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ON IMPROVING WORKING SAFETY: A REVIEW OF SOME RFID BASED SOLUTIONS

Sanja Bauk
Faculty of Maritime Studies, University of Montenegro
Dobrota 36, 85330 Kotor
Montenegro

Radoje Dzankic
Faculty of Maritime Studies, University of Montenegro
Dobrota 36, 85330 Kotor
Montenegro

ABSTRACT
The paper contains a review of secondary literature resources on RFID-Radio Frequency Identification based occupational safety solutions in harsh environments with emphasize on seaports. It also offers a review of available commercial solutions in this field. The combinations of so-called three points (helmet, vest, shoes) PPE-Personal Protective Equipment and active/passive RFID tags for tracking workers in real time or pinpointing their positions periodically are considered. The communication channel between workers' body area network and fixed readers monitored at strategic points, e.g., at crossroads at seaport perimeter and/or moving readers installed into port manipulative and transportation devices, e.g., forklifts are discussed, as well. The suggestions for more extensive adoptions of such solutions are given, especially for the seaports which function in transitional environment which commonly suffers the lack of contemporary smart working safety systems.
Keywords: RFID, PPE, seaport

1. INTRODUCTION
Seaports (hereafter ports) tend to be associated with water and air pollution and soil contamination problems related to dust and noise, generation of waste, dredging operations, warehouse storage of hazardous substances [1], etc. Therefore permanent, real-time, monitoring of sea, air, and soil contaminants is recommended in order to protect the port ecosystem and workers' health [2,3,4]. Besides the mentioned emerging environmental problems, ports are dangerous places for on port workers and pedestrians in terms of operational risks connected to un/loading operations, managing on port traffic and transportation, handling manipulative equipment, warehousing, etc. It is the duty of an employer to protect the health and safety of workers and to improve occupational safe systems, but unfortunately, the accidents in seaports are not rare. On the contrary, due to the statistical data [5,6]: "The estimated annual accident rate for all direct on-port employees was 1.1%, or 1,100 per 100,000 employees; an employee of a direct on port company is more than fifty times more likely to have an accident (across all severities) in comparison to an employee based in office." The last stated is worth for the UK. Furthermore, due to the findings given in [3], 83% of 471 analyzed ports accidents (in different countries) occurred in the past 20 years, and 58% in the past decade. This data reveals a worrying trend in the frequency of accidents. It means that safety measures in various aspects of port operations are to be improved. The reason for the growing number of accidents might be caused by the considerable increase in the ports' turnover. On the other side, the relatively low turn over at developing ports in transitional economies (e.g., in Montenegro, SEE) should be in favor of workers'

safety, even there is no official statistical data concerning this issue due to our best knowledge. Nevertheless, improving safety measures is something what must be done. The appropriate info-communication solutions, e.g., junction of PPE and RFID technology, should be outspokenly adapted at the ports terminals, including those which function in transitional economies.

2. THE PPE AND RFID: RESEARCH WORKS AND READY-MADE SOLUTIONS

In this section, firstly, three ways of using RFID technology for identifying, localizing and/or inspecting the functionality of PPE at the industrial working sites, will be presented. These methods are primarily presented through the original academic research papers. The first one is developed for the needs of the construction industry [7], but there are no obstacles for its implementation at ports. The second one is applied at port [8,9,10]. The third one is designed as a prototype with the intention to provide a permanent PPE traceability, or real-time monitoring, and checking whether PPE is correctly used or not [11].

Scenario 1: Before entering the working place, a worker has to pass through the control gate. The worker's ID, fingerprint, and PPE must be uniquely identified. The intelligent system and user interface provide real-time feedback to the worker. The system is able to recognize multiple tags and fingerprint scan simultaneously, thus the worker is immediately notified if the ID or fingerprint are not proper ones, and/or which PPE component(s) is(are) missing. Once the worker has been properly identified and proved to be wearing the required equipment, the turnstile at the terminal entrance opens. Otherwise entrance will be denied [7]. The main shortcoming of this solution is the impossibility of locating and monitoring workers and their PPE pieces after passing through the gate, unless the whole working area is covered by the sufficient number of the long range RFID readers. This system should be used not only for the worker's safety, but also against thefts and illegal working on the site.

