply chain consists of one factory, one or more distributors and wholesalers, and multiple retailers each with one or more stores. We still assume that the supply chain delivers the same category of product, but now assume that there are multiple product variants made by the factory and delivered through the supply chain. We assume that consumers have preferences amongst the different variants of the product. Section II in Table 1 presents four initiatives for improving this supply chain.
The first initiative is to predict sales of different products at different stores (i.e., different geographic regions). This initiative uses more types of data (i.e., consumer profiles based on web and social media activity, geotrack records from mobile phones or fitness trackers, listing of events that influence product consumption in a region, regional weather, etc.) collected from more sources (i.e., from more consumers), shared in a non-serial manner (i.e., over a cloud platform with all parties in the supply chain) and processed to identify demand patterns using predictive machine learning algorithms. The benefit of this initiative is that it enables the use of causal forecasting models to predict demand. This can forecast demand more accurately based on the demand drivers, instead of using simple time-series extrapolations of historical patterns. This can improve product availability as well as reduce product spoilage due to inventory aging and obsolescence.

The second initiative is to offer unscheduled expedited deliveries from a centralised warehouse, based on real-time product availability at retail stores. This initiative uses data about stock levels in retail stores collected frequently (i.e., using real-time inventory updates based on point-of-sales transactions), transmitted instantaneously and without distortions (i.e., as raw inventory data) in a non-serial manner (i.e., shared with all relevant supply chain players over a common platform) for algorithmic predictive analysis to determine if any unscheduled expedited deliveries need to be made to any stores to avoid loss of sales due to product stockouts. The benefit of this initiative is that it allows a retailer to augment periodic store replenishments with expedited deliveries to minimise stockouts and lost sales. Thus, the supply chain becomes more agile in responding to unexpected changes in the market demand.

The third initiative is to allow products to be customised for individuals and/or for special occasions, such as birthdays, anniversaries, and other special events. This initiative relies on the use of more data (i.e., consumer biographic details and product preferences from social media, product and/or packaging designed by consumers for the special event on the company's social media interface), more sources of data (i.e., data from more consumers) shared without distortion in a non-serial manner (i.e., shared by consumer directly with the producer, instead of going through the retailer). The benefit of this initiative is that consumers can customise products for their own events, and the producer's factory can ship the product directly to the consumer instead of sending the customised product through the four-tiered supply chain.

The fourth initiative is to create product promotions customised for individual consumers, for specific time of the day, and offered at convenient retail stores. This initiative relies on usage of more types of data (i.e., consumer's social media profiles, shopping habits and product preferences, present location, etc.) collected from more sources of data at high frequency (i.e., data collected regularly for a large number of consumers), as well as algorithmic and predictive decision making (i.e., the use of algorithms to identify the optimal offers for each consumer for a specific time of the day and offered at a particular retail location). Furthermore, the algorithms can be feedback-based so they can learn by measuring the “hit rate” (i.e., the proportion of time a consumer bought the marketed product) and updating the algorithm itself to improve the hit rate. This can increase sales due to better matching of product offering with customer needs (i.e., higher value).
In conclusion, this section portrays the use of the framework to identify opportunities for improving the performance of a supply chain. In this case, the illustration is made by identifying the opportunities for the supply chain in the “Beer Distribution Game,” and then for a more realistic version of the same supply chain. The examples presented for this context are meant to be illustrative and not exhaustive. The opportunities for improving the supply chains described above are practically unlimited; the few initiatives mentioned in this paper are a small tip of the iceberg.

Discussion

It is widely believed that the IoT will radically transform today’s supply chains. Several publications describe the potential benefits and threats of IoT (e.g., Biswas et al. 2015; Chui et al. 2010; Evans 2011; Macaulay et al. 2015; Phadnis 2015; Rose et al. 2015; The MPI Group 2016). However, no generic framework has yet emerged that can describe IoT’s implications for supply chains. This study takes a step to fill this gap in the literature. It presents a framework, based on the theoretical foundation of information processing in organisations, to explore the implications of IoT for the management of supply chains.

One of the basic tenets of the information processing model of organisations states that “the greater the task uncertainty, the greater the amount of information that must be processed among decision makers during task execution in order to achieve a given level of performance” (Galbraith 1974, 28). Given that a fundamental task of supply chain managers is to make operational decisions that seek to achieve an optimum level of performance in uncertain conditions, the proposed framework can help one explore the opportunities for deploying the IoT capabilities to elevate the performance of supply chains from their present levels.

The proposed framework is illustrated by applying it to identify opportunities for improving the performance of two supply chains: supply chain in the “Beer Distribution Game” (Sterman 1989) and a version of that supply chain modified to include more real-world features. The opportunities presented here are certainly not exhaustive, but are chosen to illustrate the framework in a concise manner.

Although this paper focuses on identifying opportunities for improving supply chain performance using the IoT, several issues need to be addressed before the implementation can be realised. Firms in a supply chain collaborating through a cloud-based IoT solution need to ensure that the devices used for collecting and sharing information are secure to prevent malicious hacking of the network or snooping attempts for industrial espionage. Firms will also need to use devices and cloud platforms with compatible information-exchange protocols to enable inter-device communication. Uninterrupted power supply and network connectivity will be necessary for optimum performance of a supply chain’s IoT implementation. Furthermore, ethical issues related to individual privacy
need to be addressed before information about individual consumers can be collected and used for commercial purposes. Data ownership issues will also need to be addressed for the data collected from consumers as well as individual firms.

Assuming the implementation hurdles can be overcome, the opportunities for improving performance of supply chains by leveraging IoT capabilities are practically limitless. They are bounded only by our creativity. A framework based on a strong theoretical foundation, such as the one presented in this study, can help practitioners identify such opportunities. After all, we strongly believe that “nothing is as practical as a good theory” (Lewin 1945).

References


Chapter 1

Internet of Things and Supply Chains: A Framework for Identifying Opportunities for Improvement and its Application


Emerging Technologies for Supply Chain Management


Introduction

Ernst & Young (2015) identified six megatrends that have the present and future capabilities to disrupt and reshape the world. These are: digital future; entrepreneurship growth, global marketplace; urban world; resourceful planet; and health re-imagined. Hausmann et al. (2015) elaborated on McKinsey’s seven important trends that are shaping or will shape the Transport and Logistics sector over the coming years:

1. New solutions from unexpected competitor.
2. The digital frontier.
3. Burdening capital expense (capex) as a prerequisite for competitiveness.
4. The impact of deregulation on growth and competition.
5. Consolidation and cooperation across the network.
6. Increased volatility of demand and input factors, and
7. Megacities and selected emerging trade routes.

More recently, according to the Logistics Bureau (2017), the six supply chain trends you cannot afford to ignore are:

1. Warehouse Robotics in the Supply Chain.
2. Autonomous Road Transportation.
3. The Blurred Line Between Logistics and Technology Services.
4. The Appeal of Supply Chain Social Responsibility.
5. The Race for the Last Mile, and


In a survey of managers at freight forwarders by the shipping software company Freightos Ltd., 68% said warehouse robotics would profoundly impact their industry (Chao 2016). According to the report from Tractica (2017), a market intelligence firm, warehousing and logistics robot units will grow from 40,000 units in 2016 to 620,000 in 2021. According to the market research study released by Technavio (a leading market research company with global coverage), the global material handling robotics market is expected to exceed USD20 billion by 2019, growing at a Cumulated Average Growth Rate (CAGR) of more than 8% during the forecast period (Modern Materials Handling 2016). Robotic shipments are expected to reach USD22.4 billion in global market value by the end of 2021, up from an estimated USD1.9 billion in 2016 (Reese 2017). Morgan Stanley quotes an International Federation of Robotics report that says 1.3 million new robots will be installed in factories over the next three years (Garcia 2017).

Financially, Manyika et al. (2015) quoted McKinsey’s estimation of a potential economic impact on the scale of USD3.9 trillion – USD11.1 trillion in 2025 for Internet of Things (IoT) applications. According to the World Economic Forum (WEF), by 2022, 1 trillion sensors will be connected to the Internet, unleashing a torrent of data. By using technology such as machine learning, Artificial Intelligence (AI) and IoT to improve supply chain transparency, leaders in the back office are able to drive product excellence, accelerate time to market and develop new products and services (Patel 2016).

The head of logistics at SAP, Hans Thalbauer says the future of the digital supply chain is robotics and automation; industries are becoming smarter, as the entire process, from demand to delivery, occurs automatically; however, robotics and automation need to be effectively integrated into the overall business processes (Francis 2017). In an annual survey by the logistics industry group, MHI and Deloitte, 80% of manufacturing and supply chain executives said that the digital supply chain will be the predominant model within five years, while 61% of respondents said robotics and automation are a source of either disruption or competitive advantage. Within the next two years, Robotics and Automation adoption is expected to reach a 63% adoption rate, followed by IoT at 54% and Predictive Analytics at 52% (BusinessWire 2017).

Accordingly, the International Labour Organisation said about 56% of Southeast Asian salaried employment is at risk of displacement by technology over the next 20 years (Garcia 2017). Across the economy, almost 25 million jobs will be lost to automation in the next 10 years, while the new technology will create 15 million jobs, according to the research firm, Forrester (Clark and Bhasin 2017).
Based on Accenture’s Strategy Supply Chain Workforce Research 2016, supply chain executives believe digital advances will augment the supply chain workforce. They expect supply chain roles over the next three years to change most significantly in the following ways:

1. 65%: More forward looking, with strategic decisions to support business goals.
2. 51%: More data-driven decision making requiring more analytical skills, and
3. 46%: More automation of transactional activities and exception handling (Kreutzer, Meyer and Puertas 2017).

Industry 4.0, which started with the computerisation/automation of the manufacturing environment is now spilling onto the supply chain area.

The following sections will elaborate on the robotics and innovations occurred at DB Schenker, scrutinization into the emerging trends of robotics and automation in the supply chain sector, and followed by the discussion held during the SCM Seminar held on 12 and 13 February 2017.

