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REVIEW ARTICLE **OPEN ACCESS**

Emerging Trends in Warehouse Automation

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ABSTRACT

Warehouse automation encompasses the incorporation of automated technological methods into warehouse management, a more sophisticated method than traditional warehouses. Warehouse automation is the new imperative in the modern era of supply chain management. Increasing automation leads to an increased speed of loading, retrieving, transportation, and shipping of the finished products, leading to increased industry turnover. Automation has also resulted in improved safety of the products and employees because continuous risk assessment of warehouses is made easy by utilising automated machines. This review discusses various emerging trends that play a crucial role in improving the efficiency of automated systems in warehouse management like Automated ergonomic handling, automated guided vehicles (AGVs), autonomous mobile robots (AMRs), gamification in automated inventory management, cobotics, automation of picking processes, automating the tote configurations, Piece picking robots or robotic arms for picking. Software systems like SCADA application and automated storage and retrieval system (ASRS) technological model are the heart of the automated machines used in warehouse and inventory management.

Keywords: *Warehouse automation, ASRS, automated guided vehicles, gamification, Cobotics.*

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INTRODUCTION

Pharmaceutical warehousing or warehouse management is the physical movement of stock into and out of the warehouse. Warehousing is the key element of pharmaceutical supply chain management as it ensures the constant availability of essential health commodities in required quantities in a timely and cost-effective manner. Functions of warehousing include inventory management, distribution of raw materials, and receiving and storing stock. The components of a warehouse are depicted in **Figure 1.**

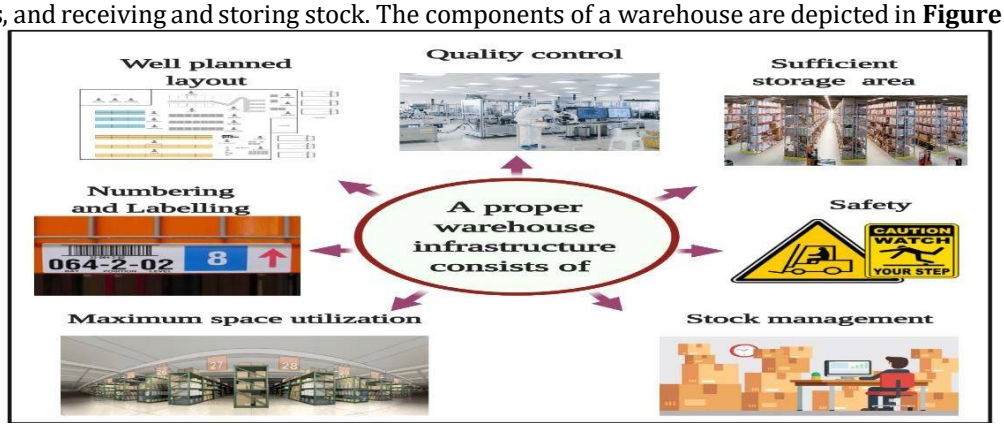

Figure 1: Components of a warehouse.

An ideal warehouse has a well-planned layout that facilitates easy operations and storage management and minimises cross-contamination. It should be supplied with abundant human resources and suitable technological equipment necessary for handling materials (1). Good storage practices often play an essential role in adequately utilising raw materials and distributing finished products. In many cases,

good storage practices have been overlooked due to compromised material and human safety.
Poor safety in the warehouse may also lead to product and human loss. Nowadays, warehouse accidents have been a major concern in the pharmaceutical industry. There are a few potential hazards like a slip or trip accident, being hit by moving vehicles and falling objects, forklift trucks, and injuries during manual handling of the materials. The risk assessment must be performed periodically to prevent such accidents. Therefore, the need for improved warehouse infrastructure for better supply chain management, inventory control, and overall safety in warehouse management. The incorporation of automation in the warehouse came into existence for improved warehouse management(2).Warehouses can be automated in several ways, from picking operations, barcode scanning and labelling, transporting materials, and automating the back-office processes. Warehouse automation is a new urgency in the current supply chain. It helps in improved efficiency, reliability, speed, accuracy, and eventually cost savings. Warehouse automation includes two different stages: they are process automation and physical automation.

1. **Process automation:** is also referred to as system automation. It involves the digitalisation of manual processes like inventory data collection and integrates the data in the form of a database or enterprise resource planning system.

The process includes barcoding and barcode scanners to enter and locate the data, which is then stored in a centralised repository through software to retrieve and review the data.

2. **Physical automation:** forms of mechanised automatic systems that include using robots and robotic systems in the storage area. Some examples of physical automation are GTP- goods-to-person technology, driverless automated guided vehicles (AGVs), and autonomous mobile robots (AMRs)(3).

