APPLICATION OF THE ANALYTIC HIERARCHY PROCESS IN DEVELOPMENT OF TRAIN SCHEDULE INFORMATION SYSTEMS

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ABSTRACT

This paper considers different choices for the optimal data model of train schedule presentation. The authors have suggested three possible models that differ in building principles, of presenting temporal data of the train schedule in Information Systems. Three popular multiple-criteria decision making methods were examined in order to choose the best model. The study presents the Analytic Hierarchy Process (AHP) as the most suitable one for comparative evaluation of different data presentation models of the train schedule. In the study, thirteen evaluating criteria are developed which are distributed in three groups: hardware, maintenance and performance. The research is carried out for four different classes of IS: web-based schedule systems, mobile schedule systems, ticket sales systems and rail traffic management systems. MS Excel 2007 was used to display the AHP method; however a visualization tool called conditional formatting has been used to present the most important criteria and the preferred alternatives.

Keywords: multi-criteria analysis, Analytic Hierarchy Process, pairwise comparison, data model, train schedule, results visualization

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1. Introduction

The principal issues of train traffic schedule storage in databases of the railway IS are related to the existence of a multitude of versions conditioned by seasonal cycles of schedule changes and the days of week, systematic and unplanned repair operations, and transfers of working and festive days. The basic problem is the complexity of the data reliability provided, and the immediacy of amending the schedule. Frequent alternations make introducing these tasks extremely urgent. Building a flexible schedule system taking into account the above limitations and rules, and giving the employees of the railway companies effective mechanisms of controlling the schedule would more successfully meet passenger transportations demands. It is a challenging scientific-technical task to develop a model of presenting the train traffic schedule data, a method of interaction with the stored data, and a method of searching an actual schedule version for a particular date (Kopytov, Demidovs, and Petukhova, 2008).

The efficiency of manipulating the schedule greatly depends on the organization of temporal data in the database. Here, various models of presenting temporal data of the train schedule are used. The multi-criteria comparative analysis is used to determine the best model in terms of the given criteria efficiency. Therefore, the author's paper (Kopytov, Petukhova, and Demidovs, 2010) contains the development of a system of quantitative and qualitative criteria; each of the criteria has been comparatively estimated by using two investigated data presentation models of the train schedule. Nevertheless, these estimations are insufficient to choose the most suitable model in the case where there is no consideration of criteria significance. It has been assumed that it is enough for an analyst to have the properties of models according to different criteria to choose the optimal one. An absence of strict methodology and criteria ranking in this process of decision making makes it too complicated and its results unreliable. An increase of the number of alternatives further complicates the decision making task.

This paper considers several choices for the optimal data presentation model of the schedule. The authors choose among three alternatives and employ the more formalised methods of quantitative and qualitative criteria analysis.

There are currently various methods that have been developed and implemented to analyse and choose from a range of alternatives. These methods include multiple-criteria decision making (MCDM), multiple-criteria decision analysis (MCDA), and multiple attribute decision making (MADM). The existence of this variety of methods makes the issue of choosing the most suitable one rather difficult (Triantaphyllou, 2000; Lootsma, Schuijt, 1995; Olson, Fliendner, and Currie, 1995). The authors have analysed the possibility of employing three of the most popular methods to solve the problem of choosing the best data presentation model of the train schedule. These three methods include the simple additive weighting (SAW) method (Hwang, Yoon 1981), the analytic hierarchy process (AHP) method (Saaty, 1980; Saaty, 2001) and collections of ELECTRE methods (Roy, 1996; Figueira, Mousseau, and Roy, 2005).

When implementing the ELECTRE and SAW methods, the authors faced the problem of arranging the alternatives in the criteria table (assigning the weights). The use of a large number of criteria, belonging to different professional knowledge areas resulted in an inadequate estimation of each criterion's significance. With the help of invited experts, the authors were only able to competently evaluate certain criteria which they know well. The estimations of other criteria have been arrived at by guess-work. Since the assigned weights of criteria have a great impact on the alternative choice, the authors have come to the conclusion that this method would result in largely inaccurate results.

The AHP seems to be a more attractive choice in this context since it allows structuring the choice procedure as a hierarchy of several levels. It allows the distribution of (cluster) the criteria by several groups, and evaluates the significance of each group's components. Consequently, the different groups of criteria have been evaluated by different qualified experts. For instance, the technical specialists have assessed the technical criteria; the experts from the supporting service have evaluated the operational criteria, while the users have estimated the functional criteria. The opportunity of the pairwise comparison of a smaller number of criteria in every group allows the experts to determine better weighted (more accurate) values according to these criteria. The authors have concluded that the optimal number of criteria in each group should be from 3 to 5. The estimation of the significance of the criteria groups was determined by the experts with greater qualification. The AHP method also allows the possibility of controlling the consistency of the experts' judgements, making it possible to increase the reliability of estimation.

In summary, the multi-criteria analysis determined the AHP as the most suitable method for comparative evaluation of different data presentation models of the train schedule.

2. Peculiarities of the trains schedule system

Generally the train schedule has several versions over a long period of time. In the course of time the various versions rotate (see Figure 1). The active schedule of the train's traffic is determined by a core fundamental (seasonal) timetable and the number of other schedules. The other schedules occur as a result of issues such as a train's removal, changes in the traffic schedule due to the accidents, pre-planned or unplanned repair operations, public events (the City Days, concerts, etc.), and short-run changes of the route.