**Robotics and innovations in DB Schenker: implementing the next generation of e-commerce in supply chain**

Since the beginning of trade, man has constantly been on the lookout for ways and means to improve the supply chain, be it to resolve an operational difficulty or to improve the effectiveness and efficiency of the supply chain. Technology has played an important role in these improvements, in the form of robotics (including automation) and innovation.

The early forms of robotics in the supply chain tend to be rigid, inflexible and mechanised with large form factors. Their roles are mainly in the material handling arena and range from the simple pallet jacks and forklifts. Later forms tend to be more automated and included the conveyor belts and Automated Storage and Retrieval Solutions (ASRS). The technological advancements in robotics today have produced robots that are flexible, versatile and come in all sizes.

The demand of the marketplace and the boom of e-commerce has resulted in the next wave of technology innovation in Artificial Intelligence (AI) or robotic automation applications leveraging on cloud computing and IoT. Out of these innovations is the Automated Guided Vehicles (AGV), an ASRS goods-to-man picking solution that is essentially a robot that utilises barcodes, QR codes, etc., to navigate the warehouse. This system improves efficiency and accuracy in storing and picking of goods.
There were three initial competing AGVs in the American and Europe markets (Wurll 2015):


2. G-Com System developed by Grenzebach in collaboration with Swisslog and introduced at BLG Logistics, Frankfurt, Germany in 2014.


E-commerce companies such as Amazon in the USA, pioneered the AGVs in its supply chain, with logistics companies such as DB Schenker in Sweden, Europe adopting the solution to participate in the e-commerce boom. When Amazon acquired Kiva Systems (now known as Amazon Robotics) in 2012, they gained competitive advantage in improved order picking productivity, reduction in labour needs and reduction in training time. The use of robots also improves product inventory control and increases order accuracy.

DB Schenker Logistics is the first 3PL worldwide to implement the Swisslog’s CarryPick system, an Automated Guided Vehicle (AGV), a goods-to-man picking solution. The adoption of this solution is part of DB Schenker’s strategy to strengthen its position in the e-commerce logistics market by implementing the next generation of e-commerce.

Combined with an integrated parcel delivery system, the solution is currently being implemented for Lekmer.com, one of Scandinavia’s largest online toy retailers. The modular CarryPick goods-to-man system uses low-profile self-driving robot vehicles (AGVs guided by QR codes on the floor) to drive underneath mobile racks and deliver them to the picking workstations. From there, workers pick and place the requested items in shipping boxes. This implementation resulted in a reduction of real estate by 20% and manpower by 65%.
The CarryPick Systems enhanced productivity through improved order fulfilment in picking, packing and shipping process through goods-to-man system, resulted in speeding up of warehouse operations and decreasing labour requirements. It improves productivity by reducing training and down time, and increasing order accuracy and product inventory accuracy. It also resulted in electricity cost savings as the warehouse can be kept dark.

**Figure 1** Rack layout in CarryPick System (Wurl 2015)

**Figure 2** An AGV drives underneath mobile racks (DB Schenker 2017)
Since 2015, top pure-play logistics corporations have made 26 investments and/or acquisitions totalling 13 each year, while logistics tech start-ups were on pace to raise $5 billion through over 300 deals in 2016, according to CB Insights, a venture capital database (Robotics and Automation News 2017). uShip, the online shipping marketplace and freight automation software provider, has closed a $25 million Series D round led by DB Schenker, one of the world’s largest logistics companies and an existing uShip partner. DB Schenker’s funding comes on the heels of unprecedented investment in logistics and supply chain technology. DB Schenker is investing in shaping the future of digital logistics. In July 2016, DB Schenker and uShip announced a milestone five-year agreement worth tens of millions to create Drive4Schenker, an online trucking platform, powered by uShip PRO, uShip’s enterprise freight automation technology. Also, Drive4Schenker recently launched in Germany will continue to be rolled out across Europe, optimising management of 5,000 loads per day with 30,000 DB Schenker transport providers. Expanding its successful partnership will expedite and streamline transport management and help DB Schenker, as a market leader in European land transport, to handle even larger volumes of freight.

AKTA project is another DB Schenker project. The Automation of Kitting, Transport and Assembly (AKTA) project is being funded by VINNOVA, Swedish Agency for Innovation Systems, and will be conducted between Autumn 2016 and Winter 2018. The project has a budget of over Swedish Krona (SEK) six million (approximately USD750,000) and is being conducted in partnership with FlexLink, AB Volvo, Schenker Logistics AB, Lorentzen & Wettre AB, CEJN AB, Väderstad AB and Mälardalen University, and Robotdalen (Robot Valley).

Emerging trends of robotics and automation in supply chain

In the past decade, Radio-frequency identification (RFID) is a device much used in supply chain applications. RFID is an embedded device which may be considered to be the intelligent agent of the product to which it is attached, since it can actually direct the entire lifecycle of the product, including its use in automated decision making and control functions connected with the product in subsequent manufacturing downstream of the supply chain (Kiritsis et al. 2003). Results indicate that RFID appears to be a disruptive technology as it supports new business models, entails major redesign of existing processes and fosters a higher level of electronic integration between supply chain members (Louis et al. 2005). RFID real-time data can be used to support dynamic scheduling in manufacturing and supply chain management so as to control production execution and logistics planning (Brewer et al. 1999).

Reported by Poon et al. (2009), RFID technology was adopted to facilitate the collection and sharing of data in a warehouse, and the feasibility of radio frequency identification case-based logistics resource management system (R-LRMS). According to Zhong et al. (2015), radio frequency identification (RFID) has been widely used where production resources attached with RFID facilities are converted into smart manufacturing objects (SMOs), and enormous data could be collected and used for supporting further decision-making in a holistic Big Data approach from massive RFID-enabled shopfloor logistics data.
Tsai (2011) found two major benefits after the RFID system was implemented in the semiconductor testing company, one being to improve efficiency, reduce human error, and eliminate manual processes, while the other was enterprise process automation. However, the use of RFID is not without obstacles. According to Angeles (2005), one of the major technical issues with RFID readers is the collision problem which occurs when readers are reading many chips in the same field. Therefore, RFID technologies should be implemented proactively, i.e. make the ROI case, choose the right RFID technology, anticipate RFID technical problems, leverage pilot project learning experiences, and manage the IT infrastructure issues of data management concerns and integration with back-end applications.

For Industry 4.0 to be realised, the supply chain has to become a completely integrated ecosystem that is fully transparent to all the players involved — from the suppliers of raw materials, components and parts, to the transporters of those supplies and finished goods, and finally to the customers demanding fulfilment. Companies that get there first will gain a difficult-to-challenge advantage in the race to Industry 4.0. The real goal will be the many new business models and revenue streams, which digital supply chain will open up (Schrauf and Berttram 2016). Industry 4.0 technologies can enable greater operational flexibility, reduce operational costs, drive more modular and adaptable automation, and promote business growth (Taliaferro et al. 2016).

According to Brody and Pureswaran (2013), three new technology revolutions — 3D printing, intelligent robotics and open source electronics promise unprecedented supply chain upheaval, thus companies and governments must understand and prepare for this new software-defined supply chain. Lee et al. (2016) suggested that the Technological Disruptions in Delivery are Advanced Algorithms and Analytics, Drones, Delivery Robots and Driverless or Autonomous Cars.

According to Merlino and Sproģe (2017), a new wave of Artificial Intelligence applications can approach and solve definitely many problems of Planning and Control of Supply Chain, while robotics is already transforming all the operational areas in Materials Handling as Amazon or Ali Baba, and Big Data new approaches can fully exploit the strategic potential of information available in supply chain areas.

Regionally, Kerry Logistics, a leading logistics service provider in Asia, has introduced six fully automated and programmed robotic butlers at its flagship facility PC3 in Hong Kong to meet the ever-growing consumer demands in online shopping, to become one of the first 3PLs in Asia to adopt robotic butlers in its operations to enhance fulfilment efficiency and accuracy (Kerry Logistics 2015). In Malaysia, MIMOS, the national R&D centre in ICT, is collaborating with China on research and development on smart manufacturing technology (Sebastian 2015). Johor Corp (JCorp) and Malaysian Investment Development Authority have invited Beijing Huize Boyuan Robot to invest RM15 billion on Robotic Future City, an industrial robotics hub and an R&D centre that creates 1,000 job opportunities (The Star, 30 April 2017).
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In terms of human resources, Gartner, Inc. (a leading research and advisory company for business leaders) predicts that by 2020, 10 per cent of large enterprises in supply-chain-dependent industries will have created a chief robotics officer (CRO) position to oversee the blending of human and robotic workers (Pettey 2017), and high-velocity distribution centres need highly trained professionals to manage these highly automated operations, such as IT engineers, maintenance employees, and operations analysts (Taliaferro et al. 2016).

Roundtable discussion: robotics and automation in supply chain sector in Malaysia

At the moment, the use of robotics in Malaysia is still very minimal, on a “need-to” basis due to the cost of robotics versus “cheap” labour. As such, many businesses are not yet ready and they are still very complacent with the existing conditions. Some businesses still want to see the success/workability of the technology e.g., RFID before investing or implementation.

Between Multi-National Companies (MNCs) and Small Medium Enterprises (SMEs), MNCs are more willing to make the switch to robotics due to their massive scale and complexity of operations, while the SMEs are less willing or unable to invest in robotics due to the high cost involved. Having said that, even for the MNCs, the decisions to switch to robotics are normally made by their Head Office. The decisions to go robotics are normally made based on the basis of product consistency or complexity, health, safety and security, rather than on human resource cost justification.

Adoption of robotics and automation has both positive and negative impacts. On the positive side, robotics and automation improve consistency and can be error-free; they have the ability to work round the clock and can handle hazardous, repetitive, complex and/or intricate tasks. These can result in total cost reduction. As robotics can be implemented in the entire supply chain from production to warehousing to logistics, the costs saved can be substantial and can be allocated to other areas.

