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MODEL OF INTEGRATED INTELLIGENT PASSENGER INFORMATION SYSTEMS

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Abstract

The developments in field of passenger information systems tend – using means of telematics – towards co-ordination and building together of these systems. The integration covering all these information systems is today already an actual aim. But scientific bases for realization are still missing. The execution of this complex development, the planning are not possible without system analysis and modelling. The quick development in information technology makes the creation of that kind of stable basis indispensable, that does not change in the same pace, in other words, is based on functions. Because of new type of this theme, the purpose was to create that kind of information system structure that gives an appropriate stable basis for a long time. Therefore the aims, functions, components, structure, operation of the integrated system and the used information and data are summarized in the article.

Keywords: modelling, computer integrated passenger transport, description by information, integrated information and data system.

1. Introduction

The information with tools of information technology are means to organize the horizontal and vertical components of passenger transport into a unified system. *As the process of transportation integrates the passengers, transport network, vehicles, energy and personnel in first grade, the informatics is means of the horizontal (in level of transport network) and vertical (among control levels) integration of the whole organization in second grade* [7], [11].

At the overview of structure of the integrated intelligent passenger information system the structure of the description was firstly put down. The logical construction of structure of the whole system – as it used in general informatics and followed at system planning – is the following [12]:

After overview of the controlled process, system and control task the next steps are, to put down

1. the information needed for control,
2. the data (database) system needed for control,

3. the structure of informatics apparatus needed for information handling,
4. the processing programme system needed for information handling.

The most important task in integration is the creation of the unified information and data system. For this reason the statement of worked out model of the information system was set as an aim writing this article. The model helps the principled interpretation of behaviour of the complex system. The system model is a simplified description of the real system, that highlights its important features from the point of view of examination. The model disregards all the features that are not relevant for the examination [11].

The *system analysis* helps examination of the complex systems. The system analysis starts with identification of the problem and summarises *the results in the model* [12]. The complex systems and the relating structures cannot be always described by exact (physical, mathematical, etc.) so called *hard models*. Often, especially at the beginning of the research we have to be satisfied with the so called *soft models*.

Wide information systems of the passenger transport, such as the integrated passenger information system can only be developed in *deductive approach* [11]. *First the circumstances of the complex information supply have to be fully clarified, then the entire information system has to be decomposed into subsystems and the priority of development determined.* The advantage of the *deductive* planning and developing *method* is that minimizes the risk in the process of development of complex systems.

Modelling of the information and data system can only be performed by introducing a complicated designation technique because of the high-level complexity. The used designation is summarized in *Table 1*. The systems, the functions of the systems and the data are indicated with complex symbols (in the first column). The used basis symbols are R, F and D (in the second column). Meaning of the basis symbols can be found as comment (in the third column). Indices belonging to the basis symbols make the differentiation possible (position of the indices are in the fourth column, symbols of the indices are in the fifth column). In the case of indices the symbols of the possible values, the comments of it (in the sixth column) and the number of values (in the seventh column) are also shown. Comments help the understanding of these numbers (in eighth column). For the sake of the easier overview the indices are distributed among four corners of the basis symbols.

Essence of integration of the passenger information systems is the integration of the needed information. When working out the model of the integrated information system the starting point was the structure of the passenger transport system.

2. Structure of the Passenger Transport System

The passenger transport system can be decomposed into

- the real process of the passenger transport (controlled basis system), and
- the control system of the passenger transport [12].

Within both systems

- the skeleton (static) structure, and
- the functional (dynamic) structure

can be separated. Within the functional (dynamic) structure

- the planned functional (dynamic) structure, and
- the realized functional (dynamic) structure

can be distinguished.

The entire structure of the passenger transport system is summarised – as a model – in *Fig. 1*. The following ones help the understanding of this model. According to the mentioned criteria the passenger transport system can be decomposed into several structures. The certain structures are determined by elements, parts of the elements and its relations.

The *preliminary planning of the controlled basis system* contains determination of the passengers to be transported in the future, and then the planning of the features of static and dynamic structures of the basis system. These planning phases are based on each other.

The passenger transport system is established to accomplish the planned passenger transport tasks. The tasks can be determined in knowledge of the *passengers to be transported (1)*. Elements of structure of the tasks are the travel demands specified for different time intervals (differentiation in time). The travel demands are characterized by volumes of demands of the source and destination points (zones) and their distribution among each other in all relations (differentiation in space).

Components and relations of the basis system are described by the *preliminary planned static structure of the basis system (2)*. The components can be classified into groups of *immobile* and *mobile components*. The immobile components contain the public transport network with its all supplementary elements and part elements together. Within the mobile components the vehicles, the manpower and the energy used for operation can be distinguished.

Operation of components of the basis system, that is the technological process is described by the *preliminary planned dynamic structure of the basis system (3)*. The dynamic structure means common operational processes of the components and relations of the processes. The processes are described by timetable co-ordinated among the subsectors. The operation can be also examined in details considering groups of the components. In this way the movement of vehicles, the movement of personnel and the energy stream can be distinguished within the processes.

Because of changes of features of the components the preliminary prepared plans have to be modified in general before the execution. Reasons of the modification can be the changing of the transport task and the changing of components of static structure of the basis system. Taking preliminary plans as bases the modifications are accomplished at *operative planning of the controlled basis system.*

In the course of planning the *passengers to be actually transported (tasks) (4)*, the *actual static structure of basis system (5)* and the *actual dynamic structure of basis system (6)* have to be determined. These planning phases are also based on each other.

Because of outer and inner effects concerning the system the operative planned operation can only be realized with various deviations. That is why the *realized dynamic structure of the basis system (7)* has to differentiate from the planned one.

The control system cannot be planned without knowledge of the controlled system. Information used in control is abstraction 'reflection', that describes the controlled system.

Preliminary planning of the control information system means planning of features of the static and dynamic structure of the control system. These planning phases are based reciprocally on each other.

Components of the control information system, its relations are described by the *preliminary planned static structure of the control system (8)*. In the control system the most important components are the information (data, databases) and the system for information handling (components of information technology and human components).

Operation of the components of the control system and relations of the operational processes are demonstrated by the *preliminary planned dynamic structure of the control system (9)*. The operational processes include the elementary operations for information handling, such as: information pickup, transmission, storage, processing and use. Within the control the processes for information handling can be differentiated how they are related to the passengers, the static or dynamic structure of the basis system.

Modification of features of the basis system within the operative planning involves the same modification of the control system, that is the *operative planning of control*. The modified features are described by the *actual static (10) and dynamic structure of the control system (11)*. The relational planning phases are also based reciprocally on each other.

Because of difference of the operative planned and realized operation the *realized static (12) and dynamic structures of the control system (13)* have to be also distinguished from the planned ones.

There are bi-directional information connections between the control information system and the basis system. These are indicated in the figure by broken arrows.

3. Skeleton Model (Static Structure) of Information System for Passenger Transport

Static structure of the information system is the carrier of the information tasks, in other words the frame, that is carrying out the information processes. In modelling it is possible to start from the fact that we take into consideration all of the components the system is composed of. Namely we still do not mention their operation [4], [10], [11].

