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DESIGNING AND EFFICIENCY OF DATABASE FOR SIMULATION OF PROCESSES IN SYSTEMS. CASE STUDY FOR THE SIMULATION OF WAREHOUSE PROCESSES

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Abstract: *The basis of each IT system is data exchange both between individual modules of program and between program and user. The number of exchanged data and the number of operations on the data, which should be performed, require application of professional tools allowing for collecting and performing operations on multiple types of data. One of these tools are databases, which are an essential part of any IT system. With database designing are connected many decision problems which can occur both during the construction of database management system and at the stage of integration of entire user application with developed database. The article presents typical decision problems connected with designing of databases. These problems mainly concern sphere of information technology (including the programming language or recovery mechanism of database after the failure). Database architecture for typical IT system from the point of view possible paths for users were discussed, and role of catalogues played in development of database were presented. In addition, modular structure of the database, which was developed for the system SIMMAG3D for modelling and visualization of warehouse facilities in 3D was shown. This system is being developed under a project financed by the National Centre for Research and Development. We discussed in detail one of the essential elements in developed database - catalogues of means of external and internal transport, non-mechanical equipment and accessories which are essential from the point of view of the work load.*

Key words: *SIMMAG3D, database, processes simulation in systems, warehouse processes.*

1. Introduction

The database is the set of records i.e. information which can be placed in the appropriate tables adequate to the record of information in arrays such as in IT systems. Each of these tables can perform different functions which are defined for a specific thematic issue e.g. calculating the result of given processes. In the base the information are storage in according to strict rules and then processed via a database management system. The database is therefore one of the elements of the information system and its management is based on identifying specific information procedures (Babaian et. al., 2013; Hasselbring, 2000). The model of the database is defined as the set of rules which characterize the data structure in the base e.g. array variables or the set of operations e.g. addition operations of records. Processing information in the database is realized by the database management system.

Databases is the basic element in designing of complex IT systems, which take into account the large amount of processed information. One of such systems are systems for the decision support in the logistics and transport issues. The authors (Jacyna et. al., 2014) proposed simulation model of environmentally friendly transport system. This model allows to calculate pollutant emissions which are generated by road transport. This system required the development of a database taking into account the characteristics of the transport network, characteristics of means of transport and distributions of passengers streams.

The study of the effectiveness of supply chains (Jacyna-Gołda, 2015) requires the development of

the decision support which is based on the characteristics of individual objects logistics network i.e. suppliers, buyers, warehouse facilities. This fact imposes the development of databases that store information such as the distance between objects network, driving times, the technical characteristics of vehicles, the demand of consumers and suppliers for specific raw materials and products.

In turn authors (Jacyna-Gołda et. al., 2015) developed a computer tool that supports the design and optimization of warehouse processes. According to the general definition a storage process is a set of tasks referring to transport or storage of the materials by the use of appropriate equipment and the staff.

This process is controlled by specialized information tools (Fijałkowski, 2003). It is therefore necessary to develop a database taking into account e.g. physical characteristics of the material, characteristics of the means of transport and employees.

An increase of the level of flight safety in civil and military aviation requires the search for methods of the decision support (Zieja et. al., 2015). The implementation of these methods is possible after entering the data which characterize the courses, flight durations and aircraft specifications.

Logistical problems associated with the location of storage facilities require the multi-criteria decision support. The authors (Jacyna-Gołda et. al., 2015) developed a tool to support the process of selecting the location of warehouse facilities based on the genetic algorithm. The problem warehouse locations is a complex optimization issue taking into account a technical and economic factors which must be entered into a computer application using the defined database.

Location problems and a description of the data processed by the optimization algorithms can be found in publications (Brandeau et. al., 1989; Szczepański et. al., 2014; Dey et. al., 2015; Belien et. al., 2014). In turn, vehicles routing problems (Lewczuk, 2015; Jacyna-Gołda et. al., 2016) require a defined database which consists of the characteristics of individual objects transport network, characteristics of the vehicles, drivers.