In addition, robotics and automation in supply chain offer new career choices or vocation for the workforce. The new career choices are in the area of design, development, configuration and implementation, handling, monitoring, and maintenance of the hardware and software related to the robotics and automation.

On the other hand, the adoption of robotics and automation poses a threat to the workforce especially the blue collar workers as their career could be affected. This can have significant social and ethical impact on the community. However, this can be addressed positively with forward planning by the regulators, educators and employers through retraining, introduction of new courses for the new vocation, and having new legislation to both embrace the innovation while protecting the party at threat at the same time.
It must also be noted that adoption of robotics and automation to an existing infrastructure of warehouse and distribution centre especially for e-commerce 3PLs can be challenging and costly. Data security against security risks is the top priority to avoid harmful attacks that could affect the entire operations (DHL Trend Research 2016, 2017). Autonomous technology such as vision-guided vehicles (VGVs) has to comply with safety regulations to avoid its effect to lives.

In addition, there are two competing labour factors facing the logistics industry that will significantly give rise to the adoption of automation technologies e.g., collaborative robotics:

1. An increasingly complex customer need for more logistics workers driven by the e-commerce revolution and its need for more parcel shipments.

2. Another factor is the need to cope with the decline in the size of the available workforce due to aging population (DHL Trend Research 2016, 2017).

Nevertheless, robots will increasingly be able to do more complex jobs, but there will always be a need for people for the most complex jobs and for the running of the machines in a hybrid system (Mizar 2016).

In order to achieve an optimum return on investment, the challenging requirements that influence a right option of warehouse automation programme include the order volumes; mix, weight and size of items; and the amount of lead time needed to fulfil orders with the upfront capital investment (Hardin 2016) in hardware, software and computing power to run advanced algorithms in real time (DHL Trend Research 2016).

According to Ames (2016), the easiest way to go robotic is to start from scratch, incorporating any required features like charging stations, Wi-Fi networks, and smooth floors into the design of a brand-new building. Though this approach is more expensive than adding robotics to an existing warehouse, it avoids the challenges of overlaying a new robotic system onto the existing systems. Furthermore, the use of computer vision transforms standard pallet trucks and tow tractors into driverless vision-guided vehicles (VGVs) that these VGVs do not require lasers, wires, magnets or tapes common to traditional AGVs. While AGVs offer some flexibility with floor designs, the floor may still require precise design and installation depending on the specific application or the load imposed (Hardin 2016). Nevertheless, the next-generation robots have changed to become lighter, more flexible, easier to program, cost-effective and thus more affordable (DHL Trend Research 2017), and require less infrastructure, using unobtrusive technologies for navigation instead of relying on permanent hardware like wires, magnets or beacons (Ames 2016).
On the implementation of robotics and automation in Malaysia, Malaysia appears to be far behind the robotics and automation trend. According to a study on Malaysia's automation investment, only 30% of Malaysian manufacturers have started to invest and leverage on modern technology despite being receptive to the concept of industry 4.0 (Malaysia Productivity Corporation 2017). For instance, state skills development centres such as Penang Skills Development Centre (PSDC) has just started to train the necessary manpower for Industry 4.0 in Malaysia. There is still lack of local technical support and talent in robotics. Furthermore, adoption of automation needs to be thoroughly considered to avoid unnecessary capital expenditures. In addition, most businesses are still doubtful of the ROI of adopting robotics and automation in view of the “cheap” labour condition in Malaysia. Moreover, if the ROI period is too long, the ROI becomes untenable as the robotics and automation generally requires an upgrade every 5 years. Thus, robotics and automation in Malaysia are generally seen in the MNCs where their Head Office mandated it, or in the public/government arena such as seaports.

As the business environment and its ecosystem change to meet Malaysia’s ambition of being a developed nation by 2020, and should the availability of the right human resource becomes scarce, adoption of robotics and automation in Malaysia will happen sooner than later.

**Conclusion**

According to HKTDC (2017), online sales only account for around 1 – 2% of Malaysia’s total retail sales, while Wong (2017) estimates 5% of e-commerce penetration in Malaysia as of 2017. Proliferation of automation in supply chain is very much contributed by the intensification of e-commerce that requires an efficient supply chain to satisfy the needs of the consumers. The innovating logistics companies are those with close partnership or subsidiaries with an e-commerce platform such as DB Schenker in Europe, Amazon Logistics in US and Cainiao Network in China. The business environment in Malaysia is changing. With Malaysia’s ambition to be a developed country by 2020, Malaysia will actively pursue to have a part in the lucrative and booming e-commerce business. Quoted by EnterpriseTV (2017), iPay88 says that surpassing the RM3 billion mark (value of transacted e-commerce) in year 2016 is only the beginning for the potential growth for Malaysia. With Alibaba Group’s regional logistics hub at Port Klang Free Zone (PKFZ) as the first Digital Free-Trade Zone (DFTZ), inevitably it will revolutionise its retailing sector in Malaysia. Led by the Government, the industry has to invest to ride on the digital economy, move on to create value, and continue to be competitive in the global marketplace.
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Abstract

Big data offers vast prospects in transforming supply chain. Application of data, storage, analysis and being connected to the Internet of Things (IOT) has brought new commercial opportunities in supply chain management. Innovative means of data consumption and analysis provide business intelligence on predicting demand trends, assisting business analytics or predictive models for e-commerce supply chain. An effective design of the supply chain at the enterprise level can be achieved through the integration of information system infrastructures which include hardware such as sensors, RFID, QR codes, barcodes and other technology means that provide competitive advantage. The abundance of data also provides challenges to supply chain managers. With the right level of data governance and business model, big data offers new sources of economic value in supply chain.

Introduction

Big data is no longer a new concept. The International Data Corporation (Morris et al. 2014) predicts that digital data will grow from 2.8 trillion gigabytes in 2012 to 40 trillion gigabytes by 2020. Implications on the domain of supply chain operation model (SCOR) can be seen on processes related to supply planning, sourcing, make and deliver processes. In the planning stage, data are analysed to predict market and consumer trends. During the sourcing process, big data enables more effective and faster supplier search, supplier negotiations, supplier evaluation and supplier selection. Data connectivity and databases are used during the make process to ensure the right supply-demand of inventories, schedules and automation of process within the array of manufacturing processes. In the shipment delivery stage, the various applications of big data improve the precision and delivery cycle time. Disruptive progress on Internet of Things (IOT) and e-commerce compel corporate leaders and operations managers to innovate and invest in the application of big data in the supply chain. Big data in supply chain is already here.
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Data explosion and ripe for commercialisation

Conceptually, big data is a term that describes the large volume of data. Industry players have categorised big data into three (3) mainstreams, namely Volume, Variety and Velocity, since early year 2000. Enormous sources of data acquired from business transactions, social media and machine-to-machine interactions from different organisations in the value chain pose data storage challenges. New technology such as Hadoop (an open source, Java-based programming framework) supports the processing and storage of extremely large data sets in a distributed computing environment. Innovations in RFID tags, sensors and smart metering addressed the velocity of data streams to manageable real time. The variety of data exists in structured or unstructured format. The structured data exist in numeric forms such as traditional databases or unstructured text documents, email, video, audio, stock ticker data and financial transactions. Recent development has also identified that data variability affects handling, and veracity affects quality of data and subsequently accurate analysis. The challenges related to data volume, variety, velocity, variability and veracity keep increasing.

As data centric technologies mature and become more accessible, organisations in supply chain are innovating new approaches to apply and introduce new data-driven products and services. Figure 1 illustrates the benefits of big data.

Figure 1 Benefits of big data (Hagen, C and Khan, K 2014)
The value from big data comes from the processing and analysis of it to provide insights on products and services. The insights link suppliers, manufacturers and retailers to customers into a more efficient supply chain. The commercialisation of big data in supply chain requires significant efforts to align the data value with targeted users, the breadth and depth of service offered, improving the customer support infrastructure and data storage accessibility. The sweeping changes in big data technologies and management approaches need to be accompanied by dramatic shifts in the manner data supports decisions and product/service innovation.

**Big data enables supply chain in a big way**

Conceptually, a supply chain involves bidirectional flows of information, products and cash. The bidirectional flows between suppliers, service providers, manufacturers and final customers occur through different supply nodes. Transactional data have been conventionally designed as Enterprise Resource Planning (ERP), Advanced Planning System (APS) or even customised supply chain execution tools to improve supply chain response between stakeholders. With the advent of data explosion, the pervasive use of big data in data mining and analytics transforms supply chain through new forms of data, solves existing business problems and creates new opportunities. For example, e-retail giant Amazon.com handles millions of back-end operations everyday, as well as queries from more than half a million third-party sellers in a capacity of terabytes. eBay uses two data warehouses (in petabytes range) as well as Hadoop cluster for search, consumer recommendations and merchandising (Wikipedia). Essentially, big data enables the supply chain in multiple ways as articulated in the following framework:

1. **Responsive sensing analytics:** The traditional supply chain model relies on historical data such as order or shipment data, to sense demand and react with series of supply chain solutions. However, such a business model creates a disadvantage where the supply chain is poor at sensing and responding to demand and supply changes. Recent development in data mining, text mining, and rule-based ontologies allow supply chain operations to understand their customers better. The digitalisation of business has allowed supply chain organisations to listen cross-functionally to customer sentiments and use advanced analytics to test market response. The data related to these feedback mechanisms is either sourced from internally-established data warehouse, procured from large database service providers or from social media.