At working out of skeleton (static) model of the integrated intelligent passenger information system – that is part of the entire control system of passenger transport – the following tasks have been accomplished:

- *The structure of subsystems has been determined.*
- *The inner structure of the subsystems has been examined by their decomposition.*
- *The input-output relations among the subsystems have been analysed.*

3.1. The Structure of Subsystems

Subsystems of the integrated passenger information system can be classified considering the following criteria and in relation to each other: (In the round brackets there are the denominations of the indices as in *Table 1* in accordance with the classification criteria.)

1. by geographical unit (left upper index),
2. by subsector (left lower index),
3. by company (right upper index),
4. by functions (right lower index).

Classification of the subsystems within a company by functions and denomination of the groups can be seen in *Fig.2*. In the right lower index the first character shows the group of systems, the second character shows the subgroup and the third character makes distinction between the systems within a subgroup possible. The names of the subgroups are given in *Table 2*. Within frames of this article we can dispense with denomination of each system.

Fig. 2 shows analytical model of the structure of subsystems with reference to *one geographical unit*. The indices can be construed by *Table1*. In the plane of the figure the information systems of one company are given. The used notation does not fix number of the subgroups and systems, making insert of additional subgroups or systems possible. The arrangement along the axis at right angles to plane of the figure makes the differentiation by subsectors and companies possible.

3.2. Inner Structure of Subsystems

The subsystems do *activities for information handling.* These activities result in production of output information by transformation of the input and stored information. Modelling of inner structure of the subsystems means description of these processes of transformation taking the outer relations of the subsystems into consideration.

The information is transformed by a well-defined method, in other words it requires some kind of algorithm. The *algorithm* is a procedure sequence to solve a task set as an aim (function). Its essence is the decomposition of the task into unambiguously defined elementary steps (operations). In what follows the algorithm is regarded as *a procedure to solve a task* (mostly by using computer). Number of the algorithms depends on the numbers of tasks executed within the subsystem. Among the different algorithms can be overlaps, namely the certain operations (operation sequences) of the subsystem can also constitute the part of several algorithms [3].

3.3. Structure of Relations among Subsystems

The systems are complex entirety of the elements and its relations. That is why not only the existence of the subsystems and its functions are of primary importance within the information system, but their relations as well. The essence of it is that outputs of the subsystems have relations with inputs of other subsystems. Consequently the information flow among the subsystems and the purposeful – according to a well-defined algorithm – information transformation join the entire information system. The net of relations of the subsystems created in this way is the part of structure of the integrated system.

Determination of inner and outer relations of the system helps planning of types and performance of the telecommunications appliances needed within the organization.

Firstly it is needed to determine where and in which directions the relations will be in action. The unambiguous way of description of relations among the subsystems is the demonstration by graphs. Then it is possible to determine the types of information flowing in these relations and finally to tell how many signs are needed for the transmission of information flowing in the certain relations.

The relations among the subsystems are very complex, therefore the relations and data flowing in the relations are summarized generally in *Fig. 3*. This general structure model is shown only in the following depth.

The subsystems can be grouped by their functions in three main groups. These groups are the group of the information systems aiding planning, accounting and control tasks of passenger transport (not passenger information systems), the group of the passenger information systems and the group of management systems of the integrated database.

The relations shall be determined within the groups and among the elements of the different groups. In the figure only one subsystem of each group is pointed out. In the case of the certain relations the data flowing there is indicated.

To illustrate data-flow among the subsystems let us see *a passenger information subsystem* ($R_{ijk}, i = 2, 3, 4$). This subsystem has relations with one part of the planning, accounting and control subsystems, management system of the integrated database, other passenger information subsystems, and – as outer relation –

passengers. Because direction of the relations generally cannot be fixed, so all of relations are considered as mutual. To designate the data the notation initiated in *Table 1* is used.

As basis of the presented general model the graph illustrating the relations among the subsystems can be built up and the data flowing in the certain relations can be described.

4. Functional Model (Dynamic Structure) of Information System for Passenger Transport

The integrated system is not a simple entirety of the elements (subsystems) and their relations, but it has higher functions and substantially new features. Execution of *functions* of the integrated system means producing of the results assuring achievement of aims of the system. The necessary information can be determined starting from these functions. Development of the information system is aided by modelling of the functions. In the course of it all of the required functions are determined and arranged in hierarchy, the common features are found and then the process of all functions is exactly described [9].

When working out the functional (dynamic) model of the integrated intelligent passenger information system – that is part of the entire control system of passenger transport – the following tasks have been accomplished:

- *Control structures have been built up on the information (control) processes.*
- *Control chain model has been created by putting the processes into order in accordance with the operation.*

4.1. Model of Control Structure

The following tasks for information handling are executed by components of the integrated passenger information system: information pickup, transmission, storage, processing and use. The most appropriate construction for realization of control, information purposes – especially in the case of dynamic processes – is the *control loop*. Therefore it is practical to organize the processes for information handling into a control loop. It can be accomplished by linking the tasks listed above. The realization of it on the one hand assures achievement and keeping of the aims set out, on the other hand determines all kinds of needed information handling [11].

The main control loops in the entire control structure of the integrated passenger information system are the following (see *Fig. 4*):

- control loop of planning of the passenger transport (1),
- control loop of operative control (co-ordination of the participants) of the passenger transport (2),
- control loop of accounting of the passenger transport (3), and

- control loop of producing the value-added information in the management system of the integrated database (4).

Operative control of the passenger transport requires real-time knowledge of the outer and inner factors influencing the transport and the features (spatial and state features) of elements of the structures of passenger transport carrying system. In connection with control of the passenger transport, at different phases of the travelling the different control loops of operations for information handling have to be distinguished. These are the following:

- control loop of processes for information handling executed when preparing locomotion (5),
- control loop of information supply during locomotion (6), and
- control loop of information supply after locomotion (7).

Reliability and 'newness' of information given to the passengers depend on operational cycle time of the control loops and reliability of its elements.

The control loops are connected to each other in chain of information handling of the passenger information system. The connections are realized in a logical order following the information flow as principle of arrangement. *Fig. 4* shows the functional chain model based on the connected control loops. Functions within the control loops are the functions of subsystems of the given group. To designate them the notation of *Table 1* is used. Boxes in the figure contain man–machine components. These components together realize the functions, but they are not designated separately, because they can be determined only when preparing the detailed plans.

Elements of chain of information handling of the integrated passenger information system use a common integrated database. The database is located in the regional passenger information centre that is part of the mobility centre. Continuous refreshing of the database is task of the management system of the integrated database. To produce value-added information the most important functions (designated with $F_l(R_{DBMS})$) of this system and its hierarchy are the following:

1. producing of resistances (static, semi-dynamic, dynamic) of the routes and its sections,
2. calculation of resistances among traffic zones,
3. preparing estimations of traffic situation in advance concerning different time-periods.

The formed control structure centrally changes the system parameters and the data influencing the operation possible.

In the case of on-board information the control loop of the locomotion (travelling) phase can be decomposed into two information loops that connect each other. So the one (the smaller) information loop means the information chain within the vehicle, while the other (the greater) information loop is created by connection of the vehicle to the entire chain of the information flow.

