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RADIOFREQUENCY IDENTIFICATION BY USING DRONES IN RAILWAY ACCIDENTS AND DISASTER SITUATIONS

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ABSTRACT

Today, railway operation procedures include the transportation of large amount of hazardous substances. Our research has been motivated by the desire to find concrete and urgent solutions to the safety issues of handling waste generated manly in case of accidents and disaster situations during the transportation of hazardous substances In order to ensure safety in the transportation of dangerous goods, and to facilitate the fast and efficient waste handling of hazardous substances released into the environment during unexpected events, we have elaborated a new method, in which we suggest the radiofrequency identification of dangerous consignments in case of disaster situations by the use of drones.

KEY WORDS

railway accidents, transportation of dangerous goods, waste management, radiofrequency identification, drone

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INTRODUCTION

DEFINING THE SCIENTIFIC PROBLEM

Disasters have always been the part of human life. Their severity, frequency, dimensions and global effects have increased to such extent that protection against them has become a task of highest priority and utmost importance today. The enormous damage caused by such disasters, which have serious economic and social effects, calls for the research into prevention possibilities, the issues and necessity of safe waste treatment [1].

Our research looks into the possibilities to ensure an easier identification of dangerous materials released into the environment during railway-related accidents or disasters, to minimise any consequent damage, and to enable the prompt responding to the effects of the generated hazardous waste. By approaching to waste treatment from the aspect of safety sciences, we focus on the environmental hazards caused by the inappropriate or delayed treatment of the generated waste.

The aim of the present article is to show the possibility of using the method of radiofrequency identification for the treatment of hazardous wastes, in the combined way as suggested by us. By using a drone equipped with an RFID reader, hazardous substances may be identified in a faster way, preventing the serious damage that may be caused by the release of hazardous wastes in the event of a disaster.

The present study consists of the following sections: following the introduction, Section 2 discusses the technical safety technology factors related to the transportation of hazardous substances. Section 3 presents the possible solutions of radiofrequency identification used in the transportation of hazardous substances. In Section 4 we make a suggestion to the specific use of drones in case of accidents and disasters to allow faster response and the prompt treatment of hazardous wastes. Finally, we present the results that have been achieved so far, formulate our statements for debate and our conclusions as well as our objectives of further research.

OBJECTIVES, STATING THE RESEARCH HYPOTHESIS

The European Union has specified the technical requirements of waste management in its policy and directives mutually agreed by its member states. Considering the results formerly achieved in this field, it can be stated that the fundamental technical-safety requirements must be ensured by a legislation which is in harmony with these directives and in accordance with the latest research results. It is very important that the members of the EU must cooperate in sharing information about the safe railway transportation of hazardous and other wastes. The purpose of this endeavour is to develop a safe method of waste identification and treatment in the situation of accidents or disasters by successfully using, as we proposed, the RFID-DRONE combination. Therefore, our objective is to examine the possible introduction of RFID identification in the railway transportation of hazardous substances. In the present article we wish to prove the hypothesis that the combined RFID-DRONE system can help to facilitate the recovery process and the mitigation of the harmful effects of the wastes of hazardous substances in case of a disaster situation.

REVIEW OF REFERENCES – WITH REGARD TO THE IMPROTANCE AND RELEVANCE OF THE TOPIC

Safety technology includes all technical and technological methods and procedures which aim to protect the life of a person/persons or the normal operation of an object/objects [2].

In case of waste management, this can be achieved by applying the results of technical sciences. During application, all elements which hinder the development, maintenance or introduction of technical safety technologies, or the possibilities to create its conditions, can be considered as influencing factors. The most significant element is the human factor, as it can cause serious damage in case of accidents or disasters which occur as a result of negligence [1].

All personnel having duties and responsibilities in the transportation of dangerous goods must receive appropriate training about the requirements on the transport of dangerous goods to the extent required by their duties and responsibilities, also considering the training requirements on public safety standards. Although the provisions of the relevant sections of the RID prescribe basic and special training, the safety issues of hazardous wastes generated in accidents are not covered even by such special training [3].

In our research, we consider it important that any unburned hydrocarbon or other special operational or transported liquid which can cause soil or water pollution in case of a disaster must be adequately treated in the course of the recovery process. The polluted area must be cleaned of all liquids and other substances which, by this time, will have become hazardous waste [4].

PRESENTING AND DEFINING THE TERMS USED IN THE RESEARCH

The knowledge of the following terms is essential for the understanding of the topic discussed in the present article:

Waste is any substance or object which the holder discards or intends to or is required to discard [5]. In other words, waste is any substance, solution, mixture or object which is generally not suitable for direct use, but which is removed for disposal through recycling procedures, storage in deposits, incineration or in any other ways [6].

According to our own definition, from the point of waste management, the substances declared by their holders as waste are those which:

- are returned to the spheres of production and consumption by various physical, chemical or biological procedures,
- are temporarily stored in comforted and safe deposits until the development of adequate recycle technologies, or degraded to their basic elements through physical, chemical or biological procedures.

