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Application of the Functional Flow Diagrams in a Design of the Level Crossing Hydraulic Barrier Drive

Mirko Karakašić*, Ilija Svalina, Daniel Novoselović, Iva Samardžić, Hrvoje Glavaš, Radomir Đokić

Abstract: In a domain of a safety increasing of railway and road traffic, hydraulic barrier drives installed at level crossings have an important role. Frequent traffic accidents at level crossings, involving road vehicles and trains, are result of inappropriately equipped level crossings with signalling and safety equipment. Limited use of hydraulic barrier drives is the result of complicated adaptation in the process of implementing such systems to the existing infrastructure of some of the equipment manufacturers and railway operators. Hydraulic barrier drive PBH21, which uses a modular architecture, was developed and designed in this paper. Applying modular design principles and functional modeling methods, using functional flow diagrams, PBH21 has ability to adapt on the technologies and infrastructures of other major manufacturers of such equipment within EU countries and other countries in the world that have developed railway infrastructure. Due to the protection of certain design solutions from competition, certain details are not presented in this paper.

Keywords: functional modeling; hydraulic barrier drive; level crossing; modular design; technical systems; traffic safety

1 INTRODUCTION

Railway market can be divided into four segments: infrastructure, vehicles, maintenance and signal-safety equipment [1]. According to [1], hydraulic barrier drives in railway traffic belong to the category of signalling-safety equipment. Their importance and significance is reflected in safety increasing of the rail and road traffic participants.

According to the Law on Safety and Interoperability of the Railway System [2], the railway system of the Republic of Croatia is divided into structural subsystems and functional subsystems. Structural subsystems consist of building subsystems, electric power subsystems, traffic-control and signal-safety subsystems on the railway, traffic-control and signal-safety subsystems on vehicles and vehicles. Railway equipment for safety, management and trains supervision was included on the traffic-control and signal-safety subsystems. Therefore, hydraulic barrier drives belong to the mentioned subsystem. Functional subsystems consist of traffic maintenance, development and management, as well as telematics applications for passenger and freight traffic.

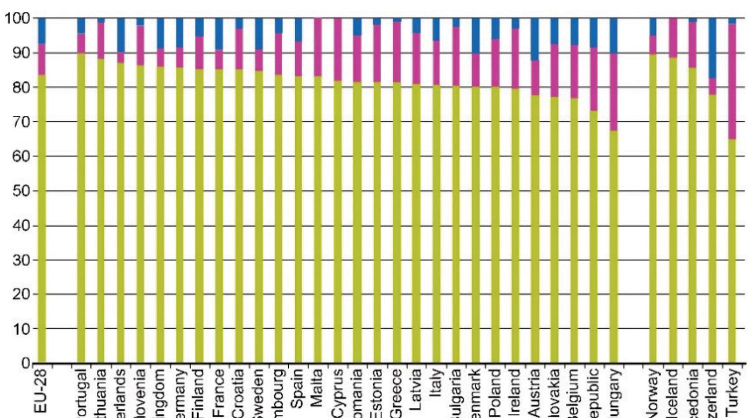

Figure 1 Share of rail traffic of EU-28 member states [3]

1.1 Rail Traffic Analysis in the EU and the Republic of Croatia

Rail transport takes an important role in the overall European transport sector. However, compared to the share of the private cars use, it lags behind significantly. According to [3], the share of passenger transport by train, between 2004 and 2016, was around 6,7% in the EU-28 member states. In Croatia, that number was smaller and was about 3% (Fig. 1). For the same period, the share of passenger car use in EU-28 member states ranged from 83% to 83,7%. In Croatia, that number was around 85%. This data indicates that the share of train travel was lower in Croatia compared to EU-28 member states, that is, less importance is given to the importance of train travel.

An analysis of the railway transport of goods in the period from 1995 to 2014 shows its growth until 2007 [4, 5]. Then came the world economic crisis, which was reflected in the drop in traffic until 2009. In the period from 2009 to 2014, there was a recovery and growth in rail transport of goods in the EU member states, which was over 400 billion tons per kilometer [4, 5]. This increase is continued until the 2018, and then there was a decrease, which in the second half of the 2020 was 400 billion tones per kilometer (Fig. 2). Then there is a recovery, i.e. an increase of transport of goods (Fig. 2).

In the passenger rail traffic there is a trend of constant growth with a smaller decline during the duration of the global economic crisis [4, 5]. During the outbreak of the pandemic caused by the corona virus, there is a sudden drop in passenger transport. Recovery is visible in the second half of the 2020 (Fig. 2).

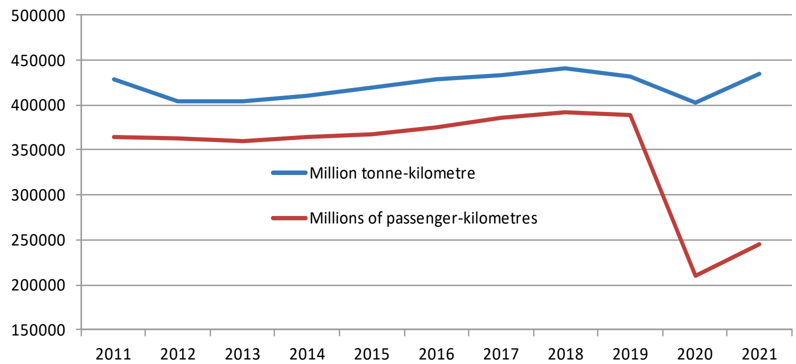

Figure 2 Movement of goods and passengers in EU countries for the period from 2011 to 2021 [6, 7]

Railway transport of goods in the Republic of Croatia had its own growth until 2007 [5, 8, 9]. Then it reached its maximum value, which was 16000000 tons [5, 8, 9]. As a result of the world economic crisis, it falls. The downward trend continued in the years to come, and in the second half of the 2013 the rail transport of goods amounted to 2000000 tons (Fig. 3). In the following years, there is an increase in the transport of goods (Fig. 3). In the period from 1996 to 2008, passenger rail traffic in the Republic of Croatia grew [5, 8, 9]. The peak was reached in 2009, when it amounted to 70000000 passengers [5, 8, 9]. Then there was a continuous decline, and in the first half of the 2020, the number of passengers was 5000000 (Fig. 3). Then there is an increase in passenger transport in the second half of the 2020 (Fig. 3).

