PROBLEMS OF INFORMATION SYSTEMS INTEGRATION IN LARGE TRANSPORT COMPANIES

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ABSTRACT

The article considers the issues of arranging the information systems (IS) interaction and their integration in large transportation company (exemplified by Latvian Railway Company). There presented the comparative analysis of integration technologies on three levels: on the level of data, on the level of messages and on the level of services. The Analytic Hierarchy Process (AHP) is employed as a tool of analysis. The evaluation of the efficiency of application of three IS integration technologies is presented for implementation in Latvian Railway Company.

Keywords: railway, information system, integration technology, Service-oriented architecture, Analytic Hierarchy Process

1. INTRODUCTION

The transport sector plays a leading role in the economy of any developed country; it consumes considerable labour, material and financial resources. In European Union the transport industry directly employs more than 10 million people, accounting for 4.5% of total employment, and represents 4.6% of Gross Domestic Product (GDP) (European Commission 2013). The search for optimal solutions in transport enterprises is greatly hindered by many factors influencing the processes of their activities. The following factors can be mentioned within them: high dynamics and speed of the processes of passenger- and freight transportation; high requirements towards reliability and safety of transportation and their regularity; substantial involvement of financial, labour and material resources; random demand for transportation; significant dependence on the variety of random factors, and first of all on meteorological conditions, large distances between related objects; a complex, far-flung routes network, and others. The above listed factors put forward their requirement towards the employment of computer engineering and information technologies for planning and managing the transportation enterprise activities. As a result, the transportation industry has a leading position among other economy sectors in implementing information technologies in its operations for many years. The recent decades are rich in constructing various IS in big transportation companies, and they are still operating along with the simultaneous implementation of new information systems (Ambrosino et al. 2010)..

Nevertheless, employment of IS based on different hardware platforms and implementing information processing technologies significantly complicates the process of their interaction with business planning and managing processes. It predetermines the importance of integrating the functioning IS for many transport companies. The procedure of integrating the IS typically gives rise to numerous problems, having their peculiarities for every company; the solution of these problems depends on the specific characteristics of employed information systems. It can be exemplified with the problems arisen in the process of integration of IS of transportation company "Latvian Railway".

Nowadays there used various IS integration technologies (Manouvrier and Ménard 2007). The choice of the optimal technology is rather complicated task and should be done with considering the peculiarities of both utilized IS and the area of their employment. It is worth mentioning that there are numerous researches oriented on substantiation of used integration technologies, see, for example (Bussler 2003; Krafzig et al. 2004; Sauser 2008; Sauser 2010). According to the authors' opinion, the choice of the best technology should be considered as a task of multi-criteria choice, taking into account the variety of indicators describing the efficiency of integration processes and entire IS.

The presented article considers the issues of arranging the IS interaction and their integration in big transportation company (exemplified by Latvian Railway Company). There presented the comparative analysis of integration technologies on three levels: on the level of data, on the level of messages and on the level of services. AHP method is employed as a tool of analysis. The assessment of integration technologies is considered for implementation of IS in Latvian Railway Company.

2. INFORMATION SYSTEMS OF THE LATVIAN RAILWAY

In spite of relatively insignificant operating length of the main railway tracks, which is under 2000 km., the freight turnover of Latvian Railway is more than 21 billion tonnes-km in 2011, and the prevailing freight turnover is East-West transit, taking more than 90% of total carried freight; and considering import and export, it is about 98% (Basic Performance Indicators 2012). The good coordination of activities is necessary for provision of this freight turnover; it should take place not only at the level of railway and its enterprises, involved in transportation process directly, but at the level of other railway administrations, as well as sea ports, providing transhipment of freights from marine transport to railway transport and vice versa. The eastern border of Latvian Republic is simultaneously the border of the European Union, and, consequently, Latvian Railway should cooperate with the united European custom system and governmental institutions. One of the Latvian Railway priorities is provision of the high-quality service for the customers of the railway. All abovementioned factors require the availability of various IS and interaction between them.

The first Computer Based Information System appeared at Latvian Railway in 1962. The computers belonging to Latvian State University and to Riga Civil Aviation Institute were used in its operations. The first ECM "Minsk 32" belonging to railway appeared only in 1969, and in 1972 the Information Technology Centre (ITC) of Latvian Railway has been created. Since that time the rapid growth of IS usage has started and it has resulted in availability of more than 100 big, medium sized and small IS at railway today (Kopytov, Demidovs, and Petukhova 2012). ITC provides 80 IT services for supporting the operation of railway. All employed IS were developed by and bought from different companies and in different periods of time; the different technologies, software and databases were used for their creation.