Hazardous waste is the waste which has at least one of the hazardous properties defined in Appendix 1 of the Act on Waste [5].

ADR the European Agreement concerning the International Carriage of Dangerous Goods by Road.

RID the European Agreements Concerning the International Carriage of Dangerous Goods by Rail, its valid version coordinated with the ADR was released in Act LXXX of 2011.

UN number (UN ID): a four-digit identification number of substances and objects specified by the “UN Model Regulations” [6].

Dangerous goods: substances and materials the transport of which is prohibited by the RID or only allowed with certain restrictions [7].

UIC: Union Internationale des Chemins de Fer, (UIC, 16 rue Jean Rey, F-75015 Paris, France) [8].

Radio Frequency Identification (RFID): the reading of chip information carriers used in railway wagons with the help of radio frequencies from a safe distance, in an extremely high speed range or in the situation of an accident or disaster (author's definition).

Drone: UAV Unmanned Aerial Vehicle.

Mini drone: remotely controlled, small, unmanned, propelled robot plane with features that allow for a very versatile use (author's definition). For example an autonomous (3D movements ability) quad-rotor microcopter [9].

SAFETY-TECHNOLOGY ASPECTS OF THE TRANSPORTATION OF DANGEROURS SUBSTANCES

An increasing global crisis affecting every people in the world, with unstable social and political systems and modern migration processes resulted by the uncertain living circumstances and the effects of globalisation, as well as the various environmental disasters must also be considered at the transportation of hazardous substances. For the above-mentioned reasons, the system of railway infrastructure is exposed to increased risk, while its protection is difficult to ensure because of its geographical extension. Thus, if this critical infrastructure is used for the transportation of such materials which are dangerous in themselves even when they are stored, the transportation of these hazardous substances must be done with extreme care and expertise.

Experts of safety-technology research reveal an increasing number of uncertainties in connection with the storage and transportation of hazardous substances and their release into the environment. At the present time it can be observed that the factors influencing safety have taken different forms. There has been a shift of emphasis in the concept of safety, bringing into the foreground such aspects which used to be of secondary importance, but which are now freely generated creating a series of new problems.

Our age is dominated by the trends of globalisation, where divergences in the prospects of development, territorial integrity, moral libertinage, separatism, nationalism, chauvinism, and many other phenomena can deter or even prevent the continuous development of human societies in the long term, where the requirements of environmental safety should also be considered. Negative entities with decreasing moral inhibitions make certain members of the societies sink to formerly unseen depths causing irreversible damage to the environment. Based on the information that is freely accessible on the internet, now any person can be able to make a bomb or a weapon and order the necessary materials, which means that the security aspects of the transportation of hazardous substances must also be reconsidered [1].

RADIO FREQUENCY IDENTIFICATION USED IN THE TRANSPORTATION OF HAZARDOUS SUBSTANCES

THE RANGE OF GOODS THAT CAN BE IDENTIFIED BY THE SYSTEM USED IN RAILWAY OPERATION

The analysis of the past five years shows that the following types of substances have been involved in railway incidents in Hungary: 27 types of flammable liquid substances, primarily gasoil, petrol, hydrocarbon fuels, 11 types of gas, primarily refrigerated-liquefied carbon-dioxide, gas mixtures, and 15 types of acid, mostly sulphuric acid, hydrochloric acid, caustic soda and nitric acid.

Types of common hazardous substances which are transferred or temporarily stored for marshalling:

- Acids and bases: acryl-nitrile, sodium hydroxide (caustic soda), sulphuric acid, hydrochloric acid, nitric acid, ammonium hydroxide (ammonia)
- Hydrocarbons: petrol, gasoil, diesel, iso-butane
- Refrigerated gas mixtures: propane, butane, carbon dioxide
- Based on the European Agreements Concerning the International Carriage of Dangerous Goods by Rail (RID), Table 1 shows the proportion of hazardous substances in relation to the total transported volume.

Table 1. The distribution of RID classified hazardous substances in railway transport.

Explosive substances or objects	0,15 %
Compressed or liquefied gases, or gases dissolved under pressure or refrigerated gases	30,34 %
Flammable liquids	42,52 %
Flammable solids	0,08 %
Substances liable to spontaneous combustion	0,33 %
Substances which, in contact with water, emit flammable gases	0,00 %
Oxidising substances	1,29 %
Organic peroxides	0,00 %
Toxic substances	3,23 %
Infectious substances	0,00 %
Radioactive substances	2,83 %
Corrosive substances	16,05 %
Other hazardous substances and objects	5,95 %
Total	**100,00 %**

Experience has shown that instead of the examination of hazardous substances occurring in large quantities, it is better to examine the most dangerous and most traded substances, as from the point of safety-technology, they can well demonstrate the main features of the system.

In Hungary, for example, among the most dangerous types of substances, the following data shows the volume of radioactive hazardous goods in the first 10 months of 2014, from the point of wagon flow (SZIR R 629 – report queried from the internet):

- Number of wagons: 4,
- Total wagon mass: 300 ton,
- Total mass of goods: 188 ton.