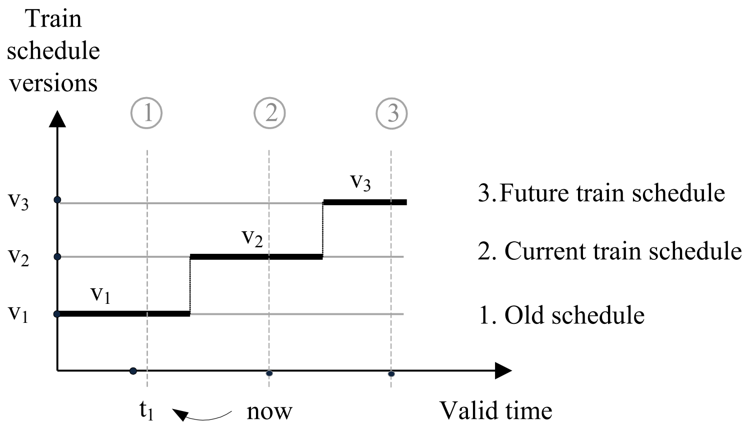

Figure 1 Multitude of train schedule versions

The schedule of passenger trains is considered is this research. The system of the passenger trains schedule possesses different peculiarities, determining a rather significant level of the complexity of its implementation which is considered below.

In practice, the train may simultaneously have several valid schedules for a long period, and one particular train might have different schedules on different days of the week. In this situation, every schedule is fixed taking into account the days of traffic, and different *periodicity characteristics,* such as weekdays, rest-days, particular rest-days, the first weekday, the last day of the weekend (which sometimes may be Monday), or even and odd days (Kopytov, Petukhova, and Demidovs, 2010).

Let us take as the example of a multi-version train schedule presented in Figure 2. As we can see, for the train with number *n* there are two basic schedules, one for the weekdays (*wd)*, and the second for the rest days (*rd)*. Both schedules are actual in the time period [t_1, t_4], but in different days of the week. Then, for repair works we make a change in the schedule of the given train on Tuesdays and Thursdays for the time period from t_2 to t_3. Thus, in the time period [t_2, t_3] three actual schedule versions exist that are valid for the days, which correspond to the characteristics *wd*, *rd* and *Tue, Thu*, with only one schedule version *wd* or *rd*, or *Tue, Thu* valid for one day.

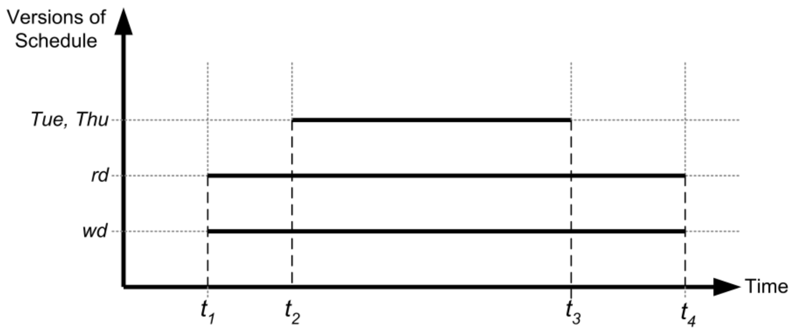

Figure 2 Variety of the train schedule valid versions: wd, rd and Tue, Thu

We shall illustrate the former statement in Figure 3, in which the axis “Day of Week” shows the days of the week in the following sequence: 1 – Monday, 2 – Tuesday, etc. The granularity level of this schedule equals one day; therefore, we can state that time in our system has a discrete character and the versions possess the property of periodicity. As we can see in Figure 3, on different days one version from the three is the actual train schedule, and the other two are in the “shadow zone”. Here, the train schedule for Tuesdays and Thursdays (characteristic *Tue, Thu*) overlaps the weekday schedule with the characteristic *wd*.

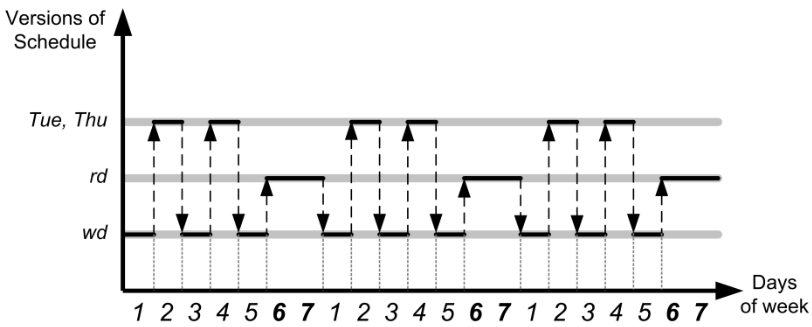

Figure 3 Periodicity in the train schedule

On holidays and other special days (i.e. NATO summit in Riga in November 2006) all the trains run in accordance with the day off schedule. There is an exception for certain trains when the special timetable is assigned for these days. However, in reality only 1% of all trains are assigned with the special schedule. Such types of changes in the timetable or special schedule assignments provoke the anomalies (paradoxes). For example, the 19th of November, Monday, in 2007 was announced as an additional day off, and all the trains ran on the weekend schedule (like on the 18th of November), This event caused the malfunction of the periodicity as shown in Figure 4. It is important to add that several trains with periodicity (Sundays) were cancelled on the 18th of November, because the trivial Sunday is not only the day off, but also the last day of weekend, and the additional Sunday's trains are considered for the passengers transportation from the traditional locations of the resting facilities on the days off.