Nowadays ITC supports IS operating on various hardware (Mainframe, IBM pSeries, Oracle Sparc, Intel) and software platforms (Operation systems: z/OS , IBM AIX, Oracle Solaris, DOS, Windows and Linux; Databases: IBM DB2 (5 different versions), MS SQL (3 different versions), Oracle, Ingres, PostgreSQL, MySQL, DBF). There used various technologies of clusterisation (HCMP, MS Clustering services, MS Network Load Balancing Services, IBM WebSphere Network Deployment, Oracle Clusterware) and virtualisation (VMWare, Oracle, IBM). Figure 1 demonstrates the principal IS employed in the Latvian Railway Company, software platforms and spheres of their implementation. The official IS abbreviation is shown inside blocks. Presented IS are divided into three groups according to the number of users (marked by colour): minor (under 50 users), middle (from 50 to 200 users) and big (more than 200 users).

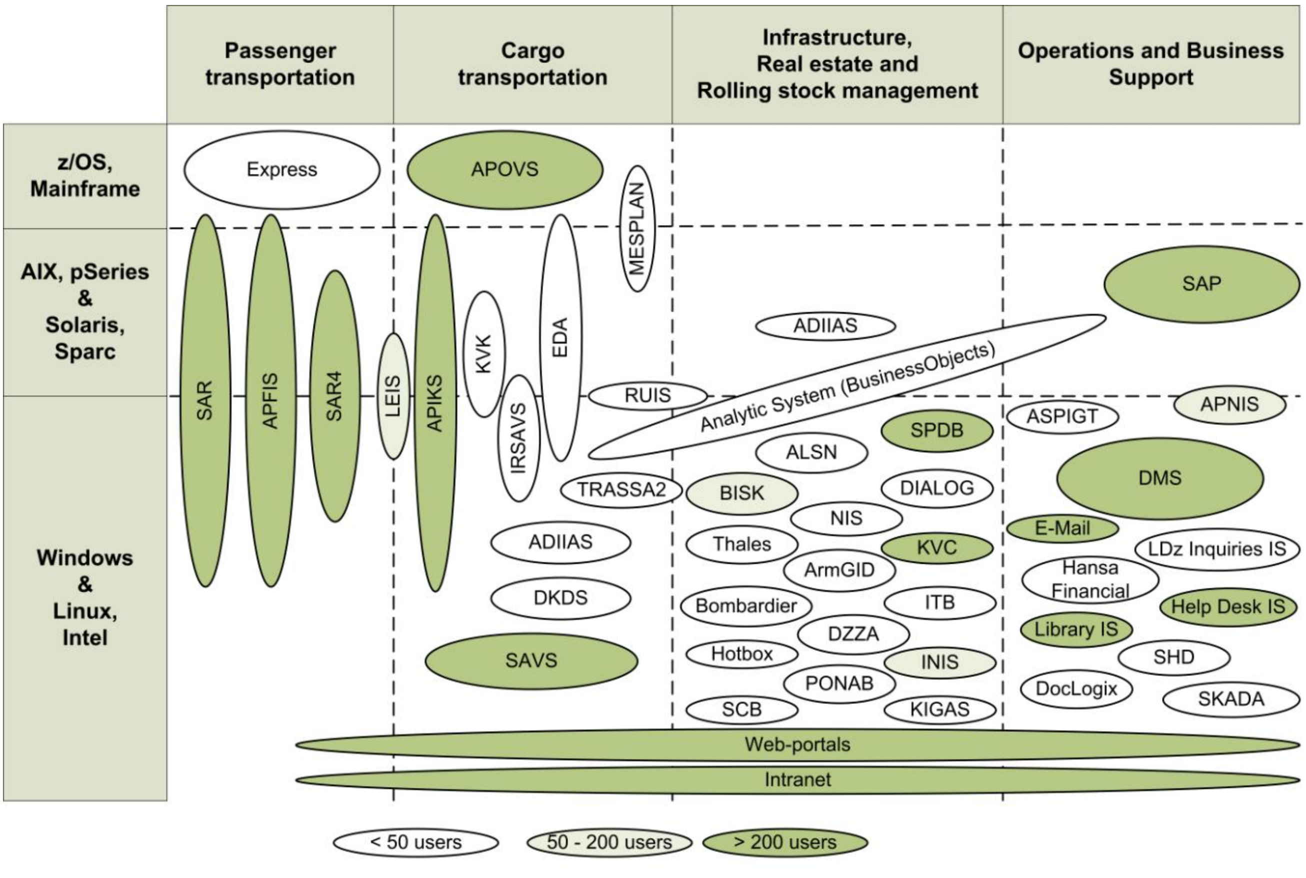

Figure 1: The principal IS in the Latvian Railway

This variety has impact on not only complexity of supporting these IS, but also on the problem of integrating these systems into the uniform information resource of an enterprise. The problem of integrating the information technologies resources at Latvian Railway exists for a rather long time. The attempts of integration of these systems employing various technologies and approaches were taken at all times. The approaches towards integration can be grouped in two directions: data-level integration and integration on the basis of business processes and messages. There is detailed consideration of these directions in IS integration at Latvian Railway.

