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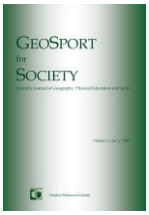

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Analysis of the effectiveness of RFID Systems in triathlon

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Abstract: Accuracy is paramount in sports competitions. Between competitions around the world, tenths of a second or a hundred seconds can be decisive when comparing individuals and race results. The measurement of time results is now done by machines and devices, almost automatically. One of the most widespread and accurate time measurements is made with the help of chips and tags. The study deals with the RFID (Radio Frequency Identification System) devices used for measurement in Hungary. It examines and compares these systems according to different aspects. Based on the results, it provides support to the organizer based on weather conditions, either economic constraints or the number of participants, which system is more advantageous to use. The findings in the study can be used by competition organizers and it may be easier to choose the system required for the competition. The limits of the organization of the competition can be determined more easily.

Keywords: Triathlon, RFID, measurement, system

Introduction

Technology is constantly changing and the pace of change seems to be accelerating year by year in all sectors. What we consider common today, 50 years ago was a science fiction (Sheldon, 2001). The development of ICT technologies and innovative solutions has also changed the field of sports, as in competitive sports (Liebermann et al., 2002; Adesida et al., 2019; Karikás and Ráthonyi, 2021), recreational sports (Ráthonyi et al., 2018, 2019a) or even in the stimulation of physical activity (Ráthonyi et al., 2019b, 2021), they are also used for different purposes in health promotion.

In this respect, sport is closely related to development. The transfer and integration of knowledge into a wide range of sciences and industries has led to rapid technological development. In recent years, not only the world of professional but also the world of leisure sports has undergone tremendous development (Ujihashi, 2008). Investors have realized that the world of hobby athletes provides a huge investment space (Wenyan, 2015). Huge crowds are moved week by week by various amateur sporting events in many parts of the world. Mass-running events, such as marathons, have become an important segment of sporting events, as evidenced by the growing number of events and participants (Running USA, 2010). In Germany, for example, the market for runners was already huge in 2010, with more than 180 marathon races and several other smaller races (Statista GmbH, 2011). Here we can also mention running, cycling, hurdles, triathlon and other competitions.

In order to increase the number of visitors to sporting events, the organizers tried to broaden their attractiveness by expanding and supplementing the possibilities of using modern technology at their events. These extra services provide a useful basis for promoting events and making the event attractive (Christine Green, 2001).

Each market player strives for continuous improvement. That is why we need to offer a little more to entrants at every event, so continuous improvement needs to be maintained so that more and more entrants and visitors attend each event.

For participants in sporting events, the attitudes towards technology-related products and sporting events and the fact that control-related factors (technical functionality and facilitation) influence the impact are of paramount importance for smart sport products (Song et al., 2018)

In the past, 20-25 years ago, the organizers measured the time of the entrants in hobby running competitions with a stopwatch, whereas today a smaller volume competition is unthinkable without chip timing systems. It has become a basic requirement during sports events, but in Hungary, too, several companies deal with such measurements, and they are measured with several different systems. We would like to present these in the next writing. Why is chip timing necessary? First, because it is much more convenient than memorizing the time of arrivals by hand. Secondly, because it is almost impossible to coordinate a larger competition and measure accurate times. In addition, it is not practical to describe the results on paper or in an Excel document, because there is a lot of possibility of deterioration, and it is almost impossible to do this properly for a larger mass. Participants cannot wait for hours or days to collect data.

Triathlon field performance reflect triathlon specificity. The results depends on a field and actual weather performance and from the other environmental parameter the individual performance (Seidl et al., 2015).

The needs of identification systems

With the development of information technology, there is a growing need to find out as much information as possible about a given product, service, or a particular person. Modern logistics and manufacturing are now unthinkable without

product identification technology and automation. Accordingly, there have been a number of technological advances in this field: from simple barcodes to smart tags - from simple data to artificial intelligence (Ten Hompel et al., 2008).

While in the case of goods, at the dawn of product identification systems, a barcode was able to store only relatively little data (product name, price, stock data) and these data also became known only with the help of a special barcode scanner. Later, with the spread of QR (data matrix codes) it is possible to find out much more information about a product, the raw material of the products, when and where it was made, the warranty period etc. Reading these codes is also very easy, as no special reader is required, but a smartphone is enough.

