Florin BĂDĂU, Ph.D. Student[1]
E-mail: florin.badau@upb.ro
[1] Department of Telematics and Electronics for Transports, Faculty of Transports
Politehnica University of Bucharest
Splaiul Independenței 313, Bucharest, 060042, Romania

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RAILWAY INTERLOCKINGS – A REVIEW OF THE CURRENT STATE OF RAILWAY SAFETY TECHNOLOGY IN EUROPE

ABSTRACT

Interlockings are an essential element of the railway system. They are necessary to command and control devices, such as points and signals in order to route trains within the bounds of railway stations. Their design must ensure the highest level of safety for all involved parties. The European continent has an extensive railway network which has slowly grown over more than 150 years. Interlockings have evolved over the same period from large mechanical devices requiring physical force to operate to computerised systems capable of complex operations. Despite the technological leap, many interlockings using older technologies are still in use in the present. This review aims to paint an accurate picture of the current state of interlockings in Europe by evaluating the share of each interlocking generation (mechanical, relay and electronic). The study covers 15 countries and over 200,000 km of railway tracks, representing over two thirds of the entire EU railway network. A brief presentation is given for each country, while comparisons made between the researched countries highlight certain key findings. The focus is only on station interlockings, not including line signalling. The conclusions of this analysis include recommendations for current and future development of the railway sector.

KEYWORDS

railway interlocking; railway safety; railway statistics; relay interlocking; electronic interlocking; railway signalling.

1. INTRODUCTION

Just as cars need to be safely guided by traffic signs and lights along motorways and streets, so do trains on railways. Instead of traffic lights and road junctions, railways use signals and points to route trains from one point to another. Any railway network can be thought of as a vast mesh of stations connected to each other by railway tracks. Not only trains, but also wayside equipment needs to be supervised constantly to guarantee an elevated level of safety [1].

An interlocking is the system responsible for safe train routing and equipment monitoring within the bounds of a station. Every command issued by the station operator goes through this system and is evaluated so that it complies with very strict safety regulations. The method by which this evaluation takes place differs from system to system. Older interlockings use analogue techniques, while current models make use of programming logic.

This research reviews relevant sources to paint an accurate picture of what interlocking technologies are prevalent in the present in various European countries and on the continent. While related to the topic, line signalling is not discussed within this paper. The accent is only put on the interlocking equipment within railway stations. Section two of this paper offers a short insight into the historical development of interlockings and seeks to explain certain key concepts. Section three presents the collected data for the analysed countries arranged after an included methodology. Section four presents a comparison between the researched countries, and an analysis of the data both on the national and European level. Conclusions and suggestions derived from the study are summarised in section five.

2. RAILWAY INTERLOCKING TECHNOLOGY

The development of railway interlockings from their beginning is summarised in this section. Relevant concepts, such as train routes and movement authority are explained alongside brief descriptions of the most relevant interlocking technologies.

2.1 Early days

The dawn of the 19th century brought forth a plethora of advancements in science and technology. Few inventions of the era were as revolutionary or as crucial as the development of modern railways. The emergence of this novel mode of transport radically changed the economic landscape by offering a fast and high-capacity alternative for both passenger and freight transport.

This innovation quickly spread out across the world. Just 40 years after the inauguration of the first railway linking Liverpool to Manchester in 1830, most European countries had already built extensive railway networks. Railway density saw an even greater increase between 1870 and 1900 across the continent [2].

Two types of equipment are necessary for train routing, namely, points and signals. Railway points are needed to split one railway track into two or more individual tracks and are essential for the development of a complex railway network. These devices were designed soon after the opening of the first railway, with a first patent being issued in 1832 to Sir Charles Fox [3].

Signals are used to authorise train movement to train drivers or to pass on relevant information to other railway staff members. While early on, coloured flags and lamps fulfilled these functions, they were quickly replaced by sturdier metallic structures installed to the side of the tracks which were easier to see from a distance [4].

Since those early years, safety has been the fundamental pillar around which the railway system was designed and built. As such, regulations which governed railway operations were drawn up and strictly enforced. With the railway network expansion, the size of the stations also grew, and train routing became more challenging [5]. The staff responsible for point operations had to coordinate with each other in order to ensure the safe train routing. Humans are, however, prone to mistakes and it soon became obvious that individual point switching could not guarantee the necessary level of safety [6].

Techniques for the remote switching of points and signals were first implemented in the United Kingdom in 1843. Further developments around 1860 brought these controls to a single command centre and allowed operators to issue commands only under specific conditions [6]. Thus, the first interlocking machines for railways were put in service. Interlockings allow signals to authorise train movement only after all points along the route are in the correct position and are subsequently locked to prevent undesired switching. Although interlocking types have been designed with different technologies over the last century and a half (mechanical, electric, hydraulic, electronic, etc.), the safety principles have mostly stayed the same [7].

2.2 Mechanical interlocking

The first generation of interlockings used mechanical means to command and control points and signals in railway stations. The interaction between the human operator, more accurately referred to as a signaller, and field equipment occurs inside the command centre, the so-called signal box. A system of wires, rods and pulleys connects the signal box to the outside, while a group of large levers inside it are used to manoeuvre the points and signals [6].