2. **Predictive supply chain scenario planning:** Current data structure within the supply chain is somewhat hard coded. Often, the data structure produces response based on average value and non-complex “if-then-else” logic. The disadvantage is the inherent inflexibility to support complex scenario planning. Supply chain managers who need more flexible options are turning to predictive analytics or rules-based ontologies to map out “multiple ifs to multiple then” through learning systems.
3. **Making delivery channels effective and visible:** Competitive development in e-commerce makes supply chain managers reconsider their delivery channel programmes. Rapid digitalisation of data and the widespread use of digital devices on various platforms offer new business solutions to different industries. For example, in the brick-and-mortar retail industry and the fast-moving goods supply chain, operation managers are aware that consumer decisions are made on the shelf but the data they see and respond to every day is limited to their own company data. The enormous data integration (ranging up to petabyte) acquired through Point of Sales, Radio Frequency Identification Tag (RFID), barcode information from mobile, social and e-commerce data enables the smooth integration of the supply chain delivery mechanism to rely heavily on sensors, which in turn rely more on the volume of data. RFID sensors send high volumes of data in different format or pattern, with improved recognition system and adaptive infrastructure which makes the delivery channel more effective and efficient. The volume, depth and variety of data transacted across supply chain organisations provide real time data feed. The impact of geolocation, mapping data and visualisation of supply sensing transmission through sensors on items, totes, trucks and rail cars, or containers transforms supply chain visibility.

4. **Digitised manufacturing and services:** The advent of IOT requires supply chain managers to think differently in the manufacturing and service sectors. The extensive expectation of mobility and digital inputs from sensors requires manufacturers to react in real time rather than to event-based execution model. Production scheduling, planning and maintenance programmes are facilitated by machine output or machine learning through extensive data transacted. In the service sector, the use of such mobility and digital inputs transforms the service industry. For example, airplanes automatically communicate the performance status of the equipment on board upon landing, expensive earth movers in remote locations transmit signals regularly, and electricity-generating windmills send signals at regular intervals to control towers. These signals are then used to plan the maintenance servicing and parts replacement. The manner of data streaming at high volumes and high variety transforms the IOT in the service industry.

The enormous data application represents a critical source of business insights and information that creates a competitive advantage for the multiple stakeholders in a supply chain. Big data improves operational efficiency and profitability through speed or visibility, thus improving the overall stakeholders’ relationship. The enhanced agility and responsiveness leads to competitive and shorter time to market especially in the supply chain IOT, and ultimately higher revenue recognition and competitive advantage.
Getting the supply chain ready

In order to harvest the positive impact on the supply chain, organisations need to innovate the approaches on big data. Firstly, the supply chain stakeholders need to redesign the market dynamics to reflect end-consumers by incorporating and segmenting the data usage and analysis in business processing to different target market. It needs to consider how different consumer groups across the value chain will consume and benefit from the data. Secondly, the supply chain manager needs to adjust, modify, implement incremental improvements, or re-engineer the manufacturing or service model to take advantage of the data stream. Improvement or investment within the upstream to downstream data chain management (hardware or software) should not be ignored. For example, part of resolving data-related issues may require reloading of data sets, running queries to ensure data integrity and consistency, or conducting data quality checks. Effective change management is required to deliver the optimised business processes which translate to increase or create new revenue streams. Responsive and agile supply chain needs to design effective alternate data storage infrastructure. An optimal data storage infrastructure should deliver targeted service quality with optimised service delivery costs. This in turn supports data replication strategy within the supply chain network, thus improving retrieval data. Staying ahead of the game through data analysis, visualisation of data sets, statistics, algorithm, machine learning, knowledge on open sources tools, or programming languages help a supply chain's product and service research development. Unknowingly, many technology or service-based companies are sitting on untapped sources of revenue in the form of operational data. It is important that enterprises leverage their human resource and staffing teams to attract and retain these skill sets to support their data-driven product portfolio.

Conclusion

Supply chain companies intending to increase efficiency and profitability should be cognisant of the impact and potentials of big data. While recognising the technical investment, industries in supply chain should institute operational efficiencies into the supply chain. Productivity, collaboration, speed and visibility can be maximised while time spent on manually monitoring events can be minimised. Improving visibility through data connectivity improves the relationship between multiple supply chain stakeholders such as vendors, suppliers, carriers, distributors, warehouses, and customers. Precise data analytics and predictive models help supply chain companies to identify issues early and proactively respond before problems surface. With big data, supply chains should be more agile and responsive. Big data revolution is here and it is timely for the supply chain to engage and reap the benefits.
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Introduction

Electronic procurement (e-procurement) is the use of electronic methods in every stage of the procurement processes from identification of requirement, through to supplier sourcing, request for quotation, purchase order issues, payment and contract management. The current technology of e-procurement has been available since beginning of 21st century. The issue is, not all procurement professionals have been fully implementing this e-procurement until now. Nevertheless, the emerging trends of procurement technologies such as artificial intelligence, Procurement 4.0, Big data, 3D printing and Internet of Things (IoT) have begun to affect procurement professionals.

A study conducted for 830 procurement decision makers across the United Kingdom, Europe and North America shows that 68% of companies have automation, 59% implement e-sourcing, 54% have predictive analytics and 54% have IoT. However, most of the companies which adopted these technologies are located in North America and their workforce is greater than 3000. In addition, North America is 8% more likely to adopt these technologies as compared to Europe. In spite of the importance of technologies in procurement, talent in technology is only ranked as the sixth most important skills and only 17% of procurement department claim the technology skills gap (Avery 2015). This scenario poses a challenge to procurement professionals who have yet to adopt the emerging technologies, especially those located in developing countries.

Current technology of electronic procurement

The two core processes of e-procurement (electronic procurement) are e-sourcing and e-requisition. E-sourcing uses the Internet to make decisions and form strategies pertaining to how and where to obtain products and services. E-sourcing is more for contractual processes with the tools of e-tendering and e-RFQs (request for quotation and e-auctions) (Baily, Farmer, Crocker, Jessop and Jones 2008). E-requisition is the web-based application used to process and monitor purchase requisition; it is more transactional with the tool such as e-catalogues. E-requisition may be called as e-ordering.
The main predictor for adoption of e-procurement techniques was perceived drivers. The perceived drivers included better decision making, better inventory management, increasing order accuracy, increasing the visibility of suppliers’ products, reducing cycle time for order completion, easy to try or switch to new suppliers, reducing inventory cost, reducing price and reducing transaction cost. Internal and information barriers were significant predictors for e-procurement in the new buying situations. The internal barriers of e-procurement comprised of lack of IT system integration with the partners, inadequate technological infrastructure of business partners, inadequate in-house technological infrastructure and IT personnel, changing the way people work, lack of top management support, lack of corporate strategy and high technological implementation cost. Information barriers of e-procurement included the concerns about security, confidentiality and privacy of information exchange (Abu-Elsamen, Chakraborty and Warren 2010). The electronic execution of procurement activities improved supplier partnership, supplier performance, buyer performance, process integration and process automation (Tai, Ho and Wu 2010).

Organisation acceptance is likely to be a stronger predictor of performance than intensity of use for e-procurement of MRO (maintenance, repair and overhaul) items. It is because indirect materials and services are distributed across different departments. Hence, the potential benefits of e-procurement are expected to be greater when the application is deployed organisation-wide. However, multiple dimensions of infusions can interact with one another and affect performance. The research suggested that when the intensity level is low, higher performance can be achieved through higher acceptance. However, when the intensity is high, performance does not receive an additional benefit from higher acceptance. As such, procurement managers may need to focus more on the level of organisational acceptance rather than the level of intensity of use in order to increase the potential benefits. It is suggested to focus on improving one usage dimension at a time in order to successfully infuse e-procurement in that dimension, before turning attention to the other dimension, akin to a staged implementation approach (Yu, Mishra, Gopal, Slaughter, Mukhopadhyay 2015).

Blue Cross Blue Shield of Rhode Island (BCBSRI) implemented the procure-to-pay solution to tie in all the processes, goals and strategies. It selected Puridiom 4.0 Enterprise Cloud solution, which enabled automation of the antiquated and manual P2P (procure to pay, from point of order to payment). This subsequently enhanced the procurement team’s ability to influence supplier spend or total spending on suppliers. Furthermore, the solution enabled suppliers to transact electronically with BSBSRI. It also increased efficiency of the cost accounting and finance teams, while allowed the procurement team to negotiate fast-pay discounts. In addition, it allowed the company to track cost saving and ensured it ties in with the budget; it assisted in measuring and improving supplier performance. It assisted procurement to focus its resources on high value items and strategic activities.
A case study of e-requisition

A case study of e-requisition was conducted in a multinational company located in Malaysia. A comparison was made between the MRO purchase before and after using e-requisition. Before the implementation of e-requisition, the traditional MRO purchase involved a lot of processes with long lead time. It starts with the requestor who submits the request using purchase requisition (PR) to the procurement department manually. The procurement department will consolidate all the requisitions from various departments to finalise the total requirement. Once the quantity is determined, the procurement department will send out an RFQ (Request for Quotation) to at least 4 to 5 qualified suppliers. The qualified suppliers will have to produce a sample each, together with quotation for approval. Upon receipt of samples with price, the procurement department will call for a tender committee comprising of the requestor’s department heads, finance, procurement and warehouse, to decide on the price and quality of samples. Once finalised, the purchasing department will place orders for the uniforms from the approved supplier decided by the tender committee. Then, the supplier will deliver the uniforms and shoes to the warehouse once an order is placed by the buyers. The warehouse will keep the uniforms and shoes as a stock item. When required, each individual department will take out the uniforms and shoes from the warehouse accordingly.

Kindly refer to the following Figure 1 for the traditional purchasing flow which takes almost 32 days.

**Figure 1** A traditional purchasing flow
However, after implementing e-requisition, the purchasing cycle is reduced tremendously. The procurement department can send the employees’ data to the qualified supplier pertaining to the name of each employee, date of employment, size of uniforms and shoes. The supplier can utilise all the employees’ information to prepare the uniforms and shoes as required. The shoes and uniforms will be delivered to the employees personally when they are due for collection. In this way, the warehouse does not have to keep the inventory. The company can eliminate the inventory-carrying costs. The employees can key in their employees’ number and acknowledge the receipt with a password and the receiving data can be forwarded to the Finance department for payment. In this process, the Finance department can verify the actual receipt of the uniforms and shoes from the employees personally. This process will eliminate all paperwork such as purchase requisitions, purchase orders, acknowledgement of receipt from the warehouse, inventory recording at the warehouse, and also matching of documents by the Finance department.

