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A STUDY OF SAFETY MANAGEMENT USING WORKING AREA INFORMATION ON CONSTRUCTION SITE

Soungho Chae
Kajima Technical Research Institute
Tobitakyu, Chofushi, Tokyo, Japan
chae@kajima.com

Tomohiro Yoshida
Kajima Technical Research Institute
Tobitakyu, Chofushi, Tokyo, Japan
yoshidto@kajima.com

ABSTRACT

The authors discussed on the development of a safety management support system to prevent construction site accidents using working area information. The past disasters on heavy equipment were evaluated to clarify the causes of the accidents, and the functions for support system to prevent collision were defined. The design of the system was proposed with working area from RFID technology that is given the role from the defined functions. A prototype was developed with active type RFID tag from the basis for the functions of support system. The RFID tag data was collected in actual construction site, and it was clarified that the prototype is applicable to estimation of working area for the prevention of collision accident.

KEYWORDS

Safety Management, RFID, Working Area, past disasters, collision accident

1. INTRODUCTION

In recent years, more than 27 thousand workers have been accidentally injured on construction site in Japan, despite the decreasing of the accident rate [1]. The several accident prevention programs, tools, and obligations have been developed, and construction sites using the prevention methods. However, many site managers recognize the continuing need for measures to ensure the job safety.

Construction site has characteristics different form the working environment of fabricating lab. The characteristics are the working conditions changing with project process, the improper use of equipments, the difference of actual safety planning according to project, etc. The characteristics of construction make the clarification of human-error notably difficult.

The human-error is defined that a planned sequence of mental or physical activities fails to achieve its intended outcome [2]. The working planned sequences and safety are required for the workers. Such a working atmosphere may be the cause of a diminished attention to hazard.

In this study, the authors intended to propose a management system which alert worker to the dangers of hazard based on the estimation results from the working area information.

The objective of this paper is development of functions to prevent collision accident of a worker with heavy equipment and evaluation of a prototype to estimate working area in actual site. The past disasters database was analyzed to developed the functions, and active type RFID technology was used to estimate the working area of workers and heavy equipments.

2. ANALYSIS OF PAST ACCIDENTS

2.1. Data collection of past accidents

Generally, the information about the occurrence situation of accident which needs medical attendance of more than four days has been recorded in Japan. The information categorized for each accident offers the information keys for defining the human-error which becomes a source of accident. The authors analyzed the past accidents information, in order to define the basic functions of the support system.

In this study, the collision accident of a worker with a heavy equipment was selected as the target, and the past accident information was colleted with the book tile of "study from case example – safety measure" by JCSHA [3]. The authors selected the cases which had a construction machine, a power material handling equipment, and a power crane as the accident initiating objects, and the number of selected past accidents was 31 cases from 138 cases.

The database of the collision accidents was built in order to analyze the factors of each accident from the collected information.

2.2. Modelling of accident factors

The collected data of accident factors on the database was modelled for design of preventing system. The authors used FTA (Fault Tree Analysis) as the modelling method. FTA method is a tool for analysing, visually displaying and evaluating failure paths in a system [4].

Figure 1 shows a FT model of the collision accident which is made on the basis of the collected data.

The authors set up the three fundamental functions required for a support system on the basis of the collision accident FT model. The followings are the functions.

1) Secure time for emergency stop

This function prevents the operator's mistakes of emergency stop which is caused by delayed awareness of the worker's location.

2) Proffer information for situation recognition

This function prevents the operator's misjudgement of situation which is caused by unawareness of workers.

3) Confirm behaviour for attention

This function prevents the worker's incaution to hazard which is caused by disregard of work process.

3. DESIGN OF ACCIDENT PREVENTION SYSTEM USING WORKING AREA

3.1. Information for preventing accidents

The authors defined the information with which the prevention system should provide workers, in order to make the functions operate. In construction site, because the different work for each worker is done, the required information about safety also changes with each individual. It is necessary to communicate updates and changes appropriately and on a timely basis.

For example, the supervisor who performs a safety management needs information, such as a location of heavy equipments, allocation of workers, process of working, etc. The operator who controls a power-shovel needs information, such as an approach distance of worker and other equipment, operating procedure of emergency stop, defect factor of machine, etc. Therefore, it is necessary to build a system which can provide the information to each worker form the collected situation data.

In this study, the working area of worker and equipment was taken as a prerequisite for the required information, and it was summarized what kind of system is required in order to apply the information in preventing collision accident.

