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Identification of Hazard for Securing the Safety of Unmanned Parcel Storage Device System Using Robot Technology

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Abstract

The development of the fourth industrial revolution and logistics 4.0 related technology, the growth of the e-commerce market, and the transition to a non-face to face society due to the pandemic are accelerating the growth of the logistics industry. Due to the growth of the logistics industry, various services are emerging to meet the requirements of the market, and research and technology development related to the parcel storage, which is an important element of the last mile service, is also underway. In the past, if it was difficult to deliver the goods directly to the recipient, the parcel storage installed near the delivery location was used, but the usability was not good and the storage of the goods was limited. In addition, the existing parcel storage has a lot of functional limitations compared to the advanced logistics technology, so it is necessary to develop a device that improves it. Therefore, this study conducted to secure safety for unmanned parcel storage devices with robot technology to improve usability and functionality in line with the advanced logistics industry. Based on ISO 10218, an industrial robot related standard, risk identification studies were conducted to derive results that contribute to the development of devices under development.

Keywords: *ISO/TS 15066, Unmanned Parcel Storage, Last Mile, Robot System*

1. Introduction

With the advent of logistics 4.0, which is centered on artificial intelligence, big data, IoT, cloud, and robots that emerged with the Fourth Industrial Revolution, related technologies are being actively developed [1]. In addition, the growth of the e-commerce market and the growth of the logistics industry due to the pandemic are accelerating the construction of efficient logistics transportation systems using advanced technologies. With the advent of logistics 4.0 like Figure 1, the innovation and change of the logistics industry is rapidly taking place. The key technology related to logistics 4.0 is to expand the connectivity through the fusion of logistics and ICT digital technology and maximize the efficiency of logistics through automation systems such as robots. Robot-related technologies for automation are being actively developed [2], logistics warehouses are becoming larger to handle the ever-increasing cargo, and new concepts of services such as lastmile and

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Fulfillment are emerging, reducing the labor burden of workers and establishing a system to classify or transport cargo around automation robots [3].

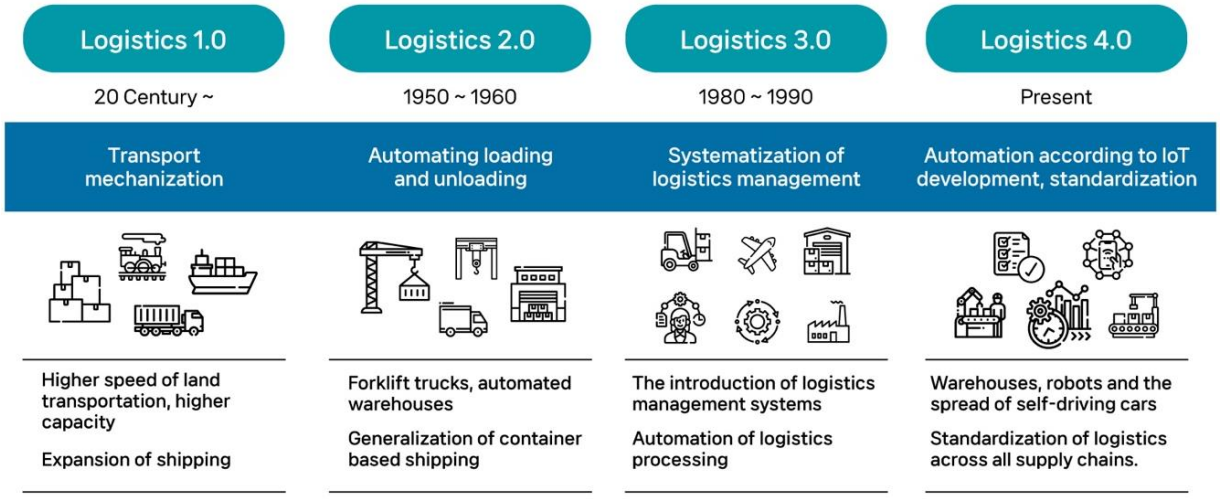

Figure 1. Development logistics and logistics 4.0

With the advancement of technology, automation-related technologies are expected to increase further, and government policy movements and related internati onal standards are being actively studied [4]. In particular, with regard to automation, standards related to rob ots have been established as Table 1 to reduce the labor burden on workers and improve work efficiency, and standards dealing with related technologies are expected to emerge due to the growth of the robot business a nd the advancement of technology.In addition to the advancement of technology, it is necessary to identify re levant standards and develop systems that comply with them for safer technology utilization and field applica tions.