3. INTEGRATION OF LATVIAN RAILWAY INFORMATION SYSTEMS

The principal integration procedures employed nowadays for providing the information exchange between information systems is asynchronous exchange with messages, for instance, on the basis of product IBM WebSphere MQ and files by scheme "point-to-point". The direct addressing to the system database in a reading mode is used for the systems constructed with employment of DBMS with SQL support.

The first fundamental attempt of systems integration was taken in 1997; the extended analysis of available IS was provided and the concept of development of Latvian Railway IS for the period 1998-2002 was developed. The IS were grouped by the principal directions of railway activities: cargo transportation, passenger transportation, infrastructure, real estate, rolling stock, financial activities (see Figure 2). The concept presupposed centralisation of the IS on the basis of creating the high-speed network of data transmission, and integration of operational information systems (OLTP) on the basis of common database (see Figure 3), as a uniform resource of an enterprise with common system of railway classifiers, and simultaneous reduction of number of IS by integration of different IS with similar functionality into uniform IS (for instance, at that moment there were about 20 accounting departments in the company with different financial systems).

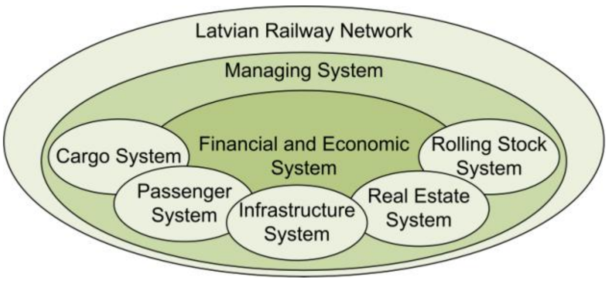

Figure 2: Main groups of IS in the Latvian Railway

Another important direction in integration of information technologies resources was development of the Data warehouse (Kopytov, Demidovs, and Petukhova 2003). This approach, oriented on creation of Decision Support System (DSS), was successfully implemented in IS for analysis and forecasting of the statistical and financial indicators of company activities in the sphere of passenger transportation. Nevertheless, the integration of OLTP systems requires another approach, namely interaction of IS at the level of business processes, implemented by these systems.

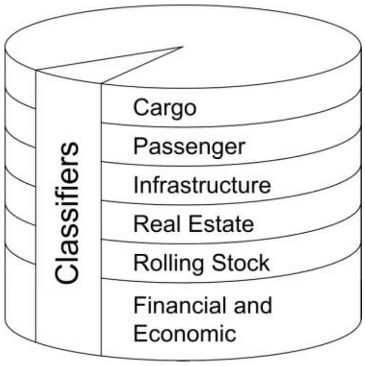

Figure 3: Common database for IS of Latvian Railway

Despite the performed work on integrating OLTP information systems during all these years, the number of problems with IS integration has increased. The total integration of IS on the basis of uniform integrated database was not completed. There can be noted several reasons of failure:

- The integration process was prolonged for more than ten years, and there was a need to implement the migration of newly developed systems to the latest versions of the Database Management System (DBMS). Unfortunately, problems with migration of some IS turned into appearance of even bigger number of databases with different versions;
- Entrance of Latvia into the European Union required prompt actions oriented on restructuring the railway, and consequently resulted in buying new IS and integration of IS not only within Latvian Railway but also together with European IS;
- Peculiarities of business of Latvian Railway, oriented on Russian and Belorussian directions, require information integration and interaction with Russian and Belorussian IS, which are promptly developing and changing;
- These peculiarities require buying or implementing of the finished IS, developed according to different technologies and implemented on various DBMS;
- Rapid dynamics of changing business environment, limited resources for development, and simultaneous necessity to improve the previous IS and to upgrade the new-developing IS for exchanging the old ones resulted in procrastination of the moment of transition to the new IS. There are examples of parallel implementation of two IS, the old and the new one, during the recent ten years.

Despite the above presented facts, IS in Latvian Railway have the minimum level of integration necessary for supporting the transportation process; nevertheless, this integration is very complicated since it employs different technologies, has different structural complexity and extremely difficult for support. Figure 4 demonstrates the instance of integration of several principal IS in the sphere of freight transportation in Latvian Railway, having the intended purposes as follows.