STEPS TO AUTOMATE A WAREHOUSE:

1. Data collection: in former ages, the data was collected through handwritten notes or manually entered or re- keyed data entry. This data is then stored digitally on a spreadsheet or a database. in contrast, automated datacollection includes capturing data through wireless barcode scanners.
2. Gaining control over the inventory: automatic inventory control is done by using an inventory management system (IMS). Software like Ship Station is used in small-scale industries, whereas RFgen software is used in larger enterprises.
3. Implementation of the warehouse management system (WMS): WMS is a software-based system that automatically collects and manages data. This software helps control and track products in storage and distribution areas (3).

Easy accessibility of warehouse automation:

Previously only multinational companies could afford automated equipment in the warehouse. Later, increasing demand for automation led to decreased purchasing costs of automated machines and transport vehicles. Through facilitating, easy accessibility to the medium-sized and small-scale industries in implementing the automation techniques. Conversely, implementing automation in the warehouse alone does not help resolve storage-related problems(4). Automation helps maintain good storage practices only when close integration of automation techniques with the warehouse management system (WMS) occurs.

The increasing need for warehouse automation:

Superior grade-structured warehouses facilitate easy incorporation of automation techniques as it allows efficient space utilisation. It ensures sustainable and more environmentally friendly warehouses by reducing physical footprint, waste, and energy consumption. There are mainly two things that can be automated in a warehouse, i.e.firstly in the decision-making process to decide where to store, how to pick and how to optimise resources, and secondly in the goods movement process, i.e. automatic displacement of goods from one place to another. The logistics world is moving towards automated solutions for storage handling where traditional assets are no longer required to be a thriving industry(4).

Role of artificial intelligence in warehouse automation:

The industry is witnessing a massive shift towards intelligent, flexible, and agile distribution and storage facilities with the help of robotics and machine learning. Robotics systems help improve order consolidation, sortation, pick and put away as well as help in enhanced productivity in warehouse and sortation centres. The goods-to-person robotics system are employed in industries. This advanced robotics adapts seamlessly to changing the inventory profiles and demand patterns, providing complete visibility in hand and movement and better inventory control (5).

Essential considerations for warehouse automation:

Many process changes are to be made before adopting automation in the warehouse. The process of automating awarehouse is depicted in **Figure 2**

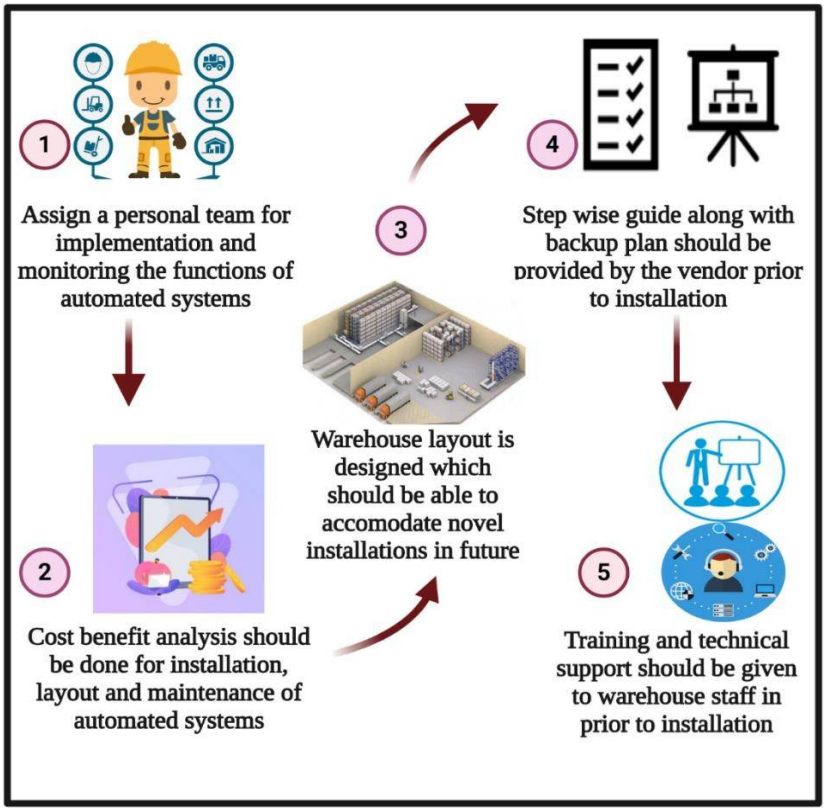

Figure 2: Process of automating a warehouse.