The main objective of this paper is to present the methodology of proceeding in the construction of databases to simulate warehouse processes i.e. the development of catalogs, the database architecture and present the main decision problems occurring in the implementation of these databases in the user application.

The warehouse process is a set of operations performed by a human by the use of devices in a certain sequence, starting with unloading external transport means, by the acceptance, the storage, the order picking up to the external loading means of transport at the exit of the object.

So warehouse processes can be defined in dynamic or functional way. In the first case these processes are considered as the change of the state of the logistic object while in the second case as a sequence of performed activities during the realization of the material flow. In order to simulate the warehouse processes the most important role plays the data referring to the transportation means, transshipment facilities etc. Additional the nature of the warehouse processes (dynamic and static processes), the time of their execution, delivery schedules, the location of the storage facility must be took into account. Considering all these aspects, the complexity of the processes of storage (e.g. storage, order-picking, cross-docking), in order to simulate warehouse processes an adequate database must be defined.

The article presented the typical decision problems related to the design of databases. Moreover the database architecture for a typical computer system was discussed, the role of catalogs in the development of the database was underlined, the modular structure of the database which was developed for the system SIMMAG3D modeling and visualization warehouse facilities in 3D was presented. One of the essential elements of the developed database i.e. catalogs of internal and external transportation means, non-mechanical equipment and equipment essential from the point of view of the loading work was characterized.

2. The decision problems related to the development of the database

2.1. Preliminary remarks

Decision problems in the development of databases occur at the stage of constructing a database management system and at the stage of integration of the entire user application with developed database.

The development of Database Management System (DBMS) (Garcia-Molina et. al., 2011; Ullman, 2013) is the one of main problems occurring at the

moment of constructing the database. Database Management System is a set of tools for defining the database. This system allows to download and modify data contained in the database. Database Management System is a versatile software which has an interface with the user application and the database. Basic problems in the development of the database may encounter in the following project issues (Hernandez, 2014):

- Defining a database using Data Definition Language (DDL) which is to determine the types, data structures and constraints for the stored information. Depending on the designed user application the type and structure of the download data takes a different form. The main decision problems of defining the data is to determine the structure of the input data for the user application and the scope of the data. The data can be entered as vector or matrix variables. The structure of the input data determines the speed of download data that is important for applications which require immediate calculations or working in the on-line mode. The data type is selected according to the range of variables processed in the application by the user.
- Manipulating the database includes such activities as making queries which allow selecting from a database specific information, updating the database and outputting information outside the database by generating reports. Making basic data operations by the users is possible by the use of Data Manipulation Language (DML). Search functions and data conversion are performed by the use of query language. The most common query language is currently Structured Query Language (Connan, 1993; Adams, 2017). The decision problem is the choice of the appropriate query language which determines the time of processing the data.
- The choice of the capacity of the system directory. The system directory also known as data dictionary is a place of storage of information describing the data in the database or in other words is a collection of "data about data" or metadata. It is assumed that the system directory is available both for users and the database management system. The amount of stored information may differ between commercial management systems. In a typical system directory one can be stored e.g. names, types, and sizes of data elements, user names authorized to access the data, database schemas, usage statistics, such as e.g. the frequency of transactions and counters references to objects in the database.
- The main advantages of using the system directory are:
  1) The ability to describe the importance of individual data which allows other users to understand their purpose.
  2) Determining the users who own or have the right to access the data.
  3) The changes in the structure of the data can be recorded.
  4) The ability to protect data against loss or damage.
- Defining the transaction, namely the development of mechanisms and algorithms that should be implemented in the database to ensure the performance of the transaction.
- The transaction is defined as an operation or set of operations performed by a user or application program referring to (reading or modifying) the content of the database (Connolly, 2005). The responsible tool for handling the transaction is a transaction manager.
- Defining the service of database restore. Database Management System should include a mechanism for recovering the database when it becomes damaged in any way. If the transaction is stopped as a result hardware error or software Database Management System must ensure the correct reading of the database.
- The development of systems which control access to the database i.e.
  1) security system, which prevents access to the database unauthorized users,
  2) integrity system, which guards the consistency of data stored in the database.
  3) multi-access control system, which allows simultaneous access to a database of many of its users,
  4) recovery system after a failure which recovers a consistent state of the database which was before the failure of software or hardware.

