Operational Research in Engineering Sciences: Theory and Applications
Vol. 6, Issue 3, 2023, pp. 326-335
ISSN: 2620-1607
eISSN: 2620-1747
DOI: https://doi.org/10.31181/oresta/060316

ROLE OF INTERNET OF THINGS IN WAREHOUSE MANAGEMENT

Abhilash Mohanta[1], Sushanta Tripathy[1], Deepak Singhal[1*]

[1]School of Mechanical Engineering, KIIT University, Bhubaneswar, India.

Received: 15 January 2023
Accepted: 18 September 2023
First Online: 08 October 2023

Research Paper

Abstract: *The main emerging technology of the current 4th industrial revolution (industry 4.0) stores an immense potential to change the current business and supply chain work and take it to a different level altogether. The communication among physical objects, manufacturer and customers could be successfully built to various platforms in real time. Mapping various journals, research the world-wide progress opens a future possibility to get an end-to-end visibility, transparency, easy updates, maintenance, and accessibility to data and predictions that would take immediate actions thus reducing defaulters. IoT has been proven to be a top notch for industries staring from Automobile and Aerospace sectors to Food and Agro-mechanical areas. But the problem lies in implementation. Many Micro, Small and Medium Enterprises or MSME has failed to implement the IoT architecture. The Inventory management system uses a prototype warehouse can easily provide real time data about the items present in the inventory. Stock levels are easily indicated to the operator without any human interference. The RFID line follower robot has an unique ability of sensing RFID tags and card attached to the items, increasing the stock security level of the entire inventory. These methods are cost effective and efficient which can be easily implemented by small industries in order to meet the customer demands in time. Moreover, with a goal of decision making, taking all the variants, that best suit the goal, for which the process mapped is taken into wider concentration by the use of Fuzzy AHP method. Once the hierarchy is made, the analysis and comprising two at a time each in between lines of hierarchic to derive the solution. The main underlying process is using the human judgment rather than decision by information.*

Key*words*: *Fuzzy AHP, Internet of Things, Radio Frequency Identity, Supply Chain Management, Warehouse Management.*

∗Corresponding Author: dsinghal.iiit@gmail.com (D. Singhal)
abhi97a@gmail.com (A. Mohanta), sushant.tripathy@gmail.com (S. Tripathy)

1. Introduction

Technological development is now in a state of exponential growth in every aspect of human life. Industries are booming and the sector of Information Things is now on a verge of changing the human life (Aliaga et al., 2011; Choi, Wallace, & Wang, 2016; Li, Dong, & Sun, 2012). Within these growing areas, Internet of Things (IoT) is a major reason of development of manufacturing industries, health, food industries and agriculture especially in the field of Supply Chain Management and Logistics.

Internet of things has a huge impact in the world we live in from shipping, servicing, driving, a way of purchasing, medical issues, almost in every sphere. Sophisticated electronic devices, chips and sensors are embedded on physical objects that are a part of our everyday life. Each transmitting valuable data, data for better understanding of the work and its work together taking resources from various other devices or systems (Da Xu, He, & Li, 2014; Liu & Guangsheng, 2008). A platform that brings diverse information together. This continuous update, sync, processing and analysis of data, to take decisions at the real-time, reduce errors or accidents, cost-efficient and eventually resulting into the efficient method.

Logistics can be referred to the art and science of obtaining producing and distributing products in proper places fulfill the required quantity. Supply chain management transforms raw material into the product and gets the finished goods to the customers, whereas logistics is the movement of materials in the supply chain. Logistics is a section of the supply chain management that makes plan, implement controls and, keep the information (Cui & Liu, 2009; Kate et al., 2015; Liu et al., 2015; Liu, Ji, & Gu, 2007; Sreedevi & Saranga, 2017). Thus, a connected intelligence product service relation could be achieved, with constant sync, analysis and real-time decision making a critical impact on asset velocity of companies which is linked to its inventory control through enhanced transparency, visibility and insights. These data science thus helps in the overall reliability process.

Barcodes and tracking numbers are used to track assets. The RF-id and GPS tracks items from "floor to store" and recording granular data of time temperature etc. The asset tracking also help companies tweaking their own production schedule and also for tracking vendors handling and supplies. Forecasting and inventory, manufacturing schedules are plotted from the trends observed from the data. Predictive and planned maintenance to limit down time, which reduces huge cost helping the manufacturers, companies, organizations to earn a stronger grip on time management, forecasting and quality control.

