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5th International Symposium

MINING AND ENVIRONMENTAL PROTECTION

10 - 13. June 2015., Vrdnik, Serbia

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Summary: *In this paper we give an outline of the approach taken by the University of Belgrade Faculty of Mining and Geology research team in the development of a business intelligence tool for accident analysis in mines. Mining engineering, as all other engineering disciplines, generates large amounts of heterogeneous data and needs interoperability among various related information technology applications and data sets, supported by analytical services implemented in a business intelligence tool. This paper describes such a system for mine safety and its application for accident analysis in mines developed to improve efficiency, offer fast answers and key business metrics reports, discover week points etc. The interoperability between diverse software components is secured by a system of ontologies developed for mining engineering named RudOnto.*

Keywords: *business intelligence, mine safety, accident analysis, online analytical processing (OLAP), mine accident (injury)*

1. INTRODUCTION

Mine safety is one of the key issues in mining industry, and it is safe to say that research in industrial safety in general originates from mine safety (Danihelka, 2012). Mining is one of those high-risk industries where errors carry such potentially disastrous consequences (a mine explosion, for instance) that new workers cannot learn through experience what happens when something goes wrong under certain conditions. Rather, they have to rely on protocols, post-hoc analyses of past incidents, and transfer of knowledge gained in other circumstances that can be applied in potentially critical situations. Mining organizations need to preserve and transfer knowledge in order to be able to respond to emergencies, and knowledge management (KM) provides a useful perspective from which to view the problem (Vaught et al., 2006). KM is a systematic approach to finding, selecting, organizing, processing and presenting information with the aim of improving an employee's comprehension within a specific domain, thus enabling an organization to gain insight and understanding from its own experience (Herschel & Jones, 2005). In mining industry KM can play a crucial role in transmission of knowledge between experienced and new workers in order to ensure the safe, competent integration of new workers as well as the retention of aging workers (Gagné, et al., 2011).

KM in a business organization manages both knowledge assets and processes related to these assets, where knowledge assets represent the knowledge this organization possesses or needs to acquire in order to improve its performance. Within knowledge processes, knowledge generation comprises of knowledge acquisition, where external knowledge is elicited from the environment to become internal organizational knowledge, and knowledge creation, where new knowledge assets are developed within the organization

itself. Knowledge mapping follows, identifying knowledge assets within the organization and defining access to them. Within knowledge sharing the knowledge is disseminated across the organization, both formally and informally, in most cases with the support of information and communication technology (ICT). As for knowledge transferring, it is the process of passing on knowledge among different units, groups or individuals within the organization. Knowledge codification aims to formalize knowledge into appropriate digital format, and knowledge storing saves it in knowledge databases. Finally, codified and stored knowledge is used within the organization in knowledge application.

Business intelligence (BI) is closely related to KM and the two of them are often confused within the entrepreneurial community. However, BI is more focused on decision making using data warehousing and online analytical processing (OLAP) techniques, where data warehousing pertains to collecting relevant data into a repository, where it is organized and validated for decision-making purposes. KM and BI, while having slightly different focuses, should be considered as integrated and mutually critical components in the management of intellectual capital (Herschel & Jones, 2005).

In this paper we outline our approach to development of a business intelligence system for mine safety illustrated with its application for accident analysis in mines. The aim of the BI system is not only to improve efficiency of mine safety procedures, enable faster answers and key safety metrics reports, but also to discover week points within these procedures. The system consist of several software components representing a combination of different information technologies, where interoperability between diverse software components is secured by system of ontologies developed for mining engineering named RudOnto.

2. USING ONTOLOGIES TO SECURE INTEROPERABILITY

Knowledge management in Serbian mining companies using ICT support for managing knowledge assets is still scarce in Serbian mining practice. However, various other applications of ICT in the field of mining have emerged in the past decade. In general, ICT is introduced in various mining engineering systems most often in the form of information systems, with the basic goal to secure reliable information for managers and decision makers. In addition to that, different ICT support systems and tools have been developed and implemented, such as diagnostic and prognostic decision support systems, computerized maintenance management systems (CMMS) and enterprise resource planning systems (ERP).