  At this stage of the design of the database decisions concerning the selection of appropriate types of control systems are very important.
- The integration of the database with software of data transmission. Database Management System must be able to work with software for data

transmission. The system receives requests from users in the form of transmitted messages and responds in a similar way. All messages are handled by Data Communication Manager. At this stage of the design decisions about a program that performs data transfer between the user and the database are very important.

2.2. The algorithm for the database design

The database design algorithm taking into account the typical decision problems in the development of these databases are shown in Fig. 1. The first stage of the project is to define the input data types and structures processed by user application. In the second stage query language is selected which processes the stored data in the database and generates reports. In the third stage the capacity of the system catalog determines the size of the stored data in the database so the selection of the capacity of this directory is important from the point of view of the size of the data stored in the database. The fourth stage is the stage in which the tools are developed to control the correctness of transactions carried out on the data. In step 5 data processing algorithms in emergency situations e.g. in the case of damage are defined. Data access control systems are developed in step 6 and defining the connections between the user and the database is developed in step 7.

2.3. Design principles of functional modules

In the process of integration of the database with user application should be developed functional modules which implement the process of processed data in accordance with the developed application. Thus it becomes problematic to connect the database with the structure of the user application and developing modules which process download data. One can distinguish the following application modules:

- Constant dictionary module contains tables of the database which are filled with the values determined during the design of the application. Dictionary serves as a data source for user interface elements.

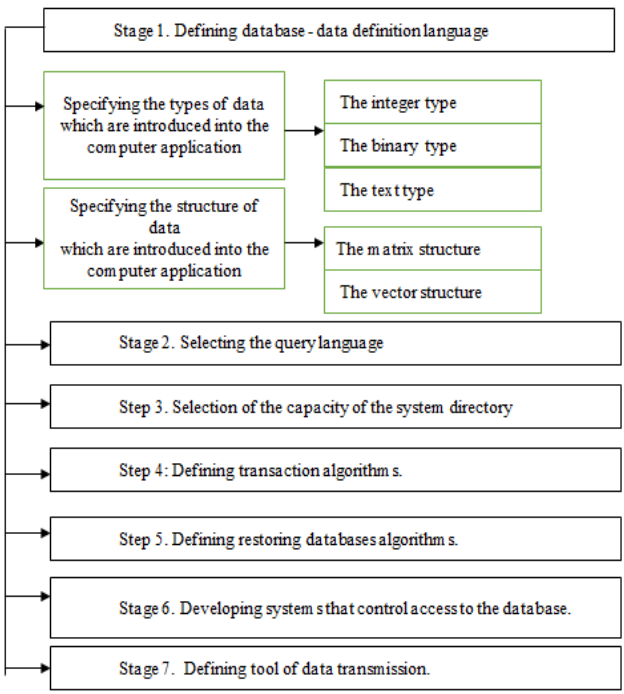

Fig. 1. The steps of the algorithm for the database design.

- Dynamic data module is designed to service the data which during the operation of the system can be added, modified and deleted by users. Dynamic data are created as a result of direct action e.g. by entering by the user), and indirectly as a result of analyzes or import from external sources. The modification and deletion of the data are acceptable only to users with appropriate privileges. The data are organized in the form of data schemes, which each of them contain a set of related tables.
- Archive module is part of a database for storing the analysis reports.
- Input module is designed to support the process of the direct introduction of the input data by the user.
- Data presentation module mediates in the process of sharing stored data in the database for authorized users.
- Optimization calculation module gives the result of the reports and data sets.
- Data sharing module provides an interface between applications based on different base systems.
- Document module allows to print a document prepared in the system.

The order of modules, the relationship between them and the database determine the correct functioning of the entire application. The scheme of modular user applications in combination with the database are shown in Figure 2. The presence of the modules in the application is an optional choice which increases the usefulness of the application. The database located in the constant dictionary module is modified in a dynamic way by dynamic data module and by a user in input module. Each module is associated with a database and all modifications of data are included in the database.