Return of investment (ROI) of automation in the warehouse:

The critical fact to be considered is that automation may not be a single answer for all the industry's needs. Automation's success can result from the careful validation of automated systems in an economic sense. There might be a chance of automation failure in poor economic planning. Calculating ROI for automation depends on changes to be made for implementing automation and the extent of yield produced before and after implementing automation techniques. Automation helps stabilise the workforce in a market with increased revenue; it also helps resolve problems raised due to a shortage of employees and employee disputes(5). Automating warehousing in hazardous areas might result in a reduction of 40% of human resources. This would prevent human casualties while working in hazardous warehouse areas, thus preventing human loss.

Advantages of warehouse automation:

Automated systems help quickly locate the items of a particular order and fast movement of the products. They also help optimise the routes of transportation of the products resulting in increased productivity during productretrieval. Using warehouse leverage robots and conveyors can offer overnight shipping, thus speeding up inventory management processes. Automation also maximises the storage space, better inventory counts, and enhanced product and employee safety in the workspace.

DISCUSSION

Automating the warehouse is a continuous process with a considerable need for continuous discovery and development of automated technologies. The latest trends in warehouse automation are:

- **Automatic Ergonomic handling:**

All the finished products are packed using totes and crates for storage purposes. The materials are packed strictlyto specific weights and arranged at the desired height for manual handling of the materials, such as lifting and moving them. Later, the implementation of automation led to the introduction of material handling machines which automatically carry totes of increased weights with excellent tolerance(6). Totes and crates can now be packed with increased weights and placed at heights because the automated systems and machines can carry and move heavier loads from one place to another. These material handling machines are also helpful in arranging heavy loads and help manufacturers in the transportation of an increased number of products more safely and efficiently (6) (7).

The machines are operated through the Automatic Storage and Retrieval System (AS/RS)where all heavy loads are deposited and redeemed from all directions automatically without human intervention. Machine operators set all the parameters in the system, which instructs the machine to handle and move

products(7). An automatic ergonomic handling system enables reduced human effort in carrying products and thus helps prevent accidents during carrying, rearranging, labelling, and locating the products arranged in taller and broader stacks. The various types of automated ergonomic machines is given in **Figure 3.**

Figure 3: Various types of automated ergonomic machines.

- **Automated guided vehicles (AGVs):**

An automated guided vehicle system is a compilation of computer software, and battery-powered material carriers that run on the floor without the aid of a driver. It is a mobile robot carrying heavy loads like carts, pellets, or trays between manufacturing stations and warehouses. There are significant variations of AGVs depending on the utility requirements in a warehouse. The components of AGV supervision system is given in **Figure 4.** AGV system runs on three main principles: map-reading by using wired or wireless navigation systems, speed control of AGV, and traffic supervision to avoid wrecking of AGV vehicles in a warehouse (7) (8). Different parts of AGVs are:

Vehicle: it is the mechanical part of the AGV system which provides space for placing materials like boxes, cartons, drums, and containers of heavy loads. It can be either a single vehicle or a group of vehicles attached to facilitate more load. The vehicle must be strong enough to be able to withstand heavy loads and should be able to transport these loads to places(8).

Host software: Host software is the heart of the AGV system, which monitors the whole system. This host software is installed in a group of IT systems. It helps to navigate the route, thus preventing any motorway hold-up. It also gives all the input parameters which instruct the machine to perform functions like lifting and carrying of materials, battery status, and automatic movement of doors(9).

It provides the facility of sensing of alarming situations and notifying them. Document information about the materials being handled and analysis reports of the system performance can be done.

Charging system: The batteries are charged using various technologies like flooded lead-acid, Nickle Cadmium, fuel cells, and lithium-ion batteries. The exhausted batteries can be replaced with new batteries or batteries can be changed periodically depending on their power requirement and shelf life(9).

User interface: It permits the user to send commands to the system for movement of material, communication, alerting the person handling the machine, and sending or receiving performance reports(9).

