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Enhancing Warehousing Operations in Cold Supply Chain through the Use of IoT and LiFi Technologies

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***Abstract*—**Several concerns fall upon the supply chain especially in cold supply chains. These concerns are mainly in the distribution and storage phases. This research focuses on the storage area, which contains several activities such as the picking activity that faces a lot of obstacles and challenges. The implementation of IoT solutions enables businesses to monitor the temperature of food items, which is perhaps the most critical parameter in cold chains. Therefore, the research at hand proposes a practical solution that would help in eliminating the problems related to ineffective picking for products especially fish and seafood products by using IoT technology, most notably LiFi technology; thus, guaranteeing sufficient picking, reducing waste, and consequently lowering costs. A prototype was specially designed and examined. This research is a single case study research. Two methods of data collection were used; observation and semi-structured interviews. Semi-structured interviews were conducted with managers and a decision maker at one of the biggest retail stores Carrefour, Alexandria, Egypt to validate the problem and the proposed practical solution using IoT and LiFi technology. A total of three interviews were conducted. As a result, a SWOT analysis was achieved in order to highlight all the strengths and weaknesses of using the recommended LiFi solution in the picking process. According to the investigations, it was found that, the use of IoT and LiFi technology is cost effective, efficient, and reduces human errors, minimizes the percentage of product waste and thus saves money and cost. Therefore, increasing customer satisfaction and profits could be achieved.

***Keywords*—**Cold supply chain, IoT, LiFi, warehousing operation, picking process.

I. INTRODUCTION

IN recent years, the demand for temperature-sensitive premium packaged food items with a shorter shelf life has risen by double digits. The biopharmaceutical storage and logistics industries have also expanded significantly in recent years. These goods frequently have temperature specifications during storage and transportation. End users track and control the temperature of these goods during cold chain storage and logistics, with a greater focus on service quality [1].

The cold chain market is divided into many applications, including fruits and vegetables, patisserie & bakery, dairy & frozen desserts, meat & seafood, and others. Among these, meat and seafood segment had the largest market share [2]. Seafood is extremely perishable by nature. Unpredictability of catch, unregulated harvesting, insufficient handling, sorting, and storage all contribute to quality issues. Quality must be preserved in the different stages before the fish reaches the user. Quality issues occur primarily as a result of microbiological pollution, the presence of heavy metals, and storage temperature [3]. Furthermore, the storage and picking of the cold chain products have a lot of challenges that cause a lot of losses for the business itself. Throughout the storage phase, a lot of problems occurred, such as insufficient operations [4]. According to the International Institute of Refrigeration, food loss due to the lack of efficient functioning cold chains can be nearly 20% globally. Food losses due to lack of refrigeration account for approximately 9% of total food production in developed countries, and 23% in developing countries on average [5].

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Recently, technology has contributed heavily in solving cold supply chain problem. The Internet of Things (IoT) tracks the conditions in which sensitive products are stored using a network of connected sensors attached to product packages, warehouse shelves, and vehicles. Also, the cloud platform – which is at the heart of an IoT system – provides storage and analytics for both Radio Frequency Identification (RFID) and sensor-generated data. The IoT system collects RFID and sensor data, processes it through using analytics algorithms, and displays the results in dashboards, reports, real-time product location maps, and other ways. Also, IoT systems communicate with users via web or mobile applications [6]. However, the use of IoT systems in cold chain has its drawbacks; security and privacy issues, lack of technical knowledge, Internet and power connectivity, time consuming and high cost are on top of the list [7].

A. LiFi Technology

Prof. Harald Haas implemented LiFi (light fidelity) for the first time at TED Global Talk in July 2011, which is a form of using visible light in communications [22]. LiFi allows a computer to link to the internet without the use of a cable. A LiFi would need a transceiver to send and receive data to form a transmission line between nodes. This transceiver will use a modulation technique to allow the light source (i.e.: LED) [8]. LiFi was created to address other technology's limitations as WiFi.