3. Architecture of database for it system and the role of catalogues in its preparation

The basis of each IT system is data exchange both between individual modules of program and between program and user. The number of exchanged data and the number of operations on the data, which should be performed, require application of professional tools allowing for collecting and performing operations on multiple types of data. One of these tools are databases, which are an essential part of any IT system.

Fig. 3 shows typical architecture of the database, which is used in IT systems.

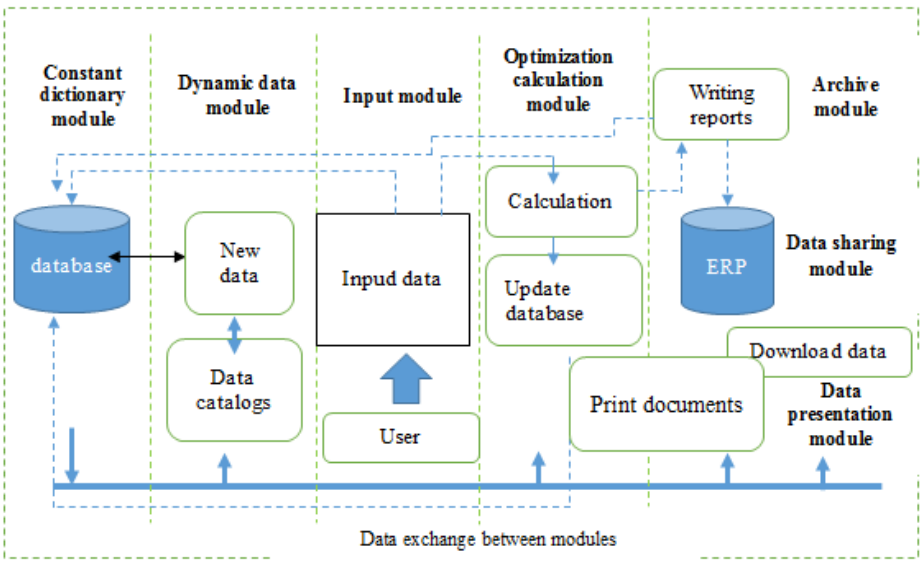

Fig 2. Modules processing the data in user application.

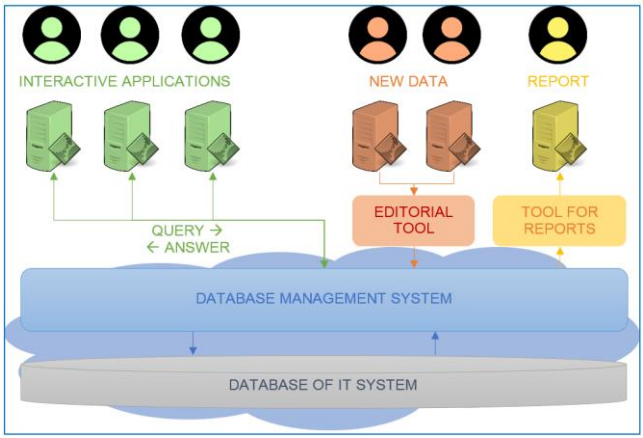

Fig. 3. Architecture of database for IT system

Essential elements of database architecture for IT system are users. Access to data contained in the database, which can be represented as a media storing the data describing the reality according to strict rules (Benedikt et al., 2015), they can obtain in three ways.

The first way is to use interactive applications that allow for sending query to the database and display the answers. Users, who wish to obtain specific values for a particular type of data, using the application send a query which goes to the database management system (DBMS) (Vossen, 1991). This system allows for (Elmasri, 2008): administration of data stored in the database, assurance data integrity and security, their disaster recovery, access to collections by many users at the same time, granting access privileges for particular types of users and optimization of database. Therefore it represents a kind of gateway to the data stored on the media. DBMS gets the appropriate values from the database and sends them to the interactive application in which they are accessed for the user.

