Journal of information and communication convergence engineering
http://jicce.org

J. Inf. Commun. Converg. Eng. 17(3): 198-204, Sep. 2019

Regular paper

Development of a Smart Supply-Chain Management Solution Based on Logistics Standards Utilizing Artificial Intelligence and the Internet of Things

Am-Suk Oh* , ***Member, KIICE***

Department of Digital Media Engineering, Tongmyong University, Busan 48520, Korea

Abstract

In this study, the author introduces a supply-chain management (SCM) solution that connects suppliers, manufacturers, customers, and other companies within a transactional relationship to enable efficient inventory management and timely product supply, which ultimately maximizes corporate profits. This proposed solution exploits Fourth Industrial Revolution technologies, such as artificial intelligence (AI) and the Internet of Things (IoT), which provide solutions to complex management issues generated by the broader market. The goal of the current study was to develop an advanced and intelligent smart SCM solution that complies with logistics standards, to enhance the visibility, safety, and efficiency of a supply chain made up of manufacturers and suppliers. This smart SCM solution aims at maximizing corporate profits through efficient inventory management and timely supply of products, and solves the complex management problems caused by operating within a wide range of markets.

Index Terms: Logistics standards, Supply Chain Management (SCM), Artificial Intelligence (AI), Internet of Things (IoT), Adequate Inventory Calculation System

I. INTRODUCTION

A. Changes in the Supply-Chain Management (SCM) Paradigm

Manufacturers' Production Process: Currently, manufacturers work under a vertically integrated system, in terms of production processes, which involves directly related suppliers and manufacturers. The vertical integration facilitates the decision-making of manufacturers, suppliers, and distributors in their drive to reduce unnecessary costs.

Problems with vertical integration: In terms of a manufacturing supply chain, effective management is difficult, as various companies in different business areas collaborate to make products. Technological advances resulting from the development of information and communications technologies (ICT) have locally optimized the overall production process, but while local efficiency has improved, the overall complexity still makes mutual connections difficult, giving rise to the lack of information flow between processes [1-2].

Companies in the manufacturing sector need to be able to identify variable information regarding product supply and demand quickly, in order to provide adequate responses. However, information imbalance among principals in the supply chain can generate a bullwhip effect, in which excessive inventory grows exponentially in each step. For example, when a distributor sends out an order for a product, the

Received 08 August 2019, **Revised** 09 September 2019, **Accepted** 10 September 2019
***Corresponding Author** Am-Suk Oh (E-mail: asoh@tu.ac.kr, Tel: +82-51-629-1211)
Department of Digital Media Engineering, Tongmyong University, Busan 48520, Korea.

Open Access https://doi.org/10.6109/jicce.2019.17.3.198 print ISSN: 2234-8255 online ISSN: 2234-8883

logistics company, manufacturer, and material supplier will each secure a safety stock, leading to excessive inventory, which in turn creates a serious waste of resources in the form of unnecessary investment in facilities and employment of labor [3-4].

B. SCM Evolution with Advances in ICT

The business paradigm is sharing with the consumer, interrelationships among processes are strengthening, and demand diversity and variability are increasing. Based on Fourth Industrial Revolution (4IR) technologies, such as the Internet of Things (IoT) and artificial intelligence (AI), more attention is being paid on the automation, autonomy, and connectivity of the entire supply chain. Advanced SCM technologies are required to break away from local optimization and achieve overall optimization, in addition to responding to the rapidly changing business environment. Smart SCM requires the 3I building blocks – Instrumented, Interconnected, and Intelligent – as its key components [5-6].

C. The Need for Smart SCM Solution Development

SCM is a system that connects suppliers, manufacturers, and customers, as well as all other companies in a transactional relationship, with the goal of achieving efficient inventory management and the timely supply of products, in order to maximize corporate profits and resolve some of the complex management problems caused by the broad scope of the market.

Recognizing the importance of standardizing the logistics system, the Korean government established the National Logistics Standardization Plan, which includes six core areas—packaging, transportation, storage, unloading, information, and infrastructure [7-8]. However, because each government agency and function is conducting standardization separately, mutual interconnectivity and consistency have been lacking across areas. With rapid technological advances, interconnectivity will be further enhanced and will increase the diversity and variability of demand. Moreover, advanced SCM must be able to respond to such a rapidly changing business environment.