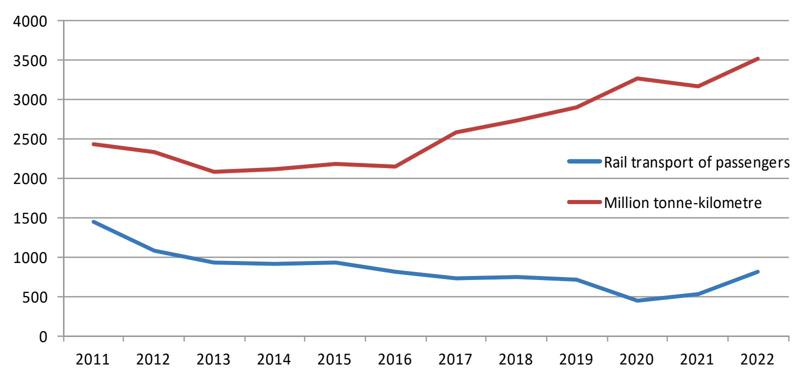

Figure 3 Movement of goods and passengers in the Republic of Croatia for the period from 2011 to 2021 [6, 7]

A well-developed and branched railway transport network is an important factor in the economic growth and integration of an individual country. The length of the transport network of the EU-28 countries is 217081 km [10]. Comparing the length of the railway network with countries such as the USA (203200 km), Japan (19200 km), China (121000 km), Russia (86000 km) and India (64600 km), the EU-28 countries have the longest railway network [10]. Despite the above, the length of the railway network of the EU-28 countries decreased by 20590 km from 1990 to 2016. The reasons should be sought in the dominance of road traffic in relation to rail traffic, which according to [10], dominates in the EU-28 countries with a ratio of 4,13.

Although a small country, Croatia has an important role in the European transport system, and is located on two corridors of the basic EU transport network. Therefore, Croatia has an important role as part of the European strategy of creating a single transport market, that is, a single European market that the EU is aiming for. Railway network of the Republic of Croatia (Fig. 4), according to the data of the Croatian Bureau of Statistics, was 2604 km in 2015 [9]. According to [4], quality of the railway infrastructure in the Republic of Croatia is significantly lower than the EU average. Therefore, modernization of the railway infrastructure and increasing of the safety of railway transport is imperative for the Republic of Croatia.

Through the analysis of the current state of the market, conducted by Altpro d.o.o. [11], three problems of the European railway system were observed. The first problem relates to the dependence of railway operators on specific technologies of dominant manufacturers. Multinational companies such as Alstom, Siemens, Thales, Ansaldo and Bombardier dominate in the development of the safety equipment in the segment of rail transport. Mentioned companies are not interested in the production of safety equipment that would be compatible with the equipment of the other manufacturers. Mentioned companies in the target markets want to completely replace the found existing equipment with their own equipment. Another problem relates to the fragmentation of the national railway systems. In this sense, there are 20 national signal-safety systems in the European countries. Each of these systems has its own specific requirements and norms. Because of this, cross-border rail traffic is disrupted. The third problem relates to the level of security, which is insufficiently represented [3, 4]. One of the main reasons for the low level of safety stems from insufficient investment in railway infrastructure. Low-quality maintenance of the railway infrastructure is also one of the causes of the decrease in reliability and safety in railway traffic. Problem of reliability, quality and safety of the railway infrastructure is particularly pronounced in the countries of Eastern Europe [12]. Low level of safety is partly from the limited use of signal-safety devices in railway traffic. The Law on Safety and Interoperability of the Railway System [2] prescribes importance and significance of railway traffic safety in the Republic of Croatia. The law emphasizes the need to install and use signal-safety equipment along railroad tracks and level crossings.

Figure 4 Railway network in the Republic of Croatia

Importance and advantage of rail transport for the further economic development of EU countries is also indicated by the initiative undertaken by the European Commission to further encourage the development of a single European transport area. Significant progress has been made in the area of the 4th Railway Package, Blue Belt initiatives for maritime transport, proposed Single European Sky II, EU Aviation Strategy and NAIADES Program for inland waterways [12].

Railway transport has a significant number of advantages compared to other types of land transport (primarily road transport). First of all, speed of traffic, comfort for passengers, economy in medium and long distance cargo transport and significantly lower energy consumption than road transport [12].

If the impact of EU transport on greenhouse gas emissions is taken into account, then a quarter of greenhouse gas emissions are derived from transport. In accordance with the need to reduce the impact of greenhouse gases, rail transport has a less harmful impact on the environment compared to other types of transport. Thus, over 70% of greenhouse gas emissions are produced by road traffic. Railway traffic emitted 0,6% of greenhouse gases (Fig. 5). Therefore gas emission from vehicles have significant influence on global warming and energy consumption [13, 14]. Analysing the share of total energy consumption, according to types of transport, railway traffic accounts for 1,6%. For the sake of comparison, road traffic accounts for 73,4% of the total energy consumption (Fig. 5). This is a very important indicator, which gives rail traffic, especially in the part of freight (goods) transportation, a comparative advantage compared to road freight transport and fits into the strategy of the European Green Plan [15].

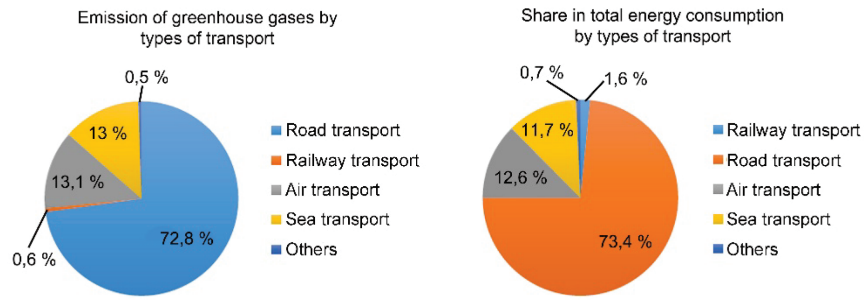

Figure 5 Influence of the type of transport within the EU on the emission of greenhouse gases and energy consumption, [5, 16]