The second way to access to the data contained in the database is important when user wants to add new data to media. Access to the database begins in this case in editing tool, which has the authority to perform operations on data. These permissions are assigned by the DBMS. Data, after saving the request to add data from editorial tools by the user, are sent to the Management System, which then according to strict rules adds data to the database.

The last way to access the database is connected with the necessity of receiving by the user specific data contained in the database. Access to them is done by reporting tool. This tool by DBMS gets data from a database and presents them in selected by user form.

It should be noted that Database Management System with the database create database system (McFadden et al., 1998). This system in various technologies can be made. After analysing the problem of designing warehouse facilities and the fact that in the future, multiple users will use the database at the same time, it was decided to use the system, which can be used in client - server architecture. It is architecture, which clearly separated the role of the client application and server application (on which the database system is installed). To ensure ease of use in setting up of the database, ability to work in the cloud was chosen.

The proper work of the application with the database requires a pre-insertion of the necessary information into that database. Most often the information stored in the database comes from the catalogues elaborated in the either traditional (paper folders, books) or electronic form. From the point of view of information systems, a much better for of the data implementation in the database is the electronic catalogues form. Hence the existence of the database system without previously developed catalogues of information implemented in the database is quite troublesome. Of course, it is possible to download the information into the database from external databases that are in the hands of private entities or government, but this type of access to the data usually requires laborious adaptation of the data to

our information system, its database structure and the functionalities.

The above-mentioned catalogues of information can take various forms. The main goal is to collect the large amount of information on certain objects or processes in one place (file) and then implement it into the database. In addition to the information characterizing the object / process, a given catalogue may also contain the illustrations to fully identify the object / process, as well as properly understand the characteristics, which has been described. Quite an important feature of the catalogues of information about objects and processes is the possibility to build them by many people simultaneously, which significantly accelerates the ability to implement the full catalogue on the system.

The very important issue for the database is the structure of information collected in the catalogue. The database that is readable for the software developer makes it easier to implement in the software without the necessity of tedious data processing. Also completeness of the information stored in the catalogues will condition the proper functioning of the database and fast access to the information

4. Case study - project of database for the SIMMAG3D system

In point 3 of the article typical architecture of the database for IT system was shown. In this part of the study was presented the structure of database, which was developed for the needs of the system for modelling and visualization of warehouse facilities in 3D - SIMMAG3D (Jacyna et al., 2016). SIMMAG3D functions include:

- modelling of warehouse facilities in 3D,
- designing of warehouse facilities in 3D,
- visualization of warehouse processes in 3D
- optimal placement of objects in the logistics network,
- designing of supply chains in different planes,
- shaping and dimensioning of warehouse facilities,
- scheduling process, internal transport,
- multi-criteria evaluation of proposed solutions,
- simulation of the flow of materials in different functional areas of warehouse facilities.

The system thus enables preparation of the warehouse facility model in 3D, visualization, planning and evaluation of processes in it, as well as the location of the object in the logistics network. To perform its functions properly it is prepared according to the modular structure, which is shown in Fig. 4.

The structure of system SIMMAG 3D includes three modules (Fig. 4):

- optimization and simulation module, which allows you to find rational solution in issues related to designing of warehouse facility (described below)
- 3D visualization module, which allows you to design warehouse facility in a graphical way and visualization of processes occurring in it using 3D technology,
- database, in which are collected data related to the operation of individual modules and processed according to specific rules; additionally it stores data from the WMS (Warehouse Management System) which are necessary to visualize the warehouse processes.

Access of the user to each program module takes place via graphical user interface. On it there are hyperlinks, which allow you to select the appropriate system module. After selecting optimization and simulation module user can access to various simulators, which have been developed under the project SIMMAG 3D, and after selecting 3D visualization module to the tool for designing of objects and graphical presenting of processes. Both modules work closely with the database module, which collects both input parameters necessary for the operation of individual modules as well as the effects of their work.