In the case of all controls the question of the *cycle time*, the determination of control points (sample points) arise. This cycle time is basically influenced by disturbance-resistance feature of the organization to be controlled and frequency of changing of conditions during the operation. The cycle time of the operative control and information can be chosen only between an upper and a lower time limit. Exact determination of the cycle time can be achieved by taking the following features together into consideration: average time for leading the vehicle between the origin and destination point, average time interval between important changes of the conditions, spatial extension of the passenger transport organization, number of the vehicles, etc.

4.2. Function of the Passenger Guidance in the Control Structure

Sub-control loop of the execution has an important role in the entire control structure. It consists of the passenger information systems and the operative control system. Lower part of *Fig. 4* (under the dotted line) shows this sub-control loop. The bi-directional information relations on the one hand continuously follow the travel demands and its features, hereby increasing the efficiency of the operative control. On the other hand the information gathered by and arising from the operative control gets – via the passenger information systems – to the passengers. This sub-control loop is practically built up so that following the changes of the public transport demands and forwarding the actual information to the passengers become possible with the shorter and shorter cycle time.

Locomotion of the passengers depends on their guidance. Control of the entire locomotion covers the movements performed on foot and also by vehicles. Consequently in entire control of the passenger transport the management, influencing, guidance of the pedestrian flows at appropriate level are also required in addition to the control of the vehicles. Its manners are the following. The notations used in (1)–(3) functions are:

h – locomotion,
i – control, (guidance),
U – passenger,
J – vehicle,
SZ – crew,
JSZ – coupled coaches (train),
x – number of passengers on the vehicle,
y – number of coaches coupled in the train,
x_a – number of passengers travelling in the vehicle a.

1. *In the case locomotion on foot*, in phases of leading to the vehicle and leading from the vehicle there is an *explicit* guidance, which is illustrated in the

following relationship:

$$h = f(i(U)). \tag{1}$$

Locomotion of the passengers is influenced by their direct guidance.

2. *In the case of locomotion by vehicle*, during travelling there is an *implicit* guidance that is realized by control of the vehicle. It is illustrated in the following relationships.

   a. In locomotion (at travelling) by vehicle running independently:

   $$h = f(i(J)) = f(i(SZ + x * U)). \tag{2}$$

   Locomotion of the passengers is influenced by control of the vehicle. Control of the vehicle means control of the crew (if there is on the vehicle) and indirect guidance of the passengers.

   b. In locomotion (at travelling) by vehicles running not independently, but coupled (e.g. trains):

   $$h = f(i(JSZ)) = f(i(SZ + y * J)) = f(i(SZ + \sum_{a=1}^{y}(x_a * U))). \tag{3}$$

   Locomotion of the passengers is influenced by control of the train. Control of the train means control of the crew (if there is on the vehicle) and the coaches coupled in the train. Guidance of the passengers is realized indirectly by control of the coaches coupled in the train.

The following modes of guidance of the passengers come after each other in entire process of the locomotion:

- individual explicit guidance (leading from the origin point to entrance of the establishment for passenger traffic),
- collective explicit guidance (leading from entrance of the establishment for passenger traffic to vehicle),
- collective implicit guidance (on board) - (individual explicit guidance inside the vehicle),
- collective explicit guidance (leading from the vehicle to exit of the establishment for passenger traffic),
- individual explicit guidance (leading from exit of the establishment for passenger traffic to the destination point).

With knowledge of the functions (control tasks) it is possible to determine the information needed for its accomplishment.

5. Relations of the Structure of Entire Passenger Transport System and the Data Describing It

Entirety of information needed for functioning of the passenger transport organization is not a simple set of the information needed for execution of certain main functions. The systematized information management requires the information supply of the whole dynamic structure on a substantially higher level, in integrated approach. In the transport the information has a very important task to describe components of the transport basis system (static structure) and its operation (dynamic structure).

The information 'mirrors' components of the organization and its operation, bears knowledge, and the management of the information requires operation of a man–machine system. For this reason *the information has a value*. The information describes the reality with a given purpose, with enough precision, but at the same time in enough extension and at the right time as well. The right time is to emphasize, because the passenger transport is a process that is co-ordinated both in time and in space.

The information flowing among the elements of the integrated system, called *inner information*, and the information coming in from the surroundings and going out into the surroundings, called *outside information* can be distinguished. Another important aspect is degree of the abstraction. There is *primary* (original) and *secondary* (processed) *information*. The primary information originates from first-degree description of components of the organization. The secondary information is created at processing of the primary information. It can have several abstraction levels.

Structures of the passenger transport basis system are depicted by information originating from the planning, accounting and operative control subsystems. This information is used by the passenger information systems. *Fig.* 5 shows this description. In lower part of the figure it can be seen that the passenger transport system is in operation to fulfil the *demands for public transport*. Its components are the elements of static structure of the basis system (*immobile components and mobile components*). Result of planned, co-ordinated co-operation of the components is dynamic structure of the basis system, the *transport basis process*, namely locomotion of the vehicles running on the transport network. The operation of the passenger transport system is also determined – in addition to the already mentioned components – by *other* inner and outer *components*. Inner component is for example the tariff system, outer component is for instance the weather as part of the surroundings. The optimum operation cannot dispense with information describing the passenger transport system and concerning the previous periods. Therefore continuous use of the *data in archives* is indispensable.

In middle and lower third of the figure, among the planning, accounting, operative control systems and the basis system, as controlled system dotted arrows show which components are described by which subsystems. The unbroken arrows among the subsystems show the most important information relations and their direction.

In accordance with the foregoing the information describing the passenger transport system can be classified into six groups, which are the following:

1. information describing tasks of the passenger transport (the passengers are to be transported),
2. information concerning immobile components,
3. information concerning mobile components,
4. information concerning transport process,
5. information concerning other components,
6. information describing the passenger transport system and concerning the previous periods.

Data bearing this information can be seen on top of the figure.

The data can be grouped by the validity in time. The groups of the *static*, *semi-dynamic* and *dynamic data* can be distinguished. The thickest arrows (joining the database) of the figure show which subsystem gives which data groups.

Data arising from the planning phase belongs to group of the static (longest validity in time) or semi-dynamic (medium validity in time) data. The 1.–4. data groups can be unambiguously joined to certain phases of the planning, that is why they are not further itemized. Sources of the dynamic data are predominantly the operative control units of the organization that follow the actual traffic situation. The 1.–4. groups of the dynamic data come from these units. One part of dynamic data concerning the transport basis process is provided by the seat reservation system (R_{22}). Sources of data concerning the other components are first of all outer systems. Semi-dynamic data concerning other components comes additionally from subsystem of the economic planning (planning of tariff system), and dynamic data comes from the following passenger information subsystems: complex information supply system (R_{21}), seat reservation system (R_{22}), systems of fare collecting (R_{23}) and luggage retrieving system (R_{41}). One subsystem of the accounting phase prepares the archivation of the static, semi-dynamic and dynamic data concerning the previous periods. This subsystem provides this data for later use.

At delineation of relations among the databases and the subsystems only the subsystem – database directions were indicated to highlight description of the passenger transport system by information.

6. Model of Integrated Data System for Passenger Transport

Data bears information describing the reality. Exact definitions of the information and data, explanation of relations between the concepts can be found in the cited literature [8], [11]. Because of these relations the information system model has to deal also with the integrated data system.