Although WiFi is the most widely used technology for connecting multiple devices to the internet at the moment, a lot of limitations exist. The main limitations are related to availability, security, efficiency and capacity, where these limitations are easily overcome using LiFi. The internet's efficiency and security are now the most important issues. The efficiency of LiFi is believed to be superior to that of WiFi. LiFi is 1000 times faster than WiFi in terms of speed. Based on the spread of the signal, LiFi is more reliable than WiFi in terms of internet protection. The light characteristic of LiFi is that it cannot pass through a wall. It differs from the WiFi signal, which can go almost anywhere. Based on those two technologies, it is easy to conclude that LiFi is more reliable than WiFi for communication. If there is a leakage in the wall when using indoor contact, the vulnerability exists. A hacker could spoof the data using the leakage wall, posing a security risk [8].

B. Research Problem

According to the facts stating food loss percentages worldwide (food loss due to the lack of efficient functioning cold chains can be nearly 20% globally, food losses due to lack of refrigeration is nearly 9% of total food production in developed countries, and 23% in developing countries on average) [5], it could be concluded that there is a need to develop solutions that would help in decreasing losses gained from the lack of continuous monitoring of products conditions fulfillment especially in fish products.

This research proposes a solution that would help in eliminating the problems related to insufficient picking of products specially fish and seafood products across storage phase of the cold chain. The solution proposed is expected to eliminate human errors through increasing transparency of important product data (as entry, production and expirations dates) to warehouse workers. The research aims at reaching its targets through the use of IoT and LiFi technology.

C. Research Questions

Q1. How can the implementation of technologies such as IoT and LiFi help in the enhancement of picking products in the cold chain?
Q2. How can the use of of IoT and LiFi decrease food waste within the storage phase of cold chains?
Q3. How can IoT and LiFi increase the transparency of products?

D. Research Aims

The study aims to help in decreasing the waste percentage of cold storage through investigating new ways for tracking products' entry dates and continuous monitoring of storage temperatures. The proposed prototype will use both IoT sensors and the LiFi technology to transmit essential product data to workers, thus decreasing food wastes through the enabling of the First in First Out (FIFO) system in warehouses.

The study will also interview experts in the cold chain field in order to validate the applicability of the proposed solution and its effect on waste reduction through the traceability system.

II. Literature Review

Reference [9] discussed the main problems that faced the warehouse activities and proposed a solution using the IoT technology. The study focused on three areas in warehousing: the first one is inbound and outbound management and its current problems is complicity of the process, low efficiency and high error rate; the second one is order pricking area in which the main problems are high error rate and low efficiency and the last one is sorting system which has the same problems of order picking. These problems were eliminated using RFID to optimize the inbound and the outbound process, monitoring goods in real time, and location management. RFID was utilized in the picking process for purpose of rapid retrieval, reducing errors, and information identification. The application of IoT technology can significantly improve the efficiency of warehousing operations. Furthermore, the synergistic development of IoT, AI, cloud computing, and big data technology is an important research and practice direction for developing intelligent warehousing.

Reference [10] proposed a system for implementing IoT in warehousing operations. When goods move through the in/out gateway, the reader attached to the gate collects data about the products registered on tags attached to them. This allows for real-time monitoring of inventory levels and helps to avoid stock-outs. Readers attached to forklifts read data such as the product's position, type, and expiry date and display it to the driver on an attached computer. When the items are placed on the shelf, connected sensors confirm this to the driver on the computer. Sensors are often used to track the HVAC (Heating, Ventilation, and Air Conditioning) system in order to optimize energy efficiency, ensure product consistency, and warehouse protection. The data collected by readers and sensors are passed to the warehouse management system (WMS), which collects the information and transforms it into usable information and behavior. The same roles exist for order picking; as an order comes, the driver goes to the position of the package that appears on the attached computer and confirms that it is the right order using the forklift's readers. When an order exits the shop, the inventory level is automatically updated. This improves the performance, ease of use, and accuracy of order fulfillment while also preventing counterfeiting.