Due to the fact that the system SIMMAG 3D has a modular structure, the database also has been developed in form of modular structure. The first module of database is connected with optimization and simulation module (on Fig. 4 marked as the internal database). In this part of the program, we can distinguish the following sub-modules of the database:

- database for the simulator for the localization of warehouse facilities and supply chain designing, which allows you to determine the optimal location for designed object and designing of the supply chain - searching for appropriate relations between links of supply chain localized in a specific space,

database for the simulator for shaping and dimensioning of warehouse facilities, which allows you to spatial formation of various zones in the facility and their dimensioning,

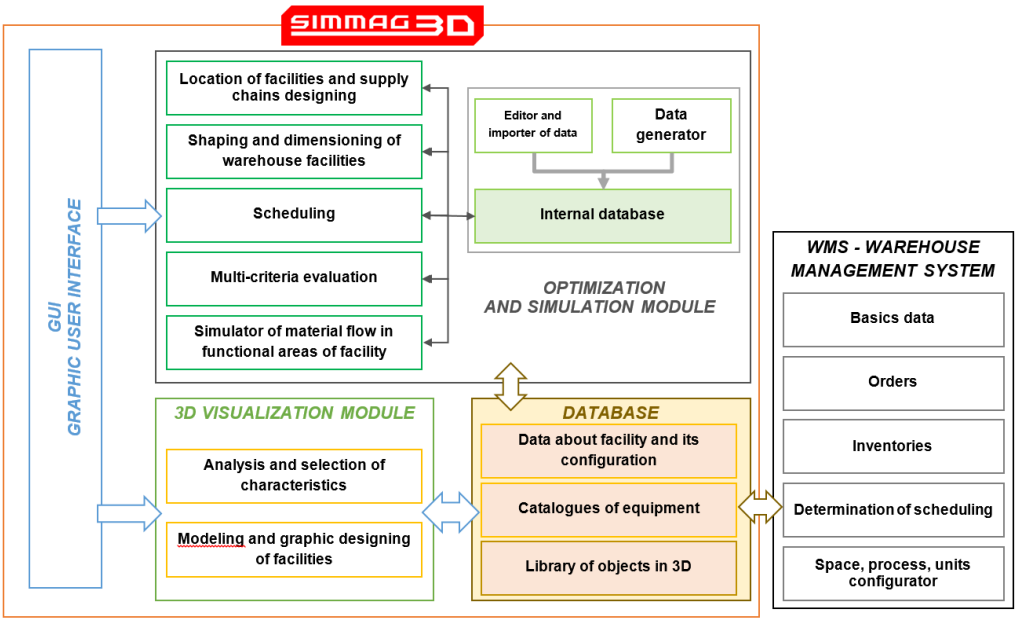

Fig. 4. The modular structure of the SIMMAG3D system

- database for the simulator for scheduling of the internal transport processes, which allows you to distribute of tasks in time and determination of their starting moments,
- database for the simulator for multicriteria assessment of variants, which using analytical methods allows you to choose the most beneficial variant based on multiple criteria,
- database for material flow simulator in the functional areas of the object, which allows you to make the distribution of freight flow in a given functional zone and analysis.

To the internal database is included the data editor (in order to edit of the data), the data importer (in order to import the data into it) and a data generator (in order to generate appropriate data in case of absence of them).

The second module of the SIMMAG3D system for visualization in 3D offers the user ability to:

- conducting analyses and selecting of characteristics - selecting of individual characteristic quantities, changing their values and carrying out analyses,
- modelling of objects and their graphical designing - the opportunity to build warehouse facilities from prefabricated unit elements using their graphical representation.

The module for visualization of warehouse facilities in 3D uses a database developed under the project SIMMAG 3D - in terms of data about the object and its configuration, in terms of equipment catalogues and library of objects in 3D. The database furthermore is supplied with the data from WMS (Warehouse Management System) in the field of basic data, data about orders and inventories, determining the schedule, configuration of space, process and stock keeping units. Data from WMS allow you to visualize the warehouse processes taking place in the facility.

