

## THE SYSTEM OF IT SUPPORT FOR LOGISTICS IN THE RAIL TRANSPORT

Piotr Kisielewski

Cracow University of Technology, Faculty of Mechanical Engineering,  
Institute of Rail Vehicles, Poland

e-mail: pkisielewski@pk.edu.pl

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**Abstract:** *The paper presents the requirements, architecture and important features of a modern IT system of logistics for rail transport. The purpose of the system is to provide logistic support of transport issues relating to the work performed in the sectors of transport and maintenance of railway enterprises. In particular, special attention was paid to optimization problems of strategic and operational planning applying modern optimization algorithms. System architecture, the basic functional modules and their relationship are presented as an example of the system used by the Polish rail operators, engaged in the transport of both passenger and freight. The system is characterized by centralized architecture, divided into an application server, a database server and a terminals server. The system takes full advantage of modern mobile technologies. The study outlines basic logistics processes implemented in the system, among others, : planning of transport using background maps and a scheme of railway network, records of vehicles and employees, allocation of transport work for individual units, planning cycles of vehicles and trains, scheduling work for vehicles, train driver crews and train attendant teams, creating work schedules, short-term and long-term dispatches, verification and accounting of the work time, accounting transport and train drivers performance.*

**Key words:** *IT system, logistics, rail transport.*

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### 1. Introduction- functional model of the system

The system specified in the title is a specialized ERP system, whose task is to support the logistics of the issues related to the work of transport, i.e. performed in the departments of transport and maintenance of railway enterprises. Specialization of the system is based on the fact that it does not support the processes in finance, accounting and administration like a classic ERP system, but focuses on the transport logistics. The universality of the system lies in the fact that it is intended for railway enterprises engaged in the carriage of both passenger and freight. Functional diagram of the system according to the concept of the author is shown in Fig. 1. A similar scheme is the backbone of a functional professional systems dedicated for logistics of rail transport used and implemented by rail operators in different countries (dpkssystem, giro, goalsystems, ivu, maior, 2016).

These systems include virtually all areas of transport rail operators activity, ranging from strategic and operational planning, through the distribution of resources, supervision of implementation, verification of performance, to accounting, reporting and statistics of transport, as shown for comparison in Fig. 2 and 3, developed by the author on the

example of another systemic solution (goalsystems, 2016). Another system - IVU.rail is a software solution specially developed by IVU Traffic Technologies AG to meet the timetabling, schedule planning, staff roster planning as well as the vehicle and personnel dispatch requirements of railway traffic (ivu, 2016). Almost all systems analyzed include related functional modules in the field of:

- Vehicle registration, vehicles approval verification,
- Records of employees, verification of employees' permissions,
- Design of the timetable,
- Design of the trains circulation,
- Allocation of transport work for each organizational unit of the operator,
- Design of duties/tasks of employees,
- Design of crew rosters,
- Dispatching of employees and vehicles / trains,
- Communications of the dispatcher with train driver crews and train attendant teams,
- Location and GPS tracking of the fleet of vehicles and cargo,
- Verification and accounting of the work time,
- Accounting of fuel,
- Accounting of transport work.