6.1. Structure of Integrated Data System

Primary requirement towards the data system is to provide the needed data for all functions. There are different solutions – following development of the computers – to store the data on computer. In the case of the initial *file-type data storage* the management of the complex data sets that functionally belong together but are stored in separated files was a considerable difficulty for the file management systems. If we want to eliminate the above mentioned problems integrated *database management systems* can be used. These systems include, in addition to the structured database, appropriate programs to process the data. The *database* is an entirety of data stored without redundant overlaps, a data set in complex logical structure. Its aim is to provide data for one or more systems in the most appropriate way.

Because of the several points of view of users and system planning, several models of the database management have come into being (e.g. hierarchical, relational etc. datamodel). The most substantiated and the mostly worked out one is the *relational datamodel*. It assures the data independence to the highest degree. Its additional advantage is that it is nearer to the users, because the data are stored in bi-dimensional tables. Nowadays it is the generally used data model.

When creating the databases, instead of whole depiction of the passenger transport system the *model of the real system* is used. In *data modelling* the *theoretical model of the real system* is created by choosing the important elements and processes and the entity types are determined. The entity types have several features (attributes) and there are various relations among them. In data modelling the high-level logical structure of data of the information systems is determined [11]. Its most important phases are the working out of the conceptual, logical and physical data models. The data modelling can differ for the different systems to be connected.

The same data structure is required for data exchange among the subsystems. *The structure of integrated data system describing the passenger transport system was worked out.* General structure of the database, the classification of the data are summarized in *Fig. 6*. In the figure the notation of *Table 1* was used. Grouping of the data can be accomplished by the following aspects considering its hierarchy:

1. The data can be *primarily* classified by structures of the passenger transport basis system into the six groups determined above.
2. Components of the certain structures mean the *second* aspect of the classification. For example the components of static structure of the basis system (mobile components) are the vehicles, the manpower and the consumed energy. The data can be grouped by its concern of these components.
3. *Third* phase of the classification can be accomplished according to the parts of components of the structures. For example in the case of the vehicles – as components – the data of technical features and the data concerning the passenger transport function can be distinguished.
4. Taking the validity of the data in time into consideration, in *fourth* phase of the classification the groups of the *static*, *semi-dynamic* and *dynamic* data

can be determined. Most part of the static data can be handled as basis data.

5. In the *fifth* phase the data groups can be decomposed into data elements. In this way the structure of the integrated database can be determined as far as level of the data elements.

The classification means at the same time the decomposition of the database. To arrange the figure clearly only the first data groups were differentiated.

In accordance with the presented general structure, the most important data groups were summarized in table. Because of the limits of this article, publishing of this table has been disregarded.

When creating the common database structure and the common database according to the model the principles of development have to be determined. The most important tasks after it are the following [2]:

- exploration of the data errors in the disposable databases, selection of the contradictory, incomplete and duplicated data, correction of the errors, replacement of deficiencies,
- determination of the commonly used data by putting data needed for the operation into coincidence chart, avoiding data redundancy,
- standardisation, creating of a unified code and symbol system.

Before the integration the subsystems get the same data from different sources, thus differences are possible. During the examinations of the integration the aim is to reveal the commonly used data. Its authenticity level can be substantially increased by using a common data source. There should be strong consistence in the common database that has to be considered at modifications of the data. Simultaneously with planning of the databases the conditions among the co-operating organizations concerning format, actuality, quality etc. of the data also have to be determined [1].

Data groups used by the subsystems in common were identified by integration examinations. The matrix of relations – called coincidence chart – among the subsystems and the data groups (databases) was created. In the course of it was determined which databases are needed for operation of the certain subsystems (database–subsystem direction) and in which databases the subsystems get output data (subsystem–database direction). Working out of the matrix allowed description of additional coherences. The subsystem–database and the database–subsystem directions were separated and analyzed.

The subsystem–database direction (depiction of the passenger transport system by information) was summarized in *Fig. 5*. To present the database–subsystem relations, that is the commonly used input data of groups of the subsystems representation in sets was chosen. In *Fig. 7* data groups used as input data by the subsystems were assigned to them. The representation in sets permitted the unambiguous determination of input data groups used by groups of the subsystems in common on the basis of the cuts.

The input data sets assigned to the groups of subsystems were designated by Greek letters in the figure. Designation of the data groups arranged in sets can be found below the figure. When forming the groups – for the sake of the comprehension – only the first and the fourth aspects, namely the structures of the passenger transport system and the validity in time of the data were taken into consideration. These aspects are designated by the right upper and the left upper indices. The left upper indices have been disregarded, where according to the validity in time of the data all the three (static, semi-dynamic and dynamic) data groups belong to one set.

After creating the common data structure the storage place of the data has to be determined. Because in the integrated system a lot of data is managed in an extension that exceeds the extension of the public transport network, the distribution of the databases is inevitable.

6.2. Distribution and Location of the Databases

As the passenger transport is a spatial process, the *storage system should be built up according to spatial aspects*. The determination of grade of the *decentralization* and *centralization*, the decision for simple or repeated data storage are to solve in system approach with full knowledge of the stored data system of the entire passenger transport organization [6].

Costs of the data supply in space come from two constituents in the telematics systems. These are the cost of the data storage and the cost of the data transmission. When creating the integrated database the joint costs have to be kept as low as possible. The centralized data supply over a certain data quantity is more expensive than the decentralized solution because of the transmission costs. Therefore in the course of the integration *distributed databases* have to be created, because their expenses are lower.

The number of types of data distribution is very high. At distribution of database of the integrated passenger information system a mixed, combined solution is expedient, which means the combined use of the territorial, functional and repeated distribution. As high proportion as possible of stored data needed for the operation of passenger information system of a given geographical unit should be available in the common database of the regional passenger information centre. In this way data of another regional passenger information centre have to be reached through telecommunications ways only in the case of long-distance travels. Aspects of the distribution vary also with the different subsectors.

At determination of spatial structure of the data storage the lowest possible level of data transmission performance of the entire system should be achieved by right choosing of location of the regional passenger information centre. It can be accomplished by calculation with full knowledge of the location of the data sources and data targets, and the quantity of data.