This is a significant amount of radioactive waste which requires special transporting conditions in order to ensure safe trafficking.

Besides, in the past 20 years there have been numerous cases of hazardous substances being released into the environment, for example:

- a tank wagon filled with vinyl chloride derailed and overturned,
- a large quantity from two wagons of acryl nitrite ran off,
- the safety valves of 6 tank wagons transporting ammonia were damaged,
- a barrel filled with etil-iso-thiocyanate was damaged,
- 30 tons of residual fuel oil ran off,
- 1 ton of gas oil ran off from the locomotive with serial number M 61,
- the valve stub of a wagon filled with etil-amino under pressure cracked,

- 20 tons of nitric acid ran off,
- 30 tons of hydrochloric acid ran off,
- 30 tons of kerosene ran off,
- 150 tons of petroleum ran off,
- an unknown quantity of styrene ran off [10].

According to investigation reports, the main reasons for railway incidents include the following cases:

- Technical reasons: central valve leakage, failure of the unloading switch, dome cover gasket or lock cap gasket, safety valve failure/blowing.
- Goods handling problems: central valve/dome cover is open/loose, lock cap missing/loose, improper loading, overloading, improper cargo securing.
- Other reasons: freight-service problems, loading or theft damage, damage from acts of nature.

Considering the above reasons, the RFID-DRONE identification system surveying and monitoring the transportation of hazardous substances can help in the early detection of the major problems, and facilitate the recovery process after the incident by providing real-time information.

THE USE OF THE AUTOMATIC IDENTIFICATION SYSTEM IN CASE OF AN INCIDENT

Experience shows that unexpected situations are mainly caused by the technical failure of a tank wagon or tank container, therefore it is very important to identify the exact location of the means of transport and the type, the parameters and the condition of the substances transported in them.

For the above reason, in the railway environment the identification of the contents of vehicles transporting hazardous substances should not be based on the UN number and the hazard label alone, but it should also be made possible by using radio frequency identification from a safe reading distance. This way the transported substances could be identified in hardly accessible sites or in high speed ranges even when the hazard label is damaged or lost.

Wagons and tank wagons, which are not always in perfect technical condition, can be easily damaged during excessive use in railway operations, especially when shunting, or due to improper loading and unloading, and handling and closing of wagon lids or doors. Therefore, railway operation regulations must be extended, with regards to waste management, to cover the prevention of emergency situations, the instant remediation of the release of hazardous substances in case of a disaster, and the measures to be taken immediately to reduce the effects of pollution.

One of the methods also followed in Hungary is the use of special Vetter-cushions as rescue devices to prevent the release of large quantities of hazardous substances into the environment. This solution is also practical for the reason that it could be instantly used by the railway personnel on site to prevent the possibility of more serious damage before the arrival of special rescue units [11].

Our suggested solutions in such situations:

- It is important to ensure the safe identification possibilities and appropriate handling of dangerous wastes generated when dangerous goods contact with their environment during normal operations or accidents and disasters, as well as the initial forms of remediation, neutralisation and disposal on site before the arrival of the special personnel and infrastructure.

- The on-site identification of wagons transporting hazardous substances should not be based on the UN number, the hazard label or the internet query of the SZIR R 629 report only, but also on the method of Radio Frequency Identification (RFID). For example, in the incident shown in figure 1, RFID identification could have provided immediate information about the properties of the transported goods.

Figure 1. In this situation only the RFID technology could provide immediate information about the transported goods [12].

It is common in case of an accident or disaster that the position of the wagon impedes the reading of labels or other written information on its side. The information carrier can be damaged or lost. However, by reading a properly embedded chip with the help of a drone first arriving at the site, the released dangerous goods can be instantly identified. The information gained by radio frequency reading can be then forwarded to the Disaster Management and Railway Chemical Protection bodies and other participants helping in the rescue operation. This way specialist could be informed about the situation before they arrive at the site, and they can prepare with suitable equipment, protective clothing, and appropriate recovery, rescue and neutralization strategy in advance.

Another advantage of this method is that it can be used even if the site is difficult to access or if it is totally inaccessible. It can also be a solution to provide information to rescue specialists, this way saving their lives or physical safety in case of poison, infection or explosion hazard. By ensuring a faster and more professional rescue operation, this system can reduce the quantity of hazardous substances turning into hazardous wastes in the track section and its environment, as time is a significant factor in the spreading of pollution.

Examples of the systems surveying and monitoring the transportation of dangerous goods

The Route project (Dangerous Goods Transportation Routing, Monitoring and Enforcement) was a common European research project to analyse accidents occurring during the transportation of dangerous goods, and to develop a system which can adequately track the vehicles of road transport. The speciality of the project was that it did not only focus on the nature of hazardous substances, but those vehicle parameters which could affect the safety of transportation (such as temperature, humidity, acceleration) were also monitored online. The hazardous materials transported in the vehicles were identified automatically by using the RFID technology. The system enables the planning of transportation routes based on real time information and cooperative systems, which also allow the replanning of the route in case of a problem [13].