This technology is also becoming more common for service companies, as in the case of an airline, for example, the code may contain passenger and flight information for the flight ticket or personal data for a concert or movie ticket. Educational institutions are also actively using these 21st century tools to engage key stakeholders, i.e. students. Scanning the code takes the user into an online digital world (Burns, 2017).

Personal identification is also extremely important, in the event of a fire alarm in an office building, it is easy to identify whether someone is in the building. Blood type, drug sensitivity etc., are also becoming more common in medical care for data storage. To use QR codes, you need a smartphone with a QR code reader and an internet connection. The QR code reader is usually free to download from apps, and some phones already have a built-in QR code reader (Law and So, 2010).

As technology advances, RFID technology is beginning to become more prevalent. The possibilities of using radio frequency identification technology are almost endless. In addition to clear logistics, identification, security and registration tasks, RFID solutions are emerging in more and more areas. Clearly, with the reduction in chip manufacturing costs, chips that it can be produced more and more cheaply can displace even the most common barcodes in some areas.

RFID technology, combined with modern positioning systems (GPS), enables the complete tracking and optimization of road, air and water transport. Some countries protect their valuable products from dangers in this way. Thanks to the advantages of the technology, most express postal services know exactly where our item is need to deliver. Identification and security capabilities are increasingly used in modern passports, digital IDs and the latest payment solutions. Attempts are being made to set up automated shops, and RFID-based highway payment solutions have already been introduced in many places around the world. The automotive industry has also recognized that RFID can create new opportunities for security solutions, so today most immobilizers and electronic keys already work with this technology.

Material and Methods

RFID (Radio Frequency Identification) systems are grouped in three ways:

According to energy supply

Passive cards or labels

Passive RFID Cards or Tags do not have their own power source (battery or accumulator). They are able to collect the electric current, which is essential for their operation, through the antenna built into them. Passive cards or tags do not contain their own transducer like active cards or tags, they only cause a change in the electromagnetic field generated by the reader through modulation, which the reader senses and then converts it into computer-readable digital signals:

- Simple design;
- Easy to make water and dust resistant version;
- Very small footprint;
- Produced in the form of a self-adhesive sticker;
- Produced under the skin.

The disadvantage is the short range, their use is usually in bank cards for contactless payment transactions.

Semi-active / semi-passive

Devices known as semi-passive or semi-active RFID tags are also called battery-assisted passive (BAP) or battery-assisted tags (BAT). Semi-active cards or tags, like their passive counterparts, have an antenna without an encoder and can only communicate in the reader's magnetic field through modulation, just like passive cards or tags, but the microchips are not powered by the antenna but by the built-in battery.

Its advantage is the relatively large reading distance and easier tracking. The disadvantages are the relatively short service life, the large space requirement, the complicated structure and the higher price compared to the passive chip.

Semi-active tags or transponders are often use in secure access control and toll systems.

Active

There are two groups of active cards and tags, the first is called transponder and the second is beacons.

Transponder: The device contains both the antenna and the power source (battery), as shown in the semi-active tags. It is not possible to use to power the antenna, but the antenna is an integral part of its own transmitter, so it modulates the reader's electromagnetic field and emits its own signals, which can detected by several readers at the same time. Transponder RFID tags do not emit a signal in their basic state, they work passively, they only respond to a query generated by the reader, which is why they are called transponders. These devices are now less implementable in a standard card format due to their higher capacity battery requirements, whereas they are often use in labels due to their significantly longer range. Reader performance and sensitivity, as well as label performance, also affect reading distance.

Signal transmitters: Both devices contain both the antenna and the power source (battery or accumulator) as in the semi-active labels and it is not possible to

use to power the antenna, but the antenna is an integral part of its own transmitter, so there is no need for the reader to be electromagnetic. Modulates its space, radiating its own signals that can perceived by multiple readers even simultaneously. Active devices (transmitters) constantly radiate the radio signal, regardless of the presence of the reader, like a lighthouse.