Dependencies between the various elements of the station are implemented inside a locking box by means of a system of interlocking tappets. Each lever is connected to one or more tappets which slide inside the locking box when commands are issued. Notches made along the tappets interact with fixed locks inside the apparatus and lock into predetermined positions. The enabling of other commands depends on their locking. For example, the lever controlling the home signal (at the entrance of the station) is mechanically locked and cannot authorise any train movements until the tappets corresponding to the points along the train route are in their correct positions [5].

2.3 Relay interlocking

The first interlockings of this kind were developed in the 1930s, but widescale use of them did not become common until twenty years later. As before, the increase in railway traffic was the driving force behind this new technology [6].

While the interlocking principles are generally identical to the previous generation of interlockings, the same cannot be said about the underlying technology. As the name says, this kind of interlocking is designed around the relay.

Relays are often used in electronics for a variety of applications. They are rather simple in design, consisting of a coil which is used for commanding the device and a series of contacts that open or close depending on whether the coil is powered or not [8]. To be used in interlockings, relays must fulfil several strict criteria mostly related to their reliability [5].

Each signal lamp, point, track section or other equipment within the station is assigned with multiple relays that indicate their state through their positions (picked or dropped). By wiring the coils of certain relays to the contacts of other relays and arranging them in different configurations, logical functions may be implemented [9]. Thus, the safety conditions are achieved by the means of electrical circuitry, rather than the earlier mechanical method [10].

An operation table serves as the interface between the interlocking and the signaller. Commands are issued by pressing mechanical buttons or by turning switches on the surface of the table. Various light indicators offer a current overview of the station (point positions, signal indications, track occupancy, etc.). Train routes are usually established by pressing the buttons corresponding to the beginning and to the end of the desired route. Other intermediate buttons may be necessary if more train routes alternatives exist [11].

It is possible to replace the operation table with a modern computer-based interface while maintaining the relay-based railway logic, thus creating a hybrid interlocking which combines the advantages of both technologies [5]. The interface for these systems must be extensively tested to ensure the same level of safety that non-hybrid systems have [12].

2.4 Electronic interlocking

New advancements in electronics brought about the development of computer-based systems with a wide array of applications in many fields. The first electronic interlocking systems for railways were designed in the 1980s [5]. They represent the state of the art in interlocking technology and are still being developed to the present day [13, 14].

While previous generations of interlockings used mechanical and/or electrical hardware logic to implement safety related functions, electronic interlockings resort to software logic for the same purpose [6]. However, electronic circuitry is less robust and additional techniques must be used to attain the same level of safety that legacy systems have. Redundancy plays a key role in ensuring the reliability of such interlockings. It is implemented via hardware and software diversity and built on established architectures, such as 2oo2, 2oo3, or 2*2oo2 [5].

To ensure an even approach in electronic interlocking design, some countries have created standards to be followed by all manufacturers. Such examples include the existing British SSI (Solid State Interlocking), Japanese SMILE (Safe Multiprocessor for Interlocking Equipment) [5] and the upcoming French ARGOS [15].

3. THE STATE OF INTERLOCKINGS IN EUROPE

This section presents interlocking data for each of the analysed countries. The methodology used to organise the collected information is explained in the first part of the section.

3.1 Methodology

The aim of this research is to offer an overview of the current state of interlockings in Europe. *Figure 1* describes the methodological approach designed for this research. Relevant data gathering was a challenge because not every European country

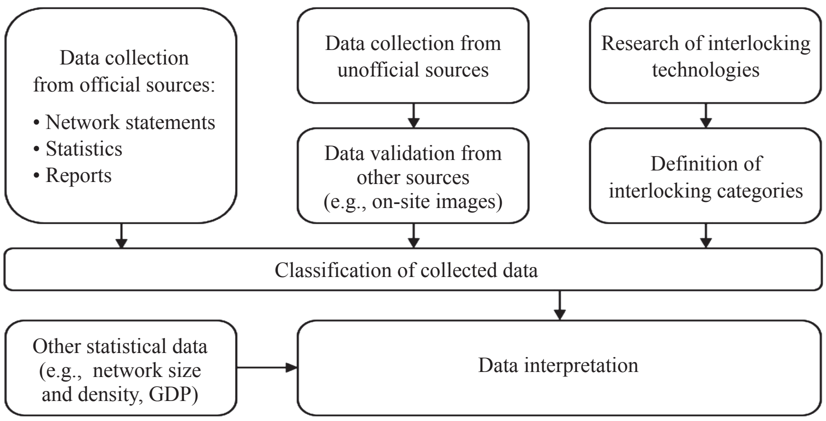

Figure 1 – Methodological approach of the research

publishes statistics on this topic, or the countries use different formats when they do. Most data were collected from sources with a high degree of credibility such as network statements, official statistics, governmental or ministerial reports and legal documents. Data from unofficial sources, such as online registers of nongovernmental institutions, were double-checked to ensure validity compared to other sources (e.g. on-site images).

