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THE APPLICATION OF GISs TO SUPPORT BELT CONVEYOR MAINTENANCE MANAGEMENT

This paper deals with the application of GISs to support belt conveyor maintenance management. Considering the dispersed, wide-area character of the machinery working in the mine, the peculiar nature of the problem was indicated. The presented survey of the literature on computer-aided mine engineering showed a need for a system dedicated to belt conveyor maintenance management problems. Principal assumptions concerning the system were formulated, an IT platform was selected and data sources were defined. The choice of the GIS environment and the database standard based on MSAccess was dictated by the widespread use of the environments in the mines. It is anticipated that the target system will be a "federation" of subsystems. The universality and open character of the GIS platform opens up prospects for fast data integration.

1. INTRODUCTION

The strategic tasks of the Polish primary sector, carried out by the managements of the individual raw materials producers [24, 26], call for the implementation of new solutions and technology transfer in order to increase the effectiveness and safety of the machinery and to reduce its operating costs. It is vital here to develop procedures for acquiring, processing, analyzing and managing operating data. It is obvious that in order to minimize costs or seek savings one must first identify and analyze the causes of the costs and ways of reducing them. Despite the intensive activities of the different

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research centres, the commercial systems offered and the measures taken by mining companies, the current situation in this regard, particularly in belt conveyor management, is not satisfactory, as shown in section 4. A comprehensive solution of this problem requires a broad-based approach and the joint consideration of energy consumption, safety, reliability, productivity and other aspects. In order to improve the existing situation the authors undertook to develop an integrated belt conveyor maintenance management system concept. The system should have a modular-layered structure based on simple database technologies and GIS. This system structure and its open character should make it possible to utilize the company's existing resources, such as digital maps and simple databases, and progressively implement new components. Consequently, the system building and implementation time can be reduced whereby the system should be more readily acceptable by its users.

2. BELT CONVEYOR TRANSPORT SYSTEMS IN MINES

The main function of mine transport systems is to transport the mined material (overburden or useful mineral) for long distances (from an excavator to a dumping conveyor or from an excavator to stacking yards or other transport systems or directly to a power plant).

The transport system may be characterized by a different degree of complexity, depending on the technical-organizational solutions adopted in a given mine. Figure 1 shows a diagram of the belt conveyor transport system in PGE KWB Bełchatów. The total length of the transport system in this lignite mine exceeds 100 km. The example, shown in fig. 2, is less complex. But one should note that the latter is only a part of the mine transport system since the Konin mine consists of several open casts located tens of kilometres apart. This means that as regards merely repairs organization, the management of the machinery is a complex problem.

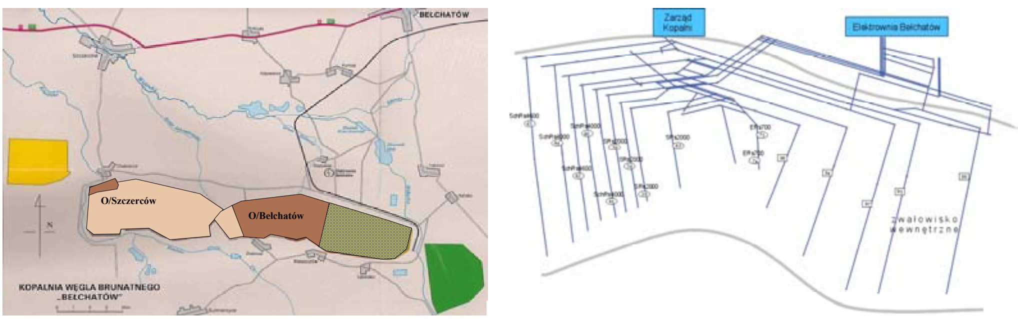

Fig. 1. PGE KWB Bełchatów and diagram of belt conveyor transport system [22]