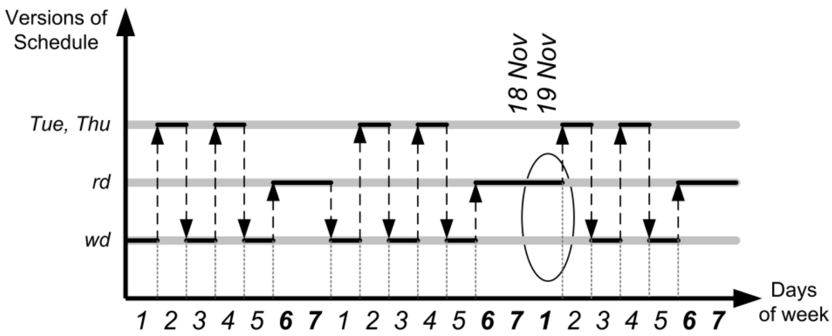

Figure 4 Periodicity malfunction in the train schedule

One of the serious problems occurring in the considered IS of the railway schedule is connected with the overlapping of the objects' lifespans, when one schedule overlaps another (see Figure 5). The variable t_n means the moment of reviewing. The railway schedule for the season is fixed in February for the period from the moment of time t_1 to t_6. Later in March, the schedule is changed for the period from the moment t_2 to t_4, and then in April, one more change is made for the period from t_3 to t_5. For the inquiry of the train traffic at the moment t_{n1}, we'll get the schedule fixed in February for $[t_{1,} t_6]$, at the moment t_{n2} we have the schedule fixed in April for $[t_3, t_5]$, and at the moment t_{n3} we again have the schedule for $[t_{1,} t_6]$.

Usually, overlapping schedules occur due to operative updates in a schedule. The peculiarity of the given situation is that when the object is changed it cannot lose the actuality of its state either in the past or in the future; –it is substituted by another version only for a certain period. As a result, more than one actual tuple describing different versions of the same object's property can exist at one time. The latter contradicts the very idea of temporal database (Tansel, Clifford, and Gadia, 1993; Date, Darwen, and Lorentzos, 2002; Jensen, 2000), therefore it is necessary to make special data queries in order to trace and settle such situations (Kopytov, Demidovs, and Petukhova, 2008).

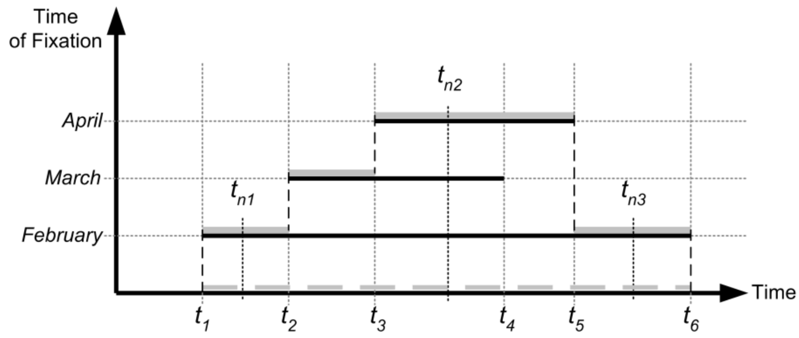

Figure 5 Crossing of object lifespans in DB of the train timetable system

The schedule changes dynamically; an updated schedule action's duration (operative changes) may be modified, and schedule versions may be cancelled. Due to these and other reasons connected with data integrity support, data storage and display laconism, version control and analysis convenience, it is preferable to arrange a schedule's temporal data in overlapping versions.

There are also peculiarities connected with the *schedule data management* (schedule registration).

First, the system obtains the core fundamental schedule, and then with the time running, the operative changes are made to this schedule. Consequently, several versions of the schedule appear. Quite often the period of operation of such an altered schedule is so prolonged that it also becomes subjected to certain corrections. The operational time of the corrections can be contracted or prolonged.

The data of the train schedule versions include the concise information about the order, in accordance with which the new schedule is introduced, the date of this schedule version comes into operation, the date this schedule version goes out of operation, the type and the number of carriages in the train, the set of stops at the stations with information on the time of arrival or departure, and the type of the transport at the stations (in case of certain repair works the train between the definite stations can be exchanged by the bus).

The train schedule system is heavily utilized by the customers. The search for the corresponding train takes place under different conditions and criteria consideration: the station of departure and arrival, the date and the time range of the departure, the possibility of travel in transit, and so on. In practice, this task is complicated by the large volume of the processed data. In the relation database one version of the timetable for one train takes about 1 KB. The takes into account the minimum amount of data without considering the reference information (such as the stations names, trains types, etc.). The integrated volume of all data of the Latvian Railway passenger trains schedules takes more than 100 MB (about 250 thousand records).