After reviewing the relevant literature regarding currently used technologies, the four categories to be used for data classification of individual station interlockings were defined as follows:

- Mechanical interlockings: this category includes any kind of interlocking where the safety conditions are verified by mechanical means.
- Relay interlockings: interlockings where relays are used to implement safety functions, regardless of whether the operation table is mechanical or electronic.
- Electronic interlockings: interlockings whose functions are implemented by software.
- Other: interlockings that use a different technology than the ones included in the other categories or that cannot be classified due to the lack of more detailed information (e.g. electro-mechanical interlockings).

Data interpretation was carried out by analysing the classified data individually (e.g. evaluating the countries compared to each other) and by comparison with other relevant statistical data (e.g. network size and density, GDP, governmental expenditure on transport). This second stage was necessary to evaluate the potential relationship between the interlocking profile of a country and other variables.

Using this methodology, relevant data were found for 15 countries with a combined network size of 167,925 km. Apart from Switzerland, all reviewed countries are members of the European Union, and their total network size represents 165,308 km or 82% of the entire 200,200 km of railways in the Union [16].

Most data of the researched countries are recent, from 2020 (Austria, Bulgaria, Romania, Hungary, Sweden), 2019 (Croatia, Germany, Poland), 2018 (France, Slovakia) or 2017 (Czechia, Switzerland, Finland). The outliers are Slovenia, for which the most recent available data are from 2015 and Spain, with data from 2014.

3.2 Reviewed countries

The Austrian railway network has a total length of 5,615 km [16]. According to the national railway infrastructure manager (ÖBB-Infrastruktur AG) in 2020 there were 298 electronic interlockings in operation from a total of 660 interlockings [17]. The infrastructure manager offers exact figures only for electronic interlockings. In the absence of information relating to mechanical and relay interlockings in Austria, the remaining number of 362 nonelectronic interlockings was classified as other to not skew the results of the research.

With 4,030 km of railway track [16] managed by the National Railway Infrastructure Company, Bulgaria had 33 operational mechanical interlockings (EMI), 177 relay interlockings (BRRI, RRI, EI) and 23 electronic interlockings in 2020 [18, 19].

The latest available data for Czechia were reported by the infrastructure manager SŽDC in 2017. On the 9,562 km long network [16] there were 516 mechanical interlockings, 385 relay interlockings, 341 electronic interlockings and 327 interlockings of other types [20]. Due to the lack of information regarding hybrid and remote-controlled interlockings in Czechia, they have been classified as other.

The 2,617 km long Croatian network [16] is managed by HŽ Infrastruktura, which in 2019 reported 51 functional mechanical interlockings, 134 relay interlockings and 9 electronic interlockings [21].

For Finland, the latest relevant figures were reported in 2017 by the Finish Transport Infrastructure Agency. According to it, only 5 mechanical interlockings were still in operation, with a further number of 108 relay interlockings, 235 electronic interlockings and 108 other types of interlockings [22, 23] active on the 5,932 km long network [16]. The interlocking models Domino 55/70, Ericsson, Siemens DrS/SpDrS and VR 76 are relay-based, while the Ansaldo, Bombardier, Mipro, Siemens SIMIS/Westrace and Thales ESTW are electronic.

On the extensive 27,483 km long French railway network [16], the infrastructure manager SNCF reported in 2018 a total of 692 mechanical interlockings, 797 relay interlockings (PRS, PIC, PRG, PRCI), 305 electronic interlockings (PAI, PIPC, SEI) and 439 interlockings of different types [24].

With 38,394 km of railway track [16], Germany is the country with the largest railway network among those included in this research. The main infrastructure manager DB Netze reported 642 mechanical interlockings, 1,197 relay interlockings, 351 electronic interlockings and 367 interlockings of other types [25]. This statistic does not count electronic interlockings individually by station, but rather by area. Because an interlocking area controls more than one station, the resulting figure for electronic interlockings will be lower. In order to maintain statistical equivalence between the reviewed countries, a secondary data source which lists individual stations by interlocking type was considered. As such, the number of individual stations equipped with electronic interlockings in Germany in 2021 was 1,644 [26].

In 2020 there were 316 mechanical interlockings in operation in Hungary with 567 relay interlockings, 106 electronic interlockings and 10 interlockings of other types according to the Rail Capacity Allocation Office [27]. Mechanical interlockings include the models FM, FMSH, FMIN and Siemens-Halske, relay interlockings the models D 55/67/70 and KA, and electronic interlockings the models Alcatel, Elektra and Siemens SIMIS/ESTW. The figures include railway network sections operated by MAV and GYSEV.

For Poland, the infrastructure manager PKP reported in 2019 the sum of 1,552 mechanical interlockings, 856 relay interlockings, 336 electronic interlockings and 85 interlockings of other types [28] on the entire 19,398 km long network [16].

Romania's 10,759 km long network [16] is managed by CFR, which in 2020 reported a total number of 60 mechanical interlockings, 590 relay interlockings and 41 electronic interlockings [29].

In 2018, the Slovakian infrastructure manager ŽSR reported 218 mechanical interlockings, 173 relay interlockings, 43 electronic interlockings and 46 interlockings of other design [30].

The latest data for Slovenia were published in 2015 by the infrastructure manager Slovenske Železnice and mention a number of 29 mechanical interlockings, 67 relay interlockings and 30 electronic interlockings [31].