It is difficult to access information about the transportation of dangerous goods, and, in case of an accident, it is necessary to conduct a collective analysis of data stored in different systems in order to be able to carefully assess the situation. Consequently, it would be necessary to ensure the accurate tracking of vehicles transporting dangerous goods in railway transport, too. There is no uniform monitoring and tracking system for railway vehicles in Europe. In Hungary, tracking is restricted to the locomotives of railway companies. Nevertheless, there are international examples for the unique identification of railway wagons. The railway systems of the United States have a strong tradition in this field.

In the United States 1,7 million types of hazardous substances are transported by railway each year. Dow Chemical has already started to use the RFID system, in order to help to identify railway wagons carrying hazardous chemicals. 26 000 railway wagons in North America transports about 650 types of TIH (toxic inhalation hazard) chemicals.

The American system uses the EverSee2 transponder with sensors, two-way satellite communication and modem GPS. With the help of the data forwarding software the company is regularly informed about the position of freight wagons and receives a warning if a failure occurs. Dow Chemical also shares these data with the partners involved [14]. Figure 2 shows the simple visual marks used in Hungary today.

Figure 2. Visual marks on a tank wagon referring to the transported goods.

The US company TransCore developed its automatic identification system in the 1980s in order to track its transporting processes with the help of the RFID technology, which had been known for about 50 years by then [7, 15]. This technology has become widely used in America, but it is also present in many parts of the world, including Europe, for example in France, Germany, Austria, Belgium, Poland, Romania, Spain, Switzerland and the UK [16]. Other sources also mention here the Czech Republic and Finland [7]. This application of the RFID technology has not yet been introduced in Hungary, nor has it been listed among the short and long term plans of railway development.

It is another peculiarity that the company Kapsch, which is also known in Hungary (for its GSM-R projects), also offers a system for wagon monitoring. Besides measuring the appropriate temperature for the transportation of goods, this system is able to detect the speed and the position of the wagons. It also supports the efficient use of the maintenance cycle. It shows if the wagons are forwarded at a speed greater than allowed or if they are loaded over the limit. Furthermore, it also helps to protect the transported goods against theft [17]. This system is shown in Figure 3.

Another company, the Belgian Ovinto offers a system particularly for the monitoring of tank wagons. The system is able to monitor various parameters of the transported - at times hazardous - substances, such as its level, leakage, pressure, shocks and temperature, besides identifying the position of the wagon [18] (Figure 4.).

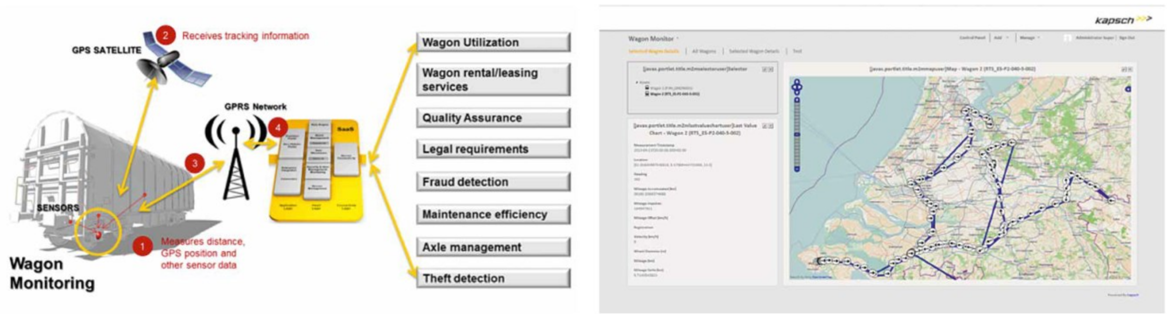

Figure 3. Kapsch wagon monitoring system [17].

Figure 4. Ovinto wagon monitoring system [18].

The modernisation of the transportation of dangerous goods by rail

The number of accidents can be further reduced by using intelligent systems. The vehicles equipped with anti-collision systems can be a very good example for this, as they will become part of our everyday life soon in road transport. Of course, this single application will not make the transport system intelligent, but it can be an important system element.

What measures should be taken to make the transportation of dangerous goods safer in the segment of railway transport? Continuous monitoring of the transported goods, making predictions about the possible obstacles on the transportation route, and maintaining the operability and safety of the means of transport in real time could help to solve this problem.