The system of IT support for logistics in the rail transport

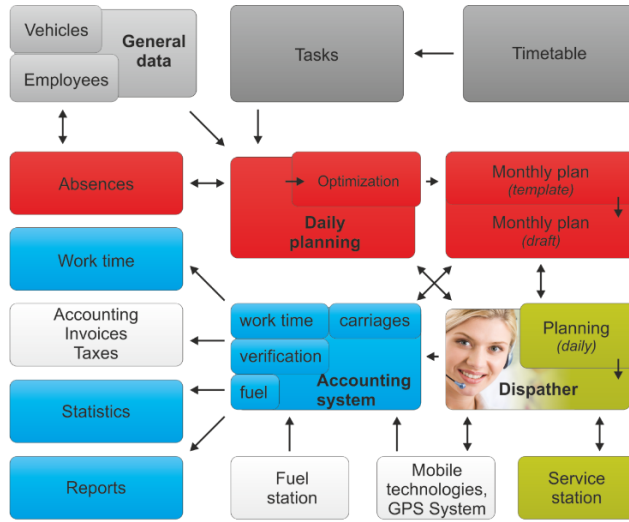


Fig. 1. Functional model of the system

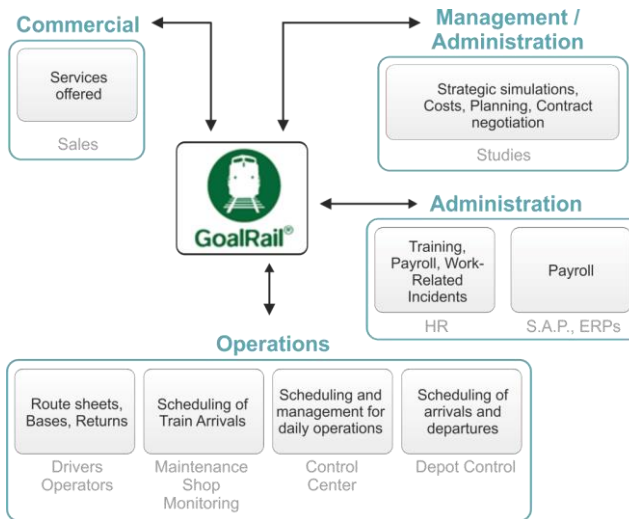


Fig. 2. Diagram of IT links of the GoalRail system

**2. Desirable features and advantages of the system**

The advantage of the presented author’s system is its modular design - with the large extent of the system, each user only supports this part of the system for which the user is responsible. The system is defined as an integrated and comprehensive because it supports transport from designing the route of the train, through the creation of transport tasks, planning the work, allocation of staff and vehicles to

accounting the task and the transferring the data to the financial accounting and payroll systems. Logistics system of transport must be fully integrated with the classic ERP of the enterprise, e.g. SAP as in Figure 2. Openness to integration with other systems is crucial and can be accomplished through the selection of open solution of the SQL Server database, e.g. MS SQL (dpksystem, 2016) or Oracle (ivu, maior, 2016).

### Modules and functionalities

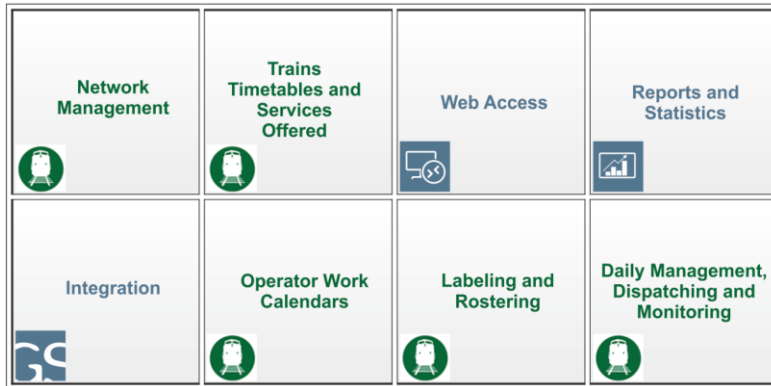


Fig. 3. Functional model of the GoalRail system

An extremely important element in the choice of the system is the possibility to automatically support difficult decision-making processes through the use of mathematical optimization algorithms, allowing the user to select the best solutions, e.g. in terms of the timetable design, planning cycles of the trains, task planning, scheduling and distribution of tasks for train driver crews and train attendant teams. These above-mentioned planning decisions belong to the so-called class of NP-hard problems; their effective solution without the application of modern methods of mathematical optimization is not possible (Ahuja et al., 2009; Ambroziak, 1998; Jacyna, 2009; Lam et al., 2003; Simch-Levy et al., 2014; Wilson, 2010).

Commercially available system solutions in rail logistics were created and have been developed as a result of long-term cooperation between the companies in the IT sector and railway companies and research centers, based on the knowledge and experience of senior engineers, transportation engineers and IT engineers (dpkssystem, giro, goalsystems, ivu, maior, 2016).

A new and significant element of logistic software are mobile applications (dpkssystem, 2016). Applications for tablets, smartphones and portable conductor cash registers provide, among others, fast and timely exchange of information between the dispatchers of train crews, automatic registration of working time, informing the employee about the roster and its changes.

This logistics system supports transport processes and operation of rolling stock in the four groups of employees of rail enterprises:

- drivers (train driver crews),
- conductors (train attendant teams),
- back office / maintenance workers,
- administration employees.