Table 1. ISO standards for industrial machinery and robots

No	Standards	Contents
1	**ISO 12100**	It is a representative safety standard for industrial robots based on general industrial robots.
2	**ISO 12100**	It explains the concepts and safety requirements related to cooperative robots, provides pressure and force limits according to body parts as an appendix, evaluates the risk of cooperative robot systems, and provides parameters for safe use of robots.
3	**ISO 13489**	It is a representative functional safety standard that is comprehensively applied to mechanical systems, and it defines reliability related requirements for safety related control systems.
4	**ISO/TS 15066**	It is the highest international standard in all machinery fields and contains comprehensive safety design guidelines required for designing machines.

2. Definition of Problem

2.1 Research of Parcel Storage

A parcel storage device is a device used when it is difficult to deliver directly to the recipient or when the parcel must be stored for a certain period. It is a device used at the last stage of the logistics transportation process [5]. Recently, with the advent of Last Mile and the advancement of services, various researches and

attempts to apply technologies related to parcel storage devices have been made [6]. Recently, technologies related to parcel storage devices have been developed to improve delivery efficiency. [7]. A study on a parcel storage device that incorporates IoT technology was also conducted [8], but it was focused on security. A study on the development of a storage system to improve the usability of a parcel storage has been conducted, but it has been focused on the concept of a system for storing goods. A study on a smart delivery box with IoT function was also conducted, but it was focused on cargo recognition and invoice information confirmation [9]. Various studies have been conducted to improve the usability of the parcel storage device, but most of the studies have focused on the implementation of the function, and there have been no cases of applying automation technology.

The unmanned parcel storage device to which the robot technology is applied, which is the subject of this study, is a state-of-the-art device to which automation technology is applied to automatically move the cargo inserted into the device to the location to be stored, unlike a general parcel storage box. The manipulator technology capable of the robot locating inside the man less delivery product storage apparatus is the phase, left, right movement and rotation is applied to. And the transfer of the shelf in which cargo is put is possible and the function which is like the manipulator of robot is performed. As advanced robot technology, which is different from existing parcel storage, has been applied, research is needed to analyze standards related to robots and secure safety in developing devices.

2.2 Research related of ISO 10218

Various standards related to robots are emerging, and as the situation of robots and humans collaborating increases due to the development of technology, standards for this are being discussed [10]. Recently, ISO/TS 15066 is being prepared for introduction due to the increase of cooperative robots, and research based on related contents has been conducted, but it is still in the early stages and needs much research and discussion [11]. In addition, ISO / TS 15066 focuses on cooperative robots, making it difficult to fully apply them to general robots. ISO 10218 is a standard for industrial robots, and it proposes safety requirements and provides related contents to enable safer robot utilization [12]. A study was conducted to identify robotic hazards based on ISO 10218 [13]. The study proposed a safety assessment to enable the safe use of robots, but the research was focused on large robots used in designated cells. A study on design considerations for a safe human-robot collaborative workplace was also conducted [14], and research was conducted in the workplace from the perspective of humans and robots but focused on human-robot collaborative safety issues based on standards.

As the use of robots has increased, various studies based on related standards have been carried out. Most of them deal with safety-related proposals and collaborative spaces between humans and robots in consideration of safety accidents caused using robots. In addition, the research related to the unmanned parcel storage device, which is the subject of this study applied with automation technology, has not been conducted. The unmanned parcel storage device, which is the subject of this study, requires the application of ISO 10218 related to robots by applying robot technology for automation. For this purpose, the analysis and definition of the application of the ISO 10218 standard should be focused on the development technology.

2.3 Objective and Scope

The purpose of this study is to develop a safer system based on international standards in the development of unmanned parcel storage devices with robot technology developed to meet the development of logistics technology and market requirements. For this purpose, the robot-related standard was analyzed, and the robot technology of the unmanned parcel storage device, which is the subject of the study, was analyzed. Based on the surveyed standards, the ISO 10218 standard applicable to the target technology and related matters were defined and the results were derived and applied to system development. In this study, we propose that the system under development can be developed as a technology that secures safety based on international standards.