In accordance with the conducted market analysis and the EU initiative for the greatest possible investment in the development of railway transport, the need for the development of safety equipment is indicated. Therefore, development and design of a new hydraulic barrier (semi-bumper) PBH21 was presented in this paper. Main purpose of this system is to secure level crossings. This is important from the aspect of the proper functioning of transport system, especially from the aspect to achieve the highest level of reliability at any stage of the transport process [17]. The system was designed with an emphasis on fulfilling the requirement to have a SIL4 (TYPE A) safety certificate according to the EN 17020 standard [18]. The PBH21 hydraulic barrier was developed to fulfil one of the main design requirements, which implies fulfilment most of the international standards and technical specifications of the individual countries for which the PBH21 is designed. Therefore, the principles of modular design were used in the development and design of this technical system. The system has a modular architecture that allows it to be adapted to the found existing infrastructure in the individual countries for which the system was designed. In this way, the reduced dependence of railway operators on the specific technologies of the dominant manufacturers was achieved. Using the method of the functional modelling of the technical systems, by using functional flow diagrams, modular functional structure of the hydraulic barrier PBH21 was developed. From the modular functional structure, in detail design phase, individual module of hydraulic barrier drive PBH21 was designed.

2 METHODS AND METHODOLOGY

Design process of a new product is a complex activity that uses methods and tools developed within the design theories [19-24] that aim to produce artifacts that fulfil the user's requirements by performing their functions. Artifacts according to [19] represent technical systems that are connected to their environment through inputs and outputs, that is, they transform input sizes into output sizes. The sizes that are transformed can be grouped into three categories. These categories are energy, material and signal (information). Pahl and Beitz divided design process into the four phases: clarification and task definition, conceptual design, embodiment design and detail design [20]. Each phase transfers activities between them, which are connected with each other by information.

If the process analysis is observed within a specific functional structure of an individual technical system, then by monitoring of the energy, material and signal flow is possible to connect individual functions through the functional flow diagrams [25]. This approach is called functional modelling and is used in the design phase [26]. Solution of the conceptual design phase was shown through the functional structure. This solution does not depend on the final form of the design. Functional models represent basis for searching of working principles and working structures that are solutions of the partial and overall functions [27].

Design process in the development and design of new artefacts also uses modular design method. According to [28], a module represents an independent building block of a more complex technical system. Each module is connected with other elements of that complex technical system by loose connections. In embodiment and detail design, modules are physical structures that fully match with the functional structures [29]. According to [20], modular design enables connection of design elements into the structures from which different variants of technical systems can be designed. Stone [30] develops methods for extracting modules from a functional structure using module heuristics. With such methods, modules are identified from functional models.

In this paper, authors modeled functional models of the hydraulic barrier drive PBH21, which were described through the functional flow diagrams, and grouped them into the functional modules. Connections between functional modules are made through input and output flows of energy, material and signal. Thus, in the conceptual design phase, by realizing of the connection between the functional modules, achieved connection between the working principles. Such working principles in the embodiment and detailed design represent modules of a certain more complex technical system. This approach through the design of the functional modules and their connection via flows enables a systematic approach in a design of the design modules from the functional structures.

After the previously described methods used in the development and design of the hydraulic barrier drive, research methodology and the structure of the paper are listed in the rest of this chapter. The necessary descriptive and technical data about the new hydraulic barrier drive PBH21 device, for the purposes of writing this paper, were collected by performing various activities during its development. This development period is divided into a two phases. First phase consists of industrial research for the development of the PBH21 prototype and a second phase consists of its experimental development. Research and analysis of the market trends was included in the first phase. In this phase, implementation of a barrier drive at railway-road crossings, was included. Also, as a final output, requirements were structured as an input to the design process of the new hydraulic barrier drive PBH21. Analysis of the market trends is described in the Introduction section. In the second phase, by applying of the functional decomposition method, was included selection of the design methods and the design of the functional structure. Also, in the second phase, tests of the prototype version of the hydraulic barrier drive device were carried out in laboratory and real working conditions. Obtained results of these tests are not presented in this paper. In the Requirement list and function decomposition section, general list of requirements and functional models of the four modules of hydraulic barrier drive PBH21 are presented. Developed functional models served as a starting point for finding of the working principles of the module solutions and designing of the modular structure of the hydraulic barrier drive PBH21. Final design solution of the hydraulic barrier drive PBH21 is described in the section Design solution of the hydraulic barrier drive PBH21. Presented hydraulic barrier drive PBH21 was developed and designed by Altpro d.o.o. within the EU project "Center of Competences for Advanced Engineering Nova Gradiška CEKOM NI NG (KK.01.2.2.03.0011)".

3 REQUIREMENT LIST AND FUNCTIONAL DECOMPOSITION

3.1 Requirements for Design of Hydraulic Barrier Drive PBH21

Development of the hydraulic barrier drive PBH21, which belongs to the category of signaling and safety equipment, complies with the prescribed norms in the domain of technical, operational and regulatory standards. During development process of the device, requirements in the field of communication security standards, standards for hardware, vibrations, temperature, electromagnetic compatibility and standards for infrastructure compatibility have been fulfilled. In the development of the device, requirements arising from the EU guidelines for the development of the trans-European transport network and directives of the European Commission on the technical specification for interoperability related to the traffic-control and signal-safety subsystems have been implemented.

Table 1 General requirements list for hydraulic barrier drive PBH21

No.	Requirements	No.	Requirements
1	Safety requirements	4	Exploitative requirements
1.1	fulfilment of safety certificate SIL4 (TIP A)	4.1	Life cycle > 30 years
2	Design requirements	4.2	reliable operation
2.1	modular design	4.3	operation possibility at low / high temperatures (-30° to 70°)
2.2	operability by barrier arm up to 12 m long	4.4	operation in an atmosphere with a high moisture content
2.3	possibility of implementation on the existing operator infrastructure	4.5	supplying system with electricity
2.4	universal specification platform	5	Maintenance
2.5	generic design	5.1	simple installation of components
2.6	standardized components use	5.2	simple configuration according to customer requirements
2.7	drive unit - electric motor	5.3	simple operation with device
3	Technological requirements	5.4	simple assembly / disassembly
3.1	independent technological solution	5.5	reduce total number of maintenance intervals
3.2	compatible hardware interface	6	Costs
3.3	use materials of next - generation in production process	6.1	cheaper maintenance
3.4	simpler production	6.2	lower operating costs of device

Independent technological solution is an extremely important requirement that the hydraulic barrier drive PBH21 should fulfill. This requirement arises from a need for a long lifecycle of devices in the railway industry (over 30 years). Equipment that does not depend on the manufacturer and that can be used with equipment from other manufacturers should protect customer from the disappearance of a certain manufacturer from the market and in this way affects on the longer lifecycle of the device.