Recently, the SCM industry has evolved into smart SCM, a new business system that emphasizes automation, autonomy, and connectivity across the entire supply chain, and is facilitated by the 4IR and its associated AI and IoT technologies [9-10].

II. SYSTEM COMPONENTS

Based on 4IR technologies such as AI and IoT, an advanced and intelligent smart SCM solution has been developed, which has the objective of enhancing the visibility, safety, and efficiency of the supply chain comprising manufacturers and suppliers, while complying with logistics standards [11]. The goal was to use a smart SCM solution with an enhanced intelligence and connectivity to develop a technology that embedded AI and IoT technologies into industry. A technology that can manage SCM with AI and IoT applications was developed.

Automated Ordering System (AOS) is a web-based system that shares product data – including production planning information, ordering information, delivery information, quality decision information, and inventory information – with vendor companies, on a real-time basis. Automated Inventory Management System is an automated inventory management (incoming / outgoing) system, based on IoT sensors. Adequate Inventory Calculation System Patterns of defective products are analyzed via AI, to develop a safety stock ordering algorithm.

A. Automated Ordering System

Using information from other connected SCM systems, the AOS supports timely delivery and efficient inventory management for vendor companies. Patterns of defective products are analyzed via AI, to develop a safety stock ordering algorithm and advance the system.

Fig. 1 is a schematic of the web-based AOS system developed as part of the current project. This system includes processes such as receiving order data from client companies to placing orders with vendor companies, as well as managing product reception, shipment preparation, quality assurance, and delivery.

B. Automated Ordering System Modules

Fig. 2 shows the AOS modules, whose features are as follows:

1. Obtain Order / Order Module: The Order Manager module displays information about the orders received and placed among vendor companies, and manages order information. The Order Monitoring module provides overall monitoring and product order information, to facilitate inventory management.
2. Safety Stock Module: This module is for manufacturers to maintain an adequate level of inventory. Using an algorithm for calculating the adequate level of inventory, the module sends appropriate ordering data to suppliers.
3. Shipment Module: Object Label Publisher module is for managing shipment information, including product labeling by manufacturers and delivery status. The Shipment Control Manager module sends shipment information to stores or manufacturers on a higher tier.