Presenting radiofrequency identification

Figure 5 shows the Auto-ID systems know today. RFID technology is one form of the Automatic Identification Systems. Its basic idea is that the object for identification is equipped

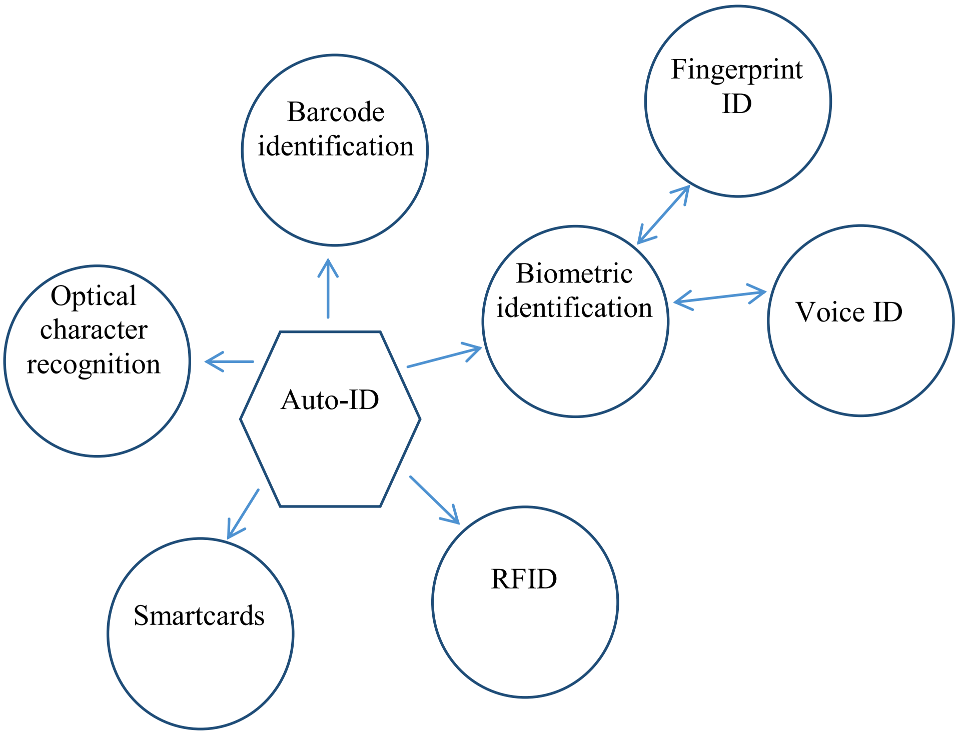

Figure 5. Auto-ID procedures [19].

with an element (transponder or tag) which is capable of data storage [19]. The microcontroller and the antenna together is called RFID "transponder", RFID "tag" or RFID hard tag [20]. The information necessary for identification and other data are stored in the memory of the microcontroller.

There are two ways of retrieving data. One way is when the reader supplies the passive tag with energy (through radio frequency waves) so that it could read the data stored in it. The other way is when the tag has its own energy supply (active system), so that the reader could receive and interpret the radiofrequency signals of the tag (the transmitter). With the latter solution the reading distance can be increased from several metres to a hundred or several hundreds of metres. The reading distance greatly depends on the applied frequency. For large distances and in metallic environment microwave systems (2,45 – 5,8 GHz) should be used.

The safe reading distance of the system used by us was 80 m, based on the first experiments. The operation of the system: the power supply without galvanic connection, data transfer and data exchange is realised by electromagnetic waves and space. This means that information is transferred between the devices through radio waves (Figure 6). This technology is increasingly used in railway environment, too. The Eurobalise S21 system is also based on the radiofrequency technology [19].

One advantage of the RFID system is that it offers machine identification which can be easily automated and used even for special devices. It is also possible to use in high-speed and medium-distance systems by choosing the appropriate technology. For example, a tank wagon transporting a hazardous substance can be uniquely identified by using tags with active and passive memory. The reading security can be improved by using multiple tags on the vehicles. This way there is a greater chance to read some of the tags not only in normal operation but also in case of an accident. The use of multiple tags has a one-off cost, which cannot be compared with the cost of the vehicle.

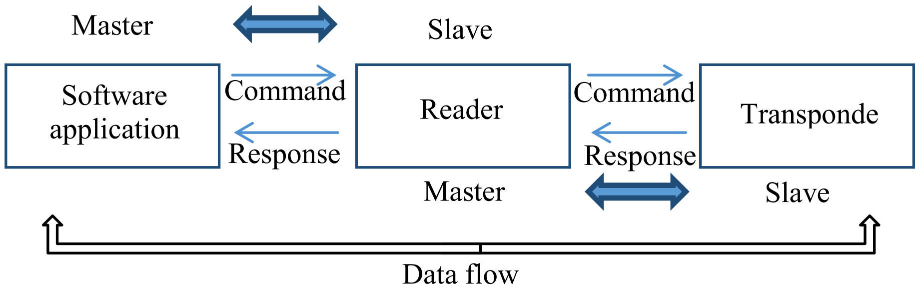

Figure 6. General structure of the RFID system with regards to Master – Slave roles [19].

In order to be able to store the changing data of each rail wagon (about the transported goods) writable memory tags must be used, as, by default, the system prefers the data stored once only. However, there is already a solution for this problem. These tags are capable of storing information for the whole lifecycle of the wagons. To ensure the unique identification of hazardous substances, upon the loading of a wagon the monitoring system reads in the information that can identify the transported goods, for example its physical and chemical parameters, so the parameters of transportation, for example the temperature, can be directly adjusted to them. Equipped with various sensors, the rail wagon can become an intelligent element, and this way the substances which require special storage parameters can be managed real time, and, with the help of the monitoring system the customer can track the current data (position, speed, expected delivery time) of the goods. Such a monitoring system can be upgraded with remote diagnostic solutions.