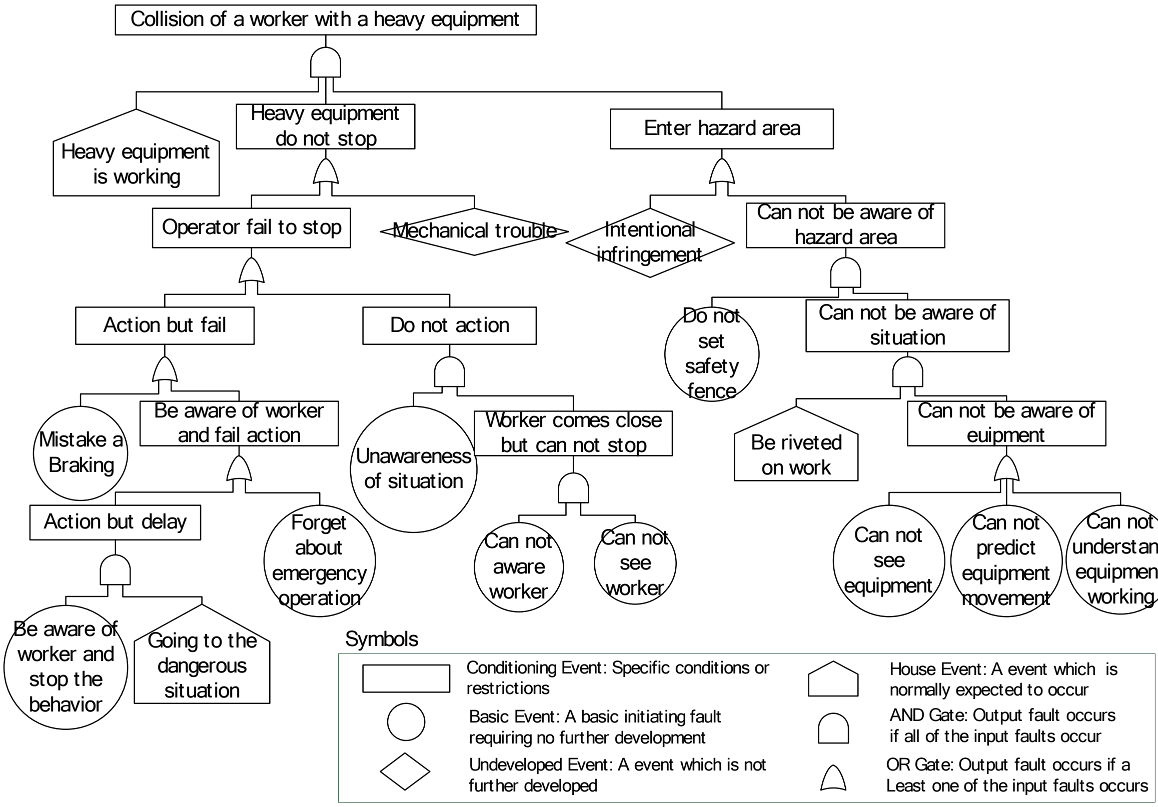


Figure-1 A FT model of the collision accident

3.2. Prevention system design

The support system for preventing accidents was designed on the basis of the defined information for the fundamental functions. The support system is composed of three parts, which are the data collection, the data analysis, and the data sending. The RFID (Radio Frequency Identification) technology was selected as the method of working area data collection. The authors have suggested monitoring method of working area with RFID [5] [6]. Followings are the elements which make up the system.

1) RFID tag

This element is used in order to emit the ID (Identification) number of an object. The object which need ID number are heavy equipment, worker, and specify place.

2) RFID Reader

This element is used in order to receive the ID number from the circumjacent RFID tag. The RFID reader is installed on the specify place and the heavy equipment. The existence area of object which has the received ID number is estimated by the installation position of RFID reader. The existence area of the RFID reader installed on the heavy equipment which moves in the site is estimated from the ID number of the tag on specify place.

3) Data Communication System

This element is used in order to send the ID number data collected from the RFID reader to the administrative server. The communication module is incorporated in each RFID reader, and the administrator server can classify ID number for each RFID reader. The RFID reader of heavy equipment which moves on the site needs to use a radio communication module.

4) Warning system

This element is used in order to send the signal to the dangerous situation. The line for sending signal need to have the capability delivered without delay. The interface for operator and worker to recognize a warning signal has a personal mobile device, warning device, shutdown device, etc.