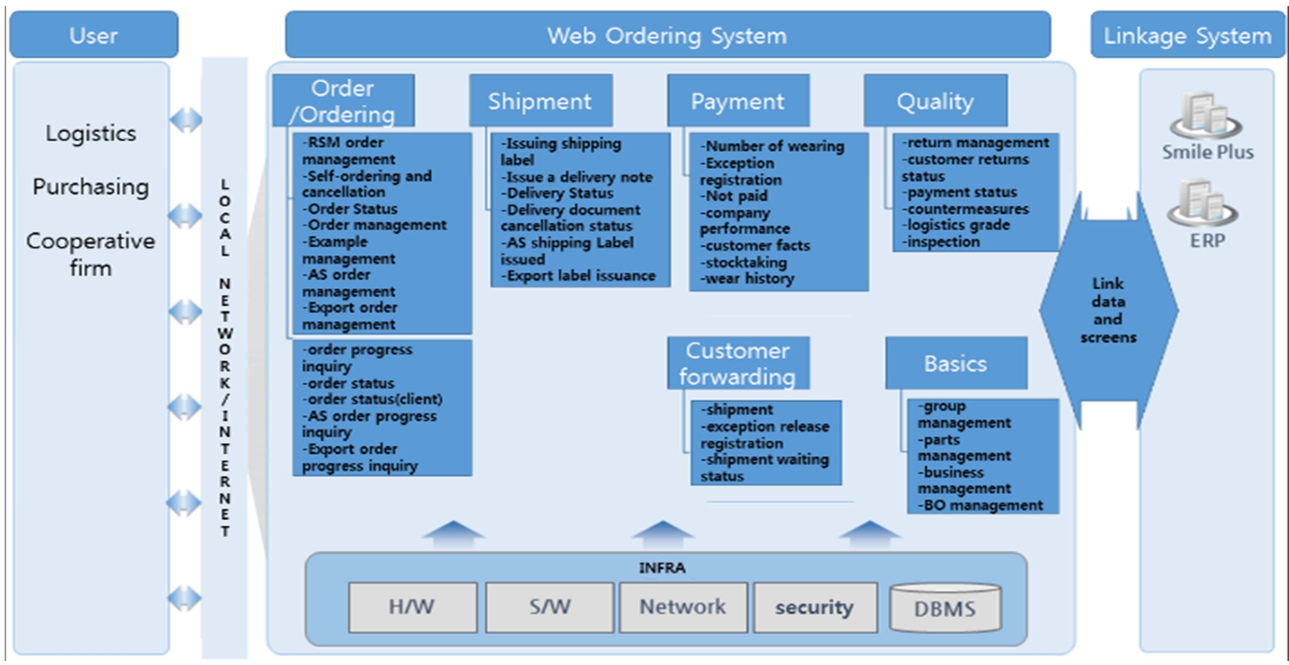


Fig. 1. Automated Ordering System Diagram.

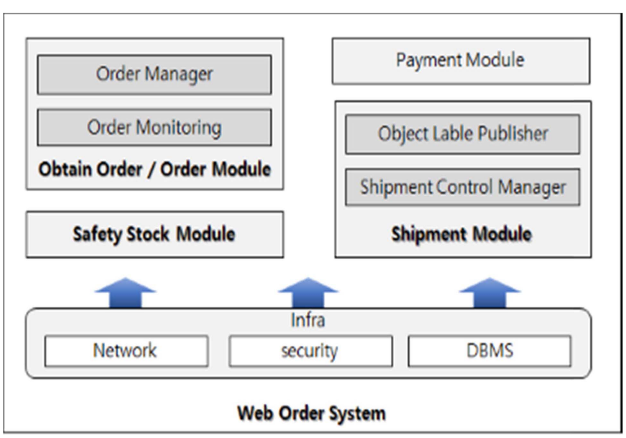


Fig. 2. Automated Ordering System Module Diagram.

C. Automated Ordering System Functional Test

The AOS within the smart SCM solution proposed in the current study aims to achieve efficient inventory management and timely product supply by providing mutual interconnectivity among suppliers and manufacturers. This will serve as a key technological factor that directly affects corporate profit maximization and cost reduction.

To conduct a functional test for the web-based ordering management system, product planning information, ordering information, delivery information, quality decision information, and inventory status were shared with vendor companies (parts suppliers and outsourcers) on a real-time basis. The test measured the ability of the system to enable vendor companies to provide timely delivery and efficient inventory management. Fig. 3 illustrates how the ordering function was tested in accordance with the workflow.

D. Users and the Web Order System

When a user enters a client order (in the front-end), the order module in the web ordering system utilizes the intelligent feature that references standard information, to place appropriate orders to vendors that manufacture the parts ordered by the client. Each vendor company monitors this information using PC and mobile platforms, uses the shipment module to issue labels for each box to be delivered, and issues a delivery statement.

The delivery module provides product receiving and shipment pending services. Defects discovered in the inspection of the received parts are entered into the quality module. Defective parts are registered to be returned to the vendor, and the information is used to evaluate vendors. Information about delivery to the clients is entered into the client shipment module, to complete order placement. The module manages basic company and parts information to make orders, in addition to processing delivery deadlines and the safety stock volume related to the ordering process. Information about the shipment, incoming / outgoing products, and inventory is reviewed to maintain the currency of the data required for the ordering process, thereby allowing client orders are placed more accurately.