One of the most important elements of the SIMMAG3D database are catalogues of equipment and means of transport including their technical, operational, and cost parameters. From the point of view of storage facilities design practice as well as the range of functionality offered by the SIMMAG3D system, catalogues of equipment and means of transport stored in the system database relate to handling equipment at the entrance to the warehouse, mechanical and non-mechanical storage equipment, as well as external and internal transport vehicles. Selection of an appropriate equipment and

means of transport for the given storage facility service, requires knowledge of not only their technical, operational and economic parameters, but also the warehouse working area and the type of cargo handled (Fig. 5).

Database development in this field firstly requires the preparation of its structure, which will allow a fast access to the stored data. The database structure is developed based on the classification of equipment and means of transport involved in the storage facility service. This classification is shown in Fig. 6.

Based on the above classification of equipment and means of transport serving the storage facility it is possible to present the structure of the data stored in the catalogue and the way of its implementation in the SIMMAG3D database.

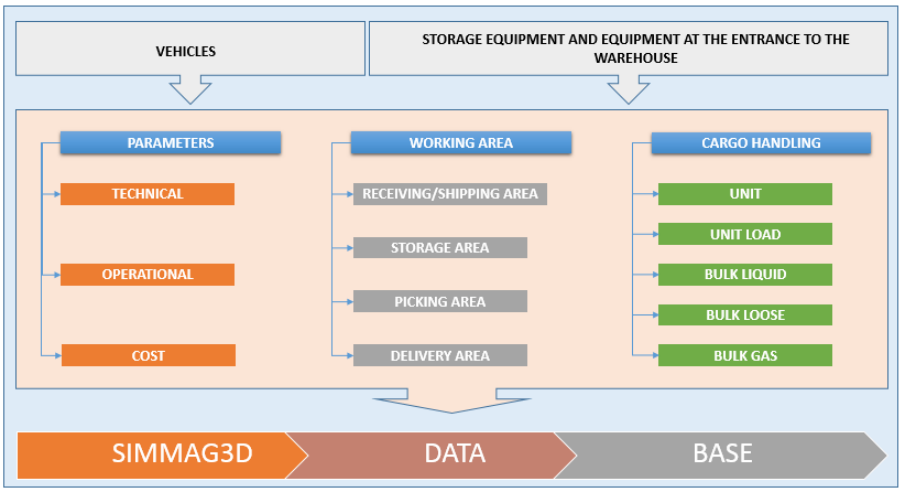

Fig. 5. The characteristics of the equipment and means of transport important for the storage facility design using SIMMAG3D database

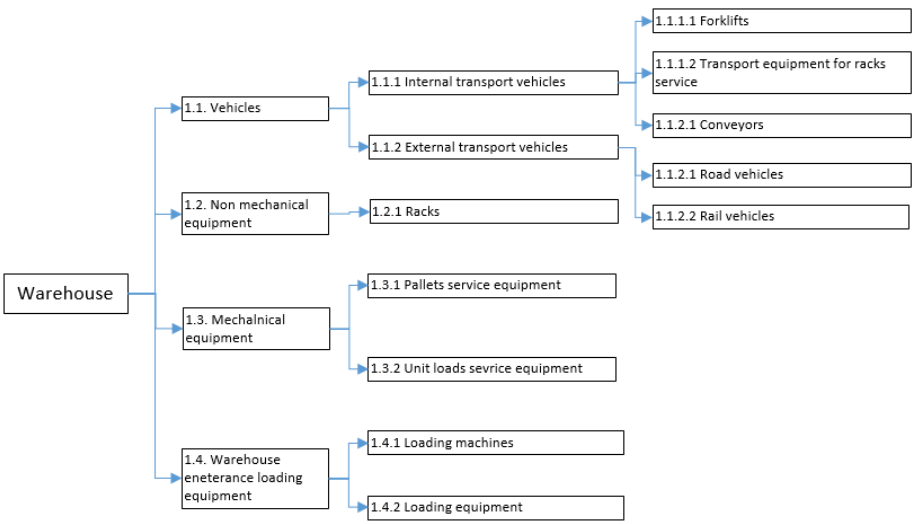

Fig. 6. Classification of equipment and means of transport for the SIMMAG3D system

The numbering shown in Fig. 6 allows quick identification of individual records in the database. An example of a catalogue structure developed for the forklift trucks which are essential for storage facilities, conditioning their technology and internal transport are shown in Fig. 7. As a concrete element of the SIMMAG3D database authors presented the battery pallet floating truck (Fig. 7).