The only available data source for Spain is a 2014 report by the Spanish Ministry for Transport where 33 mechanical interlockings are mentioned, alongside 382 relay interlockings and 666 electronic interlockings [32].

On the 10,899 km long Swedish railway network [16] in 2020 there were 12 mechanical interlockings, 545 relay interlockings and 395 electronic interlockings in operation. Besides these, there were 4 interlockings of other design [33].

For Switzerland, the latest available data were published by the infrastructure manager SBB Infrastruktur in 2017. According to it, there were 35 mechanical interlockings, 347 relay interlockings and 120 electronic interlockings in operation [34] on the 5,214 km long railway network [16].

4. DATA OVERVIEW AND ANALYSIS

The data laid out in the previous section offer an overview of interlockings in each of the 15 analysed countries. These data have been summarised in *Figure 2*.

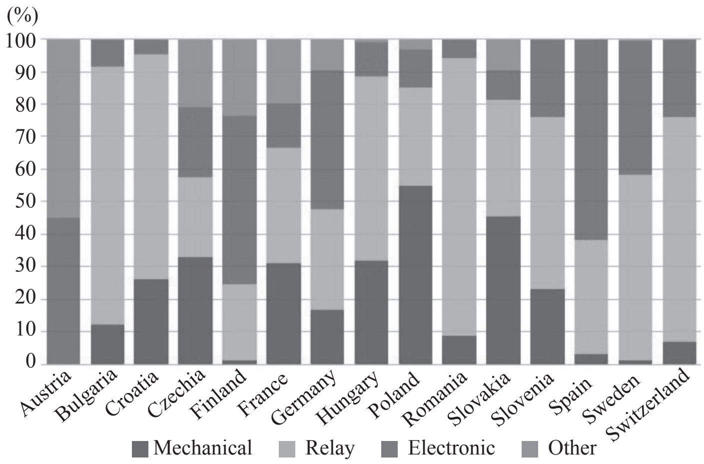

Figure 2 – Share of interlocking types by country

Table 1 – Country ranking by share of interlocking type

Ranking	Mechanical		Relay		Electronic	
1	Poland	55%	Romania	85%	Spain	62%
2	Slovakia	45%	Bulgaria	79%	Finland	52%
3	Czechia	33%	Switzerland	69%	Austria	45%
4	Hungary	32%	Croatia	69%	Germany	43%
5	France	31%	Sweden	57%	Sweden	41%
6	Croatia	26%	Hungary	57%	Switzerland	24%
7	Slovenia	23%	Slovenia	53%	Slovenia	24%
8	Germany	17%	Slovakia	36%	Czechia	22%
9	Bulgaria	12%	France	36%	France	14%
10	Romania	9%	Spain	35%	Poland	12%
11	Switzerland	7%	Germany	31%	Hungary	11%
12	Spain	3%	Poland	30%	Slovakia	9%
13	Sweden	1%	Czechia	25%	Bulgaria	8%
14	Finland	1%	Finland	24%	Romania	6%
15	Austria	-	Austria	-	Croatia	5%

The data review reveals that each of the researched countries has a unique blend of interlocking types on their railway networks. The share of each interlocking type varies greatly from country to country. *Table 1* shows a ranking of all reviewed countries according to the share of each interlocking type.

Poland is the only country included in the analysis in which mechanical interlockings represent the majority of all interlockings (55%), while Finland and Sweden have the smallest share of such devices (1%). Relay-based interlockings were most used in Romania (85%) and least used in Finland (24%). For electronic interlockings the largest share was recorded in Spain (62%), with Croatia on the last position (5%).

Another aspect worth mentioning is that, despite their age, relay interlockings are still dominant in 9 out of the 15 analysed countries. Seven of these countries (Romania, Bulgaria, Switzerland, Croatia, Sweden, Hungary, Slovenia) have most of their interlockings built on this technology. Even in countries less reliant on them, like Finland, relay interlockings still have a share of at least 24%.

Looking at the researched countries from a geographic point of view (*Figure 3*), no pattern relating to the interlocking profile can be discerned. While there is a grouping of countries in Central and Eastern Europe whose railway traffic control systems are mostly composed of relay interlockings, similar or higher shares are also present in other regions