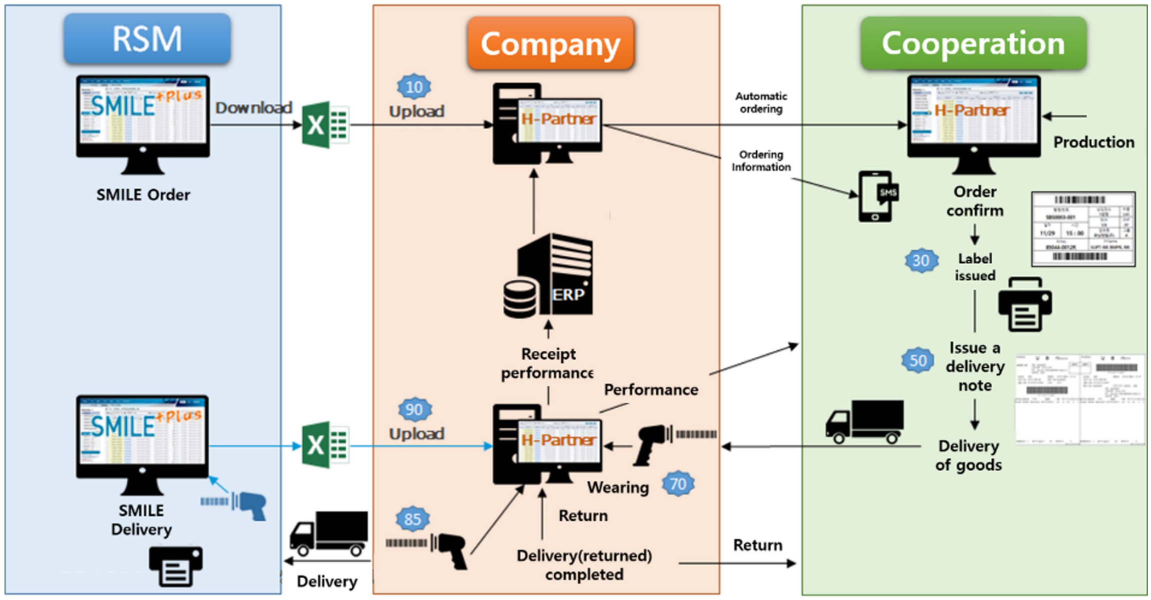
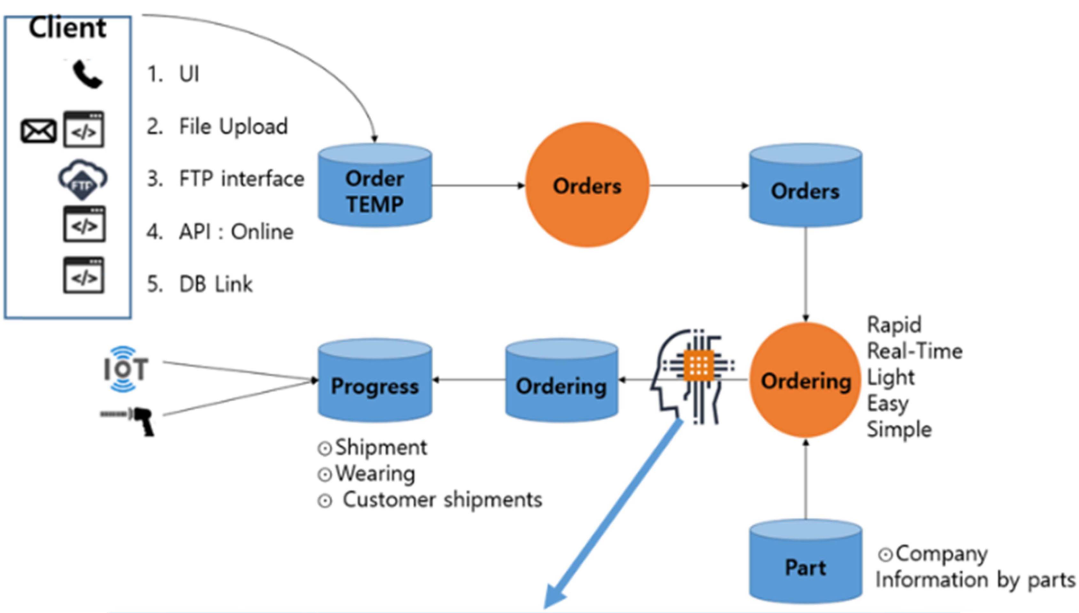


Fig. 3. Ordering Function Test According to the Work Flow.



ITEM	Contents
Due date	Set Delivery Time Zone, Daily Delivery Timing Variance
Safety stock Quantity	Properly provided parts quantity
Safety stock Day	Allowed Safety Date
Minimum Order	Orders per order(Depending on Option, order Quantity)
Lead Time	Lead time considering different loads assigned by period and workplace
Allowable delay of Supply	Change the time by analyzing the delivery completion period after ordering by the supplier ← Limitations of supplier production resources ← Delivery Delay Prediction
Lot Size	Number of parts per BOX
Expected Loss	Analysis technique (Ai application: failure, occurrence prediction)

Fig. 4. Automated Ordering Process.