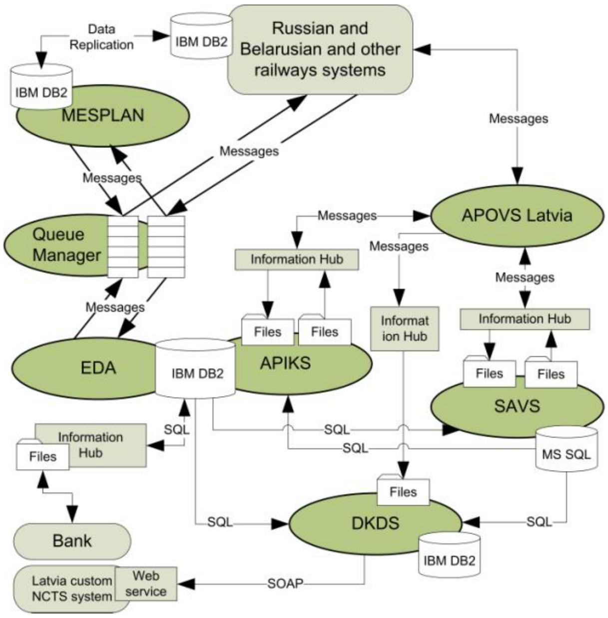

Figure 4: Integration of CARGO information systems

- APOVS is an Industrial Control System of freight transportation operational management. It is the basic system in the area of managing the transportation process. The system integrates the entire information about the procedure of transportation process as an aggregate of interconnected dynamic modules of all objects participating in the transportation process. APOVS comprises about six thousand programmes.
- APIKS is an Industrial Control System of controlling the freight transportation revenues; the system embraces the following modules: loading planning; handling the consignment notes; services sales records; arranging the bank documents; analytical information system; bookkeeping the materials – registration of accountable forms.
- EDA is the system of electronic data exchange (electronic consignment notes) between Latvian Railway and Russian Railways, and between Latvian Railway and Byelorussian Railways (according to MQSeries protocol).
- SAVS is an Industrial Control System of managing the stations.
- DKDS is an Industrial Control System of electronic reporting the railway freights in transit; the system complies with the peculiarities of Latvian Railway; it provides the information exchange within the frameworks of New Computerised Transit System (NCTS) between Latvian Railway and State Revenue Service following the agreement "On order of registering the custom procedure: transit of railway freight transportation" (NCTS, pan-European computer-based system of managing the transit freights, worked out on the basis of UN/EDIFACT standard for electronic documents circulation).
- MESPLAN is a system of arranging the month plan of freight transportation.

The considered example of IS integration implements four levels of integration: level of data, level of messages, level of services and mixed integration, which are presented below.

Integration on the level of data.

- Using the general database for several IS. Every IS implements its set of functions, and the data of these systems are saved in unified database with logical division. The data exchange between the IS is implemented via the common tables. The instance of such type of integration for EDA – APIKS is shown in Figure 2;
- Employment of SQL queries or stored procedures for data extraction. Every system has its own database, but there are special tables, views and stored procedures intended for access from other systems for data exchange within the database of these systems. Examples: APIKS – SAVS; and APIKS – DKDS;
- Data replication on the database level. Examples: MESPLAN of Latvia – MESPLAN of Russia;
- Exchange with files of .txt, .xml and so on types. Example: APOVS – APIKS; SAVS, DKDS, and APIKS – IS of the Bank.

Integration on the level of messages.

- System APOVS has its own API and a protocol of massages, used for massages exchange between APOVS and other IS (APIKS, SAVS, and DKDS);
- Employment of separate system of messages manager, for instance, IBM WebSphere MQ Series. Examples: EDA of Latvia – EDA of Russia; EDA of Latvia – EDA of Belorussia; and MESPLAN of Latvia – other IS of Russia;

Integration on the level of services.

- Employment of activations of web-services IS NCTS from DKDS (see Figure 4), providing the exchange with information within the frameworks of NCTS between Latvian Railway and State Revenue Service.
- Service-oriented architecture (SOA) (Cummins 2009; Krafzig et al. 2004). In year 2012 Latvian Railway initiated the project with employment of SOA technology for integrating information systems EDA, APIKS, SAVS, APOV, and MESPLAN. Another objective of the project is creating the portal via which the users can utilize the functions of these IS (see Figure 5).

Mixed integration.

- Integration on the level of messages and data (by implementing the files exchange). The exchange between the IS takes place with employment of the Information Hubs. Examples: APOVS – APIKS; SAVS, DKDS, and APIKS – IS of the Bank (see Figure 2.). Information Hub transforms the received massages from information system APOVS into files and places them on file-server in the directories of corresponding IS. Files, placed in directories for transmitting to APOVS, are transformed into the messages, which are sent to APOVS;

- Integration on the level of messages and data (employing SQL queries to the databases). Example: instead of transformation into files, Information Hub exchanges with SQL queries with IS APIKS.