Installed readers, as soon as the signals emitted by the tags are detected and the reading takes place, there is no query. Instead of continuous broadcasting, depending on the label, the identification signal is sent every few seconds, so their lifespan can be longer. The life of batteries or accumulators determines the usability of the device (Figure 1).

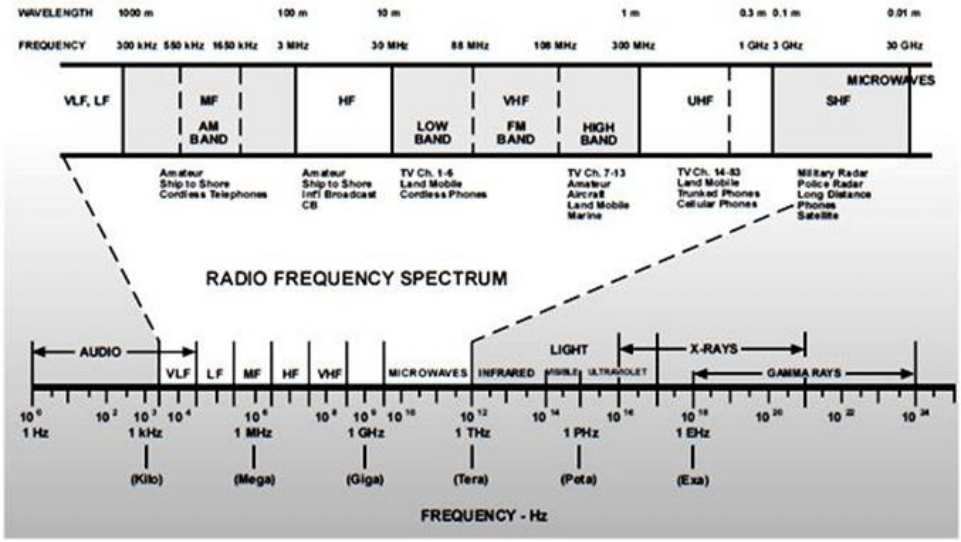

Figure 1. Operating Radio frequency spectrum (Radio Communications in the Digital Age, 1996)

Active RFID tags typically have a lifespan of 3-5 years, but in the event of a battery failure, the active tag must be replaced. Signals from the modern active label can be read from hundreds of meters away, but to conserve battery life, they are usually set to lower transmission power, to reach approx. 100 meter reading range. Reader sensitivity and label performance affect reading distance.

Its advantages are long reading distance and easy tracking. Disadvantages are short service life, space requirements, complicated construction and high cost

Transmitters are very common in the oil and gas industry, used in shipping and logistics, construction, mining and high value manufacturing.

RFID-based technology is used worldwide for sports timing. These technologies are also present in Hungary. It allows a very accurate number of identifications. Use MyLaps, MTS J-Chip, WinningTime Active or RaceResults, among others.

Low Frequency (123-134 kHz)

It is very sensitive to environmental noise and has difficult logistics. This is a passive system. The big disadvantage is that the antenna can only communicate with

one chip at a time. This is a problem if more than one person arrives at the start line at the same time. Several alternative methods have already developed to address this; MyLaps and WinningTime also use this.

This is the 1st generation RFID technology, mature, simple and inexpensive. The reading distance is very short, and the reading speed is low. It is characterized by an extremely long wavelength usually a short reading range. Its operating distance is 1 to 50 centimeters. Access cards, parking cards etc.

Most common card types in this frequency range:

- EM4102
- HID® Indala®
- HID® Proximit

Figure 2. Low Frequency chips

The LF chip, which is in a small plastic protective case show in figure 2, must be worn in a shoelace in individual competitions, in relay competitions where the change is made by handing over the chip, it must be fastened to the ankle with a velcro, as in triathlon competitions. The LF chips ideally have a measuring height of 50 cm from the carpet. This can be as little as 25 cm, depending on the circumstances, so it is important to have the chip on your foot.

High Frequency (HF) & Near-Field Communication (NFC) (13.56 MHz)

Simple and cheap technology. Few companies use it, due to the deteriorating scan rate in noisy and wet environments. IPICO Sport Timing and the DAG System use this system.