Research [11] used multiple case study investigations integrating IoT technology such as RFID tags and readers. The technologies increased the efficiency of the storing and picking processes, while reducing human errors that were raised from the use of normal paper documents [12]. The electronic documentation is much more precise and comprehensive than, for example, barcodes. Furthermore, random commodity parking complicates the management of the picking process. The picker (human or device) still knows where the product is kept with RFID readers, even though the product is either in the buffer zone or on its way to the final spot.

Reference [11] provided a thorough overview of the IoT technologies used in various companies in all three IoT layers, IoT innovations can be applied to have a beneficial impact on warehousing operations. However, drawbacks such as financial considerations and computer security must be addressed. IoT systems can be used in all warehousing operations, but their use in receiving and shipping is restricted due to tight supply chain partner collaboration while [13] suggests a different idea for eliminating human-caused errors in stock keeping units, which is a stock tracking device. The device will capture goods in each pallet by using three IP cameras for each pallet and then using the project detection method to estimate the amount of good in the pallet. The system will alert users for three-status notifications, so warehouse workers can be aware of relevant orders from the system. The prototype is tested in a real warehouse in Thailand covering 26 square meters by comparing before and after data for put-away process and order number. According to the results of the test, the device is capable of significantly reducing human errors.

Another research by [14] proposed that organizational completeness can be improved by implementing and updating current WMS to advanced IT solutions, as well as implementing solutions and innovations of the future like IT, Big Data, sensors, robots etc. One method of adapting is to automate and robotize the warehouse system. Robotization does not imply fully replacing human labor with machines, but rather increasing the productivity of human labor through the use of robotic systems. The use of warehouse robots also implies the possibility of increasing the rate of picking from warehouse shelves by taking the shortest or simplest route of travel, thus lowering overall costs, and probably by enhancing current WMSs in warehouse systems that control and set up an order picker's route. The existence and level of competitiveness of warehousing systems are dependent on their ability to adapt to emerging technology as well as meet customer requirements.

Reference [15] highlighted some problems that mainly exist in the warehousing management of commodities; such as lack of large-scale warehouse centers. The current business model relies on suppliers to deliver goods directly to the stores, where each store’s internal warehouse is responsible for the storage and the internal deployment of the goods. Another problem is the limited storage conditions, where the storage facilities are basic and environmental monitoring equipment is lacking, besides low level of automation mainly relying on manual operations. Information about goods such as sales, storage, and waste is gathered using barcode technology which does not show real-time information and has a low level of automation. Other problems relied in procurement and delivery operations. Suppliers can only distribute goods according to the demand of each store and goods cannot be distributed uniformly due to the long-distance and delivery time and high cost of transportation. They solve these problems by using technologies such as RFID and sensors to enhance the warehouses. And finally, this study found a good solution to building a warehouse center based on RFID and sensor technology.

Reference [16] proposed an adaptive warehousing management approach that integrates RFID and Ultra-wideband (UWB) technologies, and it creates a balance between cost and positioning accuracy. The device is equipped with two main sensing functions: 1) products sensing and 2) position awareness. A novel algorithm called M/N-K sliding window was proposed to identify goods loading and unloading on a forklift with the aim of goods sensing. Experiments showed that the M/N-K sliding window algorithm can define the loading and unloading status of goods easily, accurately, and efficiently. The approach is simple and easy to implement, making it ideal for embedded devices. They suggested a novel algorithm based on the Received Signal Strength (RSS) residual weighting (RRW) approach to location recognition.

Reference [17] demonstrated the application of RFID and IoT sensors for use in a perishable food supply chain traceability device. The suggested traceability scheme was tested on the kimchi supply chain. The proposed RFID and IoT sensor-based traceability framework offers an interconnected interface for perishable food supply chains that can not only track product movement but also control the temperature and humidity of the food product, thus improving the safety and consistency of perishable food items. Furthermore, the RFID reader's performance and the effect of tag orientation were evaluated; the findings indicate that the RFID readers used were ideal for use in a high-performance traceability scheme and could effectively read tagged items despite different tag orientations.