Similar to other engineering disciplines the application of ICT in mining engineering results in different software components, which makes their mutual interoperability a critical issue. One of the means to secure this interoperability within a specific domain is the use of ontologies, containing a comprehensive common domain vocabulary. This means that all terms used within a domain need to be standardized, with a clear and unambiguous definition, accompanied by lexical and semantic relations with other terms. The example of lexical relations is established between general and more specific terms, such as "coal mine", and "open pit", which is a specific type of coal mine, also with synonyms such as "opencast", "surface mine", and "quarry". One example of development of mining ontologies has been reported by Cheng et al (2011). Interesting results on ontology-based modeling and inference for occupational risk prevention were presented by (Galatescu & Alexandru, 2010).

One of the first terminological resources in the field of mining was developed at the University of Belgrade Faculty of Mining and Geology (FMG) within the Technological coal mine information system (Kolonja et al, 2006). Further growth and variety of terminological resources for specific domains developed at FMG resulted in the initiative for building a general reference resource for mining terminology in Serbian. The niche for this resource was found in SUKU, a mining engineering information system, also developed at FMG (Stanković et al, 2012).

Given the importance, and at the same time, lack of ontologies in mining industry, a methodological approach to development of a system of ontologies for Serbian mining industry has been undertaken (Stanković et al, 2012). This ontology system, Rudonto, is envisaged as a general resource, with the main goal to enable knowledge structuring and efficient knowledge management in the mining domain. RudOnto has specifically been used for ontology-based knowledge management for occupational risks

prevention. It enables automatic discovery of prevention documents and actions that provide personalized training for a specified context, e.g. a given activity, workplace, operator type, work machine, etc.

The approach to mine safety knowledge codification in RudOnto was mainly based on the Taxonomy for Indexing Web-Based Mining Safety and Health Research (Glowacki, 2008) developed at the U.S. National Institute for Occupational Safety and Health's (NIOSH), which is the leading world organization in this area. At the beginning of June 2014, the Office of Mine Safety and Health Research (OMSHR) within NIOSH has announced the implementation of a taxonomy-based navigation tool called "Site Browser" (http://wwwn.cdc.gov/niosh-mining) that allows researchers and other users to browse content tagged with subject terms from their taxonomy.

Besides improving their performance using ICT, companies within Serbian mining industry are also striving towards advancing collaboration with their business partners' networks both within the country and abroad. Thus ICT support is needed not only within intra-business processes, but also within inter-enterprise business processes, in order to secure better performance and interoperability in business networks (Albani & Dietz, 2006). The concepts of enterprise ontology and reusable knowledge assets are essential for knowledge management and business intelligence within mining industry enterprises and enterprise networks.

In addition to providing intra-business interoperability RudOnto also secures this inter-enterprise interoperability by offering a unique knowledge codification scheme, which enables software agents and human actors of different mining companies and related organizations to share knowledge assets and organizational data as a common resource.

3. ONLINE ANALYTICAL PROCESSING IN MINE SAFETY

Safety management relies on job standards, rules, regulations, performance evaluations, and policies, which are used within the chain of command to secure that employees fulfill their assigned responsibilities satisfactorily (Grimaldi & Simonds, 1989). The fundamental objective of safety management is to eradicate human anguish and suffering and to achieve economy of operation in an effective manner (Dhillon, 2003).

The BI system for support of decision making in safety management uses a combination of various information technologies, such as OLTP (On Line Transactional Processing), OLAP (On Line Analytical Processing), WEB, SQL Server Reporting Services, etc. Hence, it is a system for direct analytical data processing implemented through Microsoft® SQL Server™ 2008 Analysis Services, which supports multidimensional views on business data, using the technology of multidimensional or relational databases. Managers and analysts who often require higher levels of aggregated views on business data use this technology.

Online analytical processing is a capability of management, decision support and executive information systems that enables managers and analysts to interactively examine and manipulate large amounts of detailed and consolidated data from many perspectives. OLAP involves analyzing complex relationships among thousands or even millions of data items stored in multidimensional databases to discover patterns, trends, and exception conditions. An OLAP session takes place online in real time, with rapid responses to manager's or analyst's queries, so that their analytical or decision-making process is undisturbed. Online analytical processing involves several basic analytical operations, including consolidation, "drill-down" and "slicing and dicing" (Kolonja et al, 2006).