5) Administrative Server

This element is used in order to seamlessly estimate the risk level of site situation with the ID number data from the RFID reader. The estimation refers to the RFID device installation position, ID number of each worker, feature parameter for alert, etc. which are the information inputted into a system preliminarily.

4. EXPERIMENTAL RESULTS

4.1. Collection of RFID data

The authors performed the RFID data collection in order to develop the preventing system. The data was obtained from hydraulic excavators and workers.

The RFID equipment used was composed of readers and receiving signals from the tag and active tag with a battery embedded. The operating frequency of the reader and tag is 315 MHz and maximum detection range of about ten meters. The detection range can be adjusted by change of radio wave signal strength. The reader has wireless LAN function which is operated by ad hoc network mode for transmitting collected tag data to the administrative server. The ad hoc network mode is a network connection method which is associated with wireless devices without base station. It is an effective means in construction site where broadcast of radio waves from a base station to wireless devices is difficult. Table 1 shows the RFID specification.

Twelve readers and twenty-seven tags are set in the site and collected data. The area of the site was about 1,722 m^2 (82 m by 21 m), the depth of excavation was about 10 m. Figure 2 shows the situation of the site and the installed RFID devices.

Five readers are placed on the guard rail installed in gantry and two readers are placed on the temporary beam of excavation area. A reader is installed on the each heavy equipment which is a Crawler Crane with Clamshell Bucket, a midsize Hydraulic Excavator, two compact size Hydraulic Excavators. Each reader sends ID number of the tag to a server with own name, when the signal of a tag has been recognized in the set-up area.

Eight tags are placed on the nearby guard rail of the readers, five tags are placed on the around temporary beam of the readers, a tag is attached in every one helmet of ten workers each, and a tag is attached in the every one heavy equipment.

The data collection was performed in about eight hours from 8:00 am to 5:00 pm and the all reader's data was arranged in time series of one second interval. Table 2 shows the results of collected data.

Table 1 RFID specification

Reader	Size	100 by 120 by 115.2mm	
	Weight	190g	
	Power	3W	
	Frequency	RFID	315MHz
		Wireless LAN	2.402GHz
Tag	Size	34 by 54 by 9mm	
	Weight	14g	
	Power	9mW	