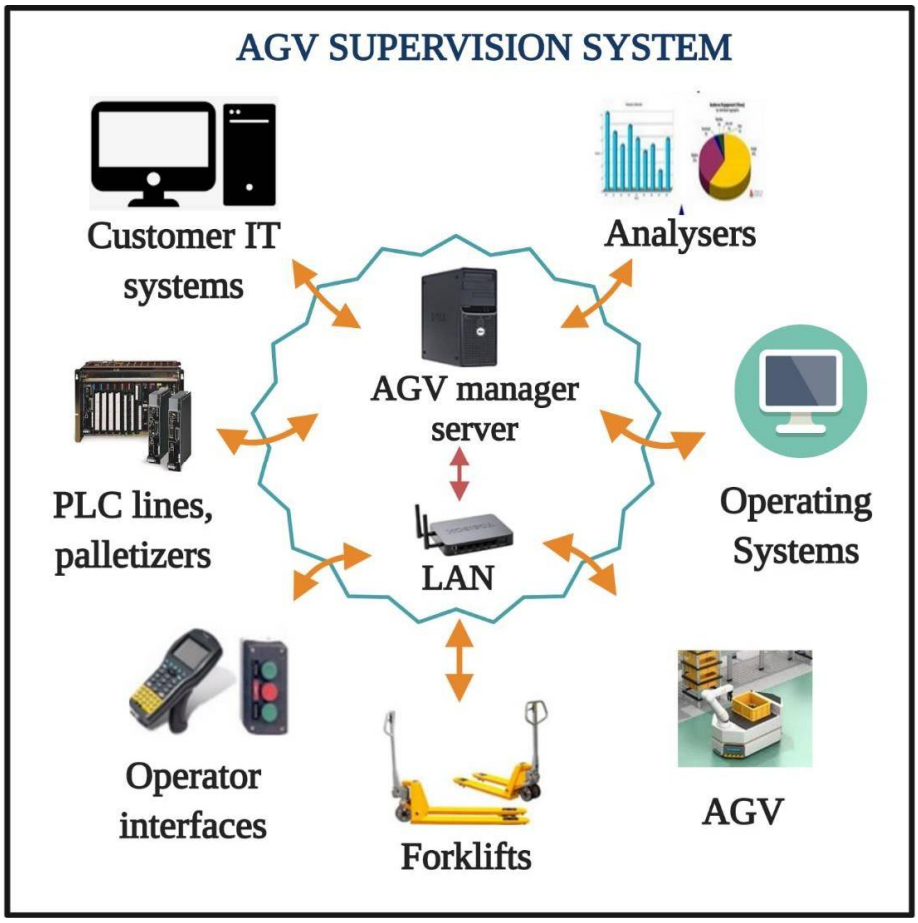

Figure 4: Components of AGV supervision system.

AGVs utilisation has increased in the modern era of pharmaceutical manufacturing for different functions like raw material transportation, equipment movement, removal of waste, racking operations, picking and movement of finished goods.

- **Autonomous mobile robots (AMRs):**

Autonomous mobile robots are new-age mobile transporters that are slightly different from AGVs as AMRs work based on navigating maps constructed into software on-site or through a previously inserted layout drawing. The software helps in generating a direct path to transfer products from one place to another based on simple landmarks on the map(10). Evolution of a warehouse with AMRs is given in **Figure 5**. There are different types ofAMRs used in the warehouse:

GTP picking robots: Good-to-person (GTP) picking robots are specially designed to carry large carts in flexible routes that facilitate workers to pick products directly from the carts. Thus, it saves time for walking and picking up the products as the worker directly receives the product from the cart(10). It also helps in changing the location of stored products. It is effortless to handle as it requires basic computer knowledge to operate the computer interface of the GTP system.

Self-driving forklifts: The automated forklifts are designed with features like navigating laser light, scanners, a 3D camera, visual warning indicators. These machines with multiple features can enhance transportation safety and prevent warehouse accidents while transporting(10)(11). Automated forklifts can also identify and calculate the number of goods loaded and their arrival in advance. It helps identify the suitable route, joins with other forklifts and rearranges and reviews the positioning of the goods in the warehouse and inventory.

Autonomous inventory robots: These are specialised robots used to monitor the inventory count of stored goods. It can calculate whole inventory goods number within hours and thus helps faster periodic inventory storage auditing (11).

Aerial vehicles: Aerial inventory robots are small-sized robots used to monitor and get an aerial view of the inventory and warehouse. They are used to identify any defects in storage conditions, placing of the goods, and any accident-prone areas in the warehouse and help to calculate the overall inventory count of goods. These are used for overall scanning of the warehouse and designing suitable and safe route maps to move finished products and raw material goods(11).

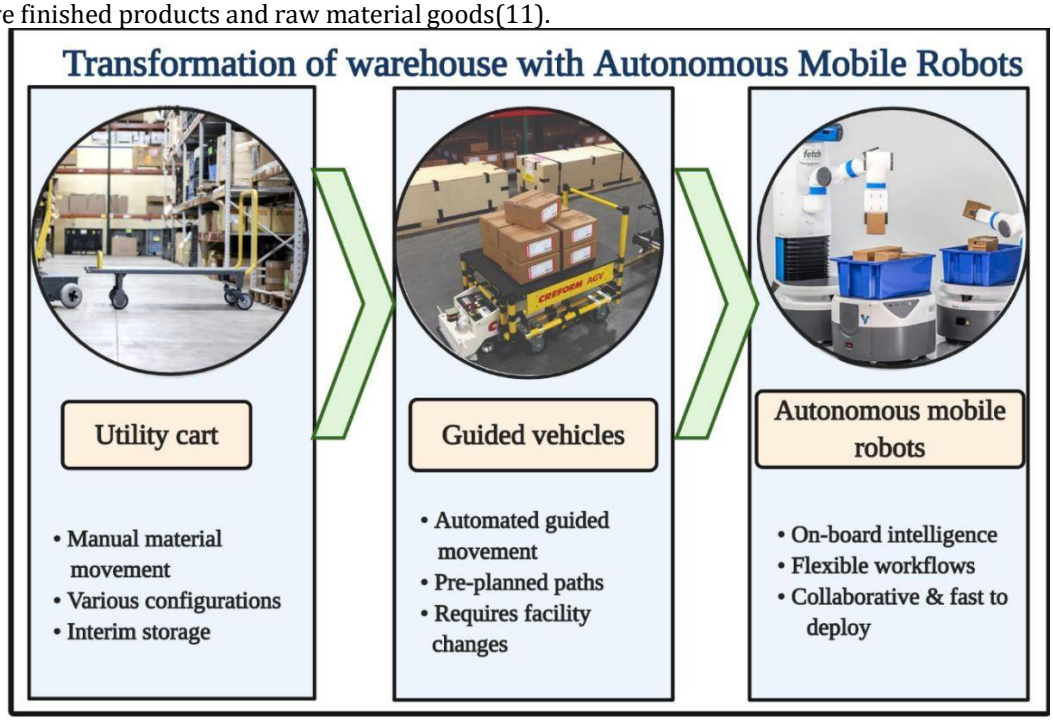

Figure 5: Evolution of a warehouse with AMRs.

- **Gamification in warehouse automation:**

Incorporating a game-like thesis into warehouse logistics is one of the new approaches in warehouse automation. It helps acknowledge one's performance in the organisation and thus helps enhance the healthy competition among the employees(12). The working capacity of the employees can be improved by adding a cheerful workingenvironment through gamification apps and technologies. Gamification aids the workers in setting realistic goals and also helps in self-criticising one's performance(12). This sort of workplace increases employee engagement and hence aids in lower employee turnover, enhancing the employer's constructive reputation.

Various gaming applications incorporated into the logistics attract young minds and gamers into the workplace. These gaming technologies helps in the maintenance of transparency and accountability among employee and the employer and also helps in quickly spotting productivity and performance(13).Gamification comprises allotting points, rewards, prizes etc to the employees based on their performance, these sort of schemes in the workplace can greatly enhance the workforce's productivity. To sum it up, incorporating gamification into the warehouse can ease the way of work, but it cannot be an immediate switch to gamify the logistics completely, it is still a transformation phase where traditional logistics are in the process of improving gaming technologies and apps relating to the warehouse management system(13).

- **Cobotics in the warehouse:**

The evolution of cobots took place in the early 1990s in the form of robotic arms on conveyor belts, containers used for unloading and loading them to the conveyor belt. They are also called collaborative robots; today's cobots are inflated with artificial intelligence with enhanced agility, which offers more support to human workers. Cobots are advantageous because they do not necessitate perpetual or costly infrastructure changes as they easily merge with subsisting infrastructure(14). Cobotics industry has evolved from $100 million to $13 billion by 2026. The investment for cobots is returned swiftly because of the increase in logistics fecundity. The return of investment is more rapid than compared other automation processes. Also, there is a flexibility to rent cobots during peak times. The software used in warehouse cobots is effortless to install, thus facilitating cobots to run in short periods as there is no need for infrastructural changes for installing cobots(15).

Warehouse workplace is more susceptible to accidents that may lead to human and material loss, but cobots havereduced the chances of accidents to a larger extent. They help minimise the peril of accidents

that might cause due to handling hazardous chemical substances and drugs. They widely aid in automating the picking process of heavy loads and crates, which in turn helps improve the associates' efficiency without forgoing one's own safety(16).

The occurrence of human fallacies too often can affect the payback and reputation of the company.This can be erased by the efficient working of cobots as they are not only programmed for performance but also consist of quality control features like barcode scanning, which are built into the system(15)(16). There is always an increased apprehension of robots replacing the human force in warehouse management, but this was proved wrong in case of cobots, as they typically work as human associates but not replace them. They also aid in freeing up the man force and to focus on further composite tasks. Although there are many advantages of cobots, they still carry a few drawbacks with them; it becomes tougher to manage the functioning of cobots in more thronged, inconsistent environment. As the cobots are being subjected to novel habitats, they open up new uses(17). Variants of Cobots is given in **Figure 6.**

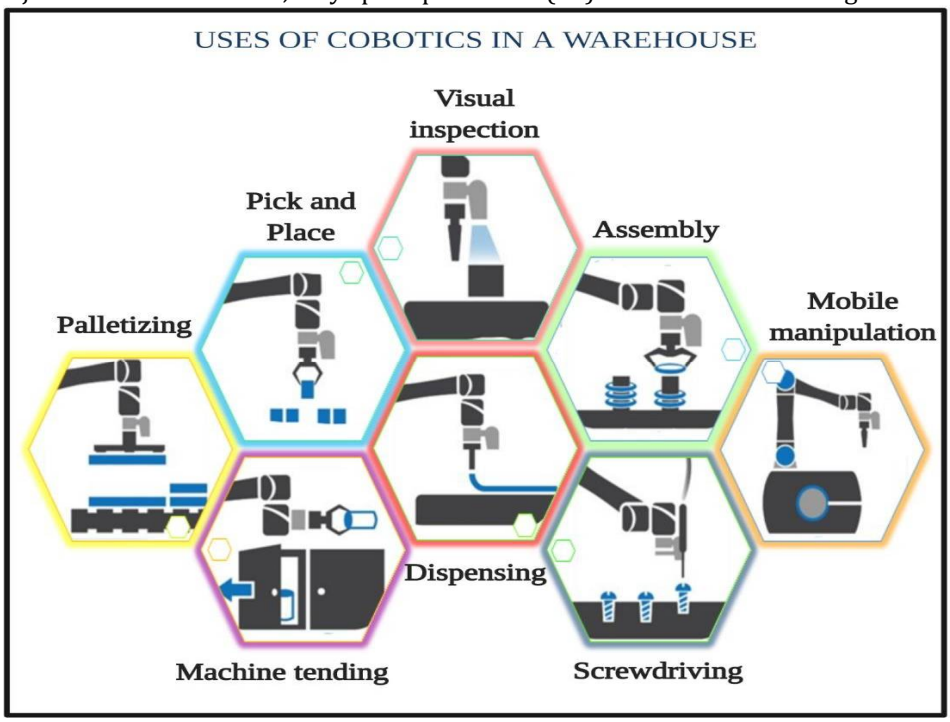

Figure 6: Variants of Cobots

- **SCADA Application:**

Supervisory Control and Data Acquisition is a software application that is used for collecting and inspecting the data and also facilitates control of equipment used in warehouse. This application helps in foreseeing and identifying any defects in the machines and execute automatic responses accordingly(18). Off lately use of wireless SCADA has increased tremendously which is beneficial in new manufacturing sites as installation of wireless system is cost effective and also aids in minimising hardware failure and permit costs (18).

Wireless SCADA works on ethernet network that allows a real time transmission between SCADA application and equipment(19). Some attributes of this application are they facilitate navigation and supervision of equipment in warehouse, it graphically represents the location and arrangement of crates and totes, emergency stops and system failures are detected instantly, statistical analysis and data logging is performed periodically by using this application(19). Working of wireless SCADA system is given in Figure 7.

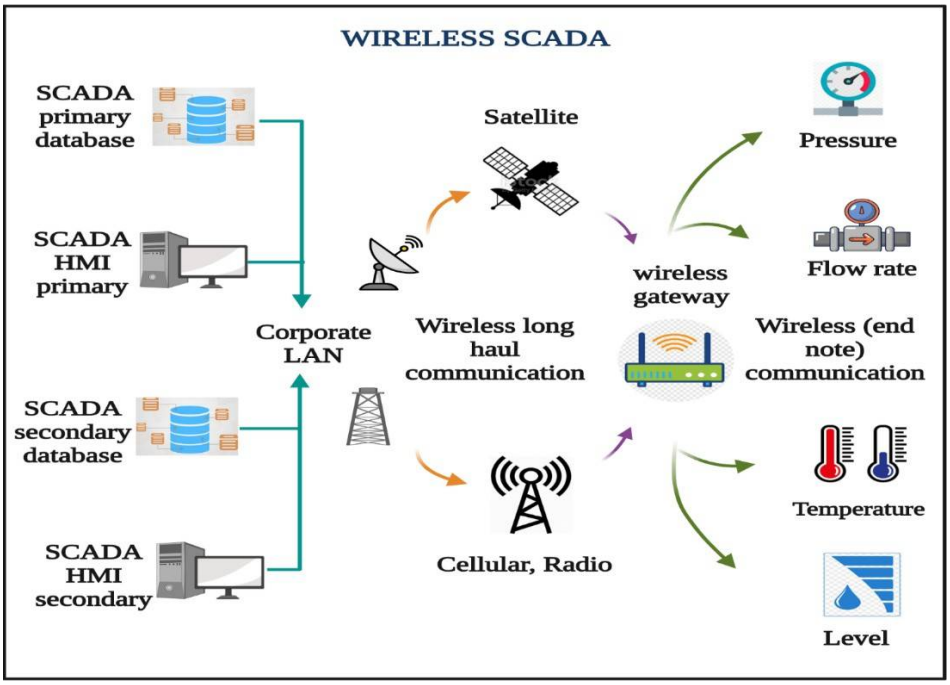

Figure 7: Working of wireless SCADA system.

SAP Warehouse Management System

SAP program is a software consisting of group of specifications written in a programming language called Advanced Business Application Programming (ABAP), which will be installed in a set of IT systems for monitoring and analysing miscellaneous functions in an organisation where the enterprise completely relies on automated machines. This software is highly sophisticated to handle copious tasks of multinational companies which have capacity to maintain large group of IT systems. Although there are many alternatives of SAP software for minor enterprises(20). SAP has been introduced into warehouse management over the recent years in the era of warehouse automation. A complete automated warehouse is monitored, analysed and sustained by using SAP WMS and SAP IMS i.e. SAP Warehouse Management System and SAP Inventory Management System(21). Basic model SAP warehouse structure is depicted in Figure 8.

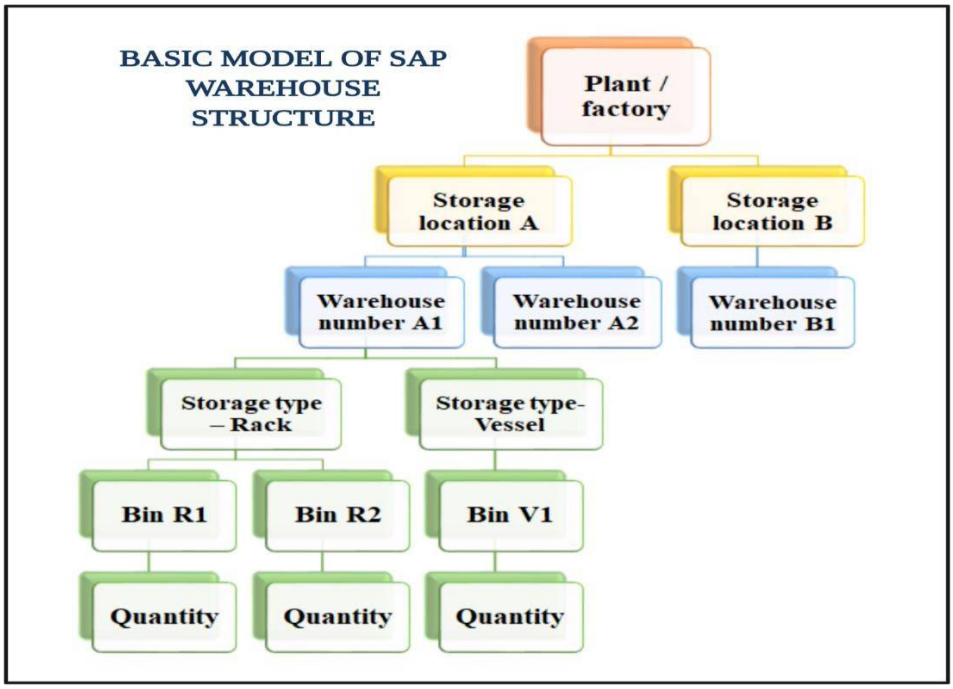

Figure 8: Basic model SAP warehouse structure

Different features of warehouse SAP system include:

1. Regulation of storage bin: Storage bins are portrayed individually in the software thus, facilitating monitoring the record of storage and retrieval of material from bin.
2. Movement of cargo: Operations like issuing and transfer of cargo, material staging, stocking of produced load, supervising hazardous load are performed using SAP system(22).
3. Contriving and surveillance: Arrangement of stock in warehouse is completely optimised by using radio frequency monitors.
4. RF- Radiofrequency analogy: RF scanning tags are attached on all the mechanical tools and bins present in a warehouse thus, acts as a connecting tool between mechanical warehouse and SAP system(22).
5. Disseminated WMS (Warehouse Management System): operations under WMS are entirely unhampered by ERP (Enterprise Management System).

Being SAP System one of the highly sophisticated software, there are many online and offline courses available to get trained in SAP System as every enterprise hire only trained professionals for the management of SAP warehouse(20)(21).

With the aid of SAP IMS, one can supervise the quantities and price of stocks in all the storage locations of an organisation. Whereas, with the aid of SAP WMS, one can obtain an outline of the whole warehouse and thus can evaluate the current stock locations, movement of stock, complete bulk size of the goods and also be able to examine the storage bin level(22).

- **Internet of Things (IoT):**

IoT is a technology that is used to collaborate various gadgets through the internet, thus generating a flow of information between them. This technology untangles tedious operations like pallet tracing, analysis of data and prognosticating(23). This technology aids in the functioning of automated devices like cobots, AGVs and AMRs with the remote controllers and computer monitors. Different components of IoT include internet (LAN) connection, sensors on each device, radiofrequency tags, IT processors and distinctive identification for each device in a warehouse(24). Functioning of IoT enabled warehouse is given in **Figure 9.**

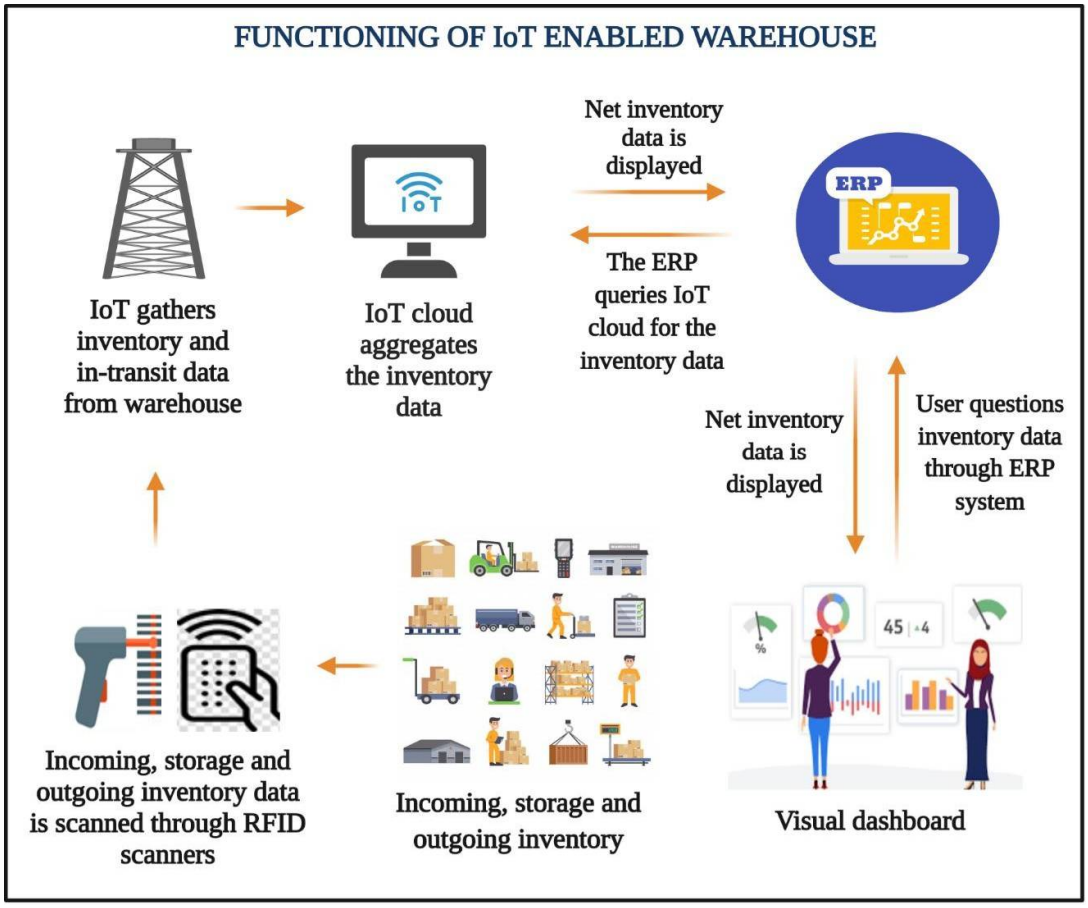

Figure 9: Functioning of IoT enabled warehouse

Radio frequency identification (RFID) is one such technology that underpins IoT. Radio frequency tags

are made to affix on racks, totes, vessels, transportation vehicles, pallets, bins, and all the devices used to warehouse which in turn expedites tracking operations(23)(24). RFID provides increased transparency of warehouse by providing real time data of the inventory. IoT and RFID have become a revelation in the automation of warehouse due to their quick actions and are also economical to minor scale industries (24).

CONCLUSION

Warehouse automation is increasing widely in many small-scale and large-scale organisations. The expanding utilisation of automated machines, robots and applications in warehouse management lead to many discoveries in the field of automation. Increasing automation lead to increased quality, speed of loading, retrieving, transportation and shipping of the finished products which in turn lead to increased turnover of the industries. Automation has also resulted in improved safety of the products and employee as continuous risk assessment of warehouse is made easy by utilisation of automated machines. Minimal warehouse accidents are observed in most sophisticated automatic warehouses. Automation process can never be a prompt action, it is an unremitting process depending on the demand and supply of the organisation. Sustained collaboration of man force and robots and software applications abet in maintaining an eminent automated warehouse management system.

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