E-sourcing

Tata Motors used the e-sourcing of Ariba Sourcing to manage the procurement of direct materials, indirect goods, services and MRO. It saved $175 million from the cost base after two years. The e-sourcing Tata Motors started with direct materials as it comprised three-quarters of the vehicle cost (Supply Chain Europe 2007).

E-auctions create an environment where suppliers bid against each other for a contract. This environment encourages competition with the result that goods and services are offered at their current market value (CIPS). In order to hold a successful e-auction event, the procurement must understand the supplier market, identify potential suppliers, assess their capabilities and the total cost of doing business with suppliers, present suppliers with a complete set of prints, specifications and requirements, and honestly communicate the way in which competing suppliers will be judged and selected. Online auctions can be efficient and bring cost saving if the process is executed properly. Hence, a critical component to a successful auction is a dedicated buyer who is willing to allocate sufficient resources to design an equitable and well-specified auction event. However, price is only one dimension in a buyer-supplier relationship. There is a need to incorporate non-price attribute into the assessment of auction success (Elmaghraby 2007).
A new business process is involved to convert a traditional business process to an electronic format. Two factors of successful design of e-business protocols include identifying the functional difference between traditional and e-business, and recognising functional limitations of cryptographic technology when it is applied to the actual business process. The security requirements for an e-tender submission protocol are submission hiding, submission binding and submission time integrity. Submission hiding ensures no party can reveal any electronically submitted e-tender document before the designated tender opening. This is to ensure the security of every party’s tender strategy before the tender closing time. Submission binding could detect any party who altered or deleted any tender submission after the tender closing time. This will prevent the business conspiracy between the principal and its favoured tenders. Submission time integrity is to ensure that the time of tender submission can be recorded in a reliable manner. This is to provide reliable evidence on whether a tender is submitted on time (Du, Foo, Boyd 2008).

**A case study of e-sourcing**

A case study of a company in Penang discovered many benefits of e-sourcing by using the tools of e-bidding or e-tendering. The lead time required from request till complete of the sourcing procedure without e-sourcing will take about 20 days, with various manpower involved. However, by using e-sourcing, the procurement department can reduce 50% of the total processing time (from 20 days to 10 days) through e-bidding. The process is also reduced from 8 steps to 7 steps. This method is transparent. It also creates a level playing field for all vendors. The details are illustrated in the following Figure 2.
E-sourcing workflow of 10 days processing time with e-bidding from the 3rd to the 5th step (7 steps)

Figure 2 The processing time of typical sourcing vs. e-bidding sourcing

The advantages of e-sourcing by using the tools of e-bidding or e-tendering are summarised as follows:

1. Procurement professionals do not have to take the suppliers to visit the site.
2. It is sufficient to obtain a blueprint with all technical specifications for various types of items, brands and models indicated as per requirement, and forward to all qualified suppliers for quotation.
3. In the event, any supplier who needs more information can indicate their requests in the bulletin board. The reply will be notified to all invited suppliers.

The case study also found that e-sourcing could reduce costs in the following ways:

1. Reduce time in obtaining quotations.
2. Reduce manpower.
3. Create level playing field with proper control.
4. Demonstrate fairness and transparency with audit trails.
5. Eliminate accusations or allegations of unfair practices.
The following Figure 3 shows an example of how e-bidding enables price reduction. The bidding started with the lowest quote at RM3.2 million. The e-bidding allowed the competitors to see each other’s price though the names of the competitors were not disclosed. As such, all the three vendors were given equal opportunity to review and revise their price. The bidding started at 10:00 am and ended at 11:30 am on that particular day. By allowing auto time extension of 15 minutes to 11:45 am, they were able to achieve the cost reduction from RM2.75 million to RM2.7 million as shown in the chart (additional reduction of RM50K).

For example, there is a company named BidAsia, which provides an online procurement auction platform for bidders to compete dynamically with multiple bid price submissions in real time. Buyers get instant responses from suppliers. Table 1 shows the three options of its quotation. The prices are just a guide and it may change from time to time depending on demand and supply.
Table 1: Example of quotations

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Unit price</th>
<th>MOQ</th>
<th>Amount</th>
</tr>
</thead>
</table>
| Option 1 | Annual subscription to 10 bidding projects at [www.BidAsia.net](http://www.BidAsia.net) e-bidding software as a service (SaaS).  
Period of subscription: 12 calendar months from date of invoice or usage of up to 10 bidding projects, whichever comes first. | RM1000.00  | 10 projects  | RM10,000   |
| Option 2 | Annual subscription to 50 bidding projects at [www.BidAsia.net](http://www.BidAsia.net) e-bidding software as a service (SaaS).  
Period of subscription: 12 calendar months from date of invoice or usage of up to 50 bidding projects, whichever comes first. | RM600.00  | 50 projects  | RM30,000   |
| Option 3 | Annual subscription to 200 bidding projects at [www.BidAsia.net](http://www.BidAsia.net) e-bidding software as a service (SaaS).  
Period of subscription: 12 calendar months from date of invoice or usage of up to 200 bidding projects, whichever comes first. | RM300.00  | 200 projects  | RM60,000   |

**The status of e-procurement in Malaysia**

E-procurement is quite common for multinational companies which use enterprise software such as SAP Solutions or Oracle Database. However, some multinational companies and SMEs in Malaysia have yet to practise e-procurement. Some companies in Malaysia still send the hard copy of purchase orders to suppliers. A case study research on a multinational company in Penang revealed that printed purchase orders were faxed to suppliers before they were sent by postal service. Another case study with a multinational company in Penang showed that scanned copies of purchase orders were emailed to suppliers before they were sent by postal service.
Emerging trends of technologies in procurement

Emerging trends of technologies affecting procurement management include Procurement 4.0, Big data, Internet of Things (IoT), 3D printing, robotics and cognitive procurement. Emerging trends of technologies require procurement managers to possess critical thinking to identify information that is both relevant and actionable. Procurement must have associative thinking to look clearly at unrelated factors and see a previously undetected connection; it includes the ability to recognise patterns and decide what they mean. Procurement must make fast decisions, and be proactive to come out with real-time solutions to manage real-time data. The emerging technologies require procurement to master mainstream technology to solve procurement problems. The IoT will provide plenty of information which requires procurement to be innovative in using it (APN Consulting 2017). A supply chain roundtable conducted in Penang in year 2017 discovered that the abovementioned emerging technologies in procurement are still in the infancy stage and are not commonly adopted by multinational companies located in Penang.

Procurement 4.0 and big data in procurement

In Procurement 4.0, the strategic procurement is crucial and the procurement workforce is shrinking because it becomes autonomous in many aspects. Traditional purchasing will become obsolete.

Due to the knowledge of purchased materials and supply markets, procurement could increase its distinctive value proposition from being a cost centre to a profit centre. Procurement could utilise customer data to manage their incoming transportations and material inventory. Procurement could also share the customer data with their suppliers. In turn, suppliers are capable of designing products which are efficient in cost and function.

New technologies in Industry 4.0 will lead to changes of purchased items in procurement. Procurement will be required to source more frequently for new technology items, such as intelligent sensors, communicating actuators and associated controllers and software. The purchase of electronics items will grow but others may shrink or disappear. Moreover, the service procurement will increase tremendously which leads to many contracting approaches. There will be many intellectual property implications around the ownership of the data collected by sensors when the end products are sold and in use. Who owns the rights to this data, the sensor supplier, the control system or the software provider?

In order for data integration to take place, procurement will need to get suppliers on board. Data integration will then lead to supplier risk management to detect supplier failure (Geissbauer, Weissbarth, Wetzstein 2016). Procurement could use digital supplier scorecards, objectives and improvement tracking. Automated tracking of target achievement could be used as well (Schreiber, Janssen, Weaver, Peintner 2016). As Procurement 4.0 data integration takes place, procurement will play an integral role in getting suppliers on board and optimising the end-to-end supply chain.
“Big data” is defined as any analysis activity with a purpose to get more insight from the large amount of data in order to generate business values. Many procurement organisations have yet to fully leverage this large amount of data from internal and external sources. Big data is helpful in updating the risks from suppliers and sourcing markets, such as natural disasters or bankruptcies. Big data solution could discover new opportunities to reduce sourcing costs. Big data could potentially improve efficiency from 10% to 30%. With big data, data-oriented evidence for all product quality and delivery issues becomes possible. The first step of big data initiative is to generate hypotheses on what correlations among the available data might have actual business value. The second step is to identify all potentially relevant data sources to support the business case. The third step is to quickly build prototypes to verify correlations and support the hypotheses. The final step is to implement a robust IT-based solution specifically for the most urgent and critical correlations. It is important to start small with rapid prototypes before implementing a full-fledged solution (Sauter 2014).

Smart technologies and algorithms allow huge volumes of data from various sources to be aggregated, processed and analysed. The resulting analyses can be used to understand suppliers and supply markets which can automatically drive procurement decisions. The big data could provide information to optimise maintenance services and the inventory management of spare parts (Geissbauer, Weissbarth and Wetzstein 2016).

Predictive information about where and when to expect the next failure will offer an opportunity to optimise maintenance services and the availability of spare parts. Procurement is to ensure that the analysis of big data is maximised to benefit both the focal companies and their suppliers (Geissbauer, Weissbarth and Wetzstein 2016).