### 3. System architecture

Railway companies operate in a multi-stage hierarchical structure over large geographical areas beyond regional, and even national borders. Logistics IT system must be designed to quickly, safely, and efficiently operate in a scattered environment (Jacyna, 1998). The system maps the organizational structure of the carrier. The central license server manages user access to the application server. In the case of very large systems it may be necessary to use a server cluster. The database server manages data by providing continuous access for all users, and at the same time protects the consistency of recording and information security.

In respect of the logistic system, modern information technology system offers two available solutions. One solution is based on the architecture of the web browser with a central application server and the database. The solution in the form of a web browser provides secure access for multiple users as well as superior performance over network requirements and hardware for the user/client application. A web browser imposes some restrictions on the advanced graphical user interface,

however, these are especially important in the case of design and planning as well as dispatching applications. The other possible solution is based on client - server architecture. This solution provides the user with virtually unlimited possibilities of the user interface, but the multiplicity of users of the system and data processing speed recommends using a three-layer architecture, as shown in Fig. 4, consisting of:

- a database layer (database server), where the database is based on SQL engine along with management and configuration tools,
- an application layer, where the application server along with tools to manage and configure is located,
- a client application layer (terminals server), where the client application system is located.

The processing of the data in the client - server architecture, taking into account historical note of recording the data in the journals is shown in Fig. 5.

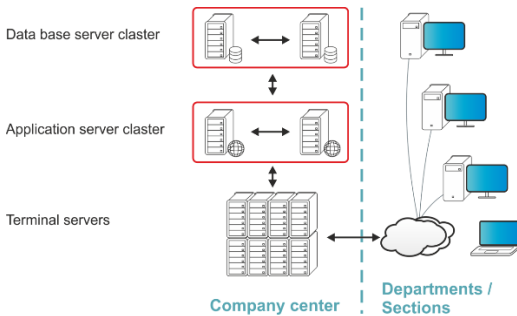


Fig. 4. Recommended system architecture

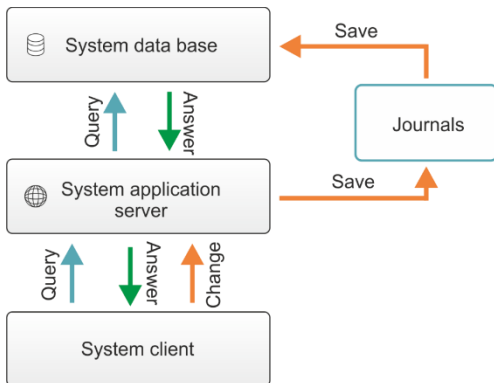


Fig. 5. Diagram of data processing in the client - server system

#### 4. The process of logical information processing

The process of logical data processing in the system is based on the flow of information in the Shewart-Deming (strefa-iso, 2016) *plan - do - study - act* cycle, schematically shown in Fig. 6. Logistics planning is the basis for good functioning of transport i.e. effective work with minimum operating costs of the fleet and minimum staff costs. Planning does not have a strict time limit, the user can at this stage use very effective but time-consuming metaheuristic optimization algorithms (Osyczka, 2002) as well as tedious "manual" modifications of timetables, plan and schedules of the transport tasks. Well-prepared plans are the basis for effective work of the dispatcher. In the current railway tasks dispatch, key elements are speed and security of the decisions taken. System hints for the dispatcher applied at this stage must be based on extremely fast algorithms for optimization and a relevant knowledge base, as in the expert systems (Grzyb et al.,2014; Kisielewski, 2004).

The accounting of logistics processes is understood as a stage associated verification of the performed work, establishing deviations in the implementation of the established plan, accounting of the working time and wages of employees, settlement of transport performance and cost analysis in terms of operating costs of the vehicle fleet. The statistics obtained on the basis of the accounting is the basis for an appropriate adjustment to the new transport plans; this closes the cycle of information flow in the logistic system (Fig.6).

#### 5. Characteristics of the modules in the system

##### 5.1. General data

Edit the basic data of the enterprise, tree organizational structure, defining a dictionary of terms used in the system, the events and their types, control and limiting user access to the data and system functions is carried out in the *General Data* module. *Vehicle Data* is a technical file of traction vehicles and wagons by type, containing all the data necessary for planning of the assignment to transport tasks and accounting, including verification of validity of approvals for railway traffic and automatic user notification system of the need for renewal. *Employee Data* is an employee file containing all the data needed for planning work, dispatch and working time accounting, specifying

the parameters defining the dimensions of the working times of employees, types of employment, modes of employment and contradictions for selected works. The module should allow to define any group of employees by criteria such as type of work, employment proportion, qualifications and preferences to perform specific work. The employee file should contain full history of employment of an employee, verification of the validity of the permissions and automatic notification of the need for renewal, e.g. knowledge of the route.