Table 1. The used symbols

1. Designation of systems by passenger transport

1. Combined symbol	2. Basis symbol	3. Comment	4. Position compared to basis symbol	5. Indices	6. Comment	7. Number of values of the index	8. Comment
${}_{B}^{a}R_{ijk}^{b}$	R	basis symbol of information system used in passenger transport	*left upper*	a	index of geographical unit the system belongs to	n_a	number of geographical units participating in the integration
			left lower	B	index of transport subsector the system belongs to $B = U, K, V, H, L$ U – urban transport K – road transport V – railway transport H – water transport L – air transport	n_B	number of transport subsectors $n_B = f(a)$: number of transport subsectors depends on geographical unit
			right upper	b	index of transport company the system belongs to	n_b	number of transport companies $n_b = f(a, B)$: number of transport companies depends on geographical unit and subsector
			right lower	i	index of information system group the system belongs to $i = 1, 5, 6$ planning, accounting, control information systems of passenger transport, $i = 2, 3, 4$ passenger information systems	n_i	number of information system groups $n_i = f(a, B, b)$: number of information system groups depends on geographical unit, subsector, and company
				j	index of information system subgroup the system belongs to	n_j	number of information subgroups $n_j = f(a, B, b, i)$: number of information system subgroups depends on geographical unit, subsector, company and information system group
				k	index of information subsystem	n_k	number of information subsystems $n_j = f(a, B, b, i, j)$; number of information subsystems depends on geographical unit, subsector, company, information system group and subgroup

2. Designation of functions of the systems by passenger transport

1. Combined symbol	2. Basis symbol	3. Comment	4. Position compared to basis symbol	5. Indices	6. Comment	7. Number of values of the index	8. Comment
$F_l\left({}_B^aR_{ijk}^b\right)$ Dependence ${}_B^aR_{ijk}^b$ symbol of information system the functions belong to	F	basis symbol of function	*right lower*	l	index of function	n_l	number of functions of the system

3. Designation of data by passenger transport

1. Combined symbol	2. Basis symbol	3. Comment	4. Position compared to basis symbol	5. Indices	6. Comment	7. Number of values of the index	8. Comment
${}_{E,F}^{C}D_m^{G,p,r}\left(F_l\left({}_B^aR_{ijk}^b\right)\right)$ Dependence: ${}_B^aR_{ijk}^b$ symbol of information system the data belongs to F_l symbol of function information system the data belongs to	D	basis symbol of data	*left upper*	C	index for groups by validity period of data $C = S, F, D$ S – static data F – semi-dynamic data D – dynamic data	n_C	number of groups by validity period of data
			left lower	E	index for data-flow, to designate the direction compared to subsystem $E = I, O$ I – input data O – output data	—	—
				F	index for data-flow, to designate the group of source or user subsystem or the borders $F = K, N, U, T$ K – outer source or user N – source or user is not passenger information system U – source or user is passenger information system T – source or user is the system for handling of the integrated database	—	—

3. Designation of data by passenger transport (following)

1. Combined symbol	2. Basis symbol	3. Comment	4. Position compared to basis symbol	5. Indices	6. Comment	7. Number of values of the index	8. Comment
	D	basis symbol of data	*right upper*	G	index of structures of the passenger transport system, that the data concerns $G = F, I, M, K, E, A$ F – persons are to be transported (demands) I – immobile components M – mobile components K – basis process of transportation E – other components A – former system features (in archives)	n_G	number of structures of the passenger transport system
				p	index for components of structures of the passenger transport system	n_p	number of components $n_p = f(G)$: number of components depends on structures of the passenger transport system
				r	index for parts of components of structures of the passenger transport system	n_r	number of parts of the components $n_r = f(G, p)$: number of parts of the components depends on structures of the passenger transport system and components
			right lower	m	index for data elements	n_m	number of data elements $n_j = f(G, p, r, C)$: number of data elements depends on structures of the passenger transport system, components, parts of the components and validity period of data

Table 2. Groups, subgroups of the passenger transport control systems and the symbols used as designation

GROUP	SUBGROUP
1. Computer Aided Planning systems of Passenger Transport System (**R**$_1$)	11. Demand Assessment, Analysis, Planning systems
	12. Transport Network Planning, Service Planning systems
	13. Vehicles, Work-force, Energy-supplier System Planning systems
	14. Timetable, Vehicle-ordering, Work-force ordering, Energy-supply Planning systems
	15. Quality Planning systems
	16. Economic Planning systems
2. Computer Aided Passenger Information systems Before Travelling (**R**$_2$)	21. Timetable, Tariff and Tourist Information systems
	22. Reservation systems
	23. Ticketing systems
3. Computer Aided Passenger Information systems During Travelling (**R**$_3$)	31. Lead TO Vehicle Information systems
	32. On Board Information systems
	33. Lead OFF Vehicle Information systems
4. Computer Aided Passenger Information systems After Travelling (**R**$_4$)	41. Lagguage Retrieving systems
	42. Passenger Retrieving systems
5. Computer Aided Accounting systems (**R**$_5$)	51. Performance Accounting systems
	52. Resources Accounting systems
	53. Financial Accounting systems
	54. Statistics Preparing systems
	55. Quality Control and Analysis systems
	56. Archives Preparing systems
Computer Aided Passenger Transport Control Management systems (**R**$_6$)	61. Transport Influencing Factors Information systems
	62. Operative Planning systems of Capacity Exploitation
	63. Operative Control systems