Supplier innovation management could be achieved by linking the R&D strategy with the procurement strategy supported through digital dashboards. Procurement could establish laboratories to be shared with the key suppliers with the intention to encourage innovation through design thinking and rapid prototyping. Big data and advance analytics could be utilised to detect new technologies, material substitutes and new suppliers. In addition, crowd sourcing is another way of innovation (Schreiber, Janssen, Weaver and Peintner 2016).

Digital technologies contribute to collaboration of procurement in the entire value chain, from sourcing to contract negotiations; order delivery; payment and supplier management. Digital procurement processes include digital request for quotations, supplier financial analysis, procurement risk analysis, verification and e-signatures. These processes go beyond purchase-to-pay, with only limited manual support required. They reduce costs and free up highly qualified procurement staff from routine and repetitive tasks (Geissbauer, Weissbarth and Wetzstein 2016).
Internet of Things (IoT) and procurement

IoT will enable procurement to know exactly what is being used and what is needed. The ability to forecast the needs will also improve procurement and contract management. IoT requires procurement to be flexible and efficient. Procurement workflows will need to be mobile and connected just like everything else. Procurement will be able to analyse the insights from users’ purchases and activities in a mobile and connected way (Spend Matters 2015). IoT may improve the communication and trust between buyers and suppliers.

IoT may help procurement to gain visibility in their spending and to analyse the suppliers and the equipment they use. IoT could provide updates about the new suppliers and directly send them an invitation for quotation after the necessary approvals. IoT assists procurement to create and monitor supplier contracts. It also alerts procurement for any suppliers who do not fulfil the contractual commitments (Bhavesh Shah 2015).

IoT will automate tactical tasks of procurement, which enable procurement functions to be more strategic. One of the challenges of IoT is that procurement will have to align processes and systems with other business units, which may have different processes and needs of IoT. With greater process automation and intelligence data, it is a real challenge for procurement to find staff with technological skills in addition to business degree graduates with passion for procurement (York 2015).

IoT will enable devices and solutions for procurement to monitor inventory and issue orders. IoT could alert procurement when inventory is getting low in the warehouse. IoT provides insightful window of performance for outsourcing suppliers. In order to realise the benefits of IoT, procurement must have the right systems and processes in place to manage the high volume of data from IoT devices and solutions (Kinder 2014).

Due to the growth of new technology and process digitisation, procurement needs to change and update the traditional procurement methods. New suppliers with breakthrough technologies may be required. Long-term contract of 3 years with suppliers may not be applicable for certain areas of procurement. Alternatively, supplier contracts need to incorporate the opportunities to adopt new technologies (Granger 2016).

3D printing and procurement

The engineers may try to use 3D printing to bypass procurement, as parts will be made at the point of use rather than in a distant factory. It potentially shifts some global sourcing to local sourcing. As costs reduce, it may become cheaper and easier to procure certain specialised 3D printed items from suppliers on a local basis, rather than plan and procure through larger distribution networks. This will lead to a change in working practices, which could have a knock-on effect in other areas of the enterprise and alter timings across the board.
“3D printing enables much faster prototyping, shorter lead times and creates an environment where direct communication of standard design files is much easier. 3D printing has high potential value for rapid prototyping and manufacturing of customised, unique and complex products and parts. For many high volume, standardised and cheap items though, mass-production will likely remain the manufacturing technique of choice for the foreseeable future” (Spend Matters 2015).

3D printing enables “less push and more pull” of supplier delivery. It could reduce obsolescence caused by economic of scale. It encourages Just-in-time inventory, less stocking of raw materials and work in progress by utilising on-demand production. Suppliers could perform 3D printing in smaller factories close to the buyers in order to achieve localisation and lower shipping costs. However, 3D printing triggers unanswered questions to intellectual property rights. Instead of selling physical goods, the right of the design could be sold (Wilson 2015). There is potential threat or legal risks when companies use 3D printing for objects under patent protection. Procurement could work with suppliers to produce driven mass customisation and build to order products (Cube 2014).

Ford used 3D printing to make prototypes of automotive parts in 2013. General Motor used 3D printing to save the time required to make prototypes in the year 2014. 3D printing contributes to cutting down tooling costs (Cube 2014). Any increase of unit price from 3D printing is now offset by the elimination of shipping and inventory carrying costs (Cube 2014). Anything the company can print by themselves may not be purchased externally. Suppliers just need to send the data for printing. It means MRO and spare parts may not need to be purchased but printed internally. Only bulk items need to be purchased (Gracht, Guinipero and Schueller 2016).

**Robotics and procurement**

Procurement automation is no longer optional. In fact, it is a key strategy to achieve operational excellence (Supply Chain Management Review 2012). The procurement trend now is, old jobs are going away and new jobs are emerging. Most traditional or repetitive procurement activities are now automated. These include purchase order generation, change of orders, spend analytics and exception detection. Even sourcing functions are going to be performed by cognitive tools that effectively learn from human professionals. These functions may include supplier identification, request for quotation, analysis and scoring. Negotiation could be streamlined as standard agreements and click-through of terms for ordinary purchases. Ultimately, the fewer jobs that remain are going to have higher competency, higher pay and are more strategic. Managing supplier relationships becomes more important than negotiating supplier contracts (Huber 2015). The robots can send out requests for bids and procurement will be notified once the bids have been received. The procurement can then decide which bid to accept based on the information provided by the robot (Jain and Woodcock 2017).
Cognitive procurement

Cognitive procurement is the application of cognitive computing systems, which combines a series of capabilities including big data analytics, nature language processing and machine learning, to analyse and process large volume of data and provide procurement with the enhanced intelligence and guidance needed to make smarter and faster decisions in supplier management (Bartolini 2017). Hence cognitive procurement is also known as application of artificial intelligence (AI) in procurement. Cognitive procurement could potentially be utilised for spot buying. Once pricing falls below a certain threshold, the system could identify it and alert category managers to purchase the commodity. The notification could also suggest which market to focus on, which suppliers to contact and the best negotiation strategy (Bartolini 2017).

Cognitive procurement could present an “in context” data-driven and scientifically-based approach to procurement that analyses large volumes of internal data. This will enhance the decision making process of procurement (Bartolini 2017). For example, if the analysis requires five suppliers to bid for an e-sourcing, the sourcing tool may pause the decision until the five suppliers are invited. In addition, the tool could propose suppliers based upon the criteria included.

Cognitive procurement contributes to dynamic supply risk modelling and alerting. It could leverage the power of multiple data sources in order to stay abreast of the future risk landscapes. It can also automatically adjust themselves in accordance to the risk landscapes changes (Bartolini 2017). For instance, if a political unstability happens in the country of a supplier, cognitive procurement will provide an early warning to enable procurement to prepare for contingency plans.

By generating real-time visibility of spend data, cognitive procurement helps to drive cost reduction, cost compliance and any exceptions. The Singapore government used artificial intelligence to identify and prevent procurement fraud. The artificial intelligence algorithm analyses procurement request and tender approvals (Darbie and Chandra 2016). If this is the case, artificial intelligence could potentially be used to identify and prevent procurement fraud in industrial organisations.

Cognitive procurement could be used to analyse the supplier contracts by identifying the various clauses and terms, build a library of the most commonly-used contracts and capture important metadata in the contracts. In addition, cognitive procurement has the capability to proactively alert procurement of critical upcoming events on contract deadlines, renewals and thresholds. Furthermore, cognitive procurement could recommend new contracts based on the frequency usage of existing contracts and similarities between contracts. A machine can learn and it means that its recommendations will become more accurate over time. If the procurement staff accepts or rejects recommendations, the system will learn from them to develop a preference scheme (Maltaverne 2017).

Predictive maintenance and cognitive procurement will order replacements parts before a machine breaks down. As such, procurement could focus their attention on the process efficiency of strategic MRO procurement tasks (Gracht, Guinipero and Schueller 2016).
Cognitive procurement could estimate the global sourcing potential for an item by comparing its unit price, quality and technology requirement with the current database. Cognitive procurement could assess which supplier is most likely to meet the sourcing needs. In addition, it can recommend selecting a specific supplier. After the suppliers are selected, the system will continue to monitor the selected suppliers based on their promised delivery, quality and cost reduction. A series of automated mitigating actions will be triggered for exceptions; procurement will only be alerted if the actions fail to get the supply back on track (Jain and Woodcock 2017).

Procurement staff will become an expert on the procurement of professional services. Procurement activities such as supplier audits, supplier meetings and supplier workshops could take place in the virtual worlds. Procurement professionals could carry out these activities with a headset and personal avatar. In this scenario, the procurement’s added value depends on data management insight and intelligent algorithms. Future procurement requires a substantial commitment to technology as well as internal and external IT expertise. Procurement becomes intensively digitalised, automated, autonomous and networked. Digital talents become very important for procurement. Procurement must become the company’s central business partner for innovation. Procurement has to be more interdisciplinary level, developing more technical skills and participating in product development process. Procurement does not replace globalisation with localisation, but rather combines both strategies to create maximum value (Gracht, Guinipero and Schueller 2016).

Blindly trusting artificial intelligence could be a risk. Hence, machines should not only present results, but should briefly explain how the results are derived. Procurement professionals should demonstrate critical thinking and have the final say, but not the machine. The enormous cost to gather enough data to train the machine poses another challenge to cognitive procurement (Maltaverne 2017). Therefore, the procurement professionals have to assess the potential of cognitive procurement to decide the timelines of adopting it.

With many jobs taken by artificial intelligence, procurement professionals will have to focus on strategic directions, genuine skills and judgments that are not easily replicated by artificial intelligence (Smith and Osagie 2016). Procurement professionals are recommended to develop a big data strategy; invest in building data science talent and capabilities; maintain and build organisational expertise; track innovations and stay abreast of the cognitive procurement technology marketplace and prepare, knowing that the pursuit for cognitive procurement is going to be iterative (Bartolini 2017).