3. Models of presenting temporal data of the train schedule in the Information System

The principal task of the train schedule information system is the storage of the information on train traffic in the past, present and future, as well as provision of access to this information for the system's users. The efficiency of manipulating the train schedule greatly depends on the organization of temporal data in the database. Two possible approaches of temporal data presentation are used: point and interval forms.

Point or daily form of schedule data presentation is convenient for processing operative and analytical queries, but requires huge memory resources and great labour consumption to maintain the train's traffic schedule in its actual state. The main problem of this approach lies not in the volume of the stored data, but in the complexity of providing reliable data and the immediacy of amending the schedule. An example of data presentation in point form is shown in Table 1. From 1st March until 31st May train number 4387 has a stop at station Riga on the working days at 17 o'clock 00 minutes, and on the days off at 17 o'clock 20 minutes. However, from 12th March until 18th May on Tuesdays and Thursdays it stops at 16 o'clock 59 minutes. In the given example 92 records were entered for 3 months to define the stopping time for one train at one station.

Table 1
Train schedule: data presentation in point form

Train ID	**Station**	**Time**	**Date**	
…	…	…	…	
4387	Riga	17:00	03.03.2011	*Thu*
4387	Riga	17:00	04.03.2011	*Fri*
4387	Riga	17:20	05.03.2011	*Day-off*
4387	Riga	17:20	06.03.2011	*Day-off*
4387	Riga	17:00	07.03.2011	*Mon*
4387	Riga	17:00	08.03.2011	*Tue*
…	…	…	…	
4387	Riga	16:59	14.04.2011	*Thu*
4387	Riga	17:00	15.04.2011	*Fri*
4387	Riga	17:20	16.04.2011	*Day-off*
4387	Riga	17:20	17.04.2011	*Day-off*
4387	Riga	17:00	18.04.2011	*Mon*
4387	Riga	16:59	19.04.2011	*Tue*
…	…	…	…	

Since the schedule is usually made for a long period of time (i.e. an entire season), it is more convenient to use *the interval form of data presentation*. This form allows substantial reduction of the volume of stored data, and provides flexibility of schedule management. The interval form allows the use of the data of the schedule's operative temporal database, and accounts for all changes in the schedule as soon as they appear in the system. However, the interval form is inferior to the point form in processing schedule queries and processing analytical queries in particular. For the same example, it is necessary to enter only 3 records shown in Table 2, where $[t_s, t_e]$ is time interval; t_s and t_e are the beginning and ending time of the event.

In practice a variety of data presentation models exist based on point or interval forms. The authors have suggested three possible models of presenting temporal data of the train schedule: the model of the daily schedule presentation (data presentation in point form), the model based on logical rules, and the model based on temporal elements (data presentation in interval form), These differ in the building principles, the capabilities, and the requirements for the resources etc. In the suggested models two basic sets are introduced for the train schedule description: the set of all stations of the railways $S = \{s_1, s_2, ..., s_l\}$, and the set of the all trains $N = \{n_1, n_2, ..., n_m\}$, where l and m are the capacities of the sets S and N correspondingly. Let us consider these models in detail.

Table 2
Train schedule: data presentation in interval form

Train ID	Station	Time	t_s	t_e	Periodicity
4387	Riga	17:00	01.03.2011	31.05.2011	Work days
4387	Riga	17:20	01.03.2011	31.05.2011	Days-off
4387	Riga	16:59	12.04.2011	18.05.2011	Tue, Thu

The duplicating model is the model of the daily schedule presentation (point form). The given model is based on making a calendar of train traffic for every day t_i. Then i-th schedule version $v_i^{(n)}$ for the train with number $n \in N$ will be determined by the tuple:

$$v_i^{(n)} = \{n, t_i, \langle s_1^{(n)}, T_1 \rangle, \langle s_2^{(n)}, T_2 \rangle, ..., \langle s_h^{(n)}, T_h \rangle\},\ i = 1,2,...,k, \quad (1)$$

where the pair $\langle s_j^{(n)}, T_j \rangle$ determines the j-th stop of train with number n, the station $s_j^{(n)} \in S$ exactly, and the train departure time T_j; h is the number of the stops of the train running on the timetable $v_i^{(n)}$; k is the number of days on which the schedule of n-th train is stored in database.

It should be noted that the number of stored records (stating on what day, at what time, at what station every train stops) will be approximately equal to the product of multiplication of the number of trains by the average number stops and by the average number of days for which the schedule is stored. For example, using this approach for storing the data of the Latvian Railway train traffic for a period of one year 2 million records will be needed. . For larger railway companies, the volume of the corresponding database could increase ten times. In order to store schedules for the period of several years, the number of records will increase to the hundreds of millions. As stated previously, the main problem of this approach lies not in the volume of the stored data, but in the complexity of providing reliable data, and the immediacy of amending the schedule.

The model LR is the model based on logical rules (interval form). This model is used to calculate a version of the active schedule based on logical rules that take into account all the specificities of the schedule: multi-versioning caused by the operative changes, multi-variance in case of a periodical schedule, and replacements and movements. For the specific schedule version identification for the train with number

$n \in N$ the tuple $\langle n, C, t_f, t_s, t_e \rangle$ is employed.