E. Web Order System and Connected System

Information about parts – which is basic information required by the web order system – is synchronized with enterprise resource planning, to be interfaced with the client company system (in the back-end). Through this system, client order information receives automatically, to support automated order placement to vendors, as shown in Fig. 4. The system provides various methods to input the order information, and order information from any client can be processed

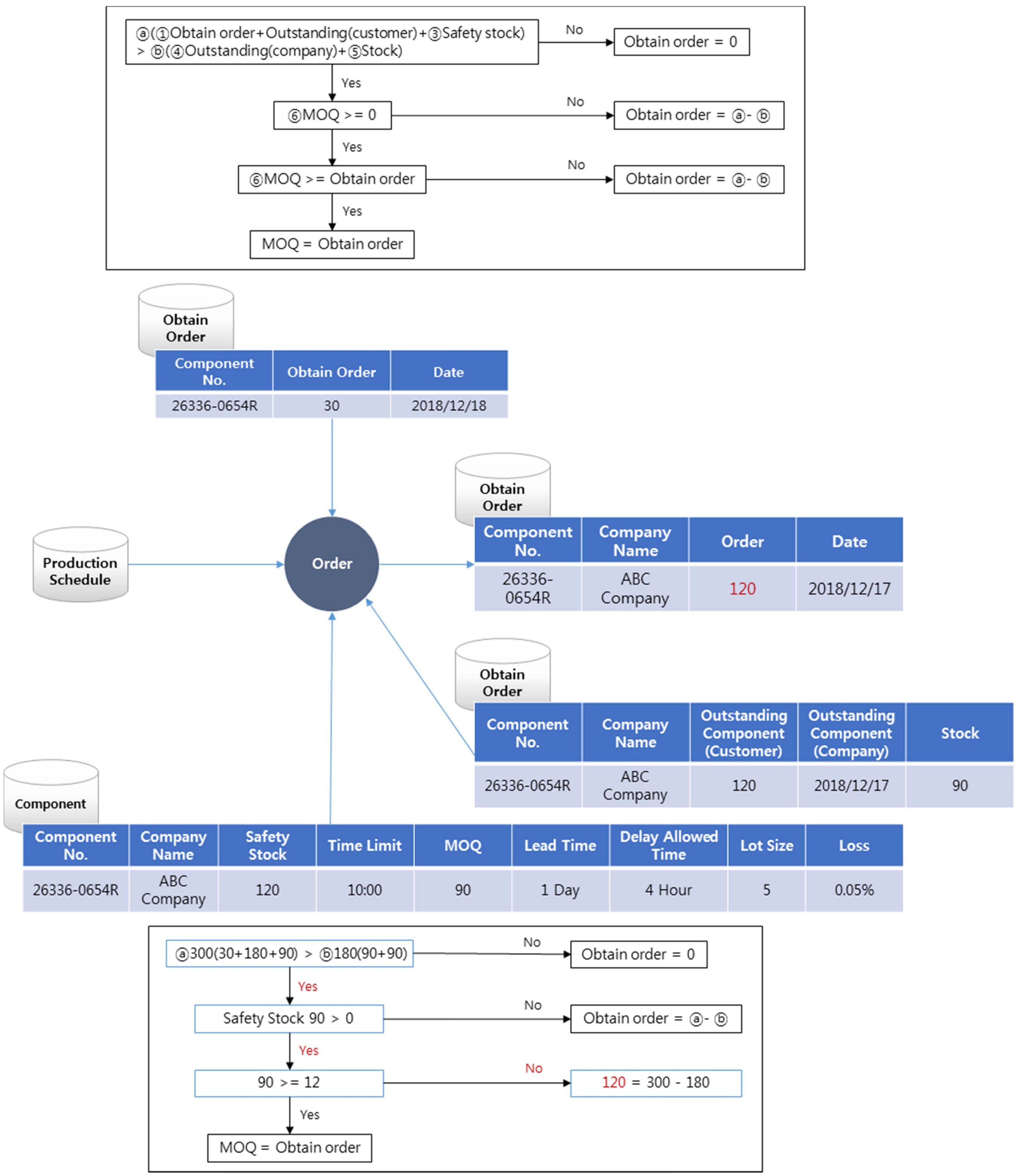


Fig. 5. Example of Automated Ordering Process.

automatically, provided they use a standardized order format. Smart orders are processed and placed to vendor companies using the basic order information provided by the client. Fig. 5 is an illustration of an example from such an automated ordering process.