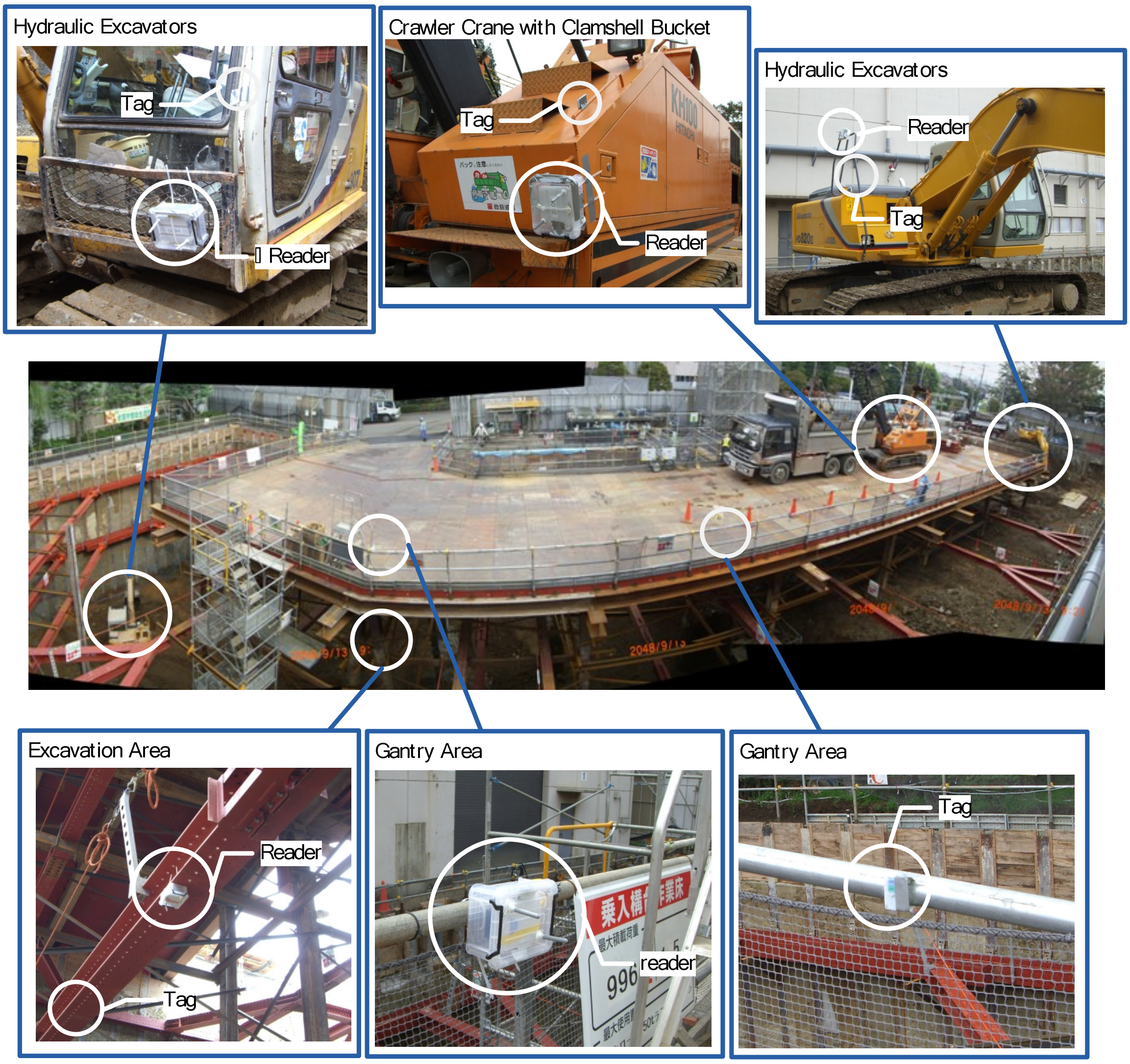


Figure-2 Pictures of construction site and installed RFID devices

Table 2. Results of collected data

Attached Place	Gantry Area					Excavation Area		Crawler Crane	Midsize Excavator	Compact Size Excavator	
Reader Name	1	2	3	4	5	6	7	8	9	10	11
Total Collected Time (second)	31405	30911	30575	31266	31068	30175	30173	29895	31401	30216	30308
Number of Collections (Times)	30017	20624	27457	28333	23495	24847	26851	24345	21645	27253	26506
Maximum Collection Interval (second)	40	461	40	52	144	40	40	41	43	41	41

4.2. Analysis of collected data

The authors analyzed the relationship tag's location and RFID reader's collection data for the purpose of verifying how the reader which installed on a place and heavy equipment actually recognizes a tag in comparison with setup radio wave signal strength.

At first, we collected the data for verifying the detecting area of the installed RFID readers. A worker who is attached a tag walked on the gantry for about ten minutes and data from the five readers was collected. Figure-3 shows the results of the data.

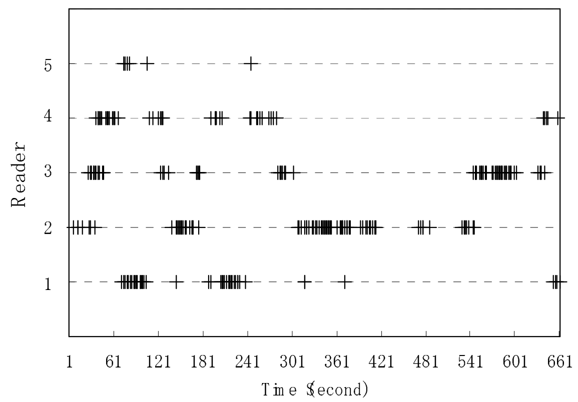


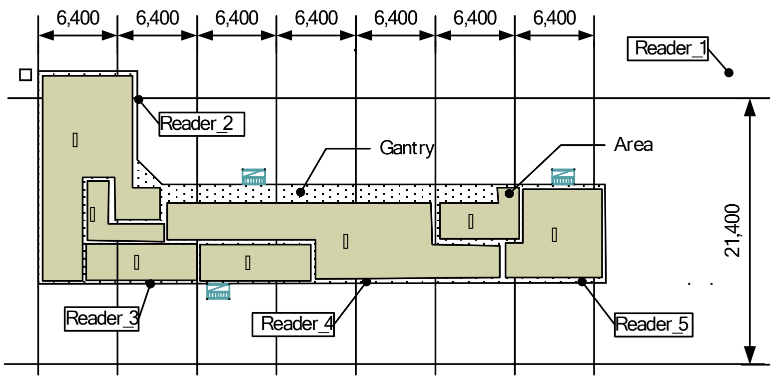
Figure 3. Results of collection data for verifying the detecting area on the gantry

The collected data of the readers was compared with the actual worker's position which was confirmed by videotape at intervals of one second. The detection areas of each reader were plotted on the gantry (Figure 4).