The above catalogue structure is readable for the potential SIMMAG3D user and allows fast data access.

To develop the database of the SIMMAG3D system are used different data types - both integer (such as number of pallet places in the facility), binary (such as handling of the facility with the use of railway transport) and text (such as name of the company who manage warehouse facility). To the user's application is entered tabular structure of data. As a query language used is SQL structured language. Due to the applied client-server architecture, data are stored on the server, which must have a large capacity due to the need to use large amounts of data. Transactions in database are executed using concurrent execution algorithm. A significant transaction that is executed in the SIMMAG3D system database is its reconstruction after the crash, which is realized through the implementation of an appropriate algorithm. Access to the database is managed by the database management system (DBMS) - Microsoft SQL Server - the edition dedicated to work at a distance that is Microsoft Azure. Data transmission is performed using the Internet and database operations will be carried out in the cloud computing.

5. Conclusions

Database design is a complex decision-making process. It requires a systematic approach, because the databases are an essential element in the design of complex systems, where large amount of information is processed.

The information system designers pay much attention to the necessity of storing the full history of data status changes in the designed system. It becomes necessary, therefore, to develop uniform rules for designing a database, which should be used by the project team at all stages of design. This approach will allow full control over the implementation of databases at all stages of their design. In addition, this will allow the subsequent management of databases and their maintenance.

The research presented in this article refer to databases used in the system for design and visualization of storage facilities - SIMMAG3D. The database of the SIMMAG3D system was prepared based on the principles of database design, taking into account its individual modules and their architecture.

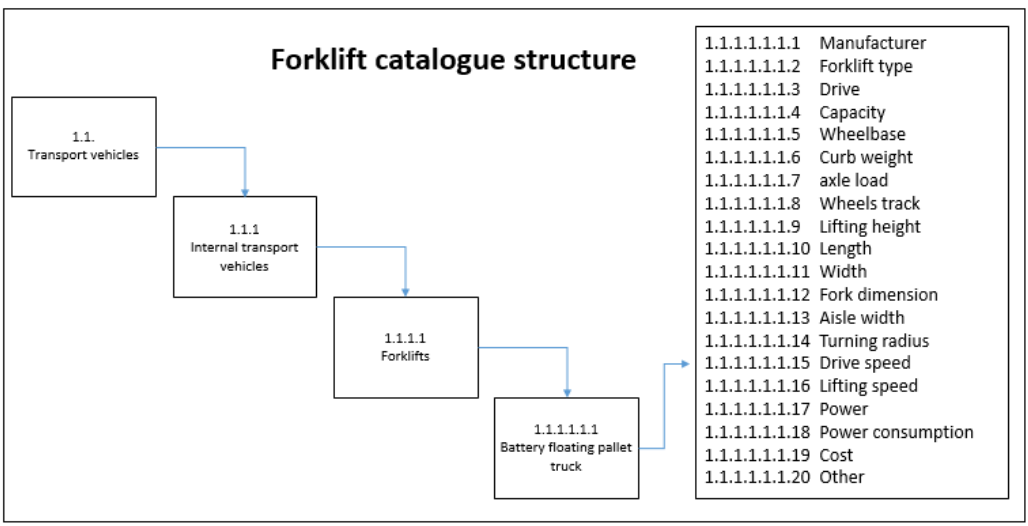

Fig. 7. Catalogue structure of the battery pallet floating truck

More over authors presented in detail one of the elements of the SIMMAG3D database module which are the catalogues of equipment and means of transport. That section presented the architecture of the catalogues in general as well as a specific database structure of a pallet lifting truck. The modular design of the SIMMAG3D database system provides quick access to data, which significantly accelerates the storage facilities design procedure.

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