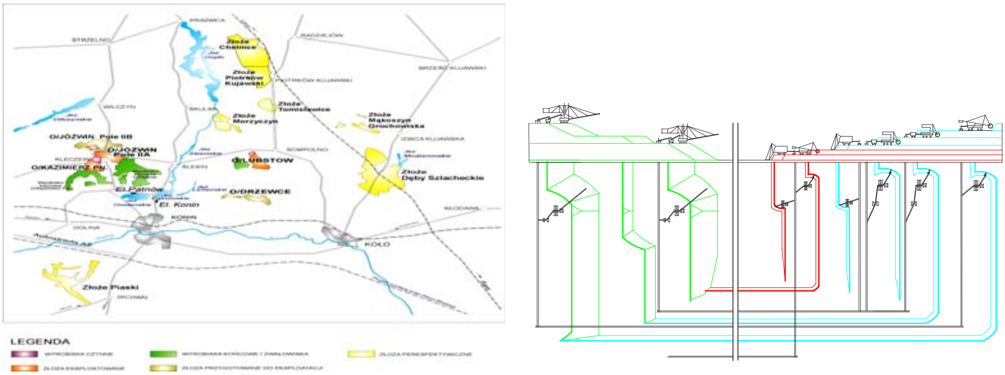

Fig. 2. Konin mine and diagram of belt conveyor transport for one of its opencasts [21]

3. STRUCTURE OF BELT CONVEYOR

The belt conveyor consists of a drive unit (a motor, a clutch and a transmission gear), a system of (head, tightening and tail) pulleys, a belt loop, idlers and several auxiliary devices, such as control and support (e.g. cleaning) equipment, monitoring and diagnostic elements, etc. Figure 3 shows two schematics of the belt conveyor structure. The failure frequency analysis carried out for the particular system components in [6] indicates that the key belt conveyor components are: the belt, the idlers, the pulleys and the drive units. Thus data on the operation of the above components are essential for belt conveyor maintenance management.

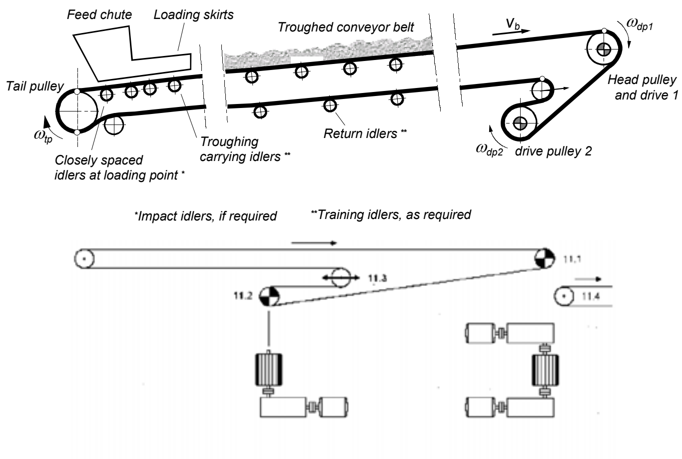

Fig. 3. Structure of belt conveyor [1]

4. LITERATURE SURVEY

4.1. IT SYSTEMS AIDING MINE OPERATION MANAGEMENT

In recent years attempts have been made by mining companies to apply IT tools to mine management. For this purpose computer programs aiding in the planning of surveying, geological, technological, geotechnical and mining work have been implemented in the opencast mines. Unfortunately, only to a small extent they cover machine systems [3, 31]. Some of the systems include data on selected mining machines and equipment but they lack a module which would aid in the management of the whole machinery in a given mining company. It is from this point of view that this paper discusses the IT tools used in the Polish mining companies.

In 2003 the MiniScape software made by Minicom (Australia), which aids in surveying-geological-mining work planning was implemented in PGE KWB Bełchatów. The software stores also graphic and descriptive data on conveyors. In addition, the mine commissioned development of procedures which would aid in planning the shift of a belt conveyor working in tandem with a wheel excavator and in creating shortwall geometry with regard to the planned conveyor position. Models of: the terrain and the conveyors and a slice model and a block model of the deposit, created using this software and flat graphics from the foreman map run in the Microstation environment, with marked locations of hazard areas and holes with equipment left in them, are the basis for developing plans of work for the excavators (cartographic documentation) in the Bełchatów mine [6].