**Conclusion**

The current technology of e-procurement has proven to be beneficial for multinational companies located in Malaysia. Electronic procurement has reduced their purchasing cycles and purchasing costs significantly. Further research is required to review the impact of e-procurement in small and medium enterprises in Malaysia.
The emerging technologies of procurement are supposed to further enhance the procurement functions. Big data could potentially reduce sourcing cost and improve procurement efficiency. IoT will enable procurement to gain visibility in every stage of the purchasing activities. Instead of buying from overseas suppliers, 3D printing is an alternative solution to produce low volume items, spare parts and prototypes. Artificial intelligence will take over the repetitive roles in supplier selection and contract management so that procurement could focus on strategic and judgemental roles. However, digital talents are crucial for procurement professionals to succeed in these emerging technologies.

References


Chapter 5  The Impact of Industry 4.0 on Supply Chain  

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Introduction

Industry 4.0 refers to the current trend of automation and data exchange in manufacturing technologies. It consists of cyber-physical systems, the Internet of Things (IoT), cloud computing and cognitive computing. Supply chain is an important pillar of Industry 4.0 as supply chain includes the flow of products or services from the first supplier until the end customer. Supply Chain 4.0 happens through the application of Industry 4.0 innovations in supply chain.

This paper explains the impact of Industry 4.0 on supply chain, with emphasis on digitalisations of supply chain. Digital supply chain may be defined as supply chain that has been driven by innovation of information technologies. Today the digital environment has evolved over time and technology has been part of the human lifestyle. Technology innovation is ever competing to improve or replace the current systems. The future of supply chain will change with ever-changing technologies.

Automation has affected supply chain with examples of autonomous shipping trucks and warehouse robotics. More and more areas may be automated with new technology being introduced to the supply chain and the trend will continue. Hence, supply chain professionals need to get prepared to master these technologies in order to stay relevant.

This article starts with how industry revolution affects supply chain and ended with the status of Supply Chain 4.0 in the Malaysian context.

Industry revolution and supply chain revolution

The First Industrial Revolution is widely taken to be the shift from our reliance on animals, human effort and biomass as primary sources of energy to the introduction of mechanical production facilities by utilising water and steam power. The term supply chain was not used in those days. Sugarcane molasses were shipped from Caribbean to New England for distilleries to transform it into rum. Besides consuming locally, the drinks were sold in bottles and barrels in Europe and Atlantic. However, shipment across countries was not common in other parts of world.
The Second Industrial Revolution started at the end of the 19th century and the first two decades of the 20th century, and brought major breakthroughs in the form of electricity distribution, both wireless and wired communication, the synthesis of ammonia and new forms of power generation. The industrial revolution in this stage introduced labour division and mass production. The term supply chain was still not common at those days. However, a global supply network was initiated with the introduction of steamships. Raw cottons from southern United States were shipped to the cotton mills in England. The finished cloth was then shipped to the whole world.

The Third Industrial Revolution started in 1950s with the development of digital communication systems, with advanced computing power that enables new ways of generating, processing and sharing information. This contributed to automation in production. Shipping revolution started and the term logistics was used by introducing standardised containers that could be sealed and loaded into ships. In addition, the standardised containers could be passed on to the trucks and trains. By 1990s, the term “supply chain” was introduced. The technologies of mobile telephony and Internet were used for information sharing among the supply chain partners, namely suppliers, distributors, transporters, retailers and manufacturers.

The Fourth Industrial Revolution involves entirely on new capabilities for human beings and machines by using cyber-physical systems. While these capabilities are reliant on the technologies and infrastructure of the Third Industrial Revolution, the Fourth Industrial Revolution represents totally new ways whereby technology becomes embedded within societies or even human bodies (Davis 2016). We are now at the beginning of a revolution that is fundamentally changing the way we live, work and relate to one another. The current industrial revolution gives birth to Supply Chain 4.0.

**Supply Chain 4.0**

Knut Alicke et al. (2016) explains that in Supply Chain 4.0, supply chain management applies Industry 4.0 innovations with IoT, advanced robotics, analytics and big data to jump start performance and focus on customer satisfaction. Supply chain concept has gone through tremendous changes over the years and is heading towards Industry 4.0 or digitisation and automation, which will lead to the following:

1. **Speed** — it enables faster processing in terms of lead-time to meet customer demand in the supply chain.

2. **Agile and flexible** to changes as demanded by customers.

3. **Customised in nature** to fulfil customer needs.
4. Accurate data recording within the supply chain.

5. Efficiency which leads to high performance and great results.

Customer perspectives are a great concern of late and more emphasis need to be addressed constantly. With the new technology today, consumers are more demanding and tend to source effortlessly via social media that is widely available at their fingertips.

The following are some of contributions from Supply Chain 4.0:

1. Automated factory production provides constant feedback on production capacity and information on shipment-production status.

2. Autonomous trucks move products to warehouses with live transit-location updates via satellite link.

3. Automated warehouses use machine to handle all operations, from picking to transporting products, with continuous information on product status.

4. Products are dispatched from warehouses to stores and online retailers based on anticipated demand.

5. Customers could track order status and input a new delivery destination.

6. Drones perform last-mile delivery and return pickups.

Automation of both the physical and planning from end to end into a single seamless supply chain with minimal human intervention will happen in the future. The network will self-setup and is continuously optimised to ensure optimal fit for the business requirements where the system leverages high degree of transparency and dynamic planning to drive advanced demand, for example special delivery times with low truck utilisation.

**Supply Chain 4.0 increases operations efficiency**

By leveraging on Supply Chain 4.0, it will improve all areas of supply chain management. At the end, the improvement enables a step change in service, cost, capital and agility.
The value drivers are the key strategic tactics that will be driven across the end to end supply chain through planning, physical flow, performance management, order management, collaboration and supply chain strategy to achieve the whole objectives of managing the organisation’s capital, cost and service to maintain its agility.

By implementing Supply Chain 4.0, there is potential increase of operational effectiveness of supply chains through adopting new technologies and eliminating waste. This potential may include 30% lower costs, 75% fewer lost sales and decrease in inventory of up to 75%, while increasing the agility of the supply chains (Alicke et al. 2016).

**Transformation into digital supply chain**

Understanding Supply Chain 4.0 is one aspect. Wanting to be transformed into a digital chain would require three key enablers which are; a clear definition, new capabilities and a supportive environment.

Recruiting of data specialists is typically required for the new capabilities of digital supply chain. The final prerequisite is the implementation of a two-speed architecture/organisation. This means that the establishment of the organisation and IT landscape must be accompanied by the creation of an innovation environment with a start-up culture (Alicke et al. 2016).

According to Mussomeli et al. (2015), there is a shift from a linear traditional supply chain (Figure 1) into a digital supply chain network (Figure 2). The digital connectivity and technology capabilities should reduce the latency between new information and material movements. Stakeholders have very little visibility in the linear supply chain compared to the digital supply network capabilities. The digital supply networks create connectivity with a multidirectional communication system in contrast to a traditional disconnected system.
The system may look simple in the diagram, however the complexity is immense and a lot of study from stakeholders is required to look at the nitty-gritty of the implementation, taking into account its returns.

Schrauf et al. (2016) illustrated that supply chain will change with the advent of digital supply chain, silos will dissolve and every link will have full visibility throughout the network. The digital supply chain is based on the concept of Industry 4.0 whereby companies are orientating themselves towards a full implementation of digital technologies throughout the supply chain.

The following are the four stages of maturity towards a digital supply chain:

1. **Digital novice.** These companies have yet to embark on the journey. Their supply chain processes remain discrete, carried out by individual departments and business units.

2. **Vertical integrator.** Companies at this stage have managed to integrate their supply chain processes internally, across departments and functions.

3. **Horizontal collaborator.** In this stage, companies have learned to work with their supply chain partners to set business goals, define and carry out common processes, and achieve a fair degree of transparency throughout the chain.
4. **Digital champion.** These companies have achieved the highest level of collaboration with partners and transparency in operations, while developing mutually beneficial processes and analytical techniques to optimise the whole supply chain.

Digital supply chain is simply called Supply Chain 4.0 and is very much an Industry 4.0 concept with the implementation of digital technologies.

**Current practices of Supply Chain 4.0**

Hoberg and Alicke (2016) of McKinsey & Company explained the importance of customer experience as they are the source of income to any organisation. With the implementation of Supply Chain 4.0 especially with digital capabilities, customers will benefit from more choices, and added convenience with simpler and more reliable processes.

Within any organisation, all the departments need to work together to a seamless integrated process supported by technology so that their customers see the entire organisation as one. Organisations need to continuously improve and look for opportunities to provide the best customer experience in order to sustain their business with the aid of technologies.

“Tomorrow’s challenges” shows that a company like Adidas sees the need to use whatever resources they could leverage in its entire supply chain including technology to gain more sales and grow their business. The use of machine and devices to meet customers’ demand as continuous improvement is the key to the success of every organisation to be ahead of competition. The initial investment may sound costly but over the long strategic plan, it can recover the returns.

Likewise Amazon also shares the same experience and has put in effort to beef up its supply chain in embracing technology into its system in order to stay competitive.

In short, the digital revolution is creating a whole new paradigm for what used to be the supply chain. It was once about delivering the right quality at the lowest cost, with the agreed service level; now it is about increasing sales, creating more value and capturing it (Cordon 2017).

Logistics, an important element of supply chain which focuses on transportation, distribution and warehousing, is also greatly impacted by Industry 4.0. Tronina (2017) illustrated that logistics would focus even harder on information technology, digitalisation and optimisation of logistic processes by using the cutting edge innovations of the world class modern technologies. Modern logistics, so called Logistics 4.0, is more often and more readily implemented in modern enterprises that want to develop their business. Logistics companies, especially those large, dynamic companies wishing to compete in the rapidly growing market, need to strive to be a market leader by all means if they want to maintain their status and position in the market.
The competition between enterprises is visible considering the choice of technologies, development of ready-made tools and implementing them depending on the needs of given companies, or establishing cooperation with implementing companies which create custom-ready solutions for TSL industry (such as transportation, shipping and logistics companies).