From the result, it was confirmed that the recognition of a tag followed the setup area in the near position from the reader. However, in the place where the position of a tag is distant from the reader, the tag was recognized simultaneously with the other reader which installed nearby. It is possible to estimate six working areas by using the each reader's recognition result on the gantry of the experimented situation.

Moreover, although the each area to estimate has an irregularity form, it is possible to monitor the approach situation of the worker to heavy equipment and to send warning. For example, when the crawler crane is working in area-4, area-4 is set as the working area which only the authorized worker can enter, area-3 and area-6 which become the operation range of the crawler crane are set as the dangerous area. Area-1, Area-2, and Area-5 which a worker can move to area-4 is set as warning area, when a worker is in this area, it is possible to prevent a worker going into a dangerous area involuntarily by sending the information of the crane.

The authors collected the data for verifying the detection area of the moved RFID reader. Five tags are attached under the temporary beam located in about four meters height from the excavation level. A worker with a RFID reader which installed on the excavator walked on the excavation area for about eight minutes and data from the five tags was collected. Figure 5 shows the results of the data.



Area	Detected Reader
[illegible]	Reader_2
[illegible]	Reader_2 and Reader_4
[illegible]	Reader_3 and Reader_4
[illegible]	Reader_4
[illegible]	Rreader_1 and Reader_5
[illegible]	Reader_1

Figure-4 Division result of the gantry area according to the detection data

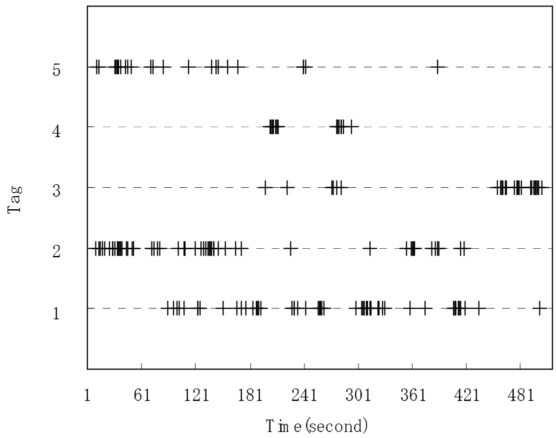


Figure 5. Results of collection data for verifying the detecting area on the excavation

The collected data of the reader was compared with the actual worker's position which was confirmed by videotape at intervals of one second. The detection positions were plotted on the ground level of excavation area (Figure 6).

From the result, it was confirmed that the recognition positions of each tag are located not only around the tags but also almost throughout the excavation area. This is partly because the earth retaining wall reflected the radio wave of RFID and the recognition range became in irregular.

The recognition results of twenty-seven tags for each installed RFID reader was arranged according to the time series, and locational relation of heavy equipments and workers was estimated based on the data.

For example, the reader of installed on the compact size excavator working on the excavation level recognized tags which was attached in excavation area, other compact size excavator, worker in excavator (Figure 7). Moreover, the reader recognized the tags attached in gantry located in the upper side depending on the moved place. It was possible to estimate the approach situation of excavator and worker in the excavation level with the experimental data.

5. CONCLUSION

The past collision disasters of a worker with a heavy equipment was analyzed and the functions were developed. Experiment for data collection was performed with a prototype, and the estimation of working area was verified.

The results showed that it is necessary to improve the estimated accuracy of working area and to integrate the functions into the management architecture for utilization of this system.