In 1991 automatic production process control systems began to be implemented in PGE KWB Turów S.A. Each mining area controller station is equipped with X-terminal emulators and computers running the ClientBuilder application controlling the operation of the belt conveyors. The emulators graphically display the state of the mining machinery and conveyor process and enable the controllers to analyze and process the data. The application software runs under the MS Windows operating system and it is based on FactoryLink packages. The software includes an alarm subsystem (with graphic and text visualization) signalling disturbances in the operation of the belt conveyors and relaying commands to the particular controllers performing the remote control function. The supervision and control of the technological process is facilitated by a telediagnosis system in the automatics division where the main system component is a diagnostic computer station serving all the excavators and dumping conveyors via a GMS mobile telephony network using industrial GMS modems of Siemens M20T type. The Simatic WinCC visualization utility running on Windows is installed on the station. The production process is monitored in a multilevel system, starting with the operators of: the excavators, dumping conveyors and belt conveyor flights and ending with the main control room. Strategic decisions on running the technological process in the future are taken by the company management on the basis of comprehensive geological data, economic indicators, mechanical-design specifications of the machines, organizational determinants and other information. The primary technological process control function is carried out by the controllers who manage the assigned parts of the technological system on the basis of data coming from the systems monitoring the operation of the machines and the belt conveyors [20].

In the early 1990s in the Konin lignite mine work began on the development of a computer system which would aid the design work in the main production maintenance departments, i.e. the mining technology department, the surveying department, the geological department and the design department. The main work environment in KWB Konin is Bentley's MicroStation software with extra modules dedicated to the specific tasks performed in the above departments. Graphic data are combined with descriptive data stored in the Oracle relational database. The software is used mainly to: keep mine land and building records, make digital models of the current state of the opencasts, produce drilling reports, create target models for each overburden, coal and dump level and make coal quality forecasts [16]. The software lacks a module for managing the machinery working on the premises of the mine.

A system called SZYK–MASZYNY is used in all the mines belonging to Katowicki Holding Węglowy (Katowice Coal Holding Company) and Jastrzębska Spółka Węglowa (Jastrzębie Coal Company) for managing the mining machinery and equipment and their components and spare parts. The system includes a central library of machines based on the ORACLE database. The latter contains technical specifications, technical drawings, documentation, photographs and various user-defined parameters relating to the particular machines [23]. The system works with a RFID (Radio Frequency Identification) reader which uses low-power radio signal to transmit data between a tag and the reader. As part of the system a central database, whose structure is developed by lining manufacturers and users and repair companies, is being built. Thanks to this system the problem of objective and reliable identification of the machine and equipment components and recording of their working life and operating conditions under the mines' materials management has been solved and the data can be processed to assess the degree of wear-out of the particular machine components. The system consists of a database MS SQL Server 200 and a client application [4, 17, 25].

Mining machinery management system EKSPERTSMG operates in KGHM Polska Miedź S.A. (Copper Mining and Metallurgical Conglomerate Polish Copper PLC). The system supplies data on the current costs and assessments of the efficiency and effectiveness with which the self-propelled mining machines and their individual subassemblies are managed. Currently the system works as part of the data warehouse technology enabling the optimization of information generation and distribution within the three mines (in which over 1280 different mining machines work) and in the management office of KGHM Polska Miedź S.A. [4, 17, 18].

Only the latter two systems, i.e. SZYK–MASZYNY and EKSPERTSMG, fully deal with machinery management problems. This means that in the opencast mines such problems require more attention. However, some partial solutions concerning conveyor belts and conveyors already can be found there.

4.2. BELT CONVEYOR MANAGEMENT SYSTEMS

Research on IT systems aiding in transport system maintenance management was initiated in Poland in 1983 in the Institute of Mining at Wrocław University of Technology (WUT). As part of this research a program for belt reliability recording and analysis, called TRWAŁOSC, for the RIAD 1032 computer was developed [14] and work on a microcomputer system which would aid in the management of conveyor belts was started. The Sufler system [13] developed for the Turów mine together with the TAŚMA (BELT) program (written for their mine and the Turów mine by the KWB Bełchatów team of IT specialists) were the first systems of this kind in Poland and one the first in the world. Adopting the systemic approach to the problem, the Institute of Mining at WUT in collaboration with the Rudna mine developed a more complex system for managing the maintenance of the whole transport system. The latter's objects, states and maintenance events were identified and classified. As a result, an integrated System of Conveyor Belts Maintenance Management, called SZEPT, was created [2]. Unfortunately, for various reasons it has not been implemented.