Reference [18] described an innovative blended approach that blends production preparation with a randomized storage assignment policy to increase visibility and traceability offered by IoT-enabled indoor positioning systems. The modern streamlined approach offers an efficient way to coordinate production preparation and randomized storage assignment in order to reduce overall production and storage costs. The technique is especially useful in situations where storage capacity is small. In contrast to prior study findings, the randomized assignment strategy increases travel distance and related travel costs. According to study, the strategy will minimize overall travel costs by assigning items to the best positions during each cycle and tracing the items using an IoT-enabled positioning system.

Reference [19] emphasized the potential of Smart Light System (SLS) in warehouse order picking as a particular industrial environment that has received little attention. And also, it first describes a generic typical manual order picking process and then, based on the evidence obtained from the literature review, examines how SLS could help order picking operations and improves the indicators energy savings, operational efficiency, and worker well-being for each process phase. The system was validated through workshops with industry warehouse experts and professionals from leading lighting companies where propositions were obtained. While the propositions in this paper were designed for a warehouse order picking scenario, they could be applied to other areas of manufacturing and logistics, such as assembly lines or quality control. Some of the propositions may hold true in these regions, and they may also have additional benefits.

According to the previous literature, most solutions implemented focused on using IoT technologies that varied from barcodes, sensors and RFID tags in warehousing activities. However, according to the authors’ knowledge only one study [19] used light to examine the use of SLSs in order to picking and to identify how light systems impact the picking process and facilitate the processes. So, it could be concluded that despite the advantages of LiFi that overcomes the known problems of WiFi, the use of light to transfer information is still not fully utilized in cold supply chains and warehousing operations.

III. Methodology

The research followed a single case study approach to investigate the storage problems in Carrefour Alexandria, Egypt through the conduction of semi-structured interviews and observations.

Three semi-structured interviews were conducted to collect as much information as possible. Also, systematic observation technique was adopted to have a full idea of how the picking process is normally done and to check the dimensions and number of racks in the fish and seafood warehouse and the present illumination system used.

IV. Data Collection

A. Observation

Data were collected through observing the retailer's warehouse noticing that the light system is all through led lamps. The warehouse has one lighting system with 3 cm space left between the last product on the top rack and the lighting system in order to give enough space for the firing system to be installed in the warehouse. The volume of the fishery warehouse is almost 10-meters length, 5-meters width, and 3-meters height. They have estimated racks from 20 to 25 racks. Also, there are 5 workers participating in the warehouse.

B. Interviews

The second method used for collecting data was through the interviews done with the Business Development Manager at Carrefour. A total of three interviews were conducted.

The purpose of the first interview was to discover the main problem causing loses in fish and seafood warehouse. According to the results, it was discovered that there are three major issues that arise in waste generation. First one is across the distribution phase and the main factor is the temperature of received goods, which is responsible for 40% of waste. The second issue arises during the storage of inbound goods, and the main cause is human error. The third one is picking of cold products to reach the shelf according to the FIFO picking method, which is insufficient and generates 60% of the waste. We discovered that the picking process contributes in the highest percentage of waste. Products might be picked randomly without taking entry dates and expiry dates into consideration and employees measure the products' temperature manually through the temperature gun every hour.

In the second interview researchers asked about details of information to be transmitted to workers in the fish and seafood warehouse in order to enhance the picking process. It was discovered that three types of information were required which are: the history of the products, the expiration date and the temperature of the product all day.

Accordingly, we used the information gathered about the warehouse and the type of data needed to be transmitted in order to enhance the picking process of fish products and designed a prototype circuit shown in Fig. 1 using IoT sensors and LiFi technology. Since LiFi Technology can be used to transfer data through the illumination light, researches decided to implement LiFi Technology in the fish warehouse of the retail store without extra cost in warehouse infrastructure or its lighting system. The implementation could be done using LEDs and the existing electric wires. However, a number of components are needed; source of data entry such as computer device, where the entrance dates and expiry dates are stored, temperature sensors, LEDs, detector and wires.