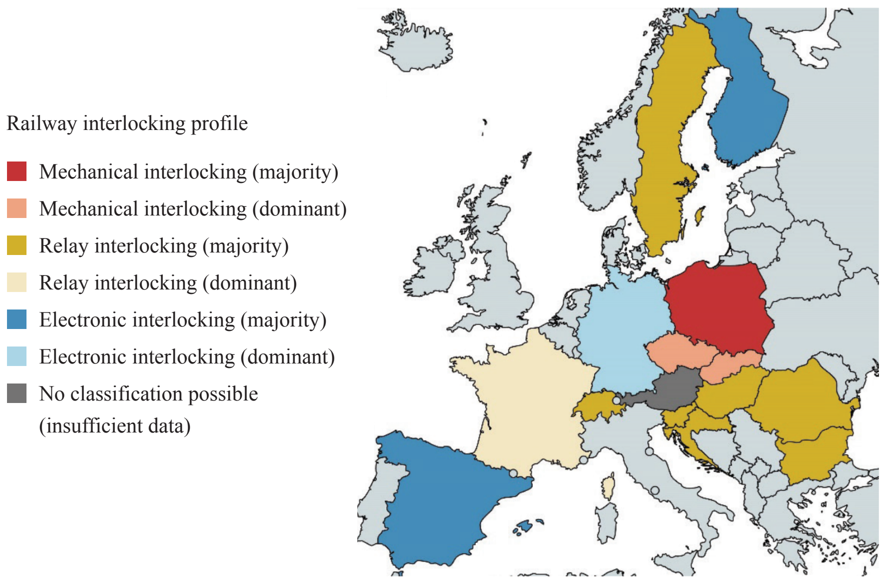

Figure 3 – Interlocking profile of researched countries

(e.g. Sweden, Switzerland). Because the data for Austria were incomplete, it could not be assigned an interlocking profile with certainty in *Figure 3*.

Figures 4–6 compare the share each type of interlocking has within each reviewed country with the size of the country's railway network [16]. A

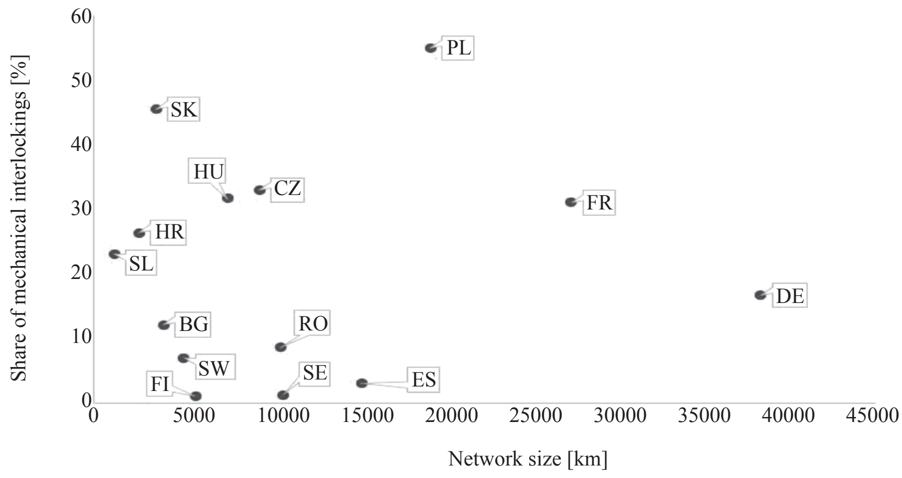

Figure 4 – Share of mechanical interlockings by railway network size

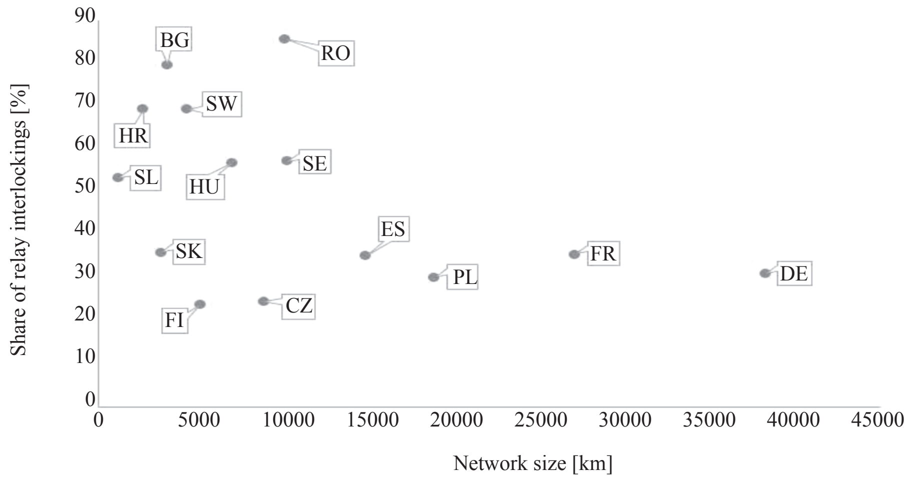

Figure 5 – Share of relay interlockings by railway network size

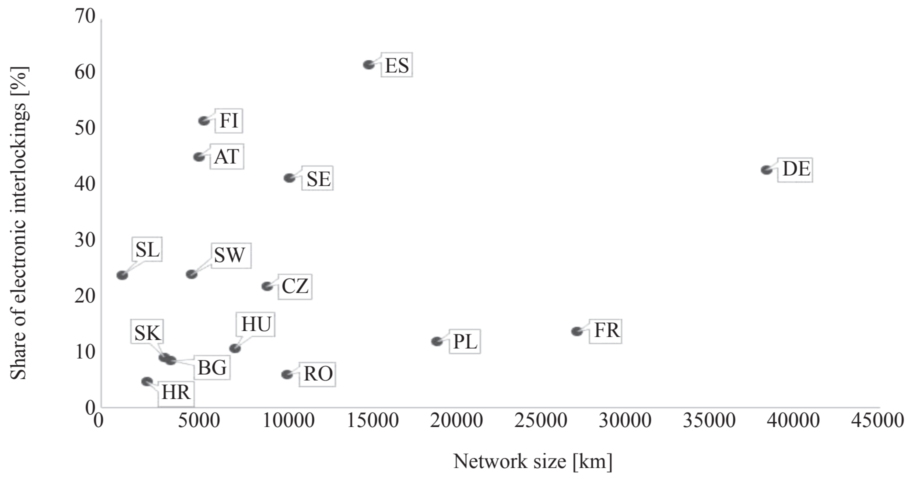

Figure 6 – Share of electronic interlockings by railway network size

relationship between these two variables cannot be established for any of the three types of interlockings based on the collected data. For example, the size of Hungary's railway network is around 20% that of Germany's, but the distribution of interlocking types is similar.