**5.2. Absenes**

Absenes is the module for management of leaves and other absences, including planning, record and

control, including the use of limited absences like, for example, vacation, leave on request, child care leave, and maternity leave. This module performs automatic planning of vacations for the incoming years based on the plans from previous years, statistics and staff absences, with the forecast demand for workers in the periods of time for the planned timetable of the company. Planning holiday masks is carried out monthly, biweekly or weekly. The module should allow for a preview of all the absences entered in the system at different stages and in different divisions of the company (human resources, planning, daily dispatch, verification), as shown in Fig. 7.

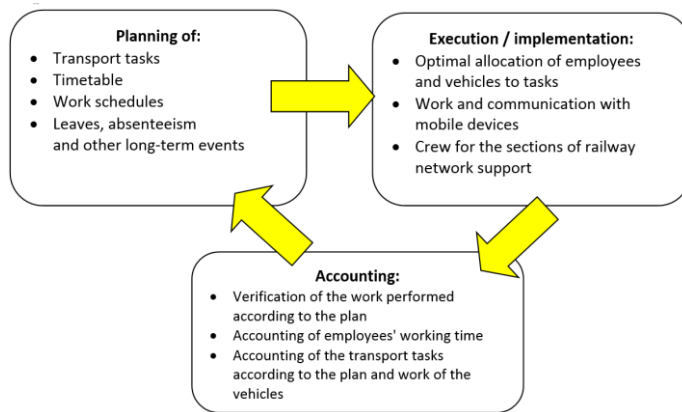


Fig. 6. Diagram of the flow of information in the system

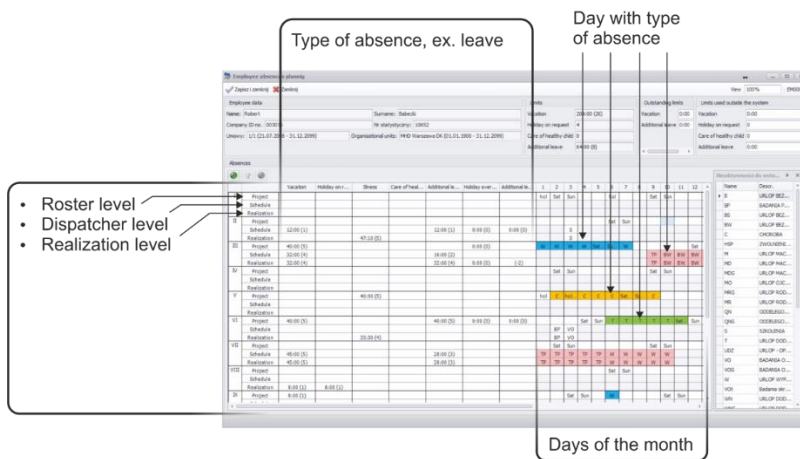


Fig. 7. Employees' absenteeism panel in the DPK Railways system  
Source: dpksystem (2016).

### 5.3. Timetable and train cycles

*Timetable* is understood as a system module for designing a train timetable. A modern timetable module is a specialized system for the design of timetables using the latest IT resources. This module should allow:

- Tabular and topographic editing of timetable on background mapping with a railway network,
- Detailed route and circulation of trains planning,
- Integration with the systems of the railway network administrators,
- Graphical tools for presenting and editing the train timetable,
- Automatic timetable generators.

An example of such a modern module is the LineDesigner program (Grzyb et al., 2014; dpksystem, 2016). This program allows full editing of the timetable, the construction of transport tasks / train including all their constituents. Key advantages of the LineDesigner program are as follows:

- Interactive map background to choose from,
- Intuitive and simple tabular and graphical editing of trains,
- Ergonomic design of tasks for vehicles and duties for employees,
- Optimization modules of trains/vehicles cycles.

Modern logistics systems for rail transport are equipped with IT tools used for optimizing the cycles of trains and vehicles (Fig. 8).