V. Proposed LiFi and IoT Prototype

A prototype experiment is executed in this research in order to validate the technology used. A block diagram for the prototype is presented in Fig. 1. A temperature sensor is placed next to the product to ensure the required temperature condition. The data collected (i.e. the product temperature) are converted to digital via the Arduino circuit connected to the sensor. This digital signal is then used to bias the light source used (i.e. feed it with the required voltage) and hence carry the data to be transmitted. The light source which is a white light emitting diode (LED) transmits the data (product temperature) through the white light used for illumination along the channel.

In Fig. 1 (block d), a photodector is used to receive the data carried by the light and converted back to an electrical digital signal. Due to the noise and other light sources within the channel, the received power is low and therefore, an amplifier is required after the signal is detected. The amplified digital signal is then recognized and the data are recovered to be displayed on any digital device. Any change in the product temperature will be directly reflected on the display device on the receiver end.

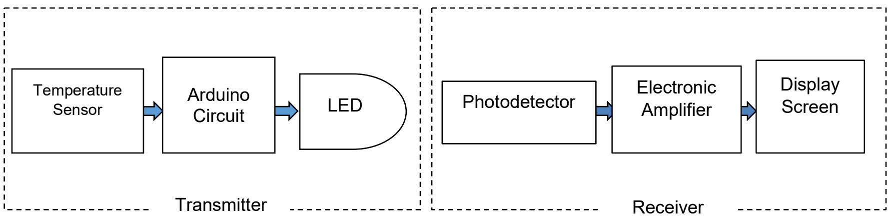

Fig. 1 Prototype Block Diagram

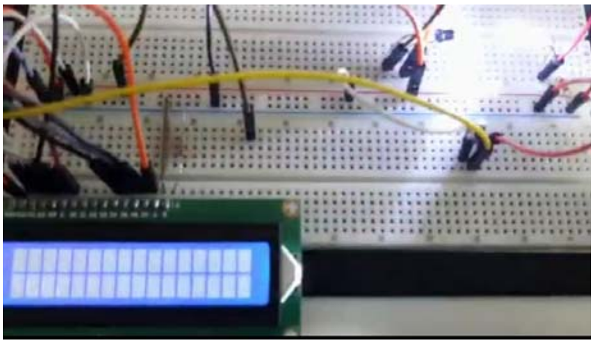

Fig. 2 Experimental Setup of the Prototype

The design in Figs. 1 and 2 will be used for two different purposes. First, the temperature of fish products will be measured by putting temperature sensors to each rack then sending the readings to the lighting system. Therefore, temperature readings will be continuously monitored. Secondly, important product data (as entry and expiration dates) that are normally stored on the warehousing system will be continuously sent to workers on their portable devices through photodetectors installed. This information will help in decreasing human errors through picking activity for fishery products, where the right product will be picked and the worker will know the history of the product temperature.

The third interview was done to validate the proposed solution using IoT and LiFi technology. As a result, it was declared that proposed LiFi solution is applicable, cost efficient, time saving, beneficial to reduce waste and eliminate human errors in picking process. However, since using light in data transmission is still relatively new, some doubts about its full utilization raised during discussions. The SWOT analysis shown in next section summarizes all pros and cons of the proposed solution.

VI. Discussion

The SWOT analysis shown summarizes the strengths, weaknesses, opportunities and threats of using LiFi in picking process according to the interviews done as follows:

Strength:

- Efficient implementation cost.
- Reducing human errors.
- High level of accuracy in transferring data.
- No need for high skilled labor.
- Security of data.
- Efficient picking process.
- Reduction of waste percentages.

Weakness:

- The resistance to change to new ways of doing work.
- Sensor's malfunction.

Threats:

- Electricity cut.
- Inappropriate infrastructure that may affect the efficiency of data entry process.