2. Literature Review

Arebey et al. (2011) discussed about the Integration of IoT in 4 layers of enterprise namely business, application, infrastructure and information and use of a series of framework in five different cases especially fulfilment case where the industries can show a stable cycle of planning, shipping and receiving materials. Cangialosi, Monaly, and Yang (2007) proposed about constructing an IoT middleware architecture for a collaborative supply chain for positioning, identification, communication, tracking and data sharing. Da Xu et al. (2014) further gave information about remote access to product status and increase in communication capabilities with the use of Cyber-Physical System in order to integrate the physical domains of IoT and PSS. Lianguang (2014) gave a prime idea of cloud auction robot

(CAR) and its implementation for transforming perishable FSCM. The Internet of Things enabled an auction surrounding which helped the system to lift up and deliver items in real time basis commands which were given. Dhumale et al. (2016) developed a software tool using IoT which enabled the farmers to monitor the state of their agricultural fields and helped navigate an autonomous Inter- Agricultural Logistics (IAL) system and had real- time interface with Google Maps in order to handle filed boundaries, find out the obstacles coordinates and real-time positioning of the vehicle. Gu and Jing (2011) implemented IoT in FSC management to present the possible advantages and scopes for immediate application of the food environment into computerized environment and proposed an IOT related device standardizes the food chain stages and different procedures and generalizes the related items and products. Tuang and Lin (2016) made research on influence on existing business by fourth party logistics, data storage, analysis, data security, carbon footprint, infrastructure provider. On the positive side are inventory management, logistic transparency and high financial efficiency.

Liu (2010) and Choi et al. (2016) talked about the improvement that needs to focus sensing and shaping that comprises capturing information across various nodes along with environmental monitoring aspects of supply chain and adaptive supply that talks about interpretation, decision making and acts on the changing environment based on analytics. Yuvaraj and Sangeetha (2016) developed a Tracking and identifying technology data integrated which RFID system provides (real-time information). Moreover, communication and clouding of information any time for analysis and more important execution. The research also focused on sensors that can communicate with other devices but these among various other devices as per requirement. Zhou and Zhou (2012) discussed about the positive Sides-Transparency-that is an end-to-end visibility in terms, thus more effective, timely decision and no delay in detecting issues. Devices can capture and share mission-critical data across the cloud to provide right data on time. Further discussed on assets intelligence and reduce backlogs accidents and hence efficient.

3. Basic Concepts and technology used

3.1 Arduino Uno

It is basically a micro controller board which is based on ATmega328. Now, this ATmega328 comprises of a 32 KB flash memory which is used for storing the code. The Arduino Uno uses a simplified version of C++ which is easier to learn. It has got 14 digital input/output pins out of which 6 are analog inputs and further it has a 16 MHz crystal oscillator, a USB connector, a reset button, a power jack, TX RX LEDs, and an ICSP header.

3.2 Arduino Mega

The Arduino Mega is similar to that of the Arduino Uno, however the former is also a micro controller board but is based on AT mega 1280 and consists of 54 digital input/output pins out of which 16 are analog inputs, has a 16 MHz crystal oscillator, 4 hardware serial ports, USB connector, a power jack, an ICSP header and a reset button. The AT mega 1280 unlike ATmega328 comprises of a flash memory of 128 kb.

3.3 Ultrasonic Sensor

By the name it suggests that the ultrasonic sensors use ultrasonic waves i.e., ultrasonic sound which is above 20,000 Hz for the detection of distance between the source and the

target. The sensor head puts out an ultrasonic wave which reflected back after striking the surface of the target and hence after receiving the wave the distance is calculated by measuring the time occurred between the emission and reception.

3.4 IR Proximity Sensor

IR proximity sensor is a type of multipurpose sensor which has its usage for sensing objects, detection of color, detection of fire etc. and sometimes can be used as an encoder sensor. It generally provides a digital output. In order to indicate the presence of an object an on-board LED has been used. To read the sensor output this digital output can be connected to Arduino, Rasberry Pi or any other micro-controller.

3.5 RFID Sensor

A RF tag that is been programmed electronically with specific information. This RF tag is also known a transponder. A transceiver which receives the waves that the RFID reader has been sending. An antenna which is also known as the interrogator. Radio waves are used for the working of RFID Sensors. Within the optimum range the radio wave is put out and the RFID tag transmit it to the reader. It is similar to that of the working of bar-code system but a lot more convenient. The RFID Sensor is basically used to sense the waves that are been discharged from the reader in order to check upon the items/objects that are in concern.