High frequency range (10-15 MHz, the most common frequency is 13.56 MHz) Development in this frequency band is very significant. These cards are mature,

inexpensive, medium read speed, work in wet environments but not in metallic environments. Its average reading range is from 1 centimeter to 1 meter. Thanks to continuous improvements, this is the frequency that appears on most cards (RFID and NFC).

Ultra High Frequency UHF (865 - 960 MHz)

A particularly sensitive system so you do not have to place the chip on your foot. It is usually placed on the start number. Its cost is low, barely a few cents abroad. It is constantly being developed and communicates perfectly with rubber cover, even in water or under neoprene. RFID is a system used by RTS Ultra, RaceResult and many other companies.

RFID cards or tags operating at ultrahigh frequencies can operate in both passive and active ways. The reading distance is very long, from 1 to 100 meters, the reading speed is high and it works even in wet environments, but the waves are easily absorbed. With the increase in commercial application, very significant growth in this sector. Used to track containers, goods, vehicles.

The UHF chip is already glued to the back of the start number, you don't have to do anything with it anymore. The start number should be recorded on the chest, on the top layer of clothing. It is important that nothing is forced on this anymore, as it can affect the measurement efficiency.

Microwave frequency range SHF: 2.45 or 5.8 GHz: super high frequencies

The reading distance is much larger than 1.5 meters, the reading speed is high. It requires the construction of an expensive, complex system and requires a direct view of its operation (this does not make it more attractive to barcode systems in many applications), used for vehicle access systems.

Active-mode microwave labels operating at 2.45 GHz have already become widespread in shipping due to their long range.

In order for communication between a card and a reader to work reliably, especially when several cards are in the reader's range at the same time, certain pre-laid rules are needed, the sum of these rules being what we call a protocol.

According to the communication protocol, we distinguish two main groups:

- RTF or (so-called reader-talks-first) protocol - "the reader speaks first";
    - According to EPC Global Gen2 standard.
- TTF (so-called tags-talk-first) protocol - "the tag speaks first";
    - Safer, Cheaper Label or card, but more complex reading algorithm.

Or a combination of these systems:

- RFID and Infrared Transmitters;
- RFID and GPS / GPRS transmitters and receivers;
- IEEE 802.15.4 RFID sensor networks;
- Metal fiber identification based on RF reflection;

- Ultrasound solutions;
- 2D codes as RFID "back-up".

Investigation of chip timing methods related to running competitions in the case of Hungarian companies

In Hungary, several companies deal with chip timing. There are companies in the market that use foreign developments, but most companies use hungarian development in Hungary. The most significant companies are:

- MyLaps;
- RaceResults;
- EvoChip Hungary;
- DarkTiming;
- Viking Timing;
- Köridő;
- Fair Timing.

Mylaps

Mylaps was founded in 1982. The invention of automatic sports time measurement is associated with the name of the company. The development of the system is named after two Dutch inventors. They decided to capitalize on their technical skills and came up with the idea of transponder timing. They installed transponders on their cars and built the world's first automatic timing system on a racetrack. They managed to create a user-friendly system.

Millions of athletes, event organizers, racetrack owners and associations around the world also use this technology. This system is use at the Olympics, NASCAR, Le Mans 24 Hours, Boston Marathon, Giro d'Italia or Ironman Triathlon. More than 20 million athletes and competitors compete in MYLAPS-measured competitions each year, and more than 700,000 users regularly use mylaps.com to analyze and share their time and performance on their social networking site.

In Hungary, the Watchman team operates this system. Mylaps uses two types of timing technologies to measure leisure sports competitions: the BibTag system and the ProChip system. The first system is used in running, cycling, triathlon, cross-country and obstacle races, while the second system is used in urban cycling, triathlon, BMX, cross-country, and skating competitions.

BibTag system

The measurement has several components. Not just every type of race, but every single race has its own characteristics. There is a specific standard equipment for measuring competition types and customers can choose several other extras. Timing can done with the following electronic equipment:

Basic equipment:

- Label decoder: connected to carpets. This will identify the competitors. They can identify up to 50 simultaneous transmissions;

- Carpet: these are sensor mats. It must also placed at the start and finish. These serve as antennas for the system. You can place more than one in a tournament;
- Labels: these are identified by the system. Competitors must wear these during the race to measure their results. They are designed for different weather conditions;
- Timer and measurement system: this software has developed for this purpose. Provides easy operation.