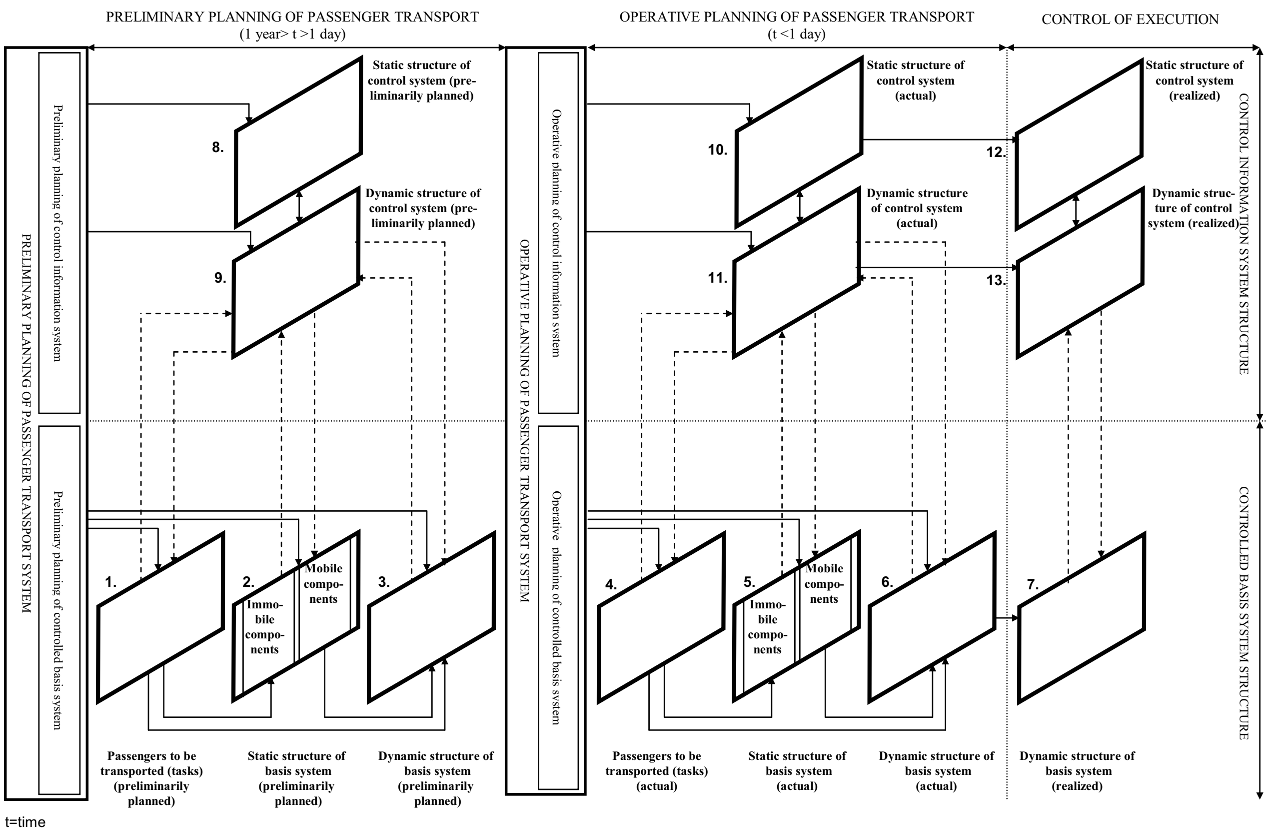


Fig. 1. Structure of the entire passenger transport system

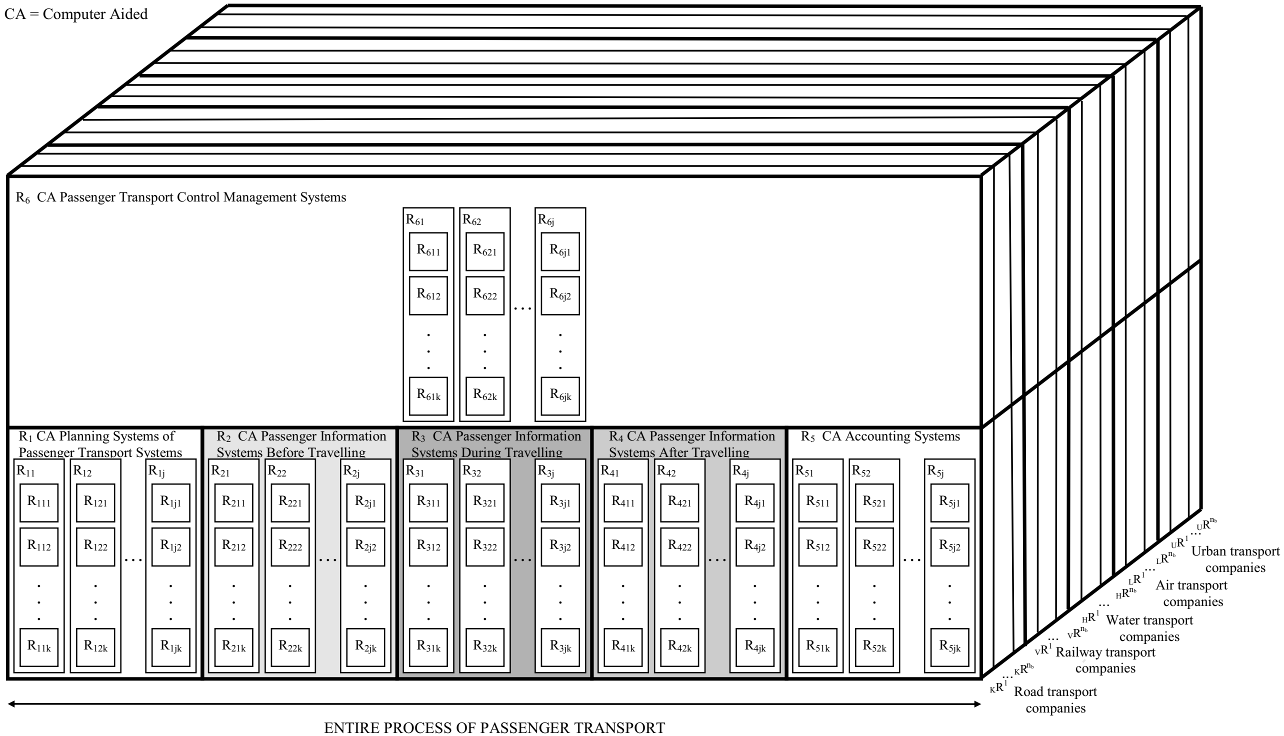


Fig. 2. Analytic model of the structure of subsystem by passenger transport

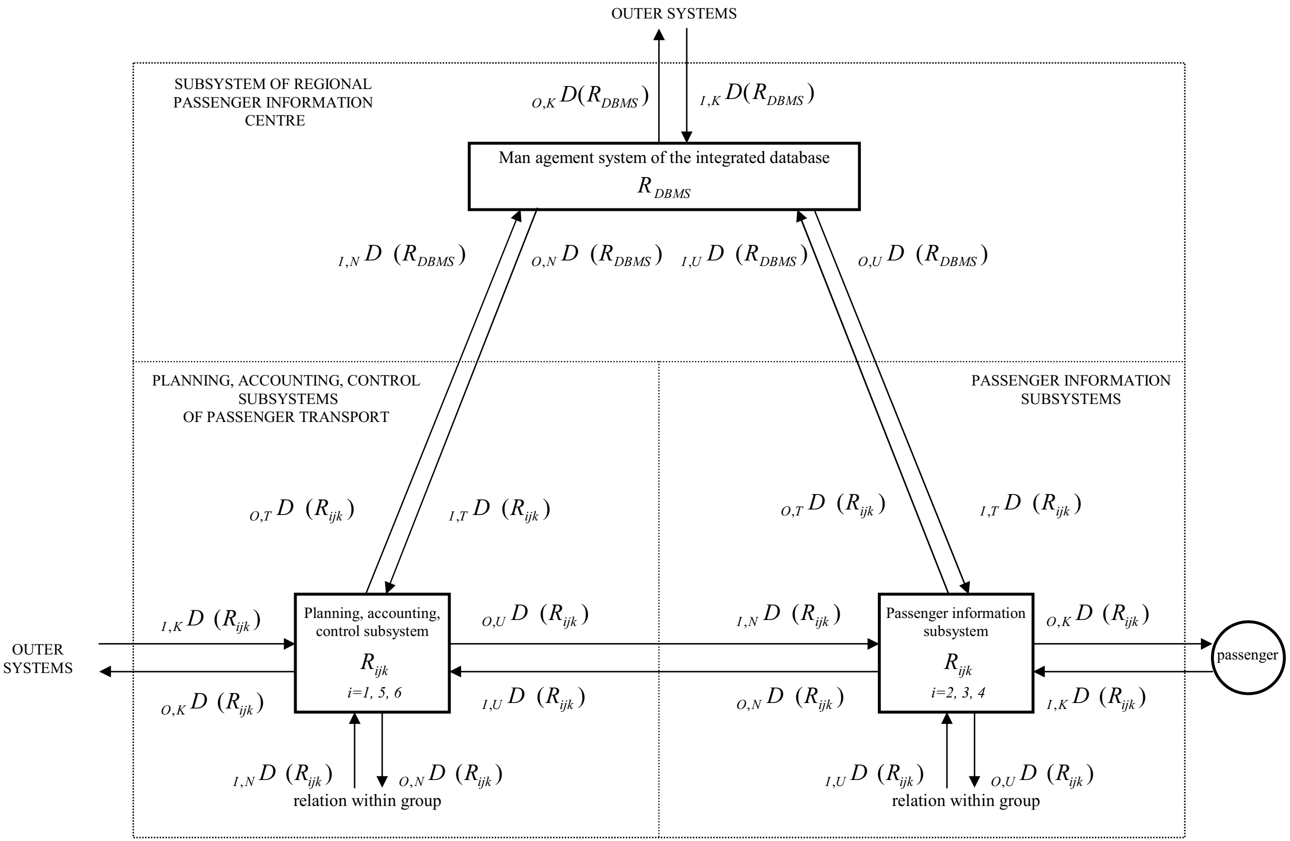
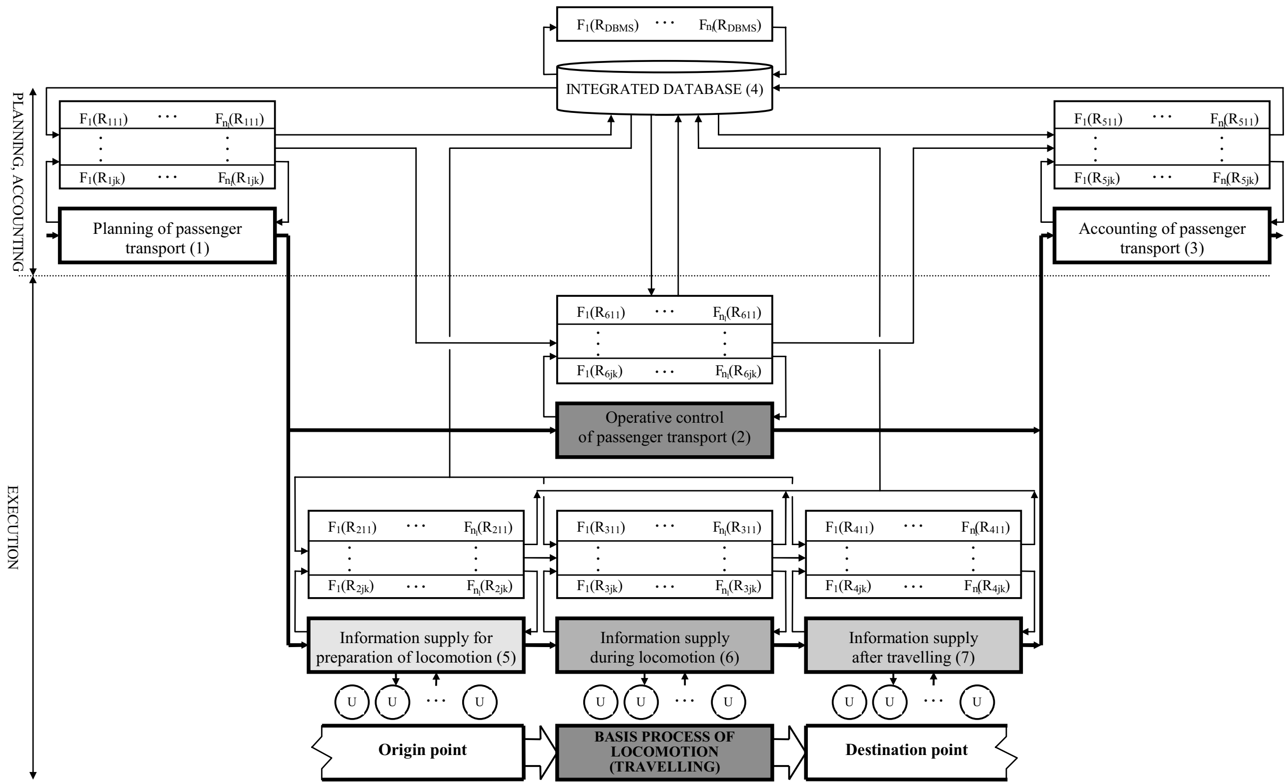