Scenario 2: In this case, assuming that the worker has passed the identification and PPE control at the entrance gate, the CCTV (Closed-Circuit Television) system installed at the terminal provides continuous monitoring in order to discover if the worker properly wears the PPE on port (Port of Cagliari, Italy). In the case of non-use, or improper use of PPE, the technician responsible for the video surveillance will warn the worker by sound or text message alarm [8]. Wearable sensor network in this case consists of passive/active RFID tags/chips which provide the ID and ambient light and temperature (helmet), and worker's plantar pressure and acceleration (shoes) data. This model has been recently re-engineered towards using Web GIS (Web Geographic Information System) and IoT (Internet of Things) concepts [9,10].

Scenario 3: This system can be treated as a novel one in comparison to the previously described systems. It is composed of BAN (Body Area Network) that collects information from the RFID tags by the readers located throughout the workers' clothing. The central unit microcontroller processes the data and transmits them by radio module to the external mesh ZigBee network composed of the set of end nodes (workers' BANs), routers, and the coordinator. The coordinator collects and stores the data coming from the end nodes, configures nodes and performs synchronization. End nodes are the critical part of the system. They are composed of central unit microcontroller, radio module and RFID readers. The readers are located at strategic points in the clothing, since the technology used allows them to be read at close range (ca. 0.5 [m]) at a frequency of 125 [kHz]. The detection rate clearly increases when the antennas of the reader and the tag (embedded to a 3 point PPE piece) are in parallel, while it decreases dramatically when the antennas are oriented orthogonally. The main shortcomings of the system are as follows: it is not utterly unobtrusive, and it is not easy to establish a proper communication between RFID tags and readers over the end points, here workers' BANs in terms of determining accurate positions of PPE garments [11].

2.1. Providers of the ready-made solutions

Besides research attempts to resolve problem of optimal merging PPE and RFID, there are a number of ready-made solutions in this domain. Some of the providers of these solutions are listed below:

- *MSA The Safety Company* (www.msafety.com);
- *3M Science Applied to Life Company* (URL: www.3m.com/PPESafety);
- *Honeywell Enabled Safety Products* (URL: http://www.enabledsafetyproducts.com);

– *RFIDentity Intelligent PPE* (URL: http://www.rfidentity.com); and,
– *RFIDnordic Safety Tracking System* (URL: http://www.rfidnordic.se), etc.

Some more data on these solutions can be found on the above given web sites. More detailed descriptions are omitted due to limitations of the paper length.

3. THE PPE AND RFID SCENARIO PROPOSED FOR THE PORT OF BAR

A satisfying and an affordable PPE-RFID safety solution for the Port of Bar (Montenegro) individual needs, should be conceived upon the previously described solutions implemented in the Port of Cagliari [8,9,10] and the solution implemented at oil and gas industry at the North Sea [12,13,14]. However, some modifications are to be done [15]. Simplified, an active UHF (Ultra High Frequency) RFID-enabled worker's badge can transmit the ID number at preset intervals to the port's fixed readers. The readers work at EU standardized carrier frequency range of 868 [MHz] and offer a flexible platform to evaluate the identification and status of the RFID transponders by supporting EPC-Class 1-Gen2 standard. Worker's ID badge can be worn around the neck, attached to clothing or placed in the pocket, and it can be read up to 0.5 [km]. It allows the smart software system and RFID hardware to track the number-identities of the port worker (name, shift, job, education, training, etc.) at any time, as well as, in some cases, pinpointing the worker's location. The system memorizes the last seen location data of the worker. On the other side, each time the worker is in the range of the reader(s), approximately, within 10-15 [m], the control system will have the information on the status of passive RFID tags attached to the PPE, i.e., if they: work correctly; don't work correctly; or, don't work at all. Figure 1 shows an example of the worker who does not have a helmet on port, and whose shoe is damaged. The dashboard is user-friendly and provides options for tracking and tracing each worker over the port operational area. In such a situation, the worker must be alerted to go to the central for wearing/changing the PPE piece(s). All readers are connected via Wi-Fi or the port's Ethernet through which the status and the information returned can be read and stored in the beck-end server connected to the central control system.