In mine safety it is necessary to follow several attributes related to injuries, perform their multi-dimensional analysis, as well as display data in different forms. Data are presented in the form of OLAP cubes that contains measures and dimensions. Compared with the standard representations of business data, dimensions are business parameters represented as row and column headings of reports. A dimension can be seen as intuitive way of organizing and selecting data for retrieval, exploration and analysis. The number of injuries, which represents a measure, is the central value of the cube that we analyze. Dimensions that are structural attributes of the cube grouping data of similar category are: type

of injury, body part, weight of injury, workers age and qualifications, time dimension, organizational structure of mine, shifts and working day in which the violation occurred, the source and cause of the injuries, etc.

Figure 1 depicts two OLAP cubes. Each cell of the cubes holds a number of injuries. In the first cube injuries are categorized according to the type of injury and the quarter in which it happened for each year. For the second cube, the measures taken into consideration are the type of injury, the day in the week on which it happened and the age of the injured worker. Based on the first cube we can conclude that the number of injuries in the year 2011 was way over the average, and that the greatest number of injuries happened in the second quarter. From the second cube we can see that the majority of injured workers were of the age between 36 and 45 years, as well as that the number of light injuries was much greater than the number of severe ones.

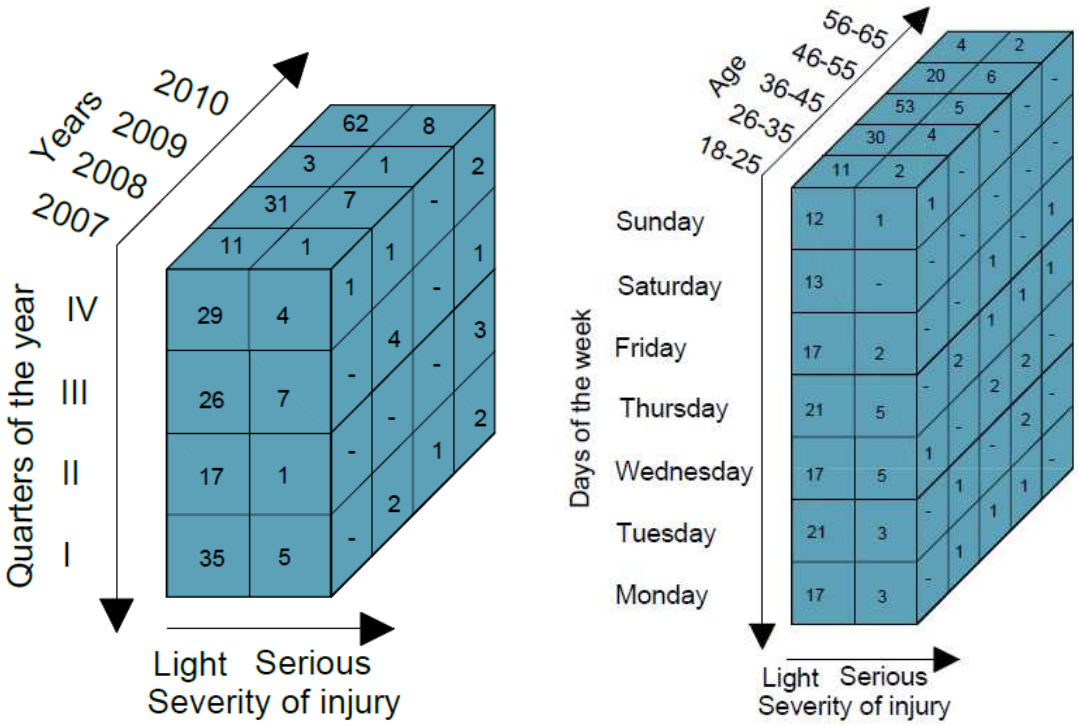


***Figure 1** OLAP cubes*

Figure 2 presents a part of the BI development environment. The left side presents measures and dimensions of the cube. "Data Source View" is used for creating links between measures and dimensions, whereas the right hand side features the project tree. The central table with numerical data is *olap_povreda,* whereas table dimensions are organizational structure (*organizaciona struktura - OJ*) and the RudOnto data dictionary (*s_koncept*) which can be related to the main table on basis of different fields, depending on the dimension we want to follow. The BI model for mine safety integrates standard OLAP techniques based on RudOnto, where dimensions of OLAP cubes are concepts of the RudOnto ontology, and the hierarchy of concepts is mapped to build flexible OLAP models with multi-level hierarchies.