Fig. 3. General model of structure of relations among the subsystems by passenger transport



Key: U - passenger

Fig. 4. Functional chain model of integrated information system of the passenger transport

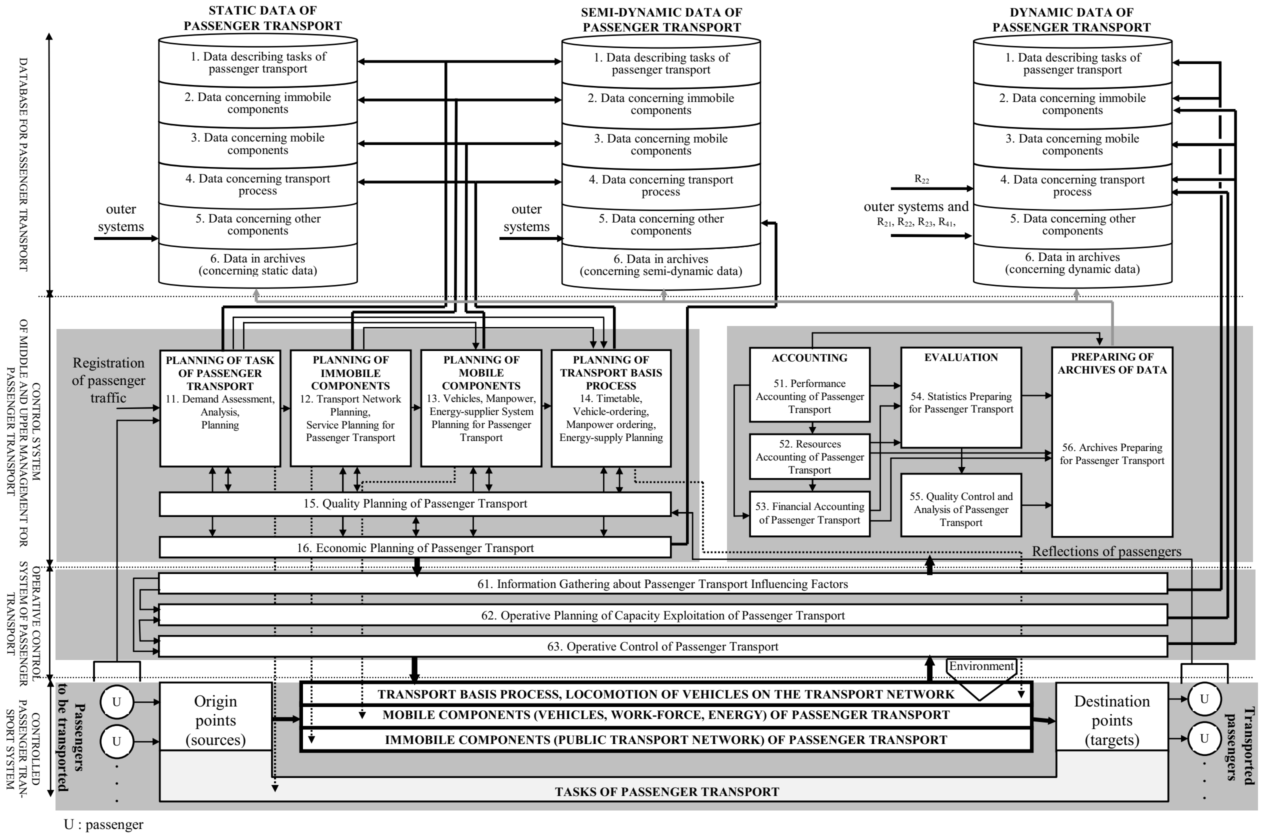


Fig. 5. Relations of the structure of entire passenger transport system and the data describing it