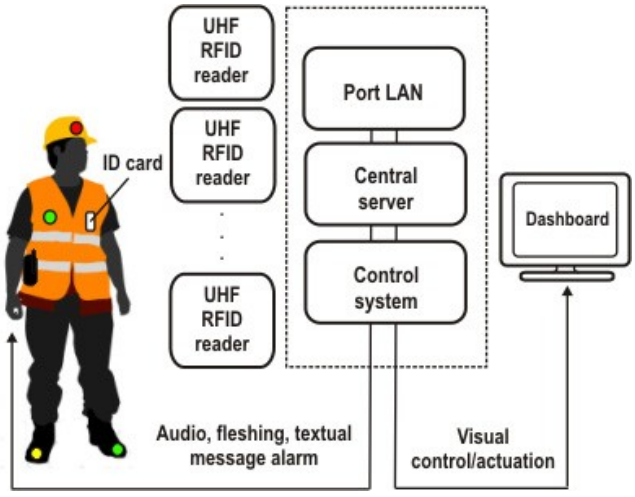

Figure 1. Scheme of the PPE-RFID solution proposed for the Port of Bar [15]

7.3. On the possibilities for providing interactivity with the environment

Workplace accidents involving moving vehicles (e.g., forklifts) are costing ports huge amount of money in terms of expensive downtime, investigations and increased insurance premises. Above all are fatal injuries and loss of human lives. Fortunately, the fatal accidents are not recently recorded in the Port of Bar, but this should not be excluded as a potential danger and therefore it should be prevented. There are several ready-made commercial solutions for reducing the risk of collision between moving vehicles and pedestrians/workers in the workplace, like: *Forklift Safety RFID Solutions*, *BodyGuard*, *Pedestrian Alert System*, *EGOpro Safety Move Proximity Warning Systems*, etc. They all improve safety through a proximity alert system for forklifts and pedestrians/workers. Main operating characteristics of these systems are (*IcnitaSafety*, http://en.icnitasafety.com/):

detection of pedestrians/workers in frontal (ca. 0.5-6.5 [m]), back (ca. 0.5-6.5 [m]), and side area (up to 4 [m]) of operation of forklift and warning forklift's driver (while maximum detection range can be adjusted smaller); alerting at the same time pedestrian/worker by visual and/or audible alarm; and, automatic reducing speed or stopping forklift (maximum speed is of 10 [km/h]). The system helps to overcome risks caused by factors such as driver inattention, poor visibility (e.g., blind entry/exit, warehouse aisles, etc.), worker non-compliance with exclusion areas around vehicles, collision between worker and moving vehicle at the common working area, etc. Future investigations at the Port of Bar should be extended toward PPE-RFID embedded into the port's prospective *smart* environment in order to increase overall level of occupational safety and environmental protection.

4. CONCLUSION

The paper considers possibilities of merging PPE and RFID at port environment with reference to the Port of Bar which functions for decades in transitional economy and suffers the lack of contemporary *smart* working safety solutions. Possibilities of employing PPE-RFID devices in reducing risks at the logical level and the level of physical communication channel between tags/chips and readers at the port perimeter are presented previously in [15]. Further research work should be directed toward examining in some more detail safety of interactions between on port workers/pedestrians and moving vehicles/heavy-mechanization/manipulative equipment, etc. These should be done with the aims of upgrading the overall level of corporation culture, occupational and environmental safety, and promotion of the developing Port of Bar as *green* and *safety* one at the permanently growing and developing market of maritime services.

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