*The train/vehicle cycle module* should allow editing the cycles for any defined periods of time – with the possibility of connecting trains for different types of timetables and types of working days, with a smooth transition between the two periods. The system should take into account the following when editing: the conditions of travel, stopping between each task, taking into account the tracks occupied state, train service conditions and other parameters specified by the user. Optimization module of the circulation is to ensure maximum utilization of owned rolling stock/fleet while ensuring the minimum possible cost of operation and the fulfillment of the conditions for implementation of transport.

Planning trains cycles comprises four stages, shown schematically in Fig. 9a, b. Stage I called a pre-processing stage is based on preparing the data, e.g. partitioning trains into groups according to types of rolling stock. In stage II optimal daily circulations/blocks of trains are generated minimizing downtime and technical commuting. In stage III daily train circuits are connected in multi-day-cycles. In stage IV, the check and evolutionary improvement of the cycles through the exchange of circuits in the cycles are carried out.

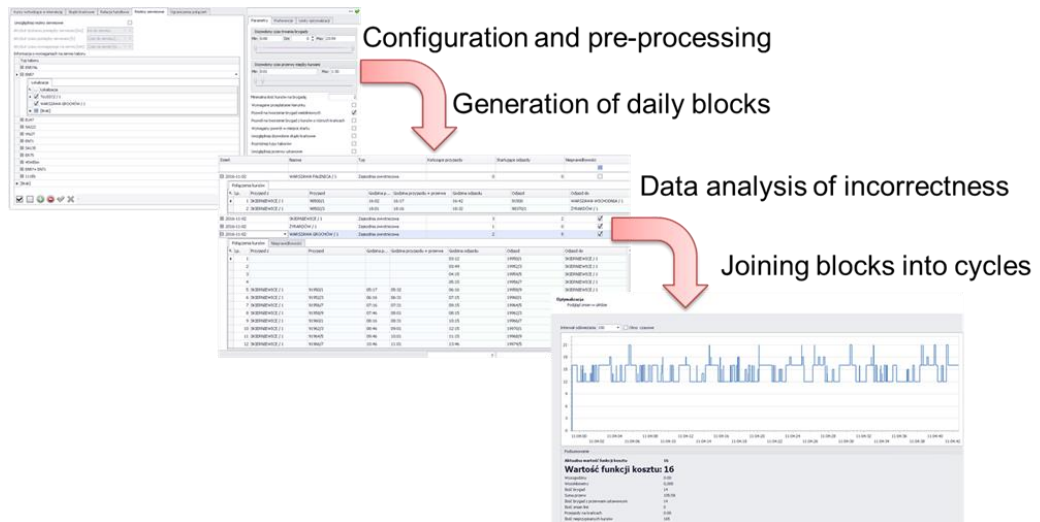


Fig. 8. The process of building train cycles in the LineDesigner system



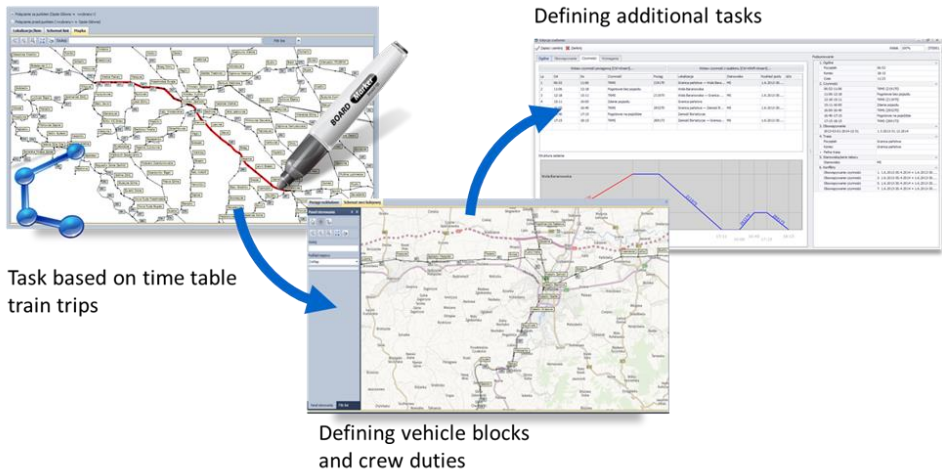


Fig. 10. Duties edition panels in the *Tasks* module of the DPK Railways system

**5.5. Roster**

*Scheduling* the work of staff and vehicles is a very important logistics module. The “engine” of mathematical optimization used in the Optigraf module (Kisielewski, 2008, 2007; Kisielewski et al. 2007) allows the user to plan the most efficient roster from the point of view of the employer, taking into account all the regulations and provisions of social contracts and, above all, the implementation of the planned transport in accordance with the timetable (Fig. 11).