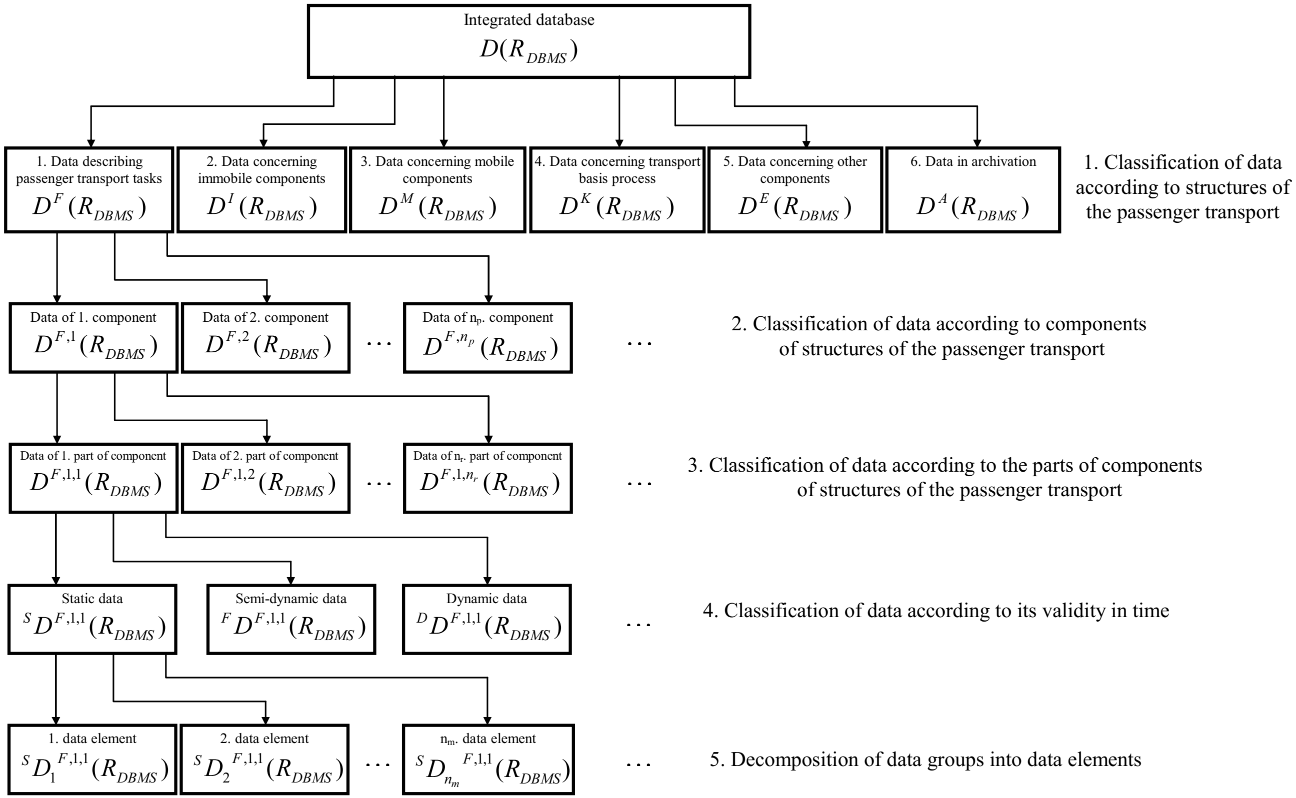
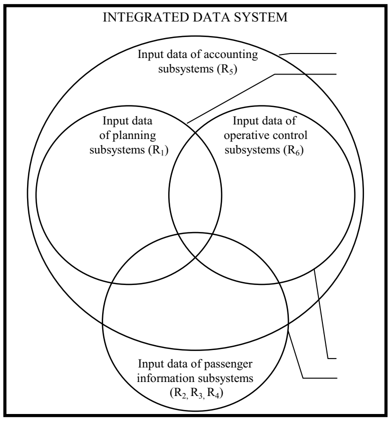


Fig. 6. Structure of the integrated database for passenger transport management



$$
\begin{aligned}
{}_I D(R_1) &= & \beta &= \left[{}^S D^F, {}^S D^I, {}^S D^M, {}^S D^K, D^A, {}^F D^F, {}^F D^I, {}^F D^M\right],\\
{}_I D(R_2) +_I D(R_3) +_I D(R_4) &= & \delta &= \left[D^I, {}^S D^M, D^E, {}^F D^K, {}^D D^K\right],\\
{}_I D(R_5) &= & \alpha &= \left[D^F, D^I, D^M, D^K, D^A, {}^F D^K, {}^D D^E\right],\\
{}_I D(R_6) &= & \gamma &= \left[D^I, D^M, D^K, {}^D D^F, {}^D D^E, {}^D D^A\right].
\end{aligned}
$$

$$
\begin{aligned}
\alpha \cap \beta &= \left[{}^S D^F, {}^F D^F, {}^S D^A, {}^F D^A\right],\\
\alpha \cap \gamma &= \left[{}^D D^F, {}^D D^M\right],\\
\alpha \cap \delta &= \left[{}^F D^E\right],\\
\alpha \cap \beta \cap \gamma &= \left[{}^S D^K, {}^F D^M, {}^D D^A\right],\\
\alpha \cap \beta \cap \delta &= [\emptyset],\\
\alpha \cap \gamma \cap \delta &= \left[{}^F D^K, {}^D D^I, {}^D D^K, {}^D D^E\right],\\
\alpha \cap \beta \cap \gamma \cap \delta &= \left[{}^S D^I, {}^S D^M, {}^F D^I\right].
\end{aligned}
$$

Fig. 7. Input data of the subsystems in the integrated data system for passenger transport

There are data (e.g. data concerning the tariff system) that have to be available even if the telecommunications network is accidentally out of order. This one has to be stored in a local computer, too, and only the refreshing from time to time via telecommunications or the access through detour way (e.g. ACS systems) have to be achieved. Terminals of the work stations with own winchesters can be considered as decentralized databases. These winchesters store the data queried – via telecommunications – most often, in an appointed segment, so the telecommunications costs are reduced. The data has to be stored usually duplicated for the sake of the safety. The safety data is a copy, which helps the avoidance of loss of the data in case of breakdowns. At archives preparing a set of data concerning the previous periods the data is transferred to the storage devices of later users, generally concentrated by the main computer.

7. Conclusions

Summarizing it can be stated that in the course of creating of model of the integrated intelligent passenger information system we succeeded in

- forming notation without redundancy (*Table 1*),
- developing structure model of the passenger transport system (*Fig.1*),
- analytical modelling the structure of subsystems (*Fig.2*),
- modelling inner structure of the subsystems, and
- modelling structure of relations among the subsystems (*Fig.3*).

As the systems are generally sets of elements and relations, we succeeded in description of the entire information system by a logical closed model. We succeeded in determination of the information management processes and functions, putting those into right control structure and hereby creating functional model of the information system (*Fig. 4*). Model representing relations of the structure of entire passenger transport system and the data describing it (*Fig.5*) and model of the integrated data system have been produced (*Fig. 6*). Matrix representing relations among the subsystems and the data groups (databases) has been constructed, and on the basis of this, we succeeded in determination of common input data of the subsystems (*Fig. 7*) [5].

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