Application principles of generic design should allow replacement of existing technology with any technology that should developed in the future. Also through the generic design, it should be possible more easily adapt system to the specific specifications of a particular market. Hardware interface of the barrier drive needs to be compatible with all types of peripheral units due to the requirement for interoperability and compatibility with products of other manufacturers.

A general overview of the basic design requirements that needs to fulfill a new hydraulic barrier drive PBH21 is collected in Tab. 1. These requirements are determined and defined at the beginning of the design process, and in accordance with them, development of the hydraulic barrier drive PBH21 began. Requirements are divided into six categories: safety requirements, design requirements, technological requirements, exploitative requirements, maintenance requirements and cost requirements.

3.2 Functional Model of Hydraulic Barrier Drive PBH21

Barrier drive is a part of Level Crossing Protection System (LCPS) outdoor elements. This device, when train approaches, increases safety of all traffic participants (road vehicles and train). Device physically prevent passage over level crossing for all road vehicles when LC is switched-on. This is also the main purpose of hydraulic barrier drive PBH21.

After analysing requirement list and determining main purpose of the device, functional model of hydraulic barrier drive PBH21 was established. "Black box" is the starting point for the functional structure of the overall function of hydraulic barrier drive. Overall function of the hydraulic barrier drive is to "*Make impossible to cross the level crossing by lowering of the barrier arm*". A functional flow diagram is used to present a functional model of the barrier drive overall function. By monitoring of the energy, material and signal flow, a connection between partial functions within the functional model is realized. Functional structure, applying functional decomposition method, is divided into four functional levels. On the first level, there is the overall function of the hydraulic barrier drive PBH21. Second level consists of the overall functions of the modules, which are using modular design, implemented in the design structure of hydraulic barrier drive PBH21. Third and fourth level of the functional structure, represent partial functions that shape overall functions of an individual module.

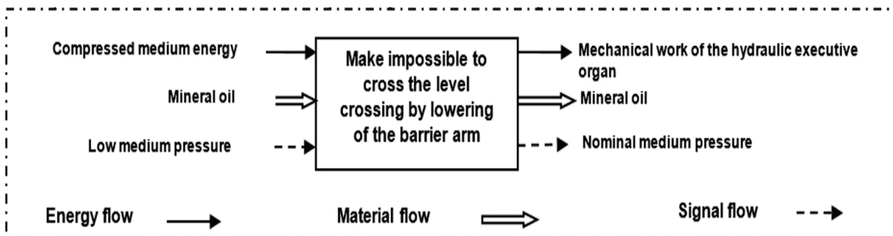

Figure 6 Functional model "black box" at the first level of the functional structure

Overall functional model of the hydraulic barrier drive at the first level of the functional structure is shown in Fig. 6. Energy flow at the input to the function is achieved through the energy of the compressed medium, that is, energy stored in the mineral oil under pressure. Through the transformation action of the overall function on the energy of the compressed medium, mechanical work of the hydraulic executive organ is achieved at the output of the function. Material flow is realized using mineral oil, as a medium used in the hydraulic system of the hydraulic barrier drive. At the first level of the functional structure, signal flow is realized by monitoring of the medium pressure at the input and output of the overall function.

Modular design principles were applied in the design of the hydraulic barrier drive. Therefore, second level of the functional structure consists of the overall functions of the modules, which are connected by energy, material and signal flows. Overall functions of the second level form main module group, which consists of four modules: Module 1, Module 2, Module 3 and Module 4 (Fig. 7).

Module 1 functional flow diagram consists of three levels of the functional structure. First level consists of the overall function "*Compress medium to the nominal pressure and supply system with the medium*". Since the functional structure of the hydraulic barrier drive has four functional levels, functional structure of Module 1 starts from the second level of the functional structure of the hydraulic barrier drive. This means that the overall function of the Module 1 is on the second level of the functional structure of the hydraulic barrier drive. Other partial functions of the Module 1 are located on the third and fourth level of the functional structure of the hydraulic barrier drive (Fig. 8). Functional structure of Module 1 uses six partial functions that solve overall function of the Module 1 by transforming energy, material and signal. When the hydraulic barrier drive is putted into operation, electrical energy supplied from the electrical network is transformed into the energy of the compressed medium. Mineral oil is used as a medium that needs to be stored in a tank, compressed to nominal pressure and used to manipulate with the barrier arm. By monitoring the signal flow, amount of the medium in the tank is controlled, as well as the pressure state of the mineral oil stored in the Module 1 system. Monitoring of these two conditions is achieved using sensors for detecting amount of the medium and a manometer for a pressure measuring. After generated functional structure of the Module 1, a Hydraulic aggregate group is working principle that represents solution of the functional structure of the Module 1 (Fig. 13 and Fig. 14).

Functional structure of Module 2, by process of functional decomposition, is divided into three levels. If the functional structure of Module 2 is viewed as a separate module, then on the first level the overall function is "*Store energy of the compressed medium*". Since the functional structure of Module 2 is part of the functional structure of the hydraulic barrier drive, within this structure, the overall function of Module 2 is on the second level (Fig. 9). Therefore, partial functions of Module 2 are located on the third and fourth level of the functional structure of the hydraulic barrier drive. Overall function of Module 2 uses five partial functions that transform energy, materials and signal (Fig. 9).

With the start-up of the hydraulic barrier drive, electrical energy of the overall function of Module 1 is transformed into the energy of the compressed medium. Due to the action of the overall function of Module 2, this energy remains unchanged. Mineral oil flow, due to the action of the overall function of Module 2, also remains unchanged. By monitoring of the signal flow, it can be seen that at the input to the overall function of Module 2, signal corresponds to the output signal of the overall function of Module 1 (Fig. 8, Fig. 9). Due to the action of the overall function of Module 2, two signals are present at the output of the function: nominal medium pressure and medium flow (Fig. 9). Nominal pressure represents medium working pressure in the hydraulic system of the device. After generated functional structure of the Module 2, accumulator group is working principle that represents solution of the functional structure of the Module 2 (Fig. 13 and Fig. 14).