The disadvantages of the RFID technology could be the electromagnetic interference and its shielding phenomena. This problem could be solved, however, by choosing the appropriate frequency, by placing the transponders carefully and by using multiple transponders or a combination of (active and passive) solutions. In case of active transponders, the devices are able to identify the reader, which also allows the protection of the stored data.

In order to maintain railway safety, it is necessary to use encryption in the RFID system. In his article, Nyikes lists a number of such solutions, out of which the Hash-based access control could be used very well in a railway environment [21]. The system must be also protected against unauthorised interception or data modification [22]. In order to ensure the safe operation of railway systems, it is necessary to examine the effect of the RFID component, as the (modified) signal reflected back by the RFID transponder could cause disturbance in other radio devices [21].

Specific examples of RFID application in railway environment to date

The above-mentioned Eurobalise (ETCS), container identification ISO 10374:1991 (Freight Containers – Automatic Identification), gas cylinders and chemical container identification.

According to Ditmeyer, Senior Lecturer of the University of Michigan, in the United States and in Canada the RFID system based on UHF radio frequency has been used for the identification of railway wagons and locomotives since 1995 [23]. There are several solutions available on the market for Automatic Equipment Identification (AEI). The major component of one of these systems is the tag made by TransCore (see Figure 7), to which the company produces both fixed installation readers and mobile readers (Figure 8).

Figure 7. TransCore tag used in railway transport [24].

Figure 8. TransCore portable RFID reader [25].

THE USE OF DRONES IN THE IDENTIFICATION OF HAZARDOUS WASTES IN RAILWAY ACCIDENTS AND DISASTERS AND DURING RESCUE OPERATION

Drones were first used by Deutsche Bundesbahn, the German State Railway, to increase the safety of railway freight transportation.

PRESENT REGULATIONS OF THE USE OF DRONES

Presently there are approximately one million drones of 2 000 different types in the USA. The estimated number of drones used in the world is around 3 million, and it is exponentially growing. Thousands of drones are flown each year in Hungary, too. The use of these devices, however, is not adequately regulated. Therefore, independent of their purpose, all unmanned vehicles fall under the current regulations of Act XCVII of 1995 on air traffic and Act CLXX of 2015 on the amendment of certain acts related to transport.

Figure 9. The device used in our experiment – there are numerous ways to use drones.

At the moment there is no consistent regulatory framework with regard to unmanned aerial vehicles or drones (see Figure 9), various international bodies are working together in the general regulation of these vehicles. Until the legal act regulating this field comes into force, the Inspection Department of the Aviation Authority of the Hungarian National Transport Authority is responsible for the elaboration of the professional background in the legislative process. During this transitional period, for remunerated activities and other non-hobby activities the Authority applies a permit granting procedure on a case-by-case basis in compliance with the currently effective legal regulations on air traffic. In the current regulatory framework the Authority does not permit the flying of drones above people and the flying of drones at night.

As for the uses for private or hobby purposes: no permit is required for such activities at the moment. On the other hand, the owner of the aerial vehicle shall bear full criminal liability for any accidents or material damage caused during the use of the vehicle and for the infringement of air traffic regulations. In order to avoid such consequences, and in view of the conditions of performing activities which require permission from the Authority, it is strongly recommended to use the device on the owner's property, to avoid use on the property of other natural or legal persons or on public grounds, and to strictly refrain from the flying of the drone above people [26].

The Hungarian National Authority for Data Protection and Freedom of Information issued a recommendation for regulating the privacy and data protection issues of the civil uses of drones, and for the uses of drones in various fields [27].

The recommendation includes the general legal analysis of the issue, on the basis of which the Authority reached to the conclusion that a legal regulation is necessary in this subject. In this context, the recommendation includes suggestions for the legislator suggesting different regulations for the different uses of drones. Moreover, the recommendation contains recommendations for state and commercial use, as well as advice for private users. The recommendation aims to give the best suggestions in this subject for the legislator, for public authorities, market participants and private users in order to ensure that this new exciting technology could be widely used, in compliance with privacy and data protection regulations [28].

Compliance with the regulations of using drones also plays an important part in our research. In any event, until these regulations are fully developed, we pursue the assurance of maximum security during the experiments carried out in our research. The use of these aerial vehicles raises further problems in railway operation areas, for example, when flying above overhead contact lines or in case of an accident causing fire.

CASES OF USING DRONES

Many times it is not possible to determine that out of ten tank wagons piled up in an accident which one is the most dangerous. An appropriately equipped drone can help in its identification. For example, the construction of such a drone requires the use of explosion proof technology.