To compensate for the large variation between network sizes, the collected data was also evaluated against network density (km of track/km^2). This approach yielded comparable results to the ones from the previous analysis, with no direct link between the shares of the three interlocking types in any of the mentioned countries.

Previous research [35] has shown a historical connection between GDP and railway network length in Europe. As such, the data collected during this research have also been analysed by taking into consideration certain economic factors. *Figure 7* illustrates the share of legacy interlocking systems with regard to GDP per capita [36] for the reviewed countries (note: legacy systems include the above classifications of mechanical, relay and other).

A look at this representation seems to indicate an indirect correlation between GDP per capita and the share of legacy interlocking systems. However, there are a few countries among the ones included in this research that call into question this relationship. Namely, Switzerland has the highest GDP per capita, but maintains a significant share of legacy interlockings (76%). Another outlier is Spain, whose lower GDP per capita level does not translate into a lower share of electronic interlockings.

Another factor which was included in the research was the influence of long-term investments in the transport sector. A 10-year average (2009 – 2019) representing the share of government expenditure on transport was calculated from public data [37] and used in a similar analysis to those explained previously (*Figure 8*).

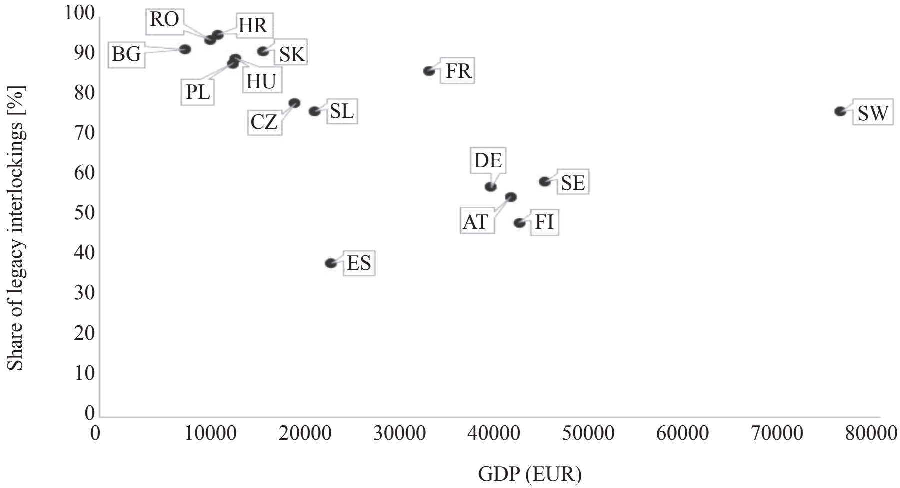

Figure 7 – Share of legacy interlockings by GDP

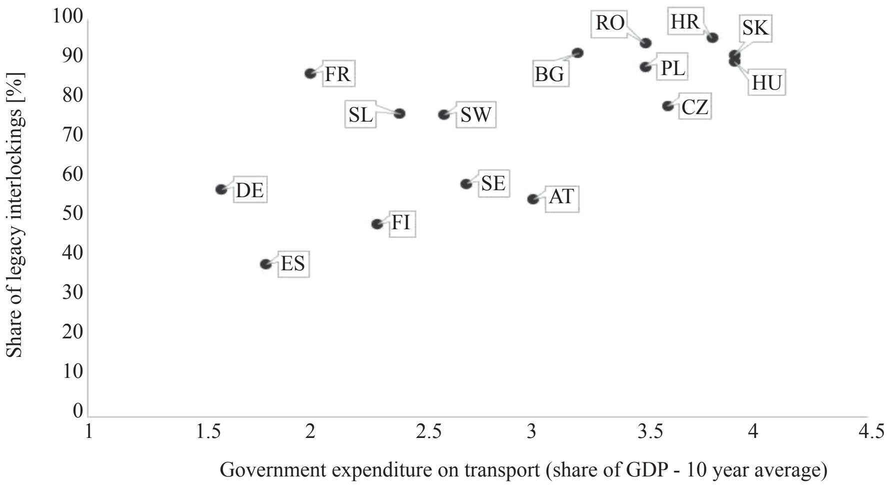

Figure 8 – Share of legacy interlockings by government expenditure on transport

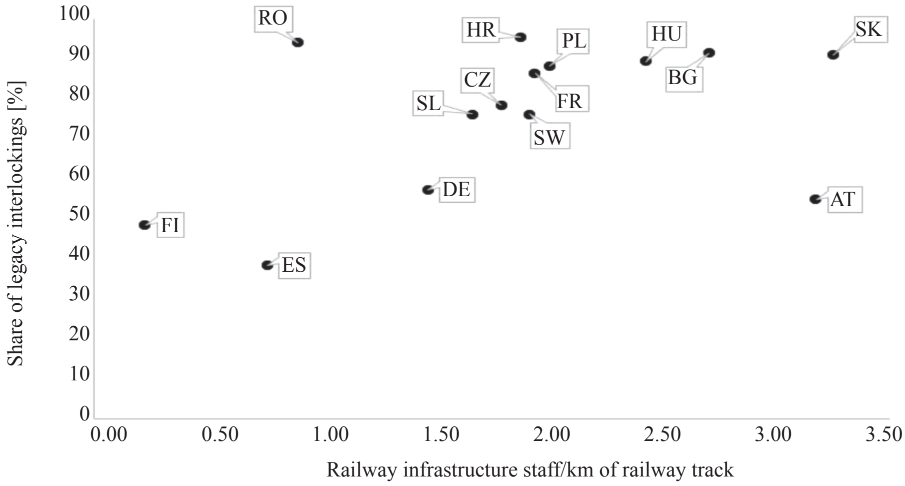

Figure 9 – Share of legacy interlockings by railway infrastructure staff/km of track

The results seem to differ to the ones from the previous GDP per capita analysis, in an apparent direct relationship. Countries which have spent a higher share of their GDP over the last 10 years on the transport sector show a higher share of legacy interlocking systems. This can be explained by the fact that countries in Central and Eastern Europe had to invest a larger share of their GDP on transport development in the last decade to catch up to their European neighbours. The drawback of the economic data used for this analysis is that the share of government expenditure is taken as a whole, and not divided by modes of transport.

Lastly, the share of legacy interlockings was compared to the number of staff belonging to the national infrastructure management of each of the researched countries. Only staff directly involved in infrastructure maintenance was taken into consideration. The latest available data for this were used in [38]. In order to compensate for the great population difference between the countries which impacts the number of the railway staff, the number of infrastructure employees was divided by the size of the network. The results are presented in *Figure 9*. Despite the expectation that countries with a higher share of electronic interlockings would have lower need for infrastructure staff, the comparison does not indicate any relationship between the two variables.