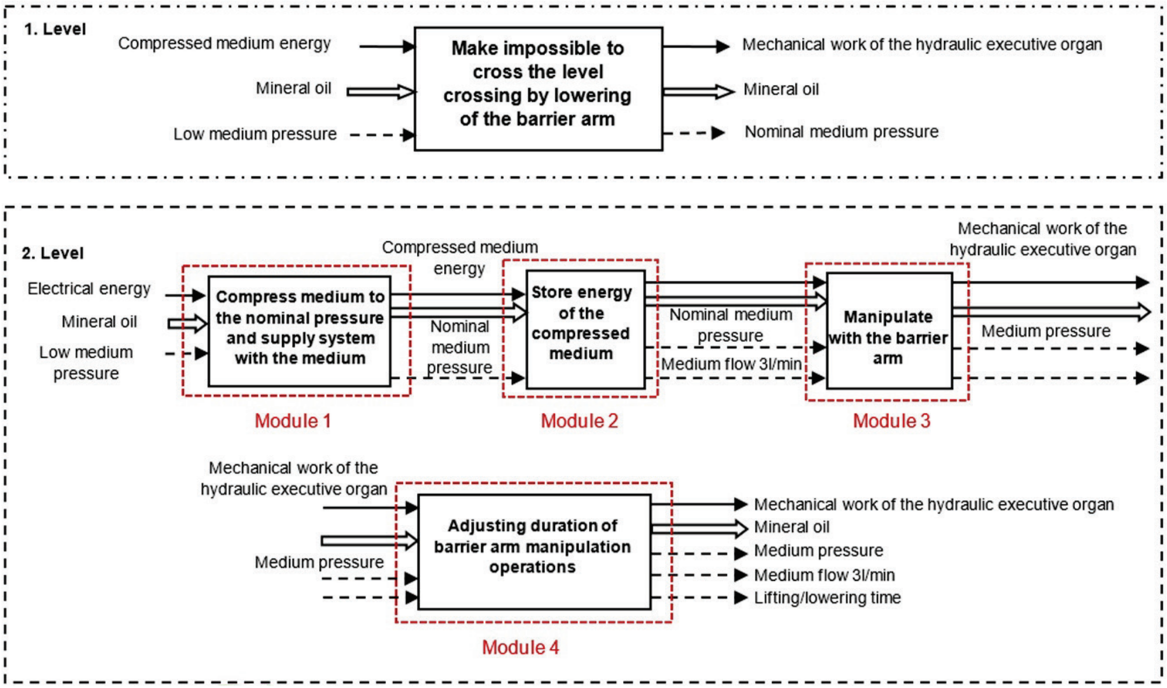

Figure 7 Functional flow diagram at the second level of the functional structure

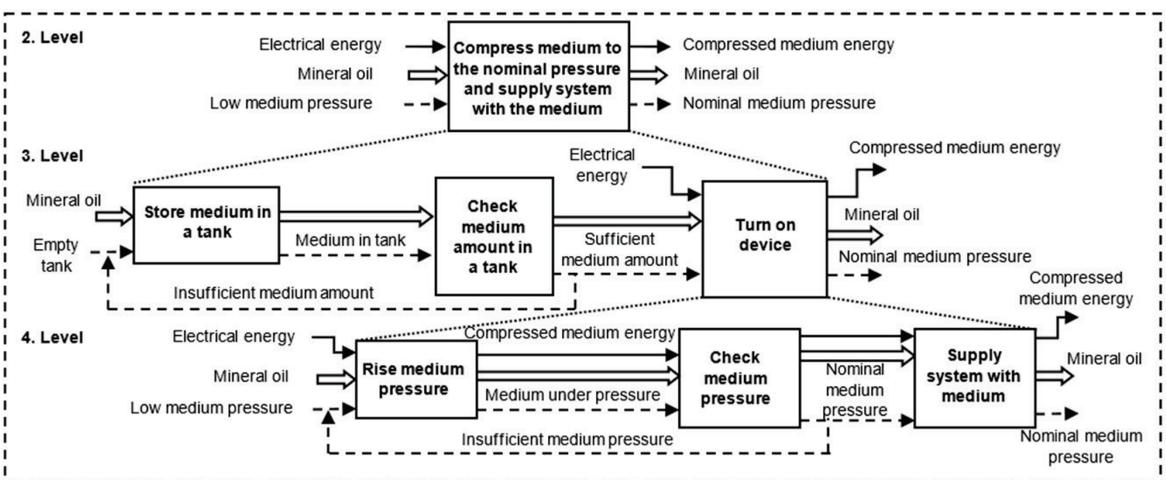

Figure 8 Module 1 functional flow diagram

Functional flow diagram of Module 3 describes functional structure on three levels. On the first level is overall function "*Manipulate with the barrier arm*". Other partial functions of Module 3 are located on the third and fourth level of the functional structure of the hydraulic barrier drive (Fig. 10). Functional structure of Module 3 uses seven partial functions that solve overall function of Module 3 by transforming energy, material and signal. Functions "*Lower barrier arm*" and "*Raise barrier arm*" transform the energy of the compressed medium into the mechanical work of the hydraulic executive organ. In a case of the system electricity supply interruption or a failure occurrence, manipulation of the barrier arm lowering and of the barrier arm raising is possible to achieve by the action of the operator (human). Therefore, functions "*Lower barrier arm"* and "*Raise barrier arm*", by functional decomposition, generate partial functions "*Manually lower barrier arm*" and "*Manually raise barrier arm*" (Fig. 10). These two functions, through the action of the operator, use the energy of human work, which they transform into mechanical work. This work performs lowering and raising of the barrier arm. Module 3, as the working principle, represents solution of the functional structure. This module, after detail design process, represents valve block module (Fig. 13 and Fig. 14).