Opportunities:

- Extending the implementation to other areas
- Raising the ability of having the least waste as competitive advantage
- No need for a radical change in the current warehouse infrastructure.

The previously mentioned points agree with the opinions of [20] and [21] who highlighted that main advantage of LiFi is providing wireless communications with high data rates, besides efficiency, availability, security and safety. Also, it is cost-effective due to the use of free unlicensed spectrum. Reference [21] discussed some drawbacks of the new technology which are:

- Limited usage - without a light source the connection fails.
- Range of signal - signal range is limited by the physical barriers due to the use of visible light.
- Interception of the signal - it is limited to outdoors applications and sunlight.
- Cost - cost of implementation increases in some cases if an entire new infrastructure is required.

VII. Conclusion

Businesses fail these days to control their cold chain warehouses and get accurate information about their product specifications, history, expiration date, and temperature leading to errors in order picking, losses in products, high cost, and time consumption. Thus, it is hard for the business to try to satisfy the market needs.

The picking process is a very important process that results in the highest percentage of waste. Some of the companies perform this process in the warehouses manually.

The proposed solution of LiFi technology will help companies to get accurate information about the history, expiration date (FIFO), and temperature of the products in the warehouse which will help the company in order picking. This solution of LiFi technology will enhance the performance of the company creating a competitive advantage over the competitors as it will decrease the time needed to make order picking in the warehouse. Having more accurate order picking will decrease the costs of the company and decrease the percentage of wastes of the products. Most of the previous studies used IoT technology varied from barcodes, sensors, and RFID tags in warehousing activities.

To sum up, LiFi could be an alternative solution for fast and secure data transmission technology. The technology has a great scope for use as it may lead to a cleaner, greener, safer communication. LiFi can be applied to numerous applications in the field of logistics and supply chains as smart transport and railway transport network, aviation, besides other applications as underwater applications, hospitals, advertising and education.

VIII. Recommendations

In order to gain full benefits from the proposed design, it is highly recommended to increase the awareness among workers and managers about the benefits and utilization of using light in data transmission.

The proposed design requires full implementation in the fish warehouse as a start to determine opportunities of improvement, if necessary, determine the type of illumination to be used to fit the amount of information transmitted and the speed of transmission and the choice of the appropriate temperature sensors to fit the purpose needed.

IX. Limitations and Future Work

The study at hand faced some limitations that were mainly due to the current pandemic of COVID-19 that contributed in its final outputs. This study had been implemented on only single case study. We had a limited ability to conduct more interviews with employees in Carrefour because most of them turned to work from home and were not available on their work premises. Besides, we were not allowed to apply the solution practically in the warehouse. Therefore, for future studies interested in the field it is recommended to use more than one case study to investigate more about problems facing warehouses and other logistics fields in which the solution could be practically tested. Also, a full feasibility study regarding the proposed solution is required.