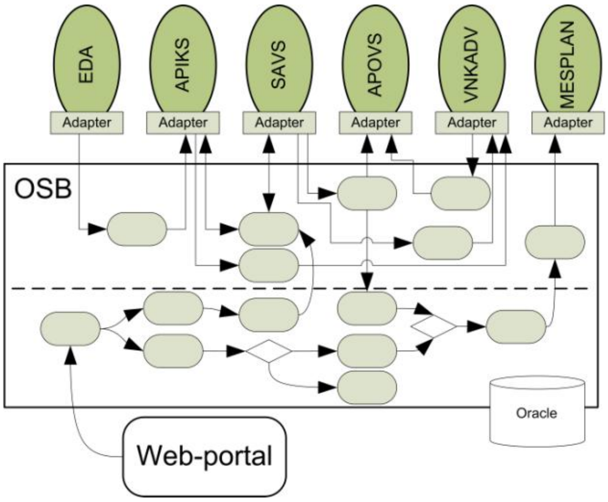

Figure 5: Integration of Latvian Railway IS with employment of Service-oriented architecture

Employment of various technologies in the process of IS integration in Latvian Railway is explained by the set of reasons, including objective and subjective ones; it also depends on the developers of integration projects. The authors suggest implementing the multi-criteria approach for comparative assessment of considered technologies; the approach is based on AHP method and described in the Section 5.

4. PROBLEMS ARISEN IN THE PROCESS OF INTEGRATING IS OF DIFFERENT CLASSES

Integration of IS of Latvian Railway, based on the exchange with messages and files, is in process for at least twenty years. But this integration is implemented between the independent systems with limited functionality and directed mainly on obtaining the necessary information from the IS source and subsequent processing and saving this information at special-purpose IS. Quite often some IS simultaneously serve as both: an information source and target information system. This interaction requires creating various interfaces for every IS involved into the integrating process. Typically these interfaces are limited with implementation of necessary functionality and they cannot be used for integration with other IS.

In 2012 Latvian Railway began the integration of IS with employment of SOA technology. Within the framework of the project it is planned to design information portal and integrator allowing not only obtaining the information important for the customers from available IS but also performing various activities within these systems via integrator equally to the users of these systems (see Figure 5). Integration of business processes on the basis of servers is very popular and well-developed technology, but the developers faced the certain problems at the very first steps towards integration.

The integration of IS was developed according to different technologies and have different users' interfaces without considering the possibilities of integration at the level of services and there is no Application Programming Interface (API) which can assist interaction with these systems at the software level. It seems to be rather strange, but the most suitable for integration are the IS which have evolved from the ones developed in the beginning of the 80es according to the centrally-distributed architecture. These IS have their own protocol for inter-computer interaction (inter-nodes) and for communication with users' terminals. This protocol was also used before for interaction with these systems according to the scheme "Point-to-point".

For integrating the IS without own API to the system kernel the authors have researched the approaches as follows:

- Development of API of the available information system;
- Organisation of interaction at the data-level;
- Development of functionality of this information system in the integrator environment.

The first approach is time- and money-consuming in its implementation, if there is a developer of the system. In case there is no developer any more, for example, the company ceased from the market or a developer does not work at the company any more, the problem of availability and actuality of source code can arise. In this case upgrade of the system can become impossible. Implementing this approach and the problems appearing in this process are considered by authors on the example of integration of information services provided for the passenger; they include: seats reservation, tickets buying, hotel reservation, car rent, and others. The peculiarities of integrating these IS lie in the fact that they were developed by different developers, they belong to different companies using different payment systems.

The second approach can result in the conflict with the developers of this IS who are tracking it. The developer can refuse to support the IS if the access to the software is direct but not via their software. There also can be the problems with blocking data at the database, appearance of phantom data, etc. This approach implementation at Latvian Railway can be exemplified by considering the system of support of freight transportation process.

The third approach implementation is also connected with additional time and money expenditures. It can also involve the problem with integrating the rewritten system with other IS previously integrated with this system. Implementation of this approach and associated problems are exemplified by development of new version of data processing system by customers of freight transportation, since actual information system operates for many years and has become obsolescent. However, new version of this system requires transformation of numerous other IS using the information accumulated at original information system in on-line regime. The compromise variant suggests itself; it supposes that new information system by customers of freight transportation, developed in the integrator environment, goes into service while the part of the previous IS continues performing simultaneously with it, supplying the numerous available systems with necessary data. The additional issue on synchronization of data between the new and the old systems appears. Evidently it requires the substantial financial expenditures.