In 2014, the company ADASA created a drone equipped with an RFID reader to scan the environment of ironmongeries and retail outlets, which is also able to monitor the stock and help the operation of a plant or a shop this way [29]. A device similar to the one shown in Figure 10 could also be suitable for railway applications.

Figure 10. A flying robot by the company ADASA capable of RFID scanning [29].

A possible uses of drones in railway operations

The most important railway applications:

- Identification of dangerous goods
- Monitoring the temperature of tank wagons
- Detecting illegal waste dumping
- En route inspection of the technical conditions of railway vehicles and tracks
- Protection against illegal opening, the theft of dangerous goods
- Checking the safety of level crossings
- Monitoring switches, interlocking systems and signalling lights and their replacement during breakdown
- Monitoring the presence of unauthorized persons (attempting suicide, drunk or deranged) on the railway track, patrol in front of trains, audible warning 13. 01. 2016 –a woman was run over by the train no. 98 036 between the stations of Pinnye and Fertőboz. 15. 01. 2016 – a man was run over by the train no. NIC204 between the stations of Dombóvár alsó and Csoma-Szabadi. 15. 01. 2016 – a man was run over by the train no. 77929-2 at the railway station of Ács. 20. 01. 2016 – a woman was run over by the train no. 6 221 between the stations of Nyírbogdány and Kemecse. 21. 01. 2016 a man was run over by the train no. 8 280 between the stations of Kaposvár and Kaposmérő [30].
- Detecting the shift, fall, leakage or dusting of load
- Surveying the damage or the doors and openings of railway wagons
- Measuring radiation level in case of transporting radioactive waste
- Detecting and lighting the site of an accident or disaster
- Taking rescue packages (medical and chemical) to the site of the disaster.

Other fields of application for drones may be: civil and military reconnaissance, video camera, photographing, environmental protection measurements, parcel delivery, monitoring crops and livestock, thermo sensor, infra camera, monitoring water movements, GPS transmitter, Bluetooth, Wi-Fi transmitter, motion sensor, face recogniser, biometric scanners, following a subject or a vehicle, gun carrier for military purposes, monitoring accidents or disasters, event and place surveillance and many other possibilities.

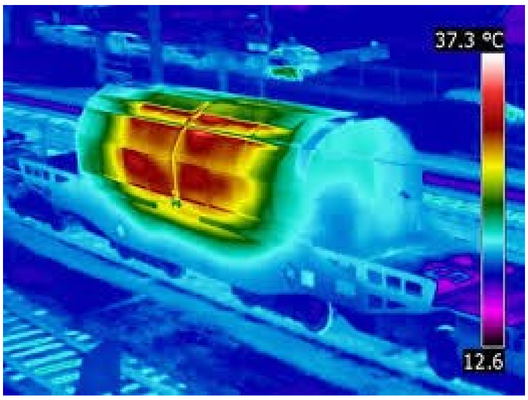

Figure 11. Information about hazardous radioactive consignment that could be provided by a drone equipped with a thermo sensor [31].

By adding easily changeable accessories, drones can offer cost-efficient solutions for retail users, while private user will most benefit from the convenience, entertainment and efficiency-enhancing functions of the new technology in the future. Furthermore, there are considerable advantages of using this technology for the purpose of state responsibilities, most typically in the fields of disaster management, crime prevention, law enforcement, border police, life safety and healthcare services [3].

RESULTS

Recommendations for the introduction of RFID technology in the transportation of dangerous goods:

1. RFID technology can be successfully applied in the railway environment for the unique identification of vehicles transporting hazardous substances.
2. Combined with the RFID system, local transponders (fixed on the vehicles) capable of dynamic data storage can be used to meet the changing needs related to transportation.

Recommendations for the introduction of the combined RFID-drone system:

1. In case of a disaster or accident, it can be used in the affected area to inspect the situation and assess the damage, and to make further predictions, for example, in case of the accidents involving dangerous industrial plants or dangerous consignments.
2. In case of fire in an extended area – involving vehicles transporting hazardous substances or railway operation areas – it can be used to detect the spreading of the fire and to precisely define the affected area.
3. It can also be used to search for survivors with the help of a thermal camera in case of a hardly accessible area.

OUR EXPERIMENT

Our experiment was carried out in a railway environment to examine the operating of the RFID reader near a large mass of metal. On the first occasion, measurements were performed without a drone, holding the reader in hand in different positions.

During the research, the commercially available drones (with GPS navigation [32] and Trajectory Tracking Control [33]) will be equipped with the following elements: a high-resolution camera, a thermal camera, a communication module, an RFID reader and an air composition sensor. We are planning to use the drones during the transportation of hazardous substances for the identification of wastes in case of an accident or disaster. Their use in such an incident can have significant benefits in comparison with the present practice.

Former experiments proved that only high-end drones are capable of carrying a load of 1-2,2 kg by air. Such aerial vehicles of higher capacity (for example: 13 kg) are also available commercially, so these can be used to carry the implemented devices during the experiment [32]. According to our plans, the extra accessories of the drone will not weigh more than 4-5 kg including the batteries which ensure the long flying time. Our measurements show that the drone will be able to perform the identification of hazardous substances from a distance up to 80 m depending on the circumstances found at the site of the accident.