Software contains tools for calculations, KPIs, actions, partitions, aggregations, etc. The browser option serves for a data survey and within this slot different dimensions that will be used for calculating the number of injuries can be defined in a quick and simple manner

The BI model can offer important information for safety management but also allows different ways of presenting data. Figure 3 depicts three ways of presenting data on the number of injuries categorized by body parts. Due to the hierarchical structure of the RudOnto dictionary the analysis can be performed on several levels of detail.

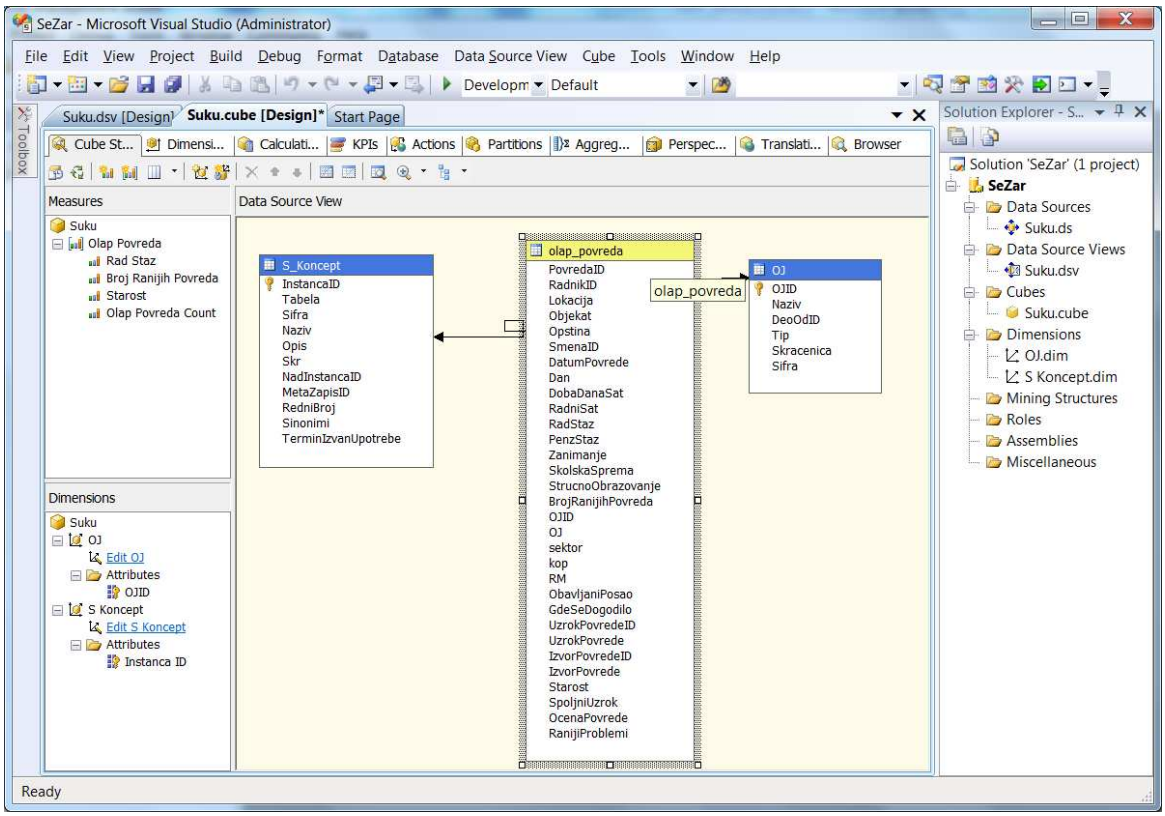