If one is to consider the total number of interlockings in the researched countries, the ranking according to technology type is as follows: relay (38%), mechanical (25%), electronic (27%) and other (10%). This distribution is illustrated in *Figure 10*. Comparing these figures to the information presented in *Table 1*, it is revealed that 6 countries have a larger than average share of mechanical interlockings, 8 countries a larger share of relay interlockings and 5 countries a larger share of electronic interlockings.

The large share of legacy interlocking systems (70%) is not without precedent in the railway sector. Similarities can be drawn with the implementation of the European Train Control System (ETCS) in Europe. It was designed to replace older national signalling technologies with a modern solution, which would allow for a greater integration between countries. While the European Union has set itself a goal of having all main railway corridors equipped with this system by 2030, with an intermediate target of 31% by 2023, the results have been far from that. At the end of 2019 only 11% of the core network had operational ETCS signalling [39].

Multiple reasons can be offered to explain the current situation. From a technical point of view, the new system does not offer sufficient advantages over the existing legacy signalling systems. Even the improvements that do exist are, however, out-

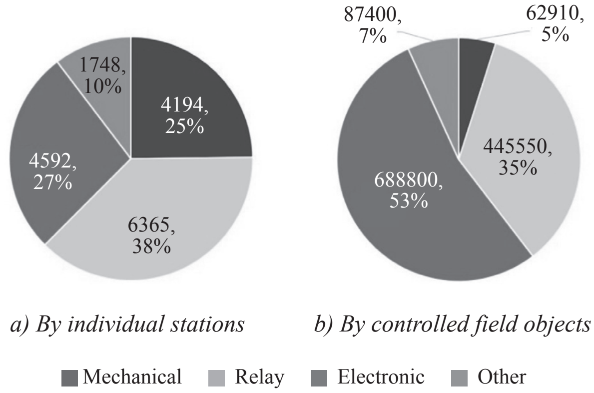

Figure 10 – Interlocking type distribution of all researched countries

weighed by the great cost of such high-tech technologies [40]. Because signalling and interlocking systems are complementary, the same reasoning can be applied to explain the persistence of legacy interlockings in such high numbers.

Railway infrastructure managers have also historically been rather conservative when it comes to the implementation of new technologies. This behaviour originates from the need to maintain a reliable safety level already proven by legacy technologies, rather than taking an unknown risk associated with implementing newer equipment.

For the main railway corridors, the common goal of all infrastructure managers is to install electronic interlockings in order to increase capacity and interoperability. The strategies for secondary lines are, however, not universally defined.

For example, the infrastructure manager in Romania plans to phase out all existing mechanical interlockings. While some of them will be replaced by electronic interlockings, others will be upgraded to relay interlockings. This second upgrade option provides a less expensive alternative to full modernisation because of the reuse of components from already upgraded stations [41]. Another advantage is the possibility of in-house design and execution which further reduces the costs of the upgrade.

One aspect which was not brought up until this moment is that while legacy systems are more frequent when counted station by station, each technology type has a limit of controllable field objects. If one is to take into account the figures offered by the Polish infrastructure manager, the average numbers of signals and points controlled by each interlocking type are as follows: 13 for mechanical, 36 for relay and 49 for electronic [28].

It must be mentioned that the numbers regarding the two latter types do not include devices and equipment such as track circuits, axle counters, ETCS or other type of balises. When taking these facts into consideration, more accurate figures would be of around 70 field objects controlled by a relay interlocking and of around 150 for electronic interlockings. Adjusting the previous analysed data for these large variations, yields a more complete overall review (*Figure 10*). For other types of interlockings an intermediate figure of 50 field objects was selected.

While most individual stations are equipped with legacy interlockings, they only control around less than half of all field elements when considering all researched countries. Looking at the national level, only 5 countries have more than half of their field objects controlled by relay interlockings (Bulgaria, Croatia, Hungary, Romania and Switzerland), and 7 countries by electronic interlockings (Austria, Czechia, Finland, Germany, Spain and Sweden). In the remaining countries (France, Poland and Slovenia) relay interlockings still maintain their dominance, even if they control less than half of all field objects.

5. CONCLUSION

The railway networks of several European countries were researched within this study in order to evaluate the current state of railway interlockings. The results show that, although dwindling, legacy interlocking systems still play an important part in the current railway landscape.

Legacy interlocking systems control, in the present, slightly less than half of all field objects. This decrease is expected to continue in the future. When only looking at individual stations, legacy systems still maintain their presence but will eventually become a minority. However, this will not happen in the foreseeable future, especially in some countries (e.g. Hungary, Romania, Bulgaria). This is mainly because of the high costs associated with replacing older technologies.

What is to be expected over the next decades is for the main railway corridors to be upgraded and for the stations along them to be outfitted with electronic interlockings in order to increase capacity and allow for a higher degree of European railway integration. This will further lead to an increased share of electronically controlled field elements. Branch lines with less traffic, on which the full upgrade cannot be economically justified will most likely maintain legacy systems in operation for as long as possible.

As such, it is still important for current and future railway engineers and technicians to be properly trained to operate and maintain these legacy systems in order to ensure a high level of safety. This aspect should not be minimised or neglected by railway policy makers.

The presented analyses have indicated that the share of the various interlocking types is not dependent on factors such as geographical location, network size, GDP or the number of employees involved in railway infrastructure maintenance. A slight correlation can be seen between the average government expenditure and the share of legacy interlockings. More detailed financial data regarding expenditure in the railway sector would be necessary to establish an accurate link.

The results of this study may be improved by including more countries. On a European level, it would be of great value to add missing countries with extensive railway networks, such as Italy, the United Kingdom, or the Netherlands. It is to be expected that the overall share of interlocking types would not change significantly with these new additions.

Similar analyses may be carried out for countries outside Europe in order to compare the findings and to draw some general conclusions on this subject. Of particular importance would be countries with considerable railway network sizes like the United States, Canada, India, China, South Korea or Japan.

As. drd. ing. **Florin BĂDĂU**[1]
E-mail: florin.badau@upb.ro
[1] Departamentul Telecomenzi și Electronică
în Transporturi, Facultatea de Transporturi
Universitatea Politehnica din București
Splaiul Independenței 313, București, 060042, România

CENTRALIZĂRI FEROVIARE: O RECENZIE A STĂRII TEHNOLOGIEI DE SIGURANȚĂ FEROVIARĂ DIN PREZENT ÎN EUROPA

REZUMAT

Instalațiile de centralizare sunt un element esențial al sistemului feroviar. Acestea sunt necesare pentru comanda și controlul echipamentelor, precum macazuri și semnale, în limitele stațiilor de cale ferată cu scopul de dirijare a trenurilor. Proiectarea acestora trebuie să garanteze cel mai înalt nivel de siguranță pentru toate părțile implicate. Continentul european are o rețea vastă de cale ferată ce s-a dezvoltat de-a lungul a mai bine de 150 de ani. Instalațiile de centralizare au evoluat în aceiași perioadă de la niște echipamente mecanice de mari dimensiuni, ce aveau nevoie de forță fizică pentru a funcționa, la sisteme computerizate capabile de operații complexe. În ciuda salturilor tehnologice, multe instalații de centralizare ce funcționează în prezent încă folosesc tehnologii vechi. Această recenzie are ca scop crearea unei imagini exacte asupra instalaților de centralizare din prezent în Europa prin evaluarea ponderii fiecărei generații de centralizări feroviare (mecanică, cu relee și electronică). Studiul cuprinde 15 țări și peste 200 000 km de cale ferată, reprezentând peste două treimi din întreaga rețea de cale ferată a Uniunii Europene. O prezentare scurtă este oferită pentru fiecare țară, în timp ce comparațiile dintre diferitele țări analizate subliniază anumite aspecte cheie. Accentul este pus doar pe instalațiile de centralizare din stații, nu și pe sistemele de semnalizare dintre stații. Concluziile acestei analize conțin recomandări pentru dezvoltarea din prezent și din viitor a sectorului feroviar.

CUVINTE CHEIE

centralizări feroviare; siguranță feroviară; statistică feroviară; centralizări cu relee; centralizări electronice; semnalizare feroviară.

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