Currently, the fully operating and continually updated (since the mid-80s) IT system is the TASMA (BELT) program from KWB Bełchatów. In 2002 two new modules written in Visual Basic, for the presentation of belt loops on selected conveyors (including the visual presentation of their run time and the planning of replacements on the basis of dynamic data breakdowns according to selected criteria), were added to the program [15]. Unfortunately, work on the system has not been systematically conducted.

The Sufler system, developed in the mid-80s for the Turów mine, after several years of running on the Schneider computer with the CP/M operating system was not transferred onto IBM computers with DOS and in the mid-90s its operation was discontinued. Today, after a period of recording some maintenance events (e.g. belt damage, repairs and splices) in Excel to a much smaller extent than it had been done in the Sufler system, a system under the name Komputerowa Karta Taśmy (COMPUTER BELT CARD) is being implemented in KWB Turów. The mine has ambitious plans to make it a comprehensive tool for not only the recording of maintenance events and the condition of the belts, but also for aiding and optimizing the taking of belt replacement and management decisions. The development of the system is based on the research published by the staff of the Institute of Mining at WUT [10, 11, 12].

In the Konin mine the Taśma system developed for KWB Bełchatów was used initially. But because of the lack of foresight with regard to the year 2000 problem on the part of the system designers and users, the use of the system after that date was severely limited. Hence the needs of the Belt Department in the mine were to be covered by inventory management computerization. However, one cannot expect that a typical inventorying program can fully meet the unique and complex needs of belt conveyor transport.

A system developed by the Poltegor Institute in collaboration with the Softproject company operates in the Adamów lignite mine. The system provides easy and quick access to information and allows one to process it and produce statements, tables and reports. A special program application graphically visualizes the system of conveyors and the construction of their bypasses.

Currently, a few interesting concepts have appeared. Paper [28] describes the development of an IT system whose task is to collect and process belt conveyor maintenance data to be used in maintenance process analysis, conveyor reliability assessment and event consequences prediction, making it easier to take prompt measures preventing failures and damage. The paper presents the ConveyorML Editor computer application developed as part of diploma dissertation in the Department of Mining, Processing and Transport Machines at the Mining-Metallurgical Academy in Cracow. The application allows one to map in detail the structure of a conveyor, the mutual position of its components, the layout of its route, the route inclination angles and the operating and loading conditions whereby data for calculations (in, for example, QNT and QNKTT) can be prepared. The system will also collect maintenance data on the operation of belt conveyors. The authors' proposal to make this program available online for free to all interested users is rather controversial since most of the companies would be reluctant to use tools generally available on the Internet as this might reveal their vital data on the functioning of their transport system to the competition and the suppliers. Nevertheless, it would be possible to use the program as an Internet application.

An interesting idea of using the GIS technology in conveyor maintenance management was put forward in [7]. Unfortunately this solution never went beyond the stage of a simple GIS application combining conveyor flights on a map with a basic database of the belts running on them. One should note that most of the solutions discussed above applied to the management of conveyor belts, and not to conveyors and their flights forming a transport system.

Comprehensive R&D work is now conducted only in PGE KWB Turów. But even here the effort is focused more on the creation and maintenance of belt databases than on developing procedures for the use of the knowledge stored in them to support management. Implementations of novel solutions based on new technologies, such as the Internet and GIS, are rare. But some promising signs in this field have appeared. Also it would be worth to make use of the conceptual achievements and experience of the authors of the earlier applications such as Sufler and SZEPT. Even though the applications are no longer functional and the technologies on which they are based are already obsolete, the experience gained when creating and implementing those systems should still be useful. The more so that they were aimed at decision taking support and management, and not merely at simple recording of maintenance events in a database and handling the latter.