3.6 RFID Card

The RFID Card is an identification card or badge whose work is to transfer its contents to the RFID Reader. Now, there are two types of systems namely Active and Passive. The former comes with its own power supply and the latter is provided with an external power supply. The RFID card has advantage over the bar-code system as on the former case there is requirement for line of sight however the later one requires such a facility. The former one can scan more than one item simultaneously which saves a lot of time however the later one is not that efficient and a single item is scanned at a time only.

3.7 L298D Motor Driver

It is a high current dual full bridge driver with high voltage designed in such a way that it is ready to accept the standard TTL (Transistor-Transistor Logic) levels. It is able to drive certain inductive loads like stepping motors, solenoids, DC, relays etc. The driver has been provided with two inputs which are capable of enabling or disabling the device without any concern off the input signals.

3.8 AHP

The AHP process stands for Analytic Hierarchy Process. For analyzing and organizing complex decisions this is the technique that is been used based on complex psychology and mathematics.

The AHP Algorithm is mainly composed of two steps, they are: Firstly, the relative weights of the decision criteria is determined. Secondly, the relative rankings of the alternatives are determined that is they are prioritized according to the advantage they are providing.

3.9 Fuzzy AHP

Fuzzy: In binary system which indicates the outcomes as 0 or 1, fuzz logy has variation of range of values, as per the user definition. Fuzzy logic is all-round like in washing machine, in airplanes etc., which deals with uncertainty. Fuzzification converting linguistics into membership function: like trapezoidal, bell-shaped and triangular etc. Crisp numbers are replaced by fuzzy number. Assigning numbers directly were not justified, thus fuzzy number was introduced. Defuzzification is nothing but quantifiable in a crisp logic. As the crisp input is fuzzifier it works in the interface where according to the rules it is processed through this, the function which de-fuzzifier where the fuzzy set is mapped. Thus, the de-fuzzifier forms a crisp output.

Fuzzy Analytic Hierarchy programming (AHP) provides to be one of the upcoming and widely research, developed and implemented areas of decision making. It is a major structure procedure of firstly organizing and analysis the sets to complex decision based on mathematical and psychological models.

4. Proposed Model

4.1 The Warehouse Model

The process involves a sophistication of different sensor output which would give a real time data to the operator about a particular item carrying RFID number. The prototype warehouse consists of 4 Ultrasonic Sensors which is being connected to an Arduino Uno micro-controller and controlled by Arduino Source Code. The Ultrasonic Sensors gives the distance of the items which is being located in the warehouse. A threshold distance is being set for every stock level which are:

- Full Stock
- Re-order Level
- Safety Stock.

Whenever all the sensors give the same output or in other words the same threshold distance for every level, LEDs light up in accordance to the inventory level being present in the prototype warehouse. Green, yellow and red are for full stock, re-order level and safety stock respectively. Figure 1 shows the warehouse prototype.

Figure 1: Warehouse Prototype.

42. RFID based Line Follower Robot

Coming to the RFID based Line Follower Robot, the bot utilizes an RFID sensor which is being connected to an Arduino AT Mega 2560 micro-controller. The bot has 2 IR proximity sensors which is being attached to the front part of the chassis, which

would enable the bot to follow a particular line starting from the prototype warehouse to the outlet of the warehouse. The items are being embedded with a unique RFID card. The bot will only move to the warehouse once it senses an RFID card. Sensing any other RFID tag or card having different number keeps the bot stopped in its initial working position without any movement to the outlet. The whole warehouse management system would have a specified track length for the bot to move starting from the warehouse to the outlet. Figure 2 shows the RFID BOT prototype.

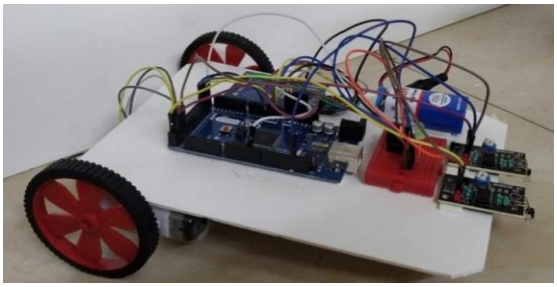

Figure 2: RFID BOT Prototype.

5. Implementation and Results

With the use of real time inventory management system improvisation in different aspects of warehouse management was achieved, following:

- Improved security of stock in warehouse using RFID.
- Indication of different stock levels of warehouse using Ultrasonic Sensor.
- Automated transfer of items from the warehouse to the outlet using Line Follower Robot.
- Less human error in transference of items from one point to other.
- Real time indication to the operator of particular item if it is available in the inventory or not.
- Ease in meeting the customers demand of a particular item before the lead time of the item approaches.