**Internet of Things (IoT) in logistics**

Logistics, an important element of supply chain is affected by IoT. Robert Bosch GMBH corporate website (2017) explains the hectic activity in a logistics centre and how Bosch implements Industry 4.0. In 2016, Bosch has initiated to automate its forklift trucks that are driving between warehouse shelves and storage areas, picking up the goods at exactly the right place, and then placing them right where they belong.

Many new ways of optimising processes are emerging for the company capitalising the Cloud. The forklift trucks are more efficient with the available data input into its systems to enable the most efficient route to be used and driving profiles are constantly stored in the database. The database also benefits the manufacturers of forklift trucks. They can make their customers additional offers and equip their vehicles with sensors and software from the start. Retrofitting would no longer be necessary if the forklift trucks were to one day become part of the networked intra-logistics.

Flexibility is the key to enable agile capabilities in Industry 4.0. Zenoway solution is currently being introduced at the Bosch site of BSH Hausgeräte GmbH in Traunreut near Munich. Data is considered the basis for intelligent production and new business models in logistics, where IoT-Clouds is the key to efficiently use data.

Forster (2017) explains that a digital supply chain is a basic requirement for Logistics 4.0 for the future. Visibility is essential today and the transportation businesses greatly rely on IoT. Digital supply chain is getting more important for companies that have great concerns on Industry 4.0. Hence, development for the next generation is inevitable though it is still in the infancy stage. Proactive companies can take the opportunities to spearhead projects in developing future digital systems and gadgets to support the logistics industry.

Kennedy (2017) on “How will the driverless revolution change transportation service?” emphasised the effects of the way service industry in particular transportation has evolved over time, whereby currently the technology has widely changed the way the business has been run.

Companies like Uber, Google and Tesla believe in technology and thus they keep on investing on self-driving technology and it will soon hit our roads. The impact will definitely take over some of the human tasks; at the same time, transportation companies will benefit, as they do not have to deal with drivers’ issues, while at the same time, able to run their operations more efficiently.
At this moment, the legal issues have to be addressed by government if they allow driverless commercial vehicles on the roads. Some countries may embrace this new concept, which is not seen in some other countries. In due time, there is a possibility to see driverless commercial vehicles operating and most likely to start in a more developed country due to its infrastructure and mature society.

**Outlook in Malaysia on Supply Chain 4.0**

In any situation, there seems to be two sides of a coin. It can be seen as a threat or an opportunity to embrace the new approach of the digital world. How is that in the context of the Malaysian scene? In some public news and articles published, there are many views and news related to Industry 4.0 in the country and it includes Supply Chain 4.0. The Ministry of International Trade and Industry (MITI) has been quite active in initiating the move to include some of the local Malaysian companies to participate in Industry 4.0.

Capabilities need to involve a large group to enable the concept of Supply Chain 4.0 to be realised, and it also includes stakeholders, not just the industry players but also from the government departments concerned. A task force has been set up with the various agencies within the government departments and their areas of responsibility, namely:

1. Infrastructure and ecosystem — the Ministry of Communication and Multimedia
2. Funding and incentives — the Ministry of Finance
3. Talent and human capital — the Ministry of HR & Ministry of Higher Education
4. Technology and standards — the Ministry of Science, Technology and Innovation
5. SMEs and Industry 4.0 — the Ministry of International Trade and Industry

They had included some main players from the different industries in a seminar, including some of the government agencies to see how the government can assist in any way to realise that Malaysia is heading towards the future. A timeline chart has been planned for year 2017 to move forward in the cabinet.
Emerging Technologies for Supply Chain Management

By end 2017, the government drafted the National Policy on Industry 4.0 which also included the national vision TN50 and tax budgeting for year 2018 for planning ahead.

The industry players and their stakeholders have to ponder as below:

1. Comprehensive national level strategy — no clear overarching policy on Industry 4.0.
2. Infrastructure and ecosystem — energy, telecommunication, ecosystem gaps.
3. Targeted incentives and funding — broad-based.
4. Human capital and talent — labour intensive and mismatch of skill sets.
5. High initial investment — substantial capital expenditure.

Resources are the key to future planning and to enable this to materialise, all the stakeholders need to look at this area where there may be job loss due to the changes. In fact, this has been shown in the previous industry evolution whenever new equipment and/or gadgets were being introduced. For example, the computers have replaced many clerical jobs and automation has taken over certain manpower in the manufacturing industry.
The Malaysian Government not only looks at the big players but also the small and medium-sized enterprises (SMEs) as this group of business may have limitations in their resources and may face difficulties when competing with the bigger players. SMEs may still operate as Industry 2.0 and it is a challenge for those players to upgrade into Industry 4.0. Hence, there are initiatives to organise awareness programmes for multinational companies to share their experience and expertise of Industry 4.0 with the SMEs.

Penang State Development Corporation (PSDC) is proactive in identifying talent gaps of Industry 4.0 in order to send employees for appropriate training. Naturally there is a need to prepare the future of human resources with the right talent and skills. However, it is always the question of when and what type of courses are appropriate for the future and jobs that may not exist yet.

PSDC is spearheading Industry 4.0 in the manufacturing industry particularly in Penang where they are indeed keeping abreast of the progress of economic businesses in the state. PSDC has been constantly in touch with most of the manufacturers, both SMEs and MNCs alike. Some of the PSDC initiatives include awareness seminars jointly organised by PSDC, MIDA and MNCs in the field.

At this point, PSDC has supported the government initiatives to drive towards the implementation of Industry 4.0 and this is just the first step in the journey towards the future. Through PSDC’s experiences in managing the economic growth for Penang and its industry players, all the stakeholders may be roped in together to ensure that the change can be implemented effectively.

An article by Lim (2017) depicts a survey conducted by the Federation of Malaysian Manufacturers and Malaysian Institute of Economics Research. It shows that only 12% of the respondents were fully aware of Industry 4.0. 41% of the respondents were somewhat aware, while 28% needed more information about Industry 4.0. The balance 19% respondents were not aware at all. Industry experts opined that most companies in Malaysia are still at Industry 2.0 due to the nature of their business, while some international companies have already embarked towards Industry 4.0.

As cyber-businesses transformed retail beyond purchasing convenience which allows consumers to be well-informed and have variable choices, logistics services (door-to-door) become essential. Consumers have the convenience of purchasing wherever that is/are available through the Internet via IoT and have the merchandise delivered to their doorstep. The automobile industry in Malaysia is also getting ready in anticipating the future trend of global sourcing through e-commerce.

Understanding the market forces is of utmost importance to every business and to compete, suppliers must understand their consumer needs and reflect quickly through the supply chain. Constant change is essential in today’s business environment and being able to react to consumer needs quickly is of utmost importance (Sahari 2017).
The Higher Education Ministry (MOHE) has initiated programmes in higher institutions in Malaysia to address the challenges of Industry 4.0. The aim is to prepare the university to produce well-balanced graduates with holistic, entrepreneurial and innovative qualities. MOHE will be sharing their ongoing efforts in redesigning the country’s higher education (Nor Ain Mohamed Radhi 2017).

Findings from industry players in Malaysia

A roundtable on Supply Chain 4.0 with participation of 50 supply chain experts held on 12 – 13th January 2017 in Penang concluded that Malaysia is still in the early stage of Supply Chain 4.0. Academics and industry experts shared the insights and outcomes of Industry 4.0. Industry experts mentioned that automation has been implemented in their overseas headquarters to take over human tasks with increased efficiency. Their headquarters see better revenue in the long run and costs being reduced. Even driverless vehicles are in the pipeline to be a reality in the overseas headquarters. However, automation and autonomous vehicles have yet to be implemented in the Malaysian operations. Some multinationals located in Penang have already planned to adopt Industry 4.0 due to their corporate strategic planning. However, the local players were still discussing how to adapt the uncertain future of Industry 4.0. Some participants have shared that their corporate level has embarked into Industry 4.0 at their corporate office level, however it has not reached Malaysia at this point of time. It may be due to many reasons such as business needs or strategic approach.

At this moment, Industry 4.0 in Malaysia is still lacking participation from members of the supply chain. Many multinational companies may have initiated Industry 4.0 internally, however it is only shared to a limited fraction of their members. Not much effort and collaboration has been done to engage their suppliers and customers pertaining to Industry 4.0. Even though companies sent participants to seminars, not all stakeholders are involved, and it may not include employees from the supply chain.

Conclusion

The findings in this article conclude that Supply Chain 4.0 will increase operational efficiency in the whole supply chain and IoT will be very useful for logistics. A linear traditional supply chain is crucial to be transformed to a digital supply chain. However, in a clear definition, new capabilities and supportive environment will be required to achieve a digital supply chain.

Supply Chain 4.0 has been implemented by global brands such as Adidas and Amazon. However, many companies in Malaysia are still in the initial stage of understanding Industry 4.0, especially the local SMEs. For multinational companies located in Malaysia, they may witness the implementation of Industry 4.0 in their overseas headquarters, but they have yet to implement it in companies located in Malaysia. As such, the Malaysian Government has initiated to create awareness of Industry 4.0,
in order to encourage Malaysian companies to be competitive as a global player in all respect of industries. Malaysian companies will have to “follow” the trend with Industry 4.0, and subsequently enable Supply Chain 4.0 as one of the important pillars of Industry 4.0.

As we conclude this chapter pertaining to Supply Chain 4.0 with the principles of Industry 4.0, it clearly shows that some SMEs in Malaysia are at Supply Chain 2.0, while some multinational companies are at Supply Chain 3.0. A small number of multinational companies in Malaysia may have already geared up towards digital supply chain or Supply Chain 4.0 but there are still much to be done. Thus, the future still remains a challenge of uncertainty and higher learning programmes need to be redesigned accordingly to suit the digital world of e-commerce and automation. What remains constant is “change”.

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Roundtable on Emerging Trends of Technologies in Supply Chain Management

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