5. GIS SYSTEMS

The continuous increase in the amount of data, the importance of information possession and the great popularity of computer databases stimulate interest in techniques of automatic, intelligent and fast data processing aimed at acquiring knowledge about objects described by data contained in a database. Geographic information systems (GIS), designed for acquiring, verifying, storing, integrating, 3-D analysis and visualizing data spatially related to the Earth's surface, in which each element is described by coordinates X, Y or optionally Z, occupy a special place in the class of database systems. The structure of GISs geared towards spatial analyses is shown in fig. 4. Such analyses are made through system-predefined reports, statements and charts with 3-D visualization, or using the structured query language (SQL) to query integrated graphic and descriptive databases. The graphic database is made up of numerical thematic maps, orthophotomaps and numerical terrain models. The particular graphic database objects are linked to the descriptive database whose contents depend on the kind and range of information stored in the database. Currently such systems are used in areas where the considered problems are particularly complex and in order to solve them large data sets coming from different sources need to be acquired and processed [5, 19, 27, 29].

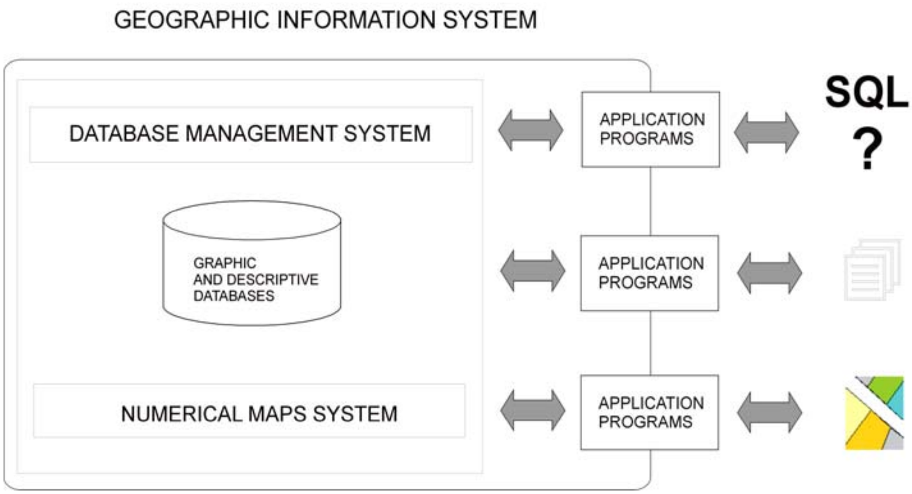

Fig. 4. Structure of GIS

6. CONCEPT OF GIS AIDING IN BELT CONVEYOR MAINTENANCE MANAGEMENT

6.1. STAGES IN BUILDING GIS

A general five-stage scheme of building GISs was developed on the basis of the literature survey presented in [8]. In the first stage, a general system basis is developed. In the second stage, methods of acquiring source data for building the system are devised. In the third stage, a general system building design is created. In the fourth stage the system is designed in detail. In the fifth stage the designed GIS is actually built. A scheme of GIS building, divided into the particular stages, is shown in fig. 5.