5. COMPARATIVE ASSESSMENT OF INTEGRATION TECHNOLOGIES EFFICIENCY

In practice the search for an optimal integration technology for a particular set of IS should be performed taking into account the different criteria determining the efficiency of the integration technology on the whole. In present research the authors have been focused on choosing the better integration technology for Latvian Railway IS in the sphere of freight transportation considered in Section 3. This choice has been made taking into consideration the requirements of various categories of enterprise employers, including top managers, developers, supporting specialists, database administrators and IS users.

In the process of the criteria system formation the authors have been focused on five groups of criteria: Costs, Time, Structural Complexity, Information Security, and Technology Universality. 20 criteria have been selected as a result of investigation. The hierarchy of criteria used in the given research is presented in Figure 6.

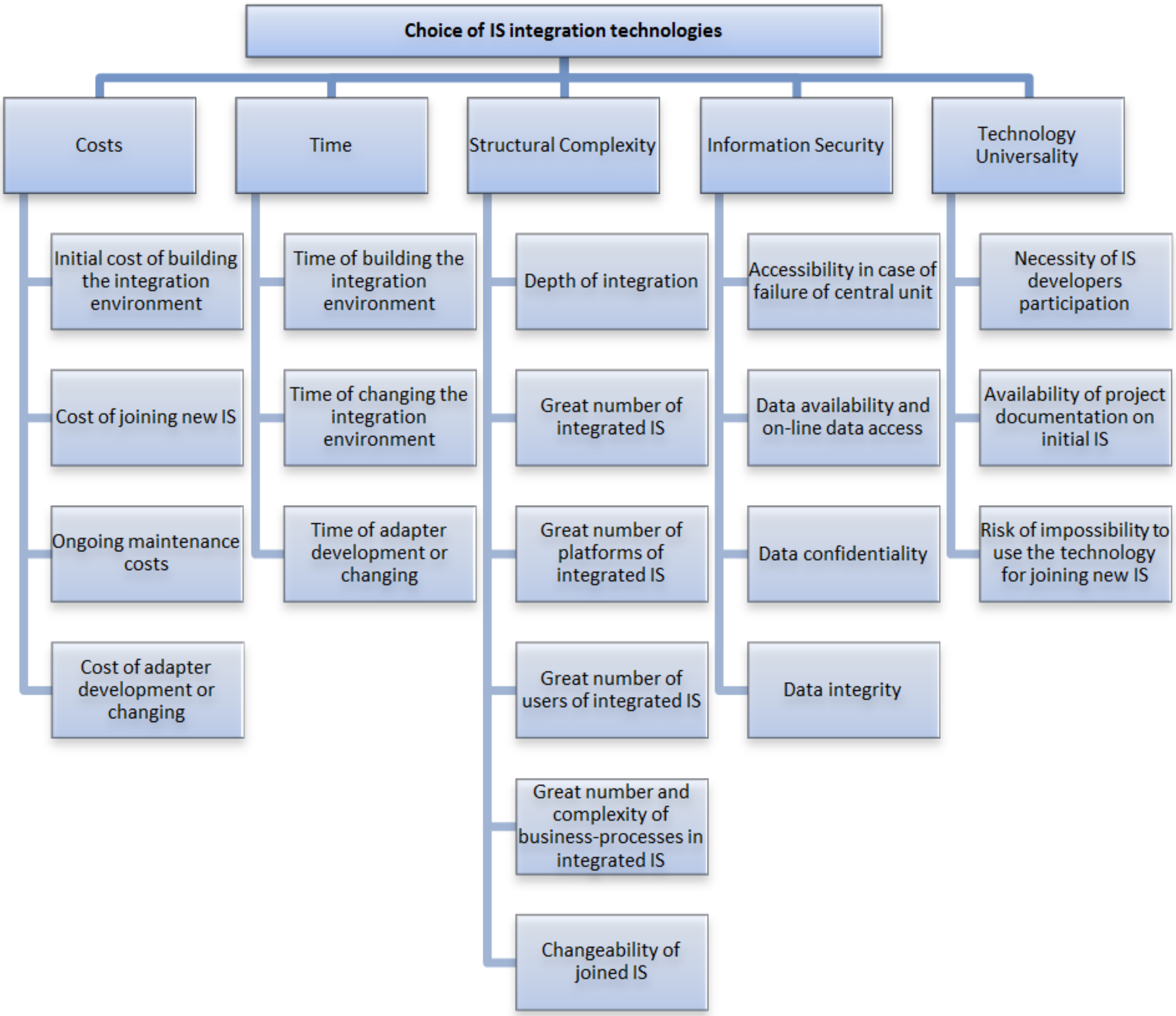

Figure 6: Hierarchy of the criteria for evaluating the considered IS integration technologies

- Group “Costs” considers expenses which the customer of the integration project has on the stages of creation, implementation and further operating the integration system;
- Group “Time” comprises temporal criteria influencing the terms of development and implementation of integration system;
- Group “Structural complexity” includes indicators describing the complexity of joined IS and the entire integration system;
- Group “Data Security” embraces the criteria, connected with the process of data access, data confidentiality, and data integrity;
- Group “Technology Universality” includes the indicators describing the dependence of technology on the initial projects of integrated IS.