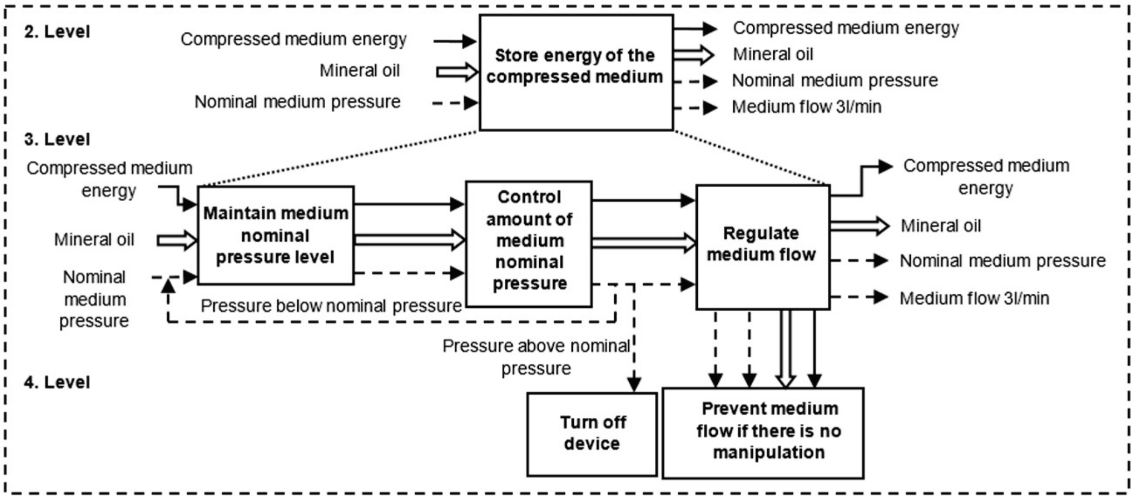

Figure 9 Module 2 functional flow diagram

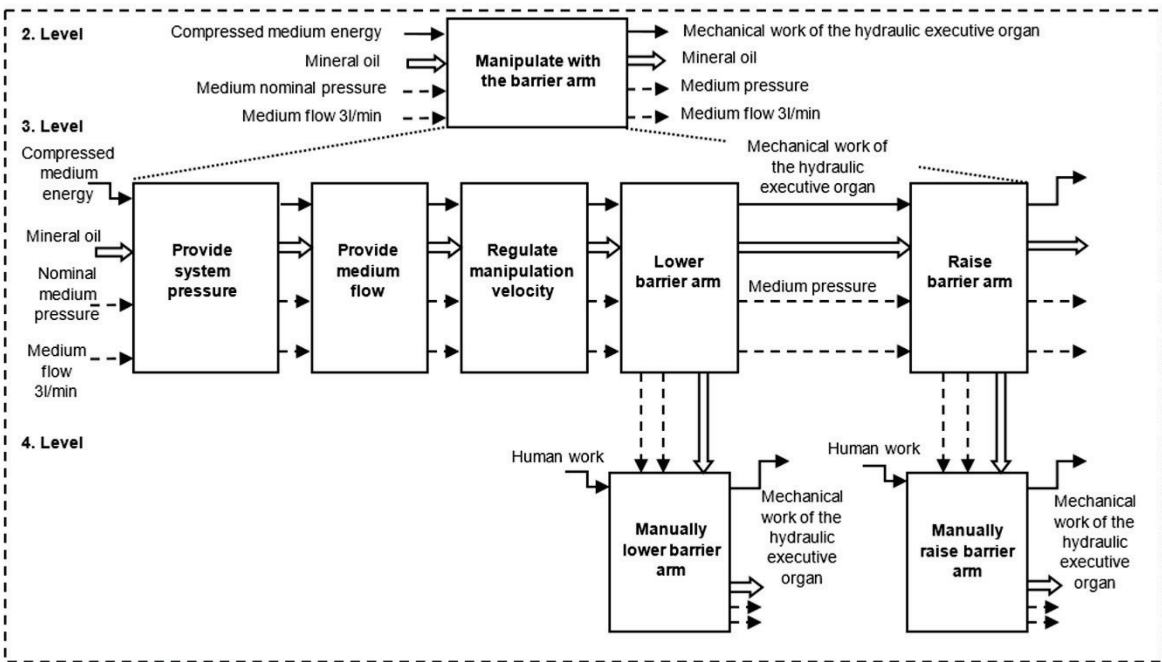

Figure 10 Module 3 functional flow diagram

Functional structure of Module 4 is described on two levels (Fig. 11). On the first level is overall function "*Adjusting duration of barrier arm manipulation operations*". Four partial functions that solve this overall function are located on the second level of the functional structure of the Module 4, i.e. on the third level of the functional structure of the hydraulic barrier drive. Input to the overall function contains two signals: medium pressure and medium flow 3 l/min (Fig. 11). By transforming of these signals, a third signal is generated at the output of the overall function, i.e. raising / lowering time of the barrier arm (Fig. 11).

Partial function "*Setting duration of the manipulation operation*" at its input includes additional energy flow described through the human work. Through this function, operator has ability to adjust duration of the barrier arm raising and lowering operations, via the control panel of the device. After generated functional structure of the Module 4, slow motion valves is a working principle that represents solution of the functional structure of the Module 4 (Fig. 13 and Fig. 14).