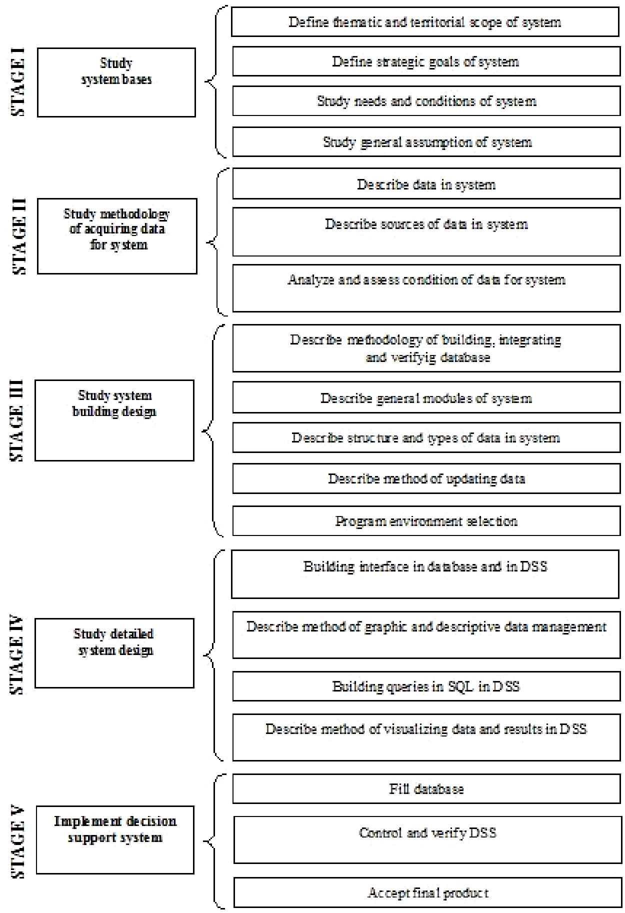

Fig. 5. General scheme of building decision support systems

6.2. GIS IN CONVEYOR MAINTENANCE MANAGEMENT – PLAN OF ACTION

As already mentioned, attempts at implementing various systems of computer support of broadly understood engineering work have been made by the mines. The concept put forward by the present authors is based on the use of some data from the already existing systems. Thematic maps, such as technological system diagrams, are continually updated (mostly in the Microstation environment) by the mine's geodetic-surveying services. All the machines are inventoried (usually in Excel tables or in MSAcces) in simple databases.

The main goal at this stage is to acquire and unify data, which represents the second stage in building GISs. For this purpose it is necessary to develop a general concept of a GIS supporting conveyor maintenance management. This means that the structure of the system of managing belt conveyors, the structure of the particular relational database tables describing the belt conveyors parameters and the structure of the graphic database covering the belt conveyors and other elements connected with their functioning need to be developed. In order to automate data transfer to the proposed system it is necessary to develop procedures and tools enabling the import, compatibility checking and, if need be, unification of the data contained in the graphic and descriptive databases so as to avoid data inconsistency and redundancy. The data acquired in this way are clearly insufficient and the existing databases need to be extended or restructured. The key question at this stage concerns the kind, format and source of acquired data. Figure 6 shows a breakdown, according to subjects and sources, of information needed to build a belt conveyor maintenance management system.

Since the following factors:
- the adopted design solutions,
- the machines manufacturing technologies and the mining technologies,
- the mine environment,
- the human factors,
- degradation processes resulting in changes in the operating parameters of the machines in comparison with the design assumptions,
- the process parameters

have a significant effect on the operation of mine machinery, they must be taken into account in the belt conveyor maintenance management system.

It seems that the graphic and descriptive database should have a structure in which tables would apply to the key belt conveyor components (i.e. the motor, the transmission gear, the pulleys, the belt, the rollers and other components) and relationally linked to other tables according to the concept shown in fig. 6. Another key task is to develop results analysis, reporting and visualization modules for the analysis system, which corresponds to the fourth stage of building GISs (fig. 5).

The analyses discussed in the previous sections were mainly based on statistical methods. Having a properly designed database one could try to introduce more advanced data/information processing techniques employing artificial intelligence (e.g. artificial neural networks or systems based on fuzzy logic).