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 scale has the following values: 1 – if two alternatives *A1* and *A2* are equal in importance; 3 – if *A1* is weakly more important than *A2*; 5 – if *A1* is strongly more important than *A2*; 7 – if *A1* is very strongly more important than *A2*; 9 – if *A1* is absolutely more important than *A2*; and 2, 4, 6, and 8 are intermediate values between the two adjacent judgments.

The summary data of the pairwise comparisons for the criteria of the first hierarchy level are presented in Table 1. It is quite visible, that experts from Latvian Railway gave high value to the criteria of groups “Data Security” and “Structural Complexity” in the procedure of choosing integration technology. Simultaneously the significance of groups “Costs” and “Time” criteria have substantially lower values. The experts’ evaluation is also reflected in calculated values of priorities vector; the priority of group “Data Accessibility” criteria is 0.3874; this value is by an order of magnitude higher than the priority 0.0362, calculated for group “Costs”. This fact supports the idea of urgency of integration problem solution for the company; the customers are ready to bear substantial expenses for obtaining the integration system of higher quality.

Table 1: Paired comparison matrix for criteria (first hierarchy level)

Group of criteria	Costs	Time	Structural Complexity	Data Security	Technology Universality	Priority vector
Costs	1	1/2	1/8	1/9	1/6	**0.0362**
Time	2	1	1/5	1/6	1/3	**0.0654**
Structural Complexity	8	5	1	1	2	**0.3364**
Data Security	9	6	1	1	3	**0.3874**
Technology Universality	6	3	1/2	1/3	1	**0.1745**

The criteria significance inside the criteria groups was evaluated by experts of different specialisation: top managers, systems developers, and IS supporting specialists. Table 2 presents an example of calculating the priorities of the second level criteria of group “Costs”. Obviously the experts give the highest significance to the indicator “Initial cost of generating the integration environment” with the highest priority 0.5450. Similar calculations were made for all other the second level criteria “Time”, “Structural Complexity”, “Data Security”, and “Technology Universality”.

Table 2: Paired comparison matrix for criteria “Costs” (second hierarchy level)

Criteria	Initial cost of building the integration environment	Cost of joining new IS	Ongoing maintenance costs	Cost of adapter development or changing	**Priority vector**
Initial cost of building the integration environment	1	4	5	3	**0.5450**
Cost of join-ing new IS	1/4	1	2	1/2	**0.1385**
Ongoing maintenance costs	1/5	1/2	1	1/3	**0.0837**
Cost of adapter development or changing	1/3	2	3	1	**0.2329**

Next step of assessment is calculating the matrices of evaluations of the priority vector for the suggested integration technologies based on the evaluation of the criteria priority vector of two levels of the hierarchy. Table 3 gives an example of the results of calculating the priorities of considered integration technologies for the second level criteria “Cost”. Similar calculations were made for all other the second level criteria.

To perform the verification of the correctness of judgments in the criteria evaluation, the consistency ratio (Saaty, 2001) has been calculated; its values are from 0.79% till 8.04 % for different groups of criteria. The values of consistency ratio under 10% indicate that the experts’ judgments are sufficiently consistent.

The final results of the evaluations of the global priority vector for the suggested integration technologies are shown below in Table 4 and Figures 7-8. The value of the global criteria priority for technology “Integration on the level of services” is **0.4208**, and it is significantly higher than the final evaluation of technologies “Integration on the level of data” and “Integration on the level of messages”, which criteria priorities are equal **0.3102** and **0.2374** respectively. So, technology “Integration on the level of services” can be recommended for usage.