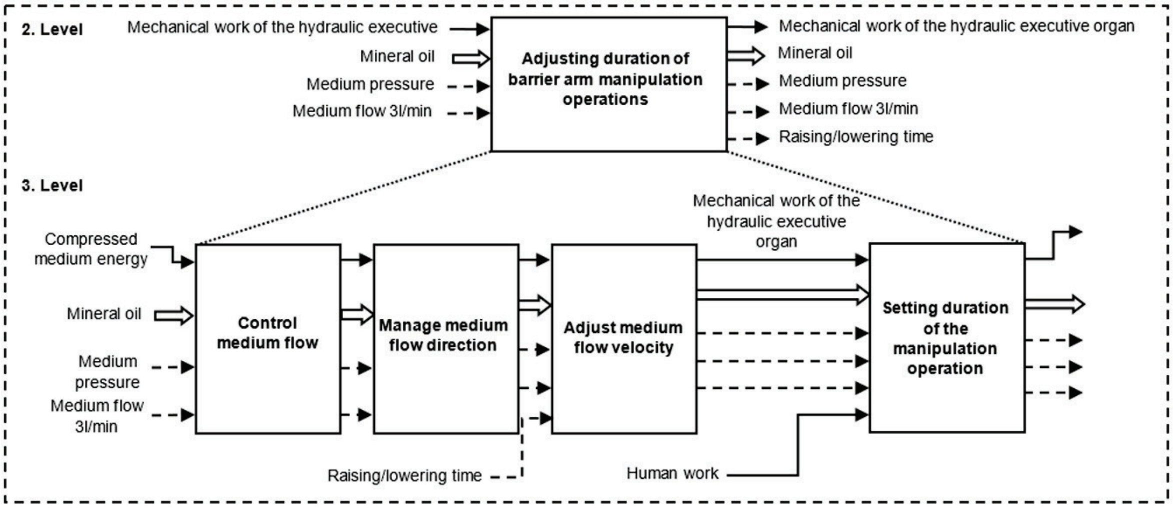

Figure 11 Module 4 functional flow diagram

4 DESIGN SOLUTION OF THE HYDRAULIC BARRIER DRIVE PBH21

Barrier drive PBH21 (Fig. 12), developed by Altpro d.o.o., is made as hydraulic type. By the process of functional decomposition, through the monitoring of the energy, material and signal flow, mineral oil is selected as a drive medium of the hydraulic system (Fig. 6 and Fig. 7). For arm rising and lowering, it uses hydraulic drive with a two-way hydraulic cylinder as executive element. In a failure occurrence, it is possible manually to control device, using a main valve block system. For that matter, operator uses combination of manually activated / deactivated valves and moves barrier arm by hand (Fig. 10).

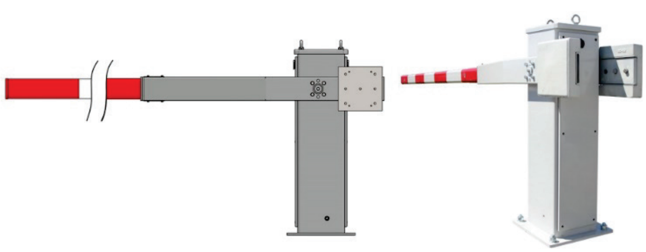

Figure 12 Barrier drive PBH21 [31]

Hydraulic barrier drive PBH21 is developed by modular design. Main system consists of sub-systems. These sub-systems in modular design represent modules. Modular architecture implemented in PBH21 product is suitable for adaptive design and easier maintenance process. Barrier drive is structured from six modules (Fig. 13). These modules is possible to divide in main module group and additional module group. Modules as accumulator group, hydraulic aggregate, slow motion valves and valve block represent main module group (Fig. 14). This group is an executive group, because it realizes by their functions, overall function of the technical system PBH21 (Fig. 6 and Fig. 7). Functional analysis, through the functional flow diagrams, preceded to the development of the mentioned modules (Fig. 6 – Fig. 11). Electric parts module and positioning group micro switches module are part of the additional module group (Fig. 13). This group is control / management group, because it manages signals and information necessary to perform overall function of the technical system PBH21.

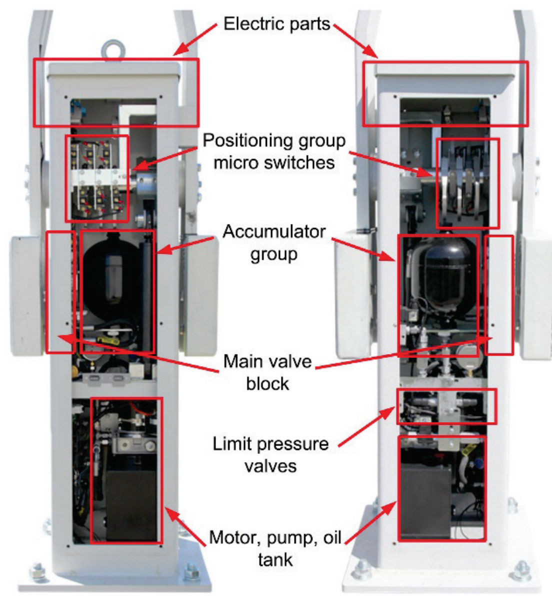

Figure 13 Barrier drive PBH21 modular architecture [31]

Principles of solution of the partial functions of Module 1, Module 2, Module 3 and Module 4 are part of the design structure of the hydraulic barrier drive. As such, they are actively involved in the energy, material and signal flow. Their fulfillment of partial functions is shown by the hydraulic scheme (Fig. 14). Scheme shows medium flow (mineral oil) through the elements that make main modules as well as manipulation operations in the executive part of the scheme.

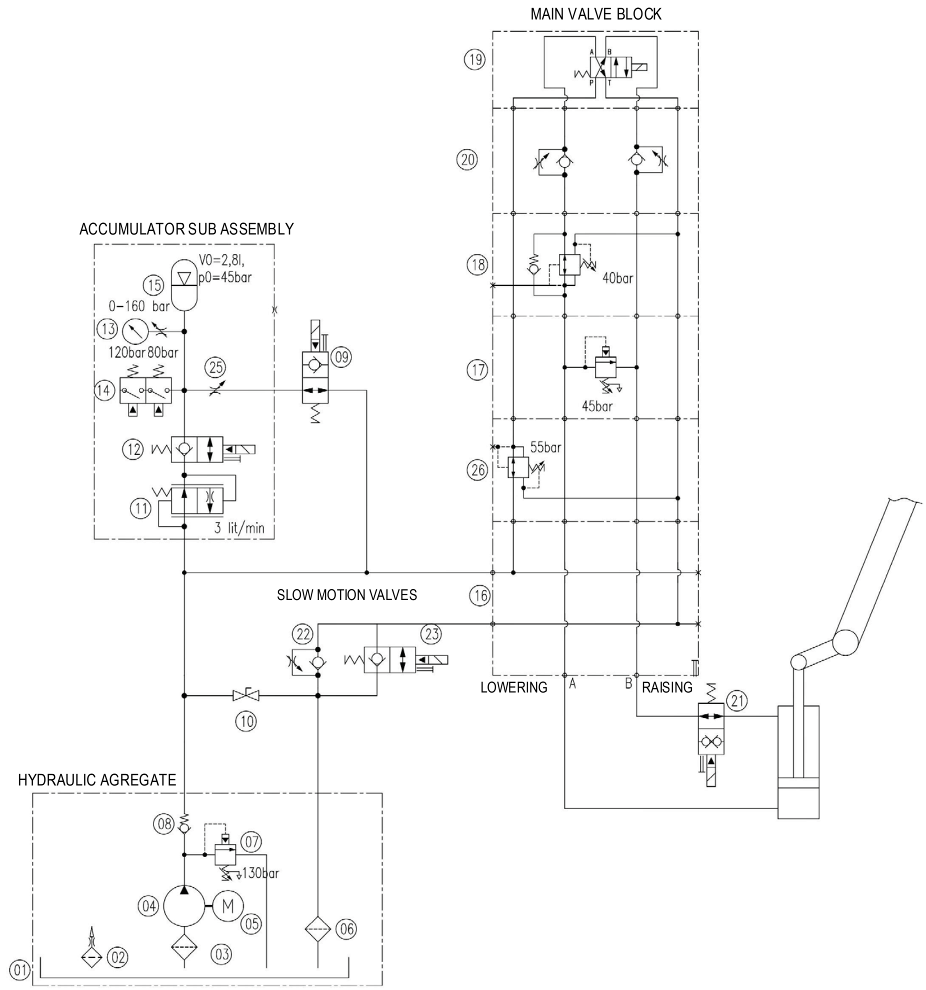

Figure 14 PBH21 hydraulic scheme with the four main module groups [31]