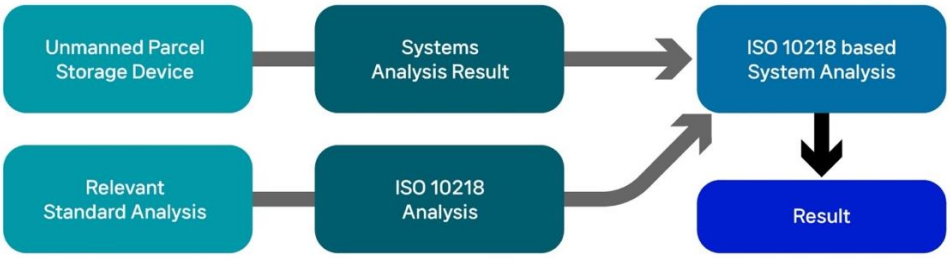

Figure 2. Objective and Scope

3. Development for securing the safety of parcel storage devices

3.1 Definition of the parcel storage system

The unmanned parcel storage device, which is the subject of this study, has been applied with various advanced technologies. Among them, the robot technology that automatically transfers and loads the goods is the most distinguished from the general parcel storage device. The development technology consists of a system in which the internal robot automatically transfers the goods to deliver the goods that need to be stored or the goods being stored. The robot transfer technology in the storage device is a technology to maximize the usability of the user's device. It is automated to reduce unnecessary processes and improves the problem that the user loads the goods directly in the existing device. In addition, unmanned courier storage devices with robot technology are expected to be used in the logistics industry because various technologies are applied to improve usability and logistics efficiency besides robot technology. The design and development based on the safety standard should be carried out so that it can be configured as a safe system at the same time as meeting the target function.

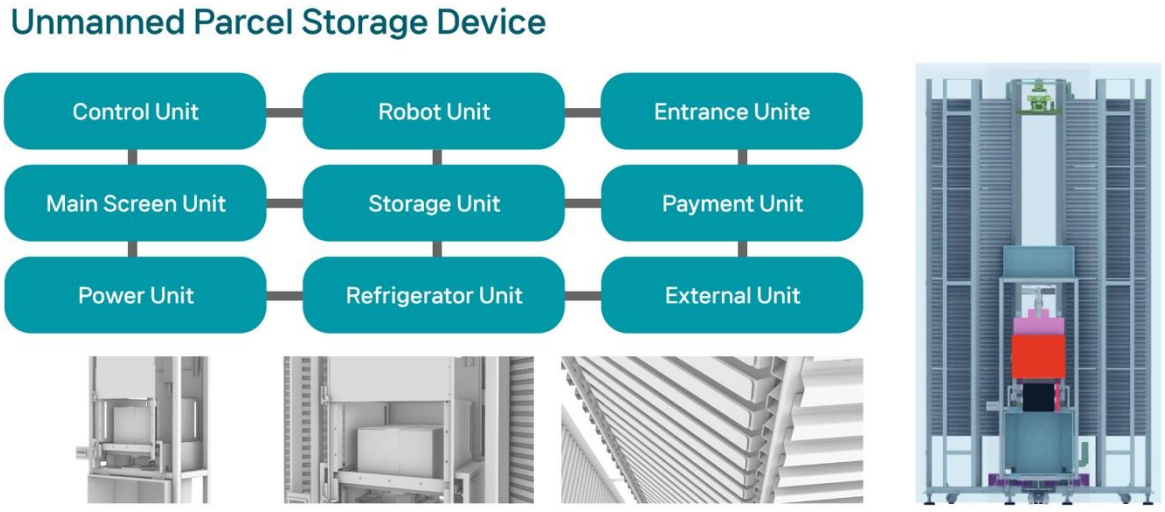

Figure 3. Unmanned parcel storage system configuration

3.2 ISO 10218 analysis

ISO 10218 is composed of safety-related contents for industrial robots and suggests that safer robot utilization is possible (additional research). ISO 10218 proposes, as shown in Table 2 for four modes of operation, that workers are not exposed to unacceptable hazards defined by the standard. At least one of the four criteria must be met, and if the operator is i

nvolved, the robot must visually indicate that it is working cooperatively. ISO 10218 also defines the causes and consequences of each hazardous source in addition to the four modes of operation for safety. The hazard ous source is defined as a mechanical hazardous source, an electrical hazardous source, a heat hazardous sou rce, a noise hazardous source, a vibration hazardous source, a radiation hazardous source, a material / water h azardous source, an ergonomic hazardous source, It is composed of several hazardous source definitions. The classification according to each risk source is as shown in Figure 4.