Table 3: Matrix of evaluations of the vector of the criteria priorities of the "Costs" group for Integration technologies

Alternatives	Criteria: Initial cost of building the integration environment	Criteria: Cost of joining new IS	Criteria: Ongoing maintenance costs	Criteria: Cost of adapter development or changing	Priorities in group "Costs"
	Numerical value of priority vector				
	0.5450	*0.1385*	*0.0837*	*0.2329*	
Integration on the level of data	0.7418	0.0852	0.7703	0.2583	**0.5407**
Integration on the level of messages	0.1830	0.6442	0.1618	0.6370	**0.3508**
Integration on the level of services	0.0752	0.2706	0.0679	0.1047	**0.1085**

Table 4: Evaluation results of integration technologies (for implementation in Latvian Railway IS)

	Criteria: Costs	Criteria: Time	Criteria: Structural Complexity	Criteria: Data Security	Criteria: Technology Universality	Global priority vector
	Numerical value of priority vector					
	0.0362	*0.0654*	*0.3364*	*0.3874*	*0.1745*	
Integration on the level of data	0.5407	0.3377	0.0851	0.5080	0.2472	**0.3102**
Integration on the level of messages	0.3508	0.3009	0.2500	0.1702	0.3149	**0.2374**
Integration on the level of services	0.1085	0.3614	0.6649	0.3219	0.4379	**0.4524**

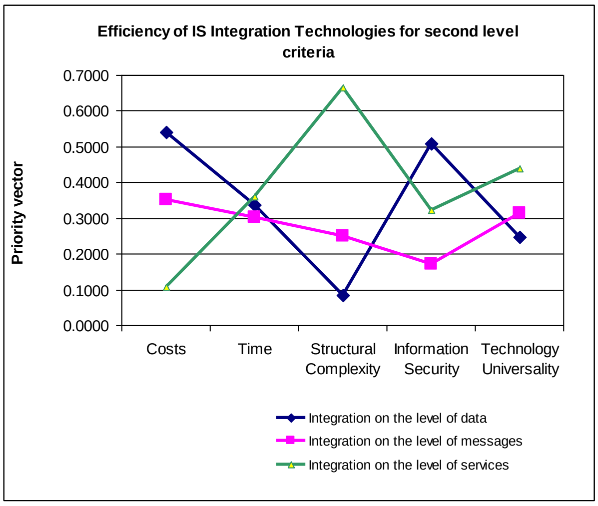

Figure 7: Evaluation results of integration technologies for groups of criteria (second level)

For groups "Structural Complexty", and "Technology University" the criteria values (priorities) of "Integration on the level of services" are greater than these criteria values of other technologies. The special note for "Integration on the level of services" should be given to the criteria "Structural Complexty" with value 0.6649. "Integration on the level of data" evaluation exceeds other technologies evaluation for groups "Cost" and "Information Security". In group "Time" all three technologies have practically the same values: 0.3371, 0.3009 and 0.3614. Consequently, the evaluation results show that the "Integration on the level of services" has the highest value of global priority and is recommended as the best integration technology for Latvian Railway IS in the sphere of freight transportation.

Nevertheless, the "Integration on the level of data" is recommended for an employment in case, when expenses (group of criteria "Costs") are very important.

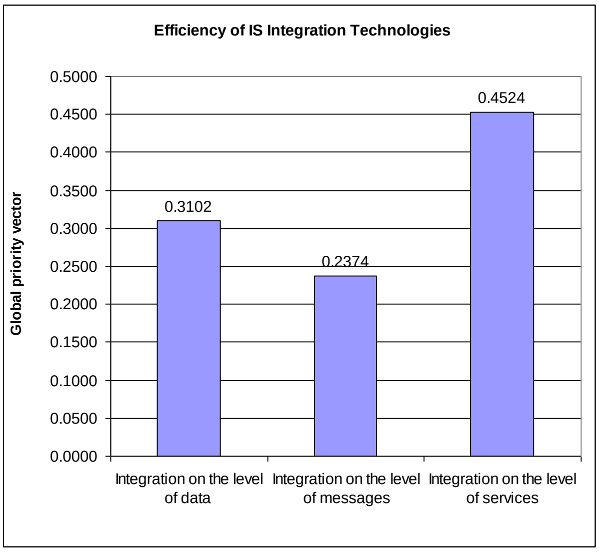

Figure 8: Evaluation results of integration technologies

CONCLUSIONS

The paper considers the evolution of development of Latvian Railway Company IS; there also have been determined the problems appearing in the process of integration. Despite the substantial investments in IS integration, allocated by company during long time, the integration of Company IS has not been finished yet. Separate integration tasks are solved with employment of various integration technologies, choice of which is often subjective and sometimes is not quite reasonable.

The paper suggests the multi-criteria approach for assessing and choosing the integral technologies. The implementation of this approach has been done with employment of Analytic Hierarchy Process. With the use of the AHP method this research fulfils the evaluation of the efficiency of application of three Integration technologies for the IS of Latvian Railway. To determine the optimal technology, a two-level hierarchy system of criteria has been developed with ranging expert evaluations.

It is worth mentioning that actually every big transportation company faces the majority of considered problems; that is why the results of the offered research can be implemented extensively. First of all it relates to the system of criteria for evaluating the comparative efficiency of integration technologies. Obviously, the expert evaluations of criteria significance can be considerably different depending on the investigated company.

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