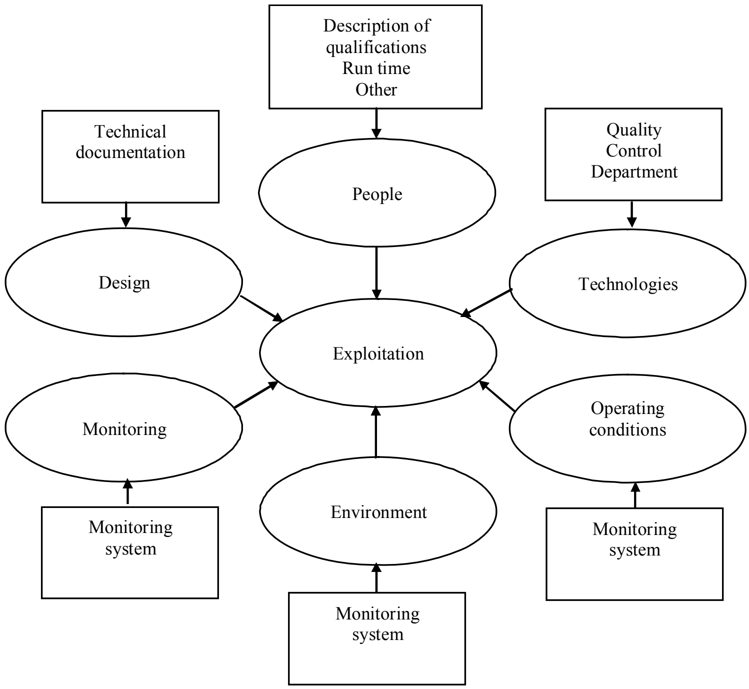

Fig. 6. Data flow diagram, taking into account data types and sources

Considering the project complexity, the analysis problem can be solved also by using methods of knowledge discovery in databases (i.e. data mining). The present authors proposed to apply data mining methods already in paper [9].

Approaches to data analysis usually cover only descriptive data, e.g. databases containing numbers and/or linguistic variables. The system proposed here is based on the GIS platform, which means that spatial data mining and/or spatial and descriptive data mining could be employed.

Even though the above data analysis methods make it possible to discover knowledge hidden in data, one still needs a module which would aid the system user in taking decisions on the basis of answers to the queries put by him/her to the system.

Let us remind ourselves that the belt conveyor maintenance management system is a decision system aided by an information system, usually in the form of a computer decision support system (DSS) [2].

Besides inventorying objects, documentation and technical data, keeping records of and analyzing work effectiveness/time (output, run time, standstills), recording and analyzing replacements, malfunctions, failures and periodic and preventive maintenance, analyzing and planning (major) materials and spare parts management, keeping records of personal data (including monitoring the qualifications and professional licences of the machine operators), the primary belt conveyor maintenance management tasks (acc. to [2]) include: preparing scenarios, strategies or individual decisions concerning maintenance. The mine's structure and organization determines the untypical, mixed structure of the belt conveyor management system, which includes features typical for centralized systems (for example, the machinery is supervised by the mine's chief mechanic, the chief power-machine engineer and finally the chief engineer), but because of the decentralization of direct supervision over maintenance and so the necessity of reporting (covering the mechanical service, the mining service, the electrical service and the vulcanization service), access to the system must be dispersed, which means that the system structure must be task-dispersed. The management structure in the case of a mine comprising several opencasts (e.g. the Konin mine) is even more organizationally complex since some aspects apply to only a particular opencast (e.g. the mechanical engineer of opencast X) while some other aspects occur only at the central level (e.g. repair shops).

7. CONCLUSION

The use of GISs to aid in belt conveyor maintenance management was discussed. The need to improve the effectiveness of belt conveyor maintenance, expressed by the research centres and the industry, was demonstrated. The effectiveness can be improved by implementing machinery management procedures. The presented literature survey showed increased activity in computer-aided engineering in the mining industry, but concerning mainly production process management, not machine machinery management. In particular, the lack of tools for belt conveyor management was pointed out. Attention was drawn to the peculiar nature of the mining sector, which makes it difficult to directly apply the solutions existing in other sectors. The GIS platform was proposed as the environment for building belt conveyor maintenance management tools. A concept of building such a system was formulated and the latter's principal assumptions and data sources were defined.

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ZASTOSOWANIE SYSTEMÓW GIS DO WSPOMAGANIA ZARZĄDZANIA EKSPLOATACJĄ PRZENOŚNIKA TAŚMOWEGO

W pracy przedstawiono rozważania dotyczące zastosowanie systemów GIS do wspomagania zarządzania eksploatacją przenośnika taśmowego. Wykazano specyfikę problemu uwzględniając rozproszony, rozległy charakter systemu maszynowego pracującego w warunkach kopalni. Zaprezentowano przegląd literaturowy z zakresu komputerowego wspomagania prac inżynierskich w kopalni zakończony konkluzją o konieczności systemu dedykowanego zagadnieniom zarządzania eksploatacją przenośnika taśmowego. Sformułowano założenie główne dotyczące systemu, wybrano platformę informatyczną, określono źródła danych. Wybranie środowiska GIS i standardu baz danych opartych na MSAcces związane jest z powszechnym występowaniem tych środowisk w kopalniach. Dodatkowo należy spodziewać się, że docelowo proponowany system będzie „federacją” podsystemów; uniwersalność, otwartość platformy GIS daje szanse na szybką integrację danych.