The periodicity property *C* presents the logical expression consisting of one or several elementary characteristics of the periodicity p_m connected by the logical operations signs $\vee$, $\wedge$ and $\neg$. Then *i*-th schedule version $v_i^{(n)}$ for the train with number $n \in N$ will be

$$v_i^{(n)} = \{\langle n, C, t_f, t_s, t_e \rangle \langle s_1^{(n)}, T_1 \rangle, \langle s_2^{(n)}, T_2 \rangle, \ldots, \langle s_h^{(n)}, T_h \rangle\},\ i = 1, 2, \ldots, q\ , \tag{2}$$

where *q* is the number of *i*-th train schedule versions, it is significant that *k* >> *q*.

The model works with the data of the schedule's operative temporal database, and accounts for all changes in the schedule as soon as they appear in the system. The central parameter of an access method, relative to which all the algorithms' logical rules pertain, is the day in which an active train schedule version is needed. However, as mentioned above, the schedule system's calendar is subject to changes which appear as exception declarations and replacement assignments.

The model TE is the model based on temporal elements (interval form with reduction to point form) (Terenziani, 2003). The peculiarity of this model of determining the active version of the temporal object lies in the preliminary reckoning of the dates of activity for every schedule version, and saving it in the temporal elements for the posterior employment. The timetable version $v_i^{(n)}$ of the train with number $n \in N$ can be determined with the temporal element:

$$v_i^{(n)} = \{\langle n, TE_i \rangle \langle s_1^{(n)}, T_1 \rangle, \langle s_2^{(n)}, T_2 \rangle, \ldots, \langle s_h^{(n)}, T_h \rangle\}, i = 1, 2, \ldots, q\ , \tag{3}$$

where the temporal element TE_i determines all the dates when the version $v_i^{(n)}$ is active.

The temporal element represents the calculable set of dates, and represents the time determination when the exact version of the train schedule on the extent of its life cycle becomes active. The temporal element comprises all information on the periodicity of the timetable, taking into consideration all operative changes, overlapping versions and special calendars (Kopytov, Petukhova, and Demidovs, 2010). One of the most serious problems of use of temporal elements is the maintenance of the temporal elements in the consistent condition because when the schedule changes the versions temporal elements might become out- dated and need to be recalculated.

The presence of various models of the data presentation is caused by the existence of a set of different systems using the train schedule, which are characterized by their functionality, resource requirements and traditions of the development. This paper gives consideration to four classes of systems which are described in Section 6.

4. Hierarchy of the criteria for evaluating the models of presenting temporal data of the train schedule in an Information System

The search for an optimal model of data organization for a particular IS must be performed taking into account the different criteria determining the efficiency of the schedule system on the whole. An initially formulated criteria system (Kopytov, Petukhova, and Demidovs, 2010) has been developed, considering the peculiarities of the choice of data presentation models of the trains schedule in order to make the criteria more universal and understandable.

In the process of the criteria system formation the authors have been focused on implementing the models in different railway schedule IS ranging from minor systems for mobile facilities (i.e. mobile phones) to global systems of the ticket selling and operating on the most powerful mainframes. This choice has been made taking into consideration the requirements of various categories of IS users, including developers, supporting specialists, database administrators, operators, cashiers and passengers. For example, operators are interested in the simplicity of the data input, and developers are interested in supporting the data integrity and necessity of creation of the data preliminary preparation procedure. Supporting specialists are concerned about monitoring the timely and correct functioning of this procedure, and the passenger's primary interest is schedule topicality.

This research offers a system of criteria. The criteria are distributed in three groups: hardware, maintenance and performance. The hierarchical structure of the criteria is shown in Figure 6. *Hardware* refers to the importance of the effective use of the allocated calculation resources, such as CPU, HDD, and RAM. *Maintenance* refers to the cost of the system's daily exploitation connected with entering a season schedule, random changes, additional data processing, integrity control and the difficulty of adjusting to new rules. *Performance* refers to the requirement to efficiently perform typical tasks of the schedule system, such as searching actual train traffic for a given day, making schedules for short and long time spans, searching activity intervals of a particular version of the schedule, and searching for the nearest schedule change.

To perform the calculations of criteria, the authors have used standard algorithms of the AHP method with the commonly used pairwise comparison scale from 1 to 9 (Saaty, 2001). This article gives the evaluations of the pair wise comparisons of criteria, and the summary results of the calculations presented in Section 7.