Premium electronic accessories:

- Lightweight carpet: an improved version of the former sensor. It can be installed quickly even in busier places, and the cabling is integrated into the carpet;
- Handheld reader: a mobile decoder that is easy to carry due to its small size. It used in places where carpets are difficult to install;
- Multi sport label: type of label used in triathlon and hurdles. Used in wet and muddy terrain;
- Saddle Tube Label: A label used in bicycle races;
- Side antenna: stronger speed is possible with this development.

Accessories:

- Live event application: provides a greater experience for participants and spectators. Participants can follow the competition live;
- Photo and video: photos and video of the competitors can be taken;
- Photo and video integrator: an innovative development that enables reliable and high-quality images, easy and fast setup, as well as fast and intelligent data management.

The technology allows for much more accurate, real-time measurement. There are sports where tenths of a second are a decisive difference. One of the characteristics of mass sports is the crowd, i.e. the many participants. With human resources, it is not possible to perfectly record the exact time result of everyone. Even if you manage to write down everyone's target time, it will be just a piece of paper with numbers, you still have to make a list of results, by gender, age group, etc. This is a lot of time and the competitor needs to know the result as soon as possible. Among the services of a good competition, chip timing and its benefits play a key role.

Net-Gross time measurement

Net timing is the measurement of the race time of each competitor from the time of the individual start to the finish. In this case, a timing point is install on the start line, so the time of the start will be recorded for each competitor. Net timing in high-weight races is a photos, as there can be a significant time difference between the start time of the first-row and last-race competitors. In gross time, everyone will

have the same start time and the race time will run from that time until they reach the finish line (net time = own time, gross time = start time) (Figure 3).

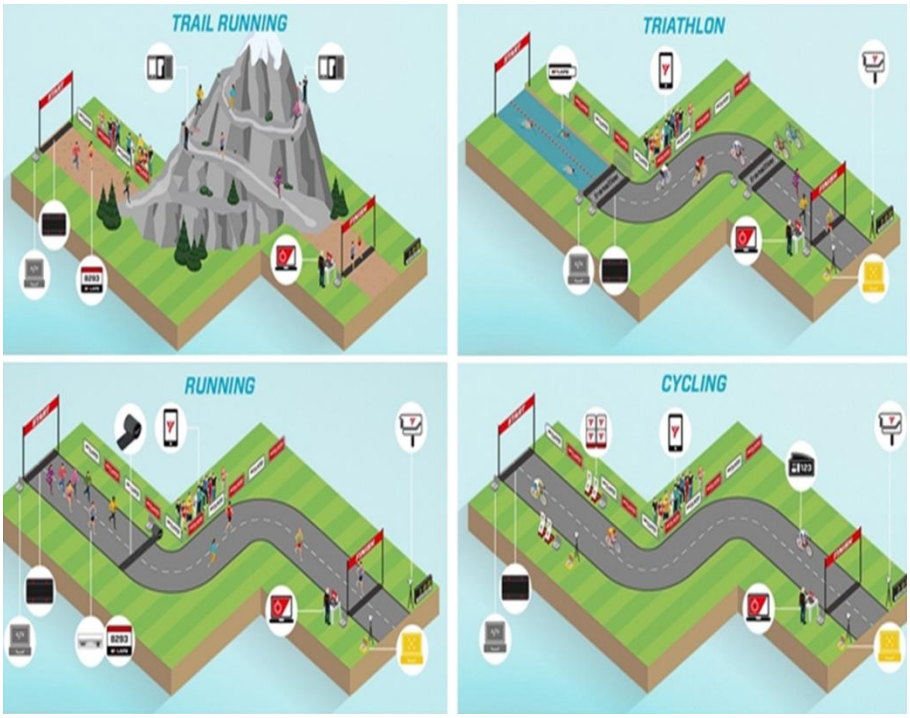

Figure 3. Timing solution for Triathlon (Timing solution for triathlon, 2022)

Wide application

Technology has also conquered other sports, not only in outdoor activities.

In indoor sports it is used already in basketball where other parameters need to be measured, such as the physical condition of individuals or the exact location of the ball (Blake et al., 2018).