References

[1] E. Mazareanu., (2020). Global market size of cold chain logistics 2020-2028 (online) Available at: https://www.statista.com/statistics/1107947/cold-chain-logistics-market-size-worldwide. Accessed at: 1/5/2022
[2] FAO. 2018. The State of Food Security and Nutrition in the World 2018. Available at: http://www.fao.org/3/I9553EN/i9553en.pdf. Accessed at: 1/5/2022
[3] Marta Castrica, Luca Maria Chiesa, Maria Nobile, Francesca De Battisti, Elena Siletti, Davide Pessina, Sara Panseri, Claudia M Balzaretti (2020). Rapid safety and quality control during fish shelf-life by using a portable device. Journal of the science of food and agriculture.
[4] Badwi, M., warehouse picking problems: 10 process solutions for optimization. (online) Available at: https://www.scjunction.com/blog/picking-process-productivity-10-solutions-for-optimisation. Accessed at: 1/5/2022
[5] Shaw, J., and Beasley, M., (2016). Improved Cold Chain Management is Key to Reducing Food Loss - October 2016 - Cool Insights. (online) Available at: https://www.foodlogistics.com/transportation/cold-chain/article/12258421/improved-cold-chain-management-is-key-to-reducing-food-loss-october-2016-cool-insights. Accessed at: 1/5/2022
[6] Egor Strashynski., (2019). Cold Chain Challenges Fixed with Technology. food logistics. Available at: https://www.foodlogistics.com/transportation/cold-chain/article/21090513/cold-chain-challenges-fixed-with-technology. Accessed at: 1/5/2022
[7] Golpîra, H., Syed, Khan, A. R. & Safaeipour, S., (2021). A Review of Logistics Internet-of-Things: Current Trends and Scope for Future Research. Journal of Industrial Information Integration. Accessed at: 1/5/2022
[8] Ramadhani, E. & Mahardika, G. P., (2018). The Technology of {LiFi}: A Brief Introduction. {IOP} Conference Series: Materials Science and Engineering}, Volume 325. Accessed at: 1/5/2022
[9] Ding. Y and Feng. D (2018). Intelligent Warehousing Based on the Internet of Things Technology. Proceedings of the 2nd International Conference on Advances in Artificial. Accessed at: 1/5/2022
[10] Noha Mostafa & Walaa Hamdy & Hisham Alawady, (2019). "Impacts of Internet of Things on Supply Chains: A Framework for Warehousing," Social Sciences, MDPI, volume 8. Accessed at: 1/5/2022
[11] Bieringer, A. and Müller, L. (2018). Integration of Internet of Things technologies in warehouses: A multiple case study on how the Internet of Things technologies can efficiently be used in the warehousing processes. Accessed at: 1/5/2022
[12] Zhao, Z., Fang, J., Huang, G. Q., & Zhang, M. (2017). Location Management of Cloud Forklifts in Finished Product Warehouse. International Journal of Intelligent Systems, volume 23. Accessed at: 1/5/2022
[13] Chatpreecha, P. and Keatmanee, C. (2018). Stock Monitoring Unit in Storage Areas Enable Flexibility, Productivity, and Reliability of Warehousing System - Volume 8. Accessed at: 1/5/2022
[14] Buntak, K. and Kovačić, M. (2019). Internet of things and smart warehouses as the future of logistics, technical journal, volume 13. Accessed at: 1/5/2022
[15] Liu, H., Yao, Z., Zeng, L. and Luan, J. (2019). An RFID and sensor technology-based warehouse center: assessment of new model on a superstore in China, Assembly Automation, Vol. 39. Accessed at: 1/5/2022
[16] Zhao, K., Zhu, M., Xiao, B., Yang, X., Gong, C. and Wu, J. (2020). Joint RFID and UWB Technologies in Intelligent Warehousing Management System. IEEE Internet of Things Journal, volume 7 Accessed at: 1/5/2022
[17] Alfian, G., Syafrudin, M., Farooq, U., Ma'arif, M., Syaekhoni, M., Fitriyani, N., Lee, J. and Rhee, J., (2020). Improving efficiency of RFID-based traceability system for perishable food by utilizing IoT sensors and machine learning model, Food Control, Volume 110. Accessed at: 1/5/2022
[18] Lin, J., Yu, W., Zhang, N., Yang, X., Zhang, H. and Zhao, W. (2017). A Survey on Internet of Things: Architecture, Enabling Technologies, Security and Privacy, and Applications. IEEE Internet of Things Journal, volume 4. Accessed at: 1/5/2022
[19] Füchtenhans, M., Grosse, E.H. and Glock, C.H. (2021). Smart lighting systems: state-of-the-art and potential applications in warehouse order picking. International Journal of Production Research, Volume 59. Accessed at: 1/5/2022
[20] Alfattani, S., (2018). Review of LiFi Technology and Its Future Applications. Journal of Optical Communications. Accessed at: 1/5/2022
[21] Meshram, S. & Meshram, S., (2020). Light Fidelity (LI-FI): A Wireless Technology, J-BNB: A Multidisciplinary Journal, volume 9 Accessed at: 1/5/2022