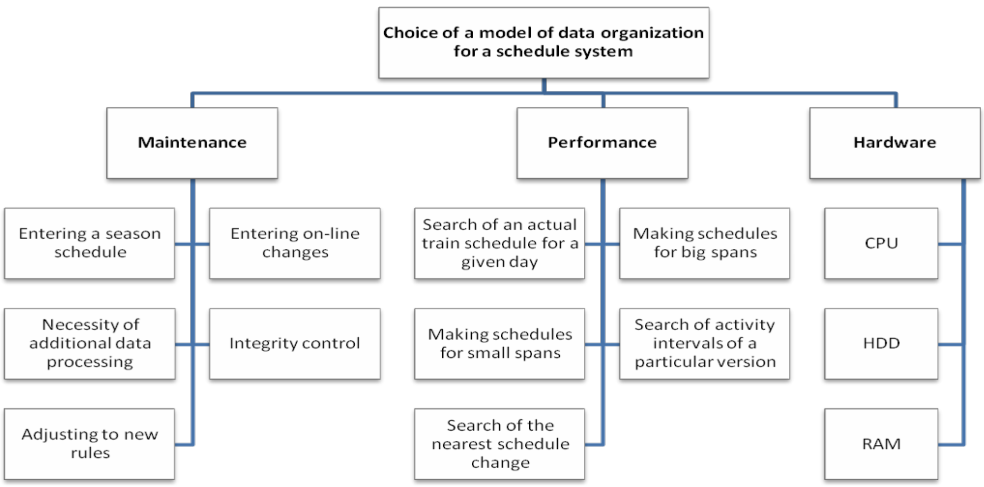

Figure 6 Hierarchy of the criteria for evaluating the considered models

5. Visualization of the evaluations' results

With a large number of criteria and various alternatives, the process of evaluation can be long and tedious. In order to facilitate this process, the authors suggest using a means of visualization (colour and symbolic) which allows for greater comprehension and verification of the results at every step of the evaluation. Verification of the numerical data, each of which consists of several numerals, allows the expert to quickly get an accurate picture of the data. This method also helps "to see" which alternative has become the "leader".

In addition to the fact that all calculations have been performed in the MS Excel 2007, conditional formatting has been used for clearer presentation. Gradient colours, data bars, and icon sets have been used to visually emphasize the most important criteria and to show the preferred alternatives (Figure 7).

Two variants of gradient colour are useful: differentiation in the saturation of one colour, and differentiation in the colour gamma. Colour visualization is not always acceptable for different reasons, such as the availability of only black and white print or special feelings the users might associate with different colours. Symbolic (sign) indication is more universal than colour visualization, and therefore it has been used in this article (Table 4 – Table 7). Note that with the evaluations change, the indication changes automatically.

In Section 7, the following icons have been used for the symbolic indication of the criteria influence: , indicating the degree of influence from the maximum value to the minimum value. For the indication of the global priorities alternatives, three icons have been used: - for the alternatives having high priority, - for the alternatives with middle priority, - for the alternatives with low priority (Figure 8).

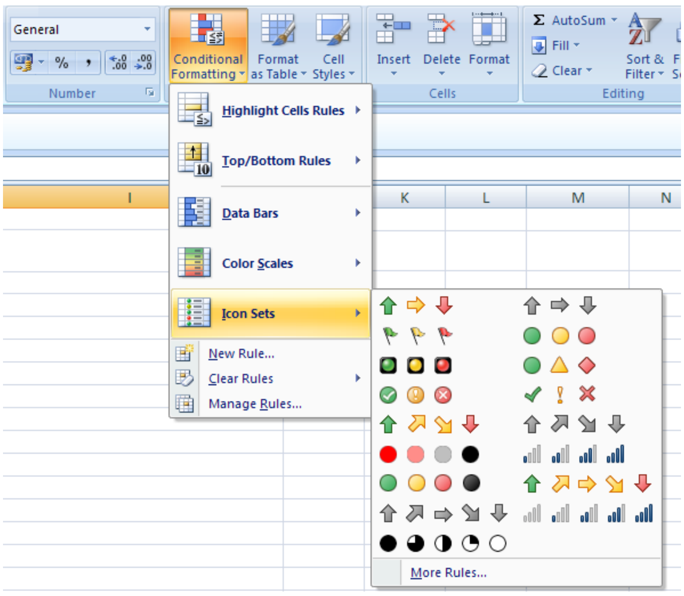

Figure 7 Conditional formatting menu in MS Excel 2007

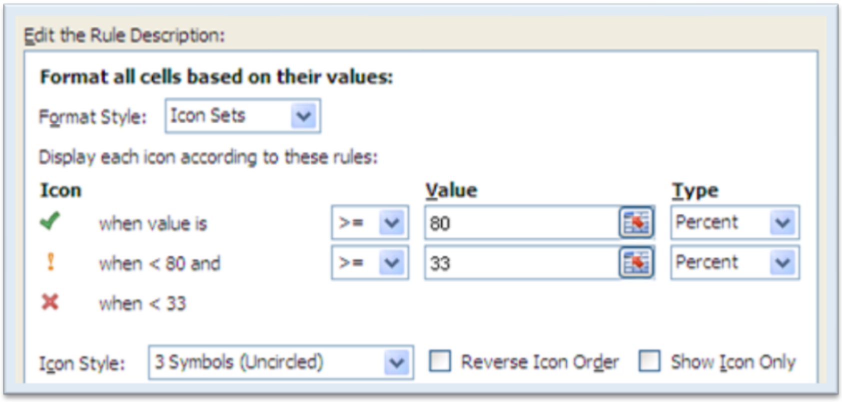

Figure 8 Conditional formatting customization (icon set)

6. Systems of the train traffic schedule

The train traffic schedule is used in different information systems (IS). According to the functional and operational characteristics, we will distinguish four classes of systems: web-based schedule systems, mobile schedule systems, ticket sales systems and rail traffic management systems.