Functionality:

- Communication module: sends the data of the devices and sensors fitted on the drone to the assessment and control centre.
- High-resolution camera: continuously pans the area above which the drone flies providing visual information to the rescue team.
- Thermal camera: can take a thermal image of the site of the accident, which can help to increase the efficiency of intervention and the making of further decisions.
- Air composition sensor: can show the presence of any polluting or poisonous sub-stance in the air at the site of the accident.

- RFID reader: provides instant information about the parameters of the transporting vehicles and the transported substances.

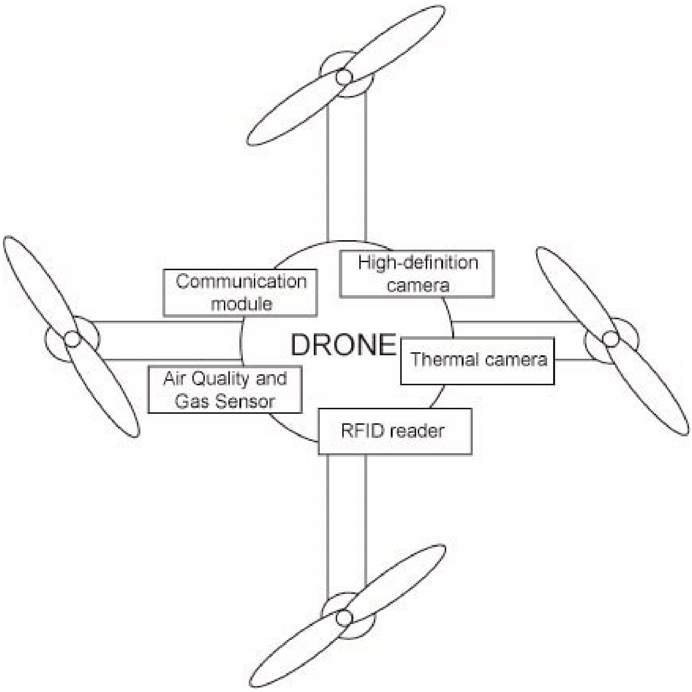

Figure 12. The module systems fitted on the drone (autonomous quadrotor architecture).

Figure 13. Devices of the experiment and the tank wagon with its tag (in red circle).

The combined RFID reader-drone method, as we suggested, is quite new, therefore, our results will be reported after further experiments and research. Our suggestion complies with the concept of the Hungarian National Directorate General for Disaster Management, as this body has the type of drones which could be further developed according to our recommendations to perform the above-listed tasks in a more efficient and safer way.

DISCUSSION

Presently, the RFID technology is used for the identification of railway vehicles in the United States, but it is not used for dynamic data storage related to hazardous substances in the railway environment. Our position is that the RFID technology could be used during incidents in the transportation of hazardous substances as listed above.

Concerning the use of drones, it is important to classify and register them. The categories used in the regulations should be defined by the aspects of usage, not only from the point of take-off weight and kinetic energy, but also from the aspect of private, commercial or safety technology use, in order to help to initiate and carry out the process of authorisation and identification.

The safety-technology purposes of drones should be distinguished from the use for hobby purposes, as they have unquestionable benefits in such application. Similarly to this topic, drones have already been used in Hungary during a flood event. Their use helped to determine the extension of the flooded area, the situation of possible critical points and the accessibility of escape routes. In case of chemical accidents, a gas detector could be mounted on the drone, which can measure the concentration of the gas escaped into the air, this way ensuring that faster and more precise measures could be taken to protect the inhabitants. There have been examples for such application in disaster management, which means that these devices are able to perform such tasks.

Previously, drones have also been used by various civil rescue organisations to find missing individuals. Small-sized drones are being continuously developed to be able to carry different devices of appropriate weight. A high-resolution, high-sensibility thermal camera is now available in a category of less than 1 kg. We suggest the use of this device, as cheaper cameras with similar features cannot provide the necessary resolution from several tens of meters height. The application of drones equipped with thermal cameras, radiofrequency readers, air composition sensors and communication modules has further potentials in the process of disaster management.

CONCLUSION

Based on the research that we have carried out to date, our conclusion is that the RFID technology can be used to identify the transporting vehicles and the dangerous goods or substances transported or stored in them. This method of identification can be performed in an easier and safer way in case of an accident or disaster situation, even without the direct involvement of human resources, by using a reader mounted on a drone.

The use of drones for civil purposes has preceded the development of legal regulations, and an ever-increasing number of drones are now used for various purposed. In order to examine the problems arising from this situation, and to draw the conclusions at an academic level, it is first necessary to ensure the safe and regulated use of airspace of these vehicles.

Once the necessary legal regulations have been developed, our suggested method of the RFID-DRONE combination could be introduced for the identification and treatment of dangerous goods and wastes in the event of railway accidents or disaster situations.

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