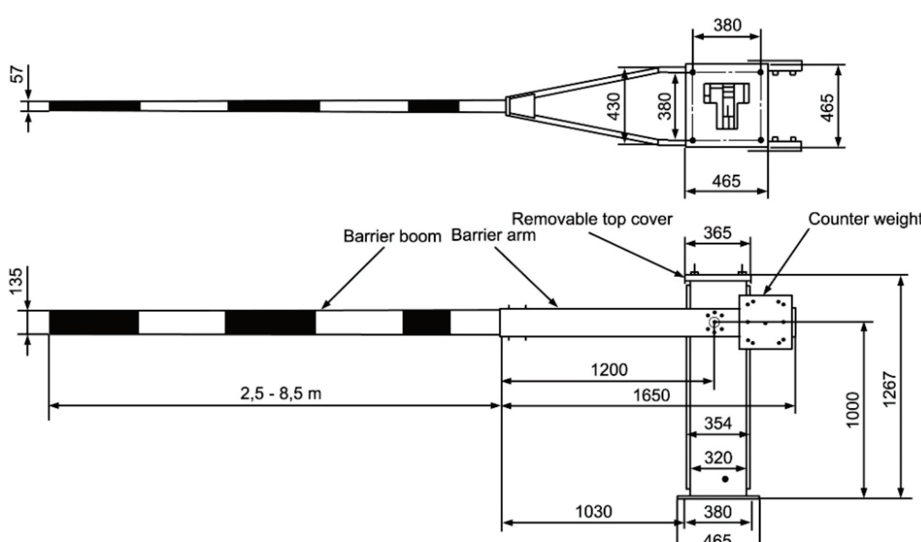

Figure 15 Top and side view of the PBH21 [31]

General measurements of the PBH21 are presented in Fig. 15. On the hydraulic barrier drive PBH21, according to customer requirement, is possible to install arm length from 2,5 m to 8,5 m. According to selected arm lengths is necessary to calculate adequate counterweight. All calculations are made in correlation with the weight positioning from the center of the shaft to the weight gravity center (Fig. 15).

5 RECAPITULATION ANNOTATION

Importance of railway transport in the development of modern world economies is extremely great. EU countries recognized this and decided to invest significantly in the modernization of their railway infrastructure, i.e. rail traffic. Special advantage of rail transport, compared to other forms of transport, is reflected in the economy of freight transport, lower energy consumption and less impact on greenhouse gas emissions caused by transport.

Therefore, it is extremely important to invest in safety increasing of the rail transport. In order to reduce traffic accidents occurring at level crossings, the need for an increase in signaling and safety equipment was observed. Such equipment also includes hydraulic barrier drives. Due to the complicated adaptation on the existing infrastructure of manufacturers of such equipment, as well as the different needs of railway operators, these devices are not installed at all level crossings. In order to solve this deficiency, in this paper is presented development and design of a hydraulic barrier drive PBH21 that have possibility of implementation on existing infrastructure. PBH21 is compatible with the existing infrastructures and technologies of major manufacturers of this type of safety equipment in the world. This device uses a modular design to be able to adapt on the aforementioned requirements.

By applying functional modeling, functional structure of the PBH21 was generated. Through the monitoring and analyzing of the energy, material and signal flow, by functional flow diagrams, overall and partial functions of the four functional modules were designed. Using functional decomposition, for the mentioned modules, a four-level functional structure of the hydraulic barrier drive is modeled. From the functional structure of the hydraulic barrier drive PBH21, in a detailed design process, following modules were designed: accumulator group, hydraulic aggregate, slow motion valves and valve block.

Through this work, the sequence of the design process is presented by connecting four design phases, respectively clarification and task definition phase, conceptual design phase, embodiment design phase and detail design phase. Also, it is presented that by means of the functional decomposition method and functional modeling method, by using of functional flow diagrams, is possible to design functional structures of modules and connect them through the flow of energy, material and signal in one unique modular functional structure.

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Authors' contacts:

Mirko Karakašić, Full professor, PhD
(Corresponding author)
University of Slavonski Brod, Mechanical Engineering Faculty in Slavonski Brod,
Trg Ivane Brlić-Mažuranić 2, 35000 Slavonski Brod, Croatia
E-mail: mirko.karakasic@unisb.hr

Ilija Svalina, Assistant professor, PhD
University of Slavonski Brod, Mechanical Engineering Faculty in Slavonski Brod,
Trg Ivane Brlić-Mažuranić 2, 35000 Slavonski Brod, Croatia
E-mail: isvalina@unisb.hr

Daniel Novoselović, Associate professor, PhD
University of Slavonski Brod, Mechanical Engineering Faculty in Slavonski Brod,
Trg Ivane Brlić-Mažuranić 2, 35000 Slavonski Brod, Croatia
E-mail: dnovoselovic@unisb.hr

Iva Samardžić, mag. ing. mech.
University of Slavonski Brod, Mechanical Engineering Faculty in Slavonski Brod,
Trg Ivane Brlić-Mažuranić 2, 35000 Slavonski Brod, Croatia
E-mail: ivasamardzic@unisb.hr

Hrvoje Glavaš, Full professor, PhD
Faculty of Electrical Engineering, Computer Science and Information Technology Osijek, University of Osijek,
Kneza Trpimira 2B, 31000 Osijek, Croatia
E-mail: hrvoje.glavas@ferit.hr

Radomir Đokić, Associate professor, PhD
Faculty of Technical Sciences, University of Novi Sad,
Trg Dositeja Obradović 6, 21102 Novi Sad, Serbia
E-mail: djokic@uns.ac.rs