III. ADEQUATE INVENTORY CALCULATION SYSTEM

The adequate inventory calculation system proposed in the current study is composed of detachable IoT components, and provides the following features:

- Inventory tracking and management from parts reception to product manufacturing;
- Using IoT devices to track item storage locations and automatically synchronize the quantity of items in storage before work orders are processed—and inventory quantity once the work is completed;
- Tag-type detachable IoT devices are used;
- Hall sensors are embedded to sense attachment / detachment of relevant tags automatically;
- When the tags are attached, registered product information is transmitted, and when detached, the information is automatically reset;
- Acceleration sensor data provide information about the movement of products, enabling the management of logistics information, such as item damage during transportation and loss during storage.

The information collected using the tags is sent to the server via the inventory management system, and is interfaced with the server database to enable inventory information management.

Fig. 6 shows the process of calculating adequate SCM inventory levels using AI technology. AI technology is used to identify adequate inventory levels, and an algorithm is applied to manage demand variations and lead times that affected the inventory.

The data obtained from worksites are used to predict order quantity, and to manage re-order timing to minimize total inventory cost. Information about defective products supplied by each vendor is accumulated, and statistics are used to compute each product's safety stock quantity.

We want to use Monte Carlo simulation (simulated sampling) for further research, to analyze and predict phenomena. The procedure will be applied to simulating probabilistic systems, with the goal of making decisions under uncertain situations. The core of Monte Carlo simulation will be to test probability elements in the model. This would be conducted using a tool that generated probabilistic or coincidental outcomes, with the latter generated from randomly selected samples, in accordance with the probability distribution assumed by the model.

IV. CONCLUSIONS

The current study has provided an SCM solution that connects suppliers, manufacturers, customers, and other companies within a transactional relationship, to provide efficient inventory management and timely product supply, to maximize corporate profits. To achieve this, this study utilized AI and IoT to resolve complex management problems, and the development of the advanced and intelligent smart SCM solution enhanced the visibility, safety, and efficiency of the supply chain composed of manufacturers and suppliers.

In addition, the following effects are expected from the

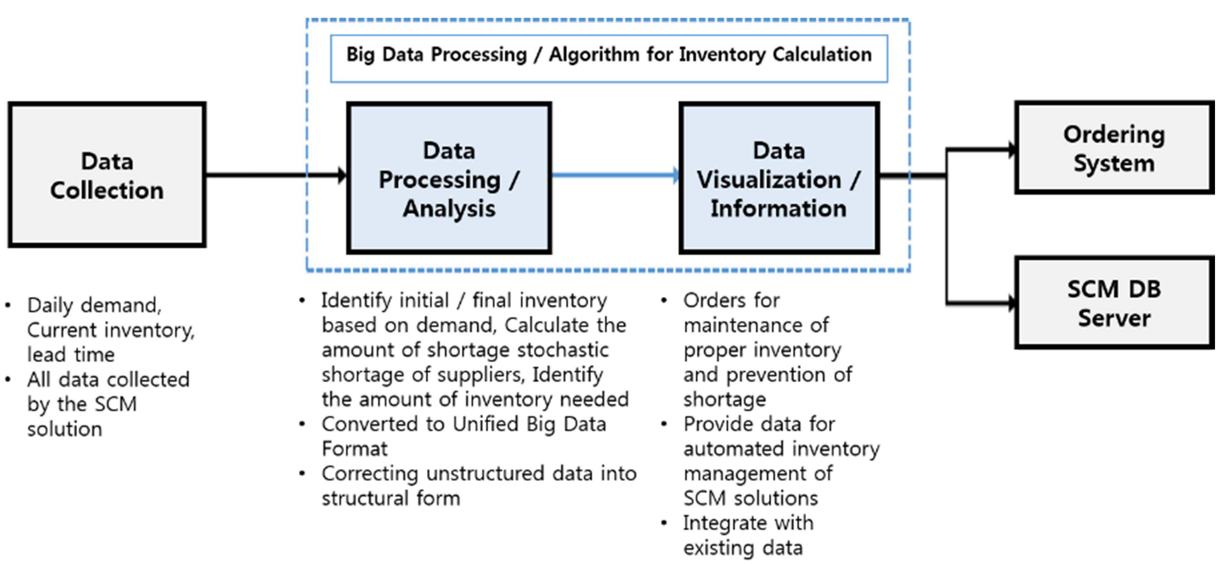


Fig. 6. Process of Calculating Adequate SCM Inventory Levels Using AI Technology.

results of the current study. First, the automated ordering system, automated inventory management system, and adequate inventory calculation system will enable overall cost reduction, which will serve as a basis for business growth. Second, as the systems for ordering and inventory management are developed with practical technologies used in the field, they can generate generalized foundational technologies. Third, efficient inventory management and timely supply of products maximizes corporate profits and solves complex management problems generated within the broader market.