In modern transport scheduling modules for transport work, an extensive functionality including, among others, the following, is required:

- Planning the work in any accounting periods,
- Roster optimization with user-defined parameters, including the applicable labor laws and internal regulations of the company,
- Edit the schedules with the option of system hints for the best scheduling options available,
- Automatic verification of the correctness of work plans,
- Allocation of reserve shifts in relation to the statistics of the train running periods,
- The possibility to work and view several projects simultaneously (schedule, modified schedule, execution)
- The possibility of building schemes of work, time off and shifts as well as allocation of work by schemes,

- The possibility to run the optimization at all stages of scheduling and for each group of employees and time interval,
- Defining the preferences of employees and vehicles to perform the work,
- Current preview of balances of work time of the employees and the status of implementation of the transport tasks,
- Forecasting the number of required human resources for future periods based on the timetable and the statistics from previous periods,
- Smart hints for use with manual editing of the changes in the schedule.

**5.6. Optimization**

Optimization tools constitute a very important module of the system. At each stage of transport management and designing the plan of transport, the optimal utilization of resources and cost control are very important. Optimization tools based on advanced mathematical methods allow choosing the best solution every step along the way. Three-level-optimization enables significant cost savings and keeping the expenses at the lowest possible level. The rail logistics should be equipped with at least three types of optimization tools (Fig. 12).



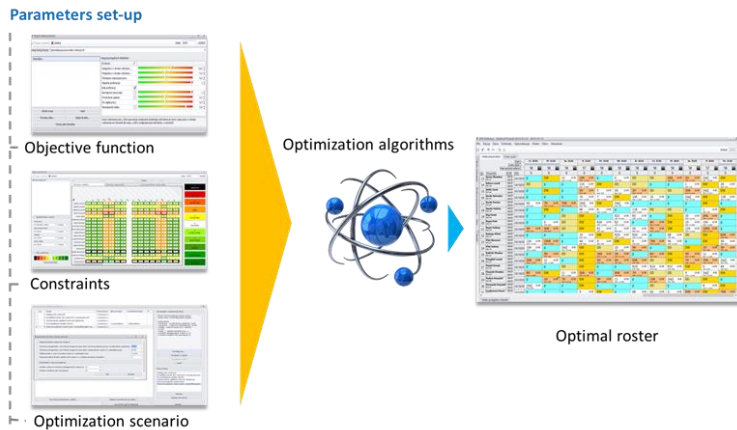


Fig. 11. Optimization of crew rosters

### 1) Optimization of the trains cycles

In the first stage, while optimizing the cycles, the software automatically builds train cycles executing the transportation according to the timetable with the maximum use of the owned rolling stock, while maintaining editable weights for the optimization criteria and constraints.

### 2) Optimization of services

At the second stage of the duties design for train crews, another optimization module based on the circuits generates tasks for employees with the maximum use of their time, minimizing breaks and unnecessary journeys while maintaining editable limitations and legal conditions (Freling et al.,2000).

### 3) Optimization of crew rosters

The third stage of optimization occurs when editing long-term schedules. At this stage tasks are assigned to specific employees. While maintaining all the legal requirements, the system must fill all services with the best possible use of the available employees (Caprara et al.,1997; Ftulis et al.,1998).

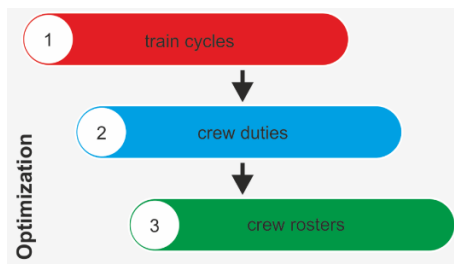


Fig. 12. Diagram of systemic optimization

### 5.7. Dispatcher

*The Dispatcher module* is a complete graphics, multi-station dispatcher panel with automatic generation of work bills for train driver crews and train attendant teams, equipped with a sub-system of hints for optimal dispatch and a number of dispatch tools (Fig.13). The dispatcher panel is a modern tool for dynamic resource management of a railway company to increase safety and transport discipline. The module cooperates with the system of board computers, tablets and mobile conductor cash registers (equipped GPS) as well as communication with vehicles (GPRS, 3G, Edge).