6. Fuzzy Analytic Hierarchy Process

Table 1 shows the fuzzy scale which is used for pair wise comparison. Table 2 shows the expert input received for the comparison between the factors. First, geometric mean operation is performed, and subsequently reciprocal operation is done to obtain the normalized matrix. Table 3 shows the geometric mean and reciprocal procedure results which form the normalized decision matrix. Table 4 showcases the fuzzification weights used to predict the rank. Table 5 represents de-fuzzified weights.

Table 1: Scale of Relative Importance.

1	**Equal Importance**
3	Moderate Importance
5	Strong Importance
7	Very Strong Importance
9	Extreme Importance
2,4,6,8	Intermediate Importance
1/3,1/5,1/7,1/9	Values for reverse comparison

Factors Affecting Application IoT in Warehouse Management:
A=Reliability
B=Price
C=Delay
D=Flexibility
E=Service
F=Certification

Table 2: Conversion in to Fuzzy numbers for FAHP.

	A	**B**	**C**	**D**	**E**	**F**
A	(1,1,1)	(3,4,5)	(2,3,4)	(1,2,3)	(5,6,7)	(4,5,6)
B	(1/5,1/4,1/3)	(1,1,1)	(2,3,4)	(3,4,5)	(6,7,8)	(5,6,7)
C	(1/4,1/3,1/2)	(1/4,1/3,1/2)	(1,1,1)	(4,5,6)	(5,6,7)	(1,2,3)
D	(1/3,1/2,1)	(1/5,1/4,1/3)	(1/6,1/5,1/4)	(1,1,1)	(1,2,3)	(2,3,4)
E	(1/7,1/6,1/5)	(1/8,1/7,1/6	(1/7,1/6,1/5)	(1/3,1/2,1)	(1,1,1)	(3,4,5)
F	(1/6,1/5,1/4)	(1/7,1/6,1/5)	(1/3,1/2,1)	(1/4,1/3,1/2)	(1/5,1/4,1/3)	(1,1,1)

Table 3: Fuzzy Geometric Mean

A	**(2.221,2.994,3.689)**
B	(1.817,2.239,2.679)
C	(1.038,1.367,1.777)
D	(0.530,0.729,0.998)
E	(0.369,0.447,0.567)
F	(0.271,0.334,0.450)
Sum	(6.246,8.110,10.160)

Table 4: Fuzzification Weights.

A	**(0.346,0.369,0.363)**
B	(0.283,0.276,0.264)
C	(0.161,0.169,0.175)
D	(0.082,0.089,0.098)
E	(0.057,0.055,0.056)
F	(0.042,0.041,0.044)

Table 5: De-Fuzzification.

A	**0.359**
B	0.274
C	0.168
D	0.090
E	0.056
F	0.042
Sum	0.999=1 (Acceptable)

From the above Fuzzy Analytic Hierarchy Process, it was found that Reliability (Factor A) carried the major fraction affecting the implementation of IoT in Warehouse Management. Whereas, the Price (B) of the implementation of IoT and Delay Period (C) involved in the process occupied the second and third position among the remaining affecting factors. However, flexibility (D) in the system, services (E) throughout and certification (F) of the process were found to be of least importance among the factors. This provides a vivid view of the factors affecting the use of IoT in the management of Warehouse by ranking them all together.

7. Conclusion

With the advent of Industry 4.0, Supply chain management has become a real critical area for development of sophistication technology using IoT, Artificial Intelligence and Block-Chain Development. During these few years IoT has been proven to be a top notch for industries staring from Automobile and Aerospace sectors to Food and Agro-mechanical areas. But the problem lies in implementation. Many Micro, Small and Medium Enterprises or MSME has failed to implement the IoT architecture. Implementation of IoT in MSMEs can lead to higher warehouse house management efficiency without any loss of items present in stock.

The Real Time inventory management system uses a prototype warehouse can easily provide real time data about the items present in the inventory. Stock levels are easily indicated to the operator without any human interference. The RFID line follower bot has a unique ability of sensing RFID tags and card attached to the items, increasing the stock security level of the entire inventory. These methods are cost effective and efficient which can be easily implemented by small industries in order to meet the customer demands in time.

Inclusion of other technological methods can be a boon to these industries but those wouldn't be cost effective as the basic IoT architecture. IoT has proven to be a bench mark in the present for Supply chain management and can lead to new pathways to experiment, evolve and evaluate different industrial areas in the future.