ACKNOWLEDGEMENTS

This Research was supported by the “Leaders in Industry-University Cooperation +” Project, supported by the Ministry of Education and the National Research Foundation of Korea.

This Research was supported by the Tongmyong University Research Grants 2019 (2019F010).

REFERENCES

[1] P. Lou, Q. Liu, Z. Zhou, and H. Wang, “Agile supply chain management over the internet of things,” in *proceeding of the 2011 International Conference on Management and Service Science*, Wuhan, pp. 12-14, 2011. DOI: 10.1109/ICMSS.2011.5998314.

[2] B. D. Mohamed, H. Elkafi, and B. Zied, “Internet of things and supply chain management: a literature review,” *International Journal of Production Research*, vol. 57, no. 1, pp. 4719-4742, 2017. DOI: 10.1080/00207543.2017.1402140.

[3] A. B. Mohamed, M. Gunasekaran, and M. Mai, “Internet of Things (IoT) and its impact on supply chain: A framework for building smart, secure and efficient systems,” *Future Generation Computer Systems*, vol. 86, pp. 614-628, 2018. DOI: 10.1016/j.future.2018.04.051.

[4] T. Nguyen, L. Zhou, V. Spiegler, P. Ieromonachou, and Y. Lin, "Big data analytics in supply chain management: A state-of-the-art literature review," *Computers & Operations Research,* vol. 13, pp. 254-264, 2018. DOI: 10.1016/j.cor.2017.07.004.

[5] M. Roel, and K. Bas, “Mapping smart cities in the EU,” European Parliament Directorate-General for Internal Policies, 2014. [Online] Available: http://www.europarl.europa.eu/studies.

[6] E. M. Tachizawa, M. S. María, M. Alvarez, and M. Montes-Sancho, "How “smart cities” will change supply chain management," *Supply Chain Management: An International Journal,* vol. 20, no. 3, pp. 237-248, 2015. DOI: 10.1108/scm-03-2014-0108.

[7] T. W. Gim and C. K. Suh, “An analysis of core functions in supply chain management information system,” *Journal of the Korean Society of Supply Chain Management,* vol. 14, no. 2, pp. 51-36, 2014.

[8] A. J. Schmitt and M. Singh, “Quantifying supply chain disruption risk using Monte Carlo and discrete-event simulation,” in *Proceeding of the 2009 Winter Simulation Conference*, pp. 1237-1248, 2009. DOI: 10.1109/WSC.2009.5429561.

[9] J. Cáceres-Cruz, A. A. Juan, T. Bektas, S. E. Grasman, and J. Faulin, “Combining Monte Carlo simulation with heuristics for solving the inventory routing problem with stochastic demands,” in *Proceeding of the 2012 Winter Simulation Conference*, pp. 9-12, 2012. DOI: 10.1109/WSC.2012.6464999s.

[10] G. Dellino, T. Laudadio, R. Mari, N. Mastronardi, and C. Meloni, “A reliable decision support system for fresh food supply chain management,” *International Journal of Production Research*, vol. 56, no. 4, pp. 1458-1485, 2018. DOI: 10.1080/00207543.2017. 1367106.

[11] C. Danila, G. Stegaru, A. M. Stanescu, and C. Serbanescu, “Web-service based architecture to support SCM context-awareness and interoperability,” *Journal of Intelligent Manufacturing*, vol. 27, no. 1, pp. 73-82, 2016. DOI: 10.1007/s10845-014-0898-3.

Am-Suk Oh

received B.S. and M.S. degrees in computer science from Busan National and Chung-Ang universities, respectively. He received his Ph.D. in computer engineering from Busan National University. He is currently a Professor with the Department of Digital Media Engineering, Tongmyong University. His research interests include Databases, Healthcare Systems, Big Data, and the Internet of Things.