Basic dispatch functions executed in the module are, among others:

- Current support of the transport plan execution - dispatch of crews for the trains,
- Downloading the plan for the selected day/period of the periodic planning,
- Current information about the performance of locomotives from the service workshop,
- Implementation of the current corrections to the task plan and roster, if necessary,
- Automatic sobriety check,
- Print of documents for the dispatched train crews,
- Editing documents in an electronic version for tablets or mobile cash registers in vehicles,
- Defining, adding and changing unscheduled tasks,
- Monitoring the implementation of the plan, geolocation of the trains on the map background,
- Current contact with the crews through mobile applications.

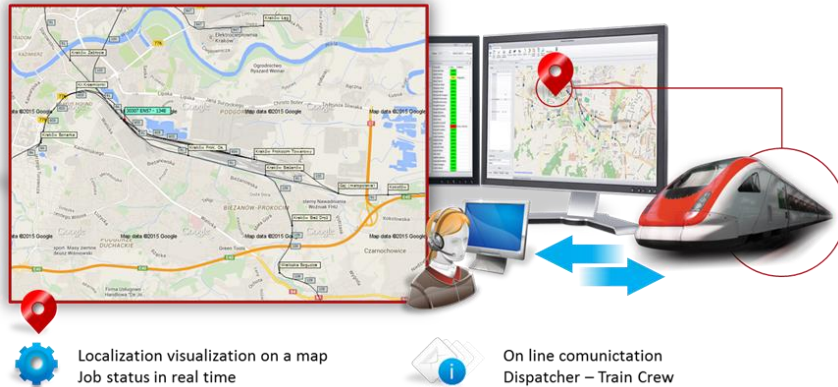


Fig. 13 The dispatcher panel

Intelligent Decision Support for the dispatcher is implemented, among others, by automatically signaling the lack of the crew for the train with timing advance offset defined and optimal hints for the necessary changes - sorted by optimization criteria, list of employees, vehicles and services.

**5.8. Mobile technologies**

Modern mobile technologies are primarily to support the work of train crews and to improve their communication with the dispatch center. Applying this solution, the user can dispense with issuing paper work bills for which the employees must laboriously record their work, and the smart application registers the employees’ work and verifies its implementation. The solution is usually designed for tablets and mobile conductor cash registers working with Android or Windows Mobile systems and equipped with GPS and packet communications like GPRS, Edge, or 3G.

The features of mobile applications as shown in the form of sample in Fig. 14 allow, among others:

- Preview the current timetable and roster for the user,
- Preview the current timetable for the train being operated and the list of constant warnings,
- Preview and editing of electronic work bills,
- Location of the crew/train,
- Messaging on the dispatcher-train crew line,
- Selection of messages from a predefined list or manually entering own messages,
- Automatic verification of the work of the crew.

**5.9. Verification and accounting**

Railway logistics system must allow for a comprehensive accounting of the working time of employees, operating of traction vehicles (Fig. 15) as well as energy/fuel and other operating consumables consumption. Including the whole transport process in the system allows quick and complete accounting of the transport work and the use of a central database enables data reporting in any ranges and sections.

**5.10. Managerial application**

The WebBI application is an example of a solution for the managers of railway companies (dpksystem, 2016). The name of the module is an abbreviation of the following: Web and BI - Business Intelligence; captures the essence of the application. This online application provides the information necessary for it to monitor the situation of the company and efficiently make the right decisions.

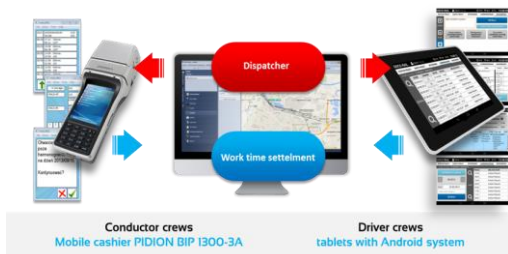


Fig. 14. The DDCS Rail mobile application  
Source: dpksystem (2016).



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