The system can be used to collect a lot of data, but it is important not to get lost in the data. The big data problem is the case. The analysis should determine exactly what data is needed and focus only on it.

Also in the case of sports marketing, managers who make strategic decisions need to be aware of how to use or not to use RFID technology (Mumcu and Fried, 2016).

Results

Competition organizers have to take into account several aspects when and what timing systems to use. The possibilities are compared in table 1. First of all, the budget of the organizing team, the sport in which the measurement takes place (street running, cross-country running, obstacle course, triathlon etc), how many entrants take part in the competition, how many organizers can take part in the event etc.

Table 1. Comparison according to different aspects

Characteristics	Traditional timing	Passive RFID chip	Active RFID chip
Measurement speed	Between 1-5 seconds	0.0005-0.02 seconds	0.1 seconds
Number of measurable runners	One operator/ one person	Hundreds of people	Hundreds of people
Measuring distance	It depends on the operator	1.5 meter	0.2-3 meters
Data entry mode	Manually	Automatically uploads to the website	Automatically uploads to the website
Water resistance	-	Only drip-proof	Waterproof
Recommended competition	Small number of runners or bike races	Street, cross-country race	Any type of competition
Deployment time	No build time	30-60 minutes	30-60 minutes
Number of operators	Minimum 6 people	1 person- In case of part time 2 people	1 person- In case of part time 2 people
Weather safety	Human factors	Soaking (chip with sponge)	It is not affected by the weather
Lifetime	-	It is easily damaged and is replaced by race	Up to 6 years
Accuracy	It depends on human factors	0.0005-0.02 seconds	0.1 seconds
Data entry speed	It depends on human factors	0.1 seconds	0.1 seconds
Cost of rent	Relatively low (stopwatch, phone, laptop / Excel)	Basic Package: measuring carpet, speaker, monitor, laptop, RFID chip	Basic Package: measuring carpet, speaker, monitor, laptop, RFID chip
System price and components	-	Basic Package	Basic Package
Suitable for	Relatively cheap, small, friendly competition	Street, cross-country, bicycle race	Any type of competition

In the case of the size proposed for the type of competition, any type of competition includes triathlon, cycling, obstacle course, open water swimming.

For smaller events, such as a rural running race where 30-40 entrants are present, there is no need to rent such a system because it is not the main attraction for a participant here. With such a small number of people, they can solve the measurement manually. Regardless, if the budget allows, they can increase the level of competition by renting a chip system.

The active and passive timing systems are similar and identical in many ways. The measurement speed is almost the same, the number of measurable runs is the same, there is a small difference between the measurement distance, the number of measurable runs, the type of data entry, the system set-up time, the number of operators, the accuracy or the data entry speed agree.

There are significant differences in water resistance, among other things. In sports such as triathlon or hurdles, organizers cannot use a passive system. In this case, they can only work with an active system. So the passive system can used in far fewer sports. Another such difference is the lifespan, as the chips in the passive system can only use in one race because it is easily damaged, but instead, it does not have to be collected at the finish gate after the race. Another important factor is that the rent for a passive system is much cheaper than that for an active system. Based on an average race of 300 people, the basic package, which includes a measuring

mat, speaker monitor, chip and laptop, is approximately 25-30% cheaper to rent than a similar package from an active system.

The starting package for the passive chip system consists of the following elements: Timing system € 4.500 -5.000 + mat 2.500 - € 3.000 + laptop software € 1.000 - € 1.500. For an average tournament of 300 people, this amount costs a system cost of € 8.000 to € 9.500.

The starting package for a system with an active chip consists of the following elements: Timing system € 3.500 - 5.000 + active chip € 50-80 / person. For an average tournament of 300 people, this amount costs a system cost of € 18.500 to € 29.000.

Conclusion

Based on the results, depending on the type of planned system to build, the ideal system can be developed depending on the accuracy, and depending of the risks, such as weather conditions.

The study is a suitable tool for companies organizing triathlon competitions. It provides a kind of support depending on the participants in the competition, the method of data collection and the financial constraints, which system should be built. The study is possible to extend and developed with the analysis in the timing aspects of other sports.

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