Web-based schedule systems provide information about the train traffic schedule for passengers using the Internet. These systems must have sufficiently broad information to satisfy most of the users' possible inquiries. These might include information about convenient changes, travel time, or a schedule for a given day, week, month, etc. The user's Internet-browser is only a terminal for the interaction with the schedule system. The storage of data and all the calculation processes take place at the specially designed servers.

Mobile schedule systems support the users of mobile devices such as mobile phones, and the portable terminal. These systems are characterized by the autonomy of functioning. In contrast to the previous class systems, all calculation processes and data storage are performed in the mobile device, but the periodically updated schedule is downloaded from a remote server. Due to the limited technical capabilities of most current mobile devices the efficiency of the available resources is questionable. The systems are characterized by a limited set of available schedule inquiries, which are quite simple (i.e. search of the trains' departure from one station to another, presentation of the train's route for the given section with the indication of the stops' time).

Ticket sales systems are designed for selling tickets, and the systems are highly specialized. Their main task is to search the actual train schedule for a given day. The most essential requirement for these class systems is on-line entry of changes in the schedule.

Rail traffic management systems are necessary for planning the train traffic. The users of such systems are the railway specialists. The systems are characterized by broad functionality because of the necessity of sorting out various planning tasks and providing results in different forms. In such systems there are issues of coordinating the railway traffic with other means of transport schedules, and issues of allocating time-windows in the train traffic for repair works, the rail traffic management system requires particular accuracy and reliability of data because of the high level of train traffic security that must be provided. These systems also support planning for the locomotive crews, and conductor's performance, and processing of the locomotive-drivers itinerary.

7. Practical application of the AHP method for choosing the model of schedule data presentation

As discussed earlier the AHP method has been chosen for evaluating the efficiency of suggested data models for the train traffic schedule presentation in different IS. The chosen criteria for the models efficiency are described in Section 5. The research carried out for the four different classes of IS is discussed in Section 6.

The summary data of the pairwise comparisons for the criteria of the first hierarchy level for each group of investigated systems, supplemented with symbolic indication, are presented in Table 3. The importance of the criteria is evident from the evaluation of the criteria priority vector for different systems. Maintenance and performance criteria with identical values 0,467 of priority vectors are more important for the web-based schedule system. Hardware criteria with value 0,761 are more important for mobile schedule systems, and performance criteria with value 0,559 are more important for ticket sales systems. Maintenance criteria with value 0,709 are more important for rail traffic management systems.

We have calculated the matrices of the evaluations of the priority vector for the suggested models for every group of systems based on the evaluation of the criteria priority vector of two levels of the hierarchy.

Table 4 gives an example of the results of calculating the priorities of the second level criteria "Maintenance" for selecting an optimal model of data presentation of the train schedule in a web-based schedule system. The evaluations of the vector of the global alternatives priorities are shown above in Table 5. It is important to note that Table 4 is supplemented with symbolic indication, but Table 5 is supplemented with colour and symbolic indications.

Similar calculations were made for the mobile schedule, ticket sales and rail traffic management systems. Table 6 gives a normalised evaluation of the priority vector of the second hierarchy level for every type of system. The results of the evaluations show substantial differences in the considered criteria priorities in the systems of different classes.

Table 3
Paired comparison matrices first hierarchy level with respect to the goal for different train traffic schedule systems

	Maintenance	Performance	Hardware	Priority Vectors
Web-based schedule system				
Maintenance	1	1	7	0,467
Performance	1	1	7	0,467
Hardware	1/7	1/7	1	0,066
Mobile schedule system				
Maintenance	1	1/2	1/9	0,082
Performance	2	1	1/5	0,157
Hardware	9	5	1	0,761
Ticket sales system				
Maintenance	1	1/2	7	0,371
Performance	2	1	6	0,559
Hardware	1/7	1/6	1	0,070
Rail traffic management system				
Maintenance	1	4	9	0,709
Performance	1/4	1	5	0,231
Hardware	1/9	1/5	1	0,060

Table 4
Matrix of evaluations of the vector of the criteria priorities of the “Maintenance” group for the web-based schedule system

Alternatives	Group priority: 0.467					Priorities in group "Maint-enance"
	"Maintenance" group's criteria					
	Entering a season schedule	**Entering on-line changes**	**Necessity of additional data processing**	**Integrity control**	**Adjusting to new rules**	
	Priority vector					
	0.334	**0.367**	**0.084**	**0.166**	**0.049**	
Model LR	0.444	0.429	0.444	0.615	0.087	0.449
Model TE	0.444	0.429	0.111	0.319	0.162	0.376
Duplicating	0.111	0.143	0.444	0.066	0.751	0.175