References

Aliaga, C., Ferreira, B., Hortal, M., Pancorbo, M. Á., López, J. M., & Navas, F. J. (2011). Influence of RFID tags on recyclability of plastic packaging. Waste Management, 31(6), 1133-1138. https://doi.org/10.1016/j.wasman.2010.12.015

Arebey, M., Hannan, M., Basri, H., Begum, R., & Abdullah, H. (2011). Integrated technologies for solid waste bin monitoring system. Environmental monitoring and assessment, 177, 399-408. https://doi.org/10.1007/s10661-010-1642-x

Cangialosi, A., Monaly, J. E., & Yang, S. C. (2007). Leveraging RFID in hospitals: Patient life cycle and mobility perspectives. IEEE Communications Magazine, 45(9), 18-23. https://doi.org/10.1109/MCOM.2007.4342874

Choi, T.-M., Wallace, S. W., & Wang, Y. (2016). Risk management and coordination in service supply chains: information, logistics and outsourcing. Journal of the Operational Research Society, 67, 159-164. https://doi.org/10.1057/jors.2015.115

Cui, A., & Liu, W. (2009). Study on capability coordination in logistics service supply chain with options contract. Chinese Journal of Management Science, 17(2), 59-65. http://www.zgglkx.com/EN/abstract/abstract13374.shtml

Da Xu, L., He, W., & Li, S. (2014). Internet of things in industries: A survey. IEEE Transactions on industrial informatics, 10(4), 2233-2243. https://doi.org/10.1109/TII.2014.2300753

Dhumale, R., Kate, G., Kulkarni, S., & Thombare, N. (2016). Reservation based S-Park System using Embedded Server and Android Application. International Journal of Research in Engineering and Technology, 5(8), 115-119. https://ijret.org/volumes/2016v05/i08/IJRET20160508021.pdf

Gu, Y., & Jing, T. (2011). The IOT research in supply chain management of fresh agricultural products. In 2011 2nd International Conference on Artificial Intelligence, Management Science and Electronic Commerce (AIMSEC) (pp. 7382-7385). IEEE. https://doi.org/10.1109/AIMSEC.2011.6011477

Kate, G., Dave, K., Kulkarni, S., & Dhumale, R. (2015). Android application for s-park system. IJRET: International Journal of Research in Engineering and Technology, 4(10), 107-110. https://ijret.org/volumes/2015v04/i10/IJRET20150410019.pdf

Li, Y., Dong, Q., & Sun, H. (2012). Research on the Framework of Logistics Service Supply Chain Management Control System. East China Economic Management, (9), 55-58. http://www.cqvip.com/qk/96459x/201209/42652597.html

Lianguang, M. (2014). Study on supply-chain of agricultural products based on IOT. In 2014 Sixth International Conference on Measuring Technology and Mechatronics Automation (pp. 627-631). IEEE. https://doi.org/10.1109/ICMTMA.2014.153

Liu, D., & Guangsheng, Z. (2008). Application of data mining technology in modern agricultural logistics management decision. Journal of Shenyang Normal University (Natural Science Edition), 3, 957-962.

Liu, W., Xie, D., Liu, Y., & Liu, X. (2015). Service capability procurement decision in logistics service supply chain: A research under demand updating and quality guarantee. International Journal of Production Research, 53(2), 488-510. https://doi.org/10.1080/00207543.2014.955219

Liu, W. H., Ji, J. H., & Gu, Q. L. (2007). Cooperation quality control and coordination in two-echelon supply chain of logistics service. Industrial Engineering and Management, 12(3), 47-52. http://www.cqvip.com/main/none.aspx?lngid=24702321

Liu, X. (2010). The IOT-the new tools of logistics and supply chain management. Commercial Times, 25, 40-41. http://www.cqvip.com/qk/96790a/201025/35170824.html

Sreedevi, R., & Saranga, H. (2017). Uncertainty and supply chain risk: The moderating role of supply chain flexibility in risk mitigation. International Journal of Production Economics, 193, 332-342. https://doi.org/10.1016/j.ijpe.2017.07.024

Tuang, L., & Lin, Y. (2016). An Architecture of Supply Chain Management Systems. Semantics Scholar, 4, 55-77. http://gebrc.nccu.edu.tw/proceedings/APDSI/2000/list/pdf/P-092.pdf

Yuvaraj, S., & Sangeetha, M. (2016). Smart supply chain management using internet of things (IoT) and low power wireless communication systems. In 2016 international conference on wireless communications, signal processing and networking (WiSPNET) (pp. 555-558). IEEE. https://doi.org/10.1109/WiSPNET.2016.7566196

Zhou, Z., & Zhou, Z. (2012). Application of internet of things in agriculture products supply chain management. In 2012 International Conference on Control Engineering and Communication Technology (pp. 259-261). IEEE. https://doi.org/10.1109/ICCECT.2012.262