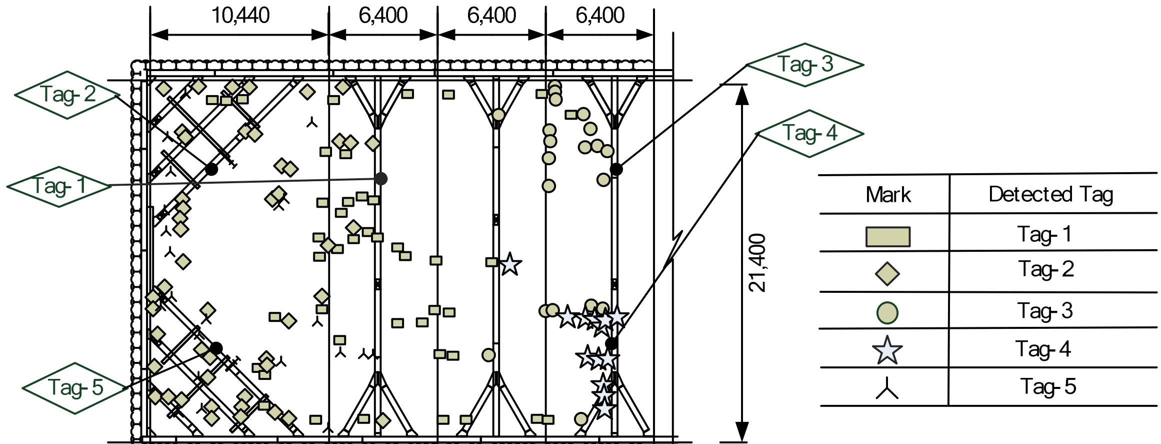


Figure-6 Division result of the excavation area according to the detection data

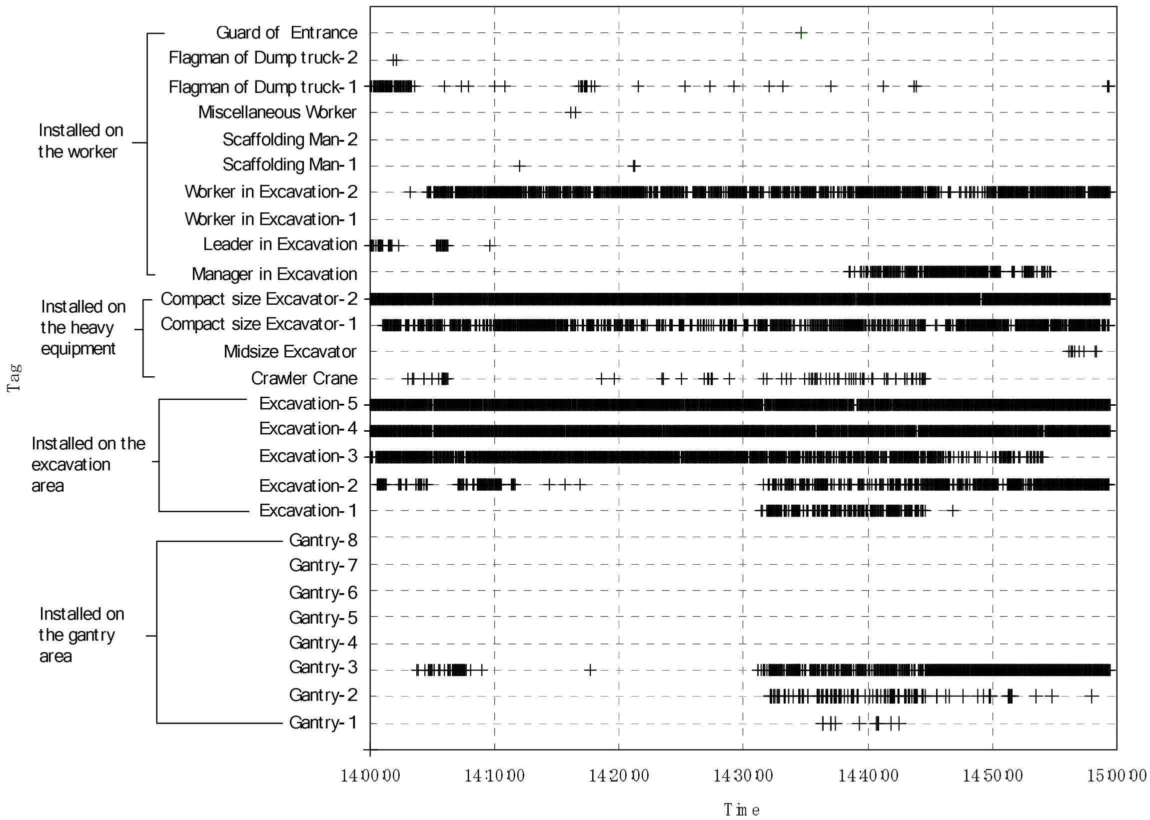


Figure-7 Collected tag data of a reader installed on the compact size excavator

6. ACKNOWLEDGEMENT

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