Table 5
Evaluation results for web-based schedule system

	0,467						0,467						0,067				
Alternatives	Criteria of "Maintenance" group					Priorities by "Maintenance" group	Criteria of "Performance" group					Priorities by "Performance" group	Criteria of "Hardware" group			Priorities by "Hardware" group	**Global priorities**
	Entering a season schedule	Entering on-line changes	Necessity of additional data processing	Integrity control	Adjusting to new rules		Search of an actual train schedule for a given day	Making schedules for big spans	Making schedules for small spans	Search of activity intervals of a particular version	Search of the nearest schedule change		CPU	HDD	RAM		
	Priorities vector						Priorities vector						Priorities vector				
	0,334	0,367	0,084	0,166	0,049		0,484	0,040	0,198	0,040	0,239		0,540	0,297	0,163		
Model LR	0,444	0,429	0,444	0,615	0,087	0,449	0,109	0,061	0,126	0,100	0,108	0,110	0,097	0,606	0,333	0,287	**0,280**
Model TE	0,444	0,429	0,111	0,319	0,162	0,376	0,345	0,353	0,416	0,800	0,789	0,483	0,570	0,333	0,333	0,461	**0,432**
Duplicating	0,111	0,143	0,444	0,066	0,751	0,175	0,547	0,586	0,458	0,100	0,103	0,407	0,333	0,061	0,333	0,252	**0,288**

We calculated the final matrix of the evaluations of the global priority vector for the suggested models of organising the schedule data based on the evaluations of the criteria priority vector of two levels of hierarchy. (Table 7), This may be used for choosing a model of data presentation in a particular schedule system.

Table 6
A normalised evaluation of the criteria priority vector for different schedule systems

Criteria		Systems: Web-based schedule system	Mobile schedule system	Ticket sales system	Rail traffic management system
Maintenance	Entering a season schedule	0,334	0,437	0,334	0,070
	Entering on-line changes	0,367	0,364	0,334	0,238
	Necessity of additional data processing	0,084	0,074	0,026	0,027
	Integrity control	0,166	0,077	0,110	0,450
	Adjusting to new rules	0,049	0,049	0,196	0,215
Performance	Search of an actual train schedule for a given day	0,484	0,574	0,692	0,556
	Making schedules for big spans	0,040	0,038	0,077	0,111
	Making schedules for small spans	0,197	0,183	0,077	0,111
	Search of activity intervals of a particular version	0,040	0,041	0,077	0,111
	Search of the nearest schedule change	0,239	0,164	0,077	0,111
Hard-ware	CPU	0,540	0,333	0,413	0,260
	HDD	0,297	0,333	0,260	0,413
	RAM	0,163	0,333	0,327	0,327

Table 7
Evaluations of the vector of the global criteria priorities for different schedule systems

Alternatives	Web-based schedule system	Mobile schedule system	Ticket sales system	Rail traffic management system
Model LR	✗ 0.280	! 0.353	✗ 0.220	! 0.359
Model TE	✓ 0.432	✓ 0.452	! 0.385	✓ 0.363
Duplicating model	✗ 0.288	✗ 0.195	✓ 0.395	✗ 0.279

The AHP method allows the models to be arranged in the order of efficiency of their use in every system, and shows their difference in the given set of criteria. By performing an evaluation of the alternatives for selecting possible variants to be used by the AHP method reveals their universal character. Thus, in the example the universal character of the TE model has been shown byit's advantage in the three systems under consideration. The TE model is greater than the nearest models competitors for a web-based schedule system by 14,40%, for a mobile schedule system by 9,90% and for a rail traffic management system by 0,40%. Only for the ticket sales system the TE model yields the duplicating model by 1,00%.

Conclusions

This article solves the issue of choosing the best data presentation model for the train schedule. This problem was formulated as the multiple-criteria decision making task, and a variety of methods has been developed for its solution. In the authors' opinion, the methods of pairwise comparison are the most suitable for the examined problem solving. The employment of methods of this group has been considered in the process of investigation. Three pairwise comparison methods SAW, AHP and ELECTRE were examined.

This study has demonstrated that a major drawback of the ELECTRE and SAW methods is the complexity of the expert's evaluation of criteria in different professional knowledge areas. Only certain criteria which the experts know well were able to be evaluated competently. The estimations of other criteria have been chosen at random.

The AHP seems to be the most attractive method in this context since it allows structuring the choice procedure as a hierarchy of several levels. It allows for the distribution of criteria into several groups and the evaluation of the significance of every group's component. Consequently, the different group's criteria have been evaluated by different experts with proper qualification.

It is necessary to mention other important advantages of the AHP method:

- It does not require special software, and can be presented in MS Excel; however, alteration of the criteria or the number of alternatives requires certain efforts to implement these changes;
- The computable consistency of the judgments allows controlling the accuracy of estimation;
- The algorithm of AHP operation and the table form of representation of the principal and intermediate results allows for a visual demonstration of the reason for choosing the certain alternative.

With the use of the AHP method this research fulfils the evaluation of the efficiency of application of the three models of data presentation for the train traffic schedule in different information systems with the account of the specifics of their application. To determine an optimal method, a two-level hierarchy system of criteria has been developed with ranging expert evaluations according to the importance and preference for all models in each system under consideration. A consistency ratio has been used to verify the judgements in the criteria evaluation which for different criteria groups, have not exceeded 5,77% for the web-based schedule systems, 8,45% for the mobile schedule systems, 6,92% for ticket sales systems and 6,14% for rail traffic management systems.

The AHP method has allowed the models to be arranged in order of efficency of their use for each of the systems, has shown their differences in the given set of criteria, and has allowed discovery of a universal model – model TE.

The AHP method has been presented in the MS Excel 2007. The conditional formatting visualization tool has allowed visual presentation of the most important criteria and of the preferred alternatives.

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