Table 2. Proposed four driving mode of the ISO 10218

No	Definition	Recommendation
1	**Monitored safe stop**	Operator has to stop operation of robot in inside of the workspace entry
2	**Manual control**	Manual control of the operator's robot movement should be possible
3	**Distance and speed monitoring**	The robot must be operated within a specified distance and speed
4	**Force and power limitation**	In the event of a contact accident, the impact should be limited

Figure 4. ISO 10218 10 risk configurations

3.3 ISO 10218 based system analysis

The unmanned parcel storage device, which is the object of this study, is composed of an automation syst em based on robot technology. For this purpose, I have defined the risk source identification and safety relate d matters considering ISO 10218, and applied it to the development process to establish a safer system. Base d on the technical analysis results of the unmanned courier storage device, related items were selected based on the mechanical risk source, electrical risk source, ergonomic risk source, vibration risk source, environme ntal risk source, and other risk sources among all risk sources. The results derived from the analysis are refle cted in the specifications of the technology under development to improve the previously unconsidered items . The ISO 10218-
based risk identification results for improving the safety of unmanned courier storage devices are shown in T able 3. Among the identified risk sources, mechanical risk sources, ergonomic risk sources, and other risk so urces were found to have the greatest impact on unmanned delivery storage devices, and based on the define d risk sources, the results that could be derived in the event of a situation were predicted to prevent accidents in advance.In addition, the unmanned courier storage device, which is the subject of this study, is usually co mpletely isolated from the user, but in the process of maintenance and repair, it is necessary to consider the s afety of the worker and the robot.

Table 3. ISO 10218 analysis of unmanned parcel storage devices

Hazardous Source	Division	Result
Mechanical hazardous	- Normal or contingent motion of the end device or robot cell - Terminal equipment failure - Accidental operation of machine or robot cell parts during operation - Accidental operation of the machine involved - Loose clothes or long hair - Between robot arms and stationary objects - Operation or rotation of sharp tools on end devices or external shafts and on parts being processed and related equipment - Accidental operation of end devices or related equipment	- Crushing - Shearing - Cutting & Severing - Entanglement - Trapping - Impact - Stabbing or Puncture - Friction & Abrasion
Electrical hazardous	- Contact with electrical components or connections - Confusion due to several voltages in the system - Electricity (electron) - Contact with several components on the circuit	- Electric shock - Burns
Ergonomic hazardous	- Mis designed human, machine interface touch screen Too far or too high a user interface - Inappropriate location of the control unit - Incorrectly designed operation permission device - Wrongly Designed Locations - Careless operation of the control unit - Accidental operation of the control unit - Exposure of access difficulties and additional hazards due to improper position of the control device - Interrupting awareness of hazardous sources and situations due to insufficient lighting - Inner parts to block lighting - Position of HMI devices that are not convenient to view	- Fatigue - Impact - Falling - Loss of awareness - Stress - Consequence of human error
Vibrating hazardous	- Loose connections and fasteners, stops due to parts or eject parts	- Nerve injury - Vascular abnormalities
Environment hazardous	- design problem due to environment	- Derived fault - Unsafe reflex behavior
Other hazardous	- Unexpected behavior of robots, end devices or related machines - Unpredictable behavior of machine control devices due to electromagnetic interference or surge in energy supply - Stop command stops robot in incomplete cycle - malfunction of the controller and malfunction of the robot arm braking device accordingly - Unexpected behavior of robots, end devices, auxiliary shafts or related equipment - Failure of the protection device not working as expected - Failure of related machines not working as expected - Parts installed incorrectly, creating unexpected behavior and hazards - Fast-rotating parts break or deviate from the fastener	- Restoration of energy supply after interruption - External influence on power - Unexpected maneuver

- Destruction or warping of mechanical elements due to overloading of robotic arms or related devices
- Failure of the part fixing device
- Falling or overturning of unfixed robots or related elements
- Accident handling during commissioning or disposal
- Possibility of parts falling off if not properly attached or cleaned - Lack of lighting in operator area or robot cell

4. Conclusion

The purpose of this study is to conduct an international standard-based risk identification study to secure the safety of unmanned courier storage devices with robot technology, and to analyze using ISO 10218 based on the target technology. In consideration of the characteristics of the unmanned courier storage device technology to which the robot technology is applied, the results of defining the issues that may affect the risk sources of ISO 10218 were derived, and the results derived to be considered in the development process were proposed in the system development process. The unmanned courier storage device to which the robot technology is applied has a higher level of automation technology than the existing courier storage box, and is a device that can be used in various fields besides storage of goods for courier service.This study aims to contribute to the establishment of a safer system through research, and to conduct a safety analysis on the target system based on the identified risk source standards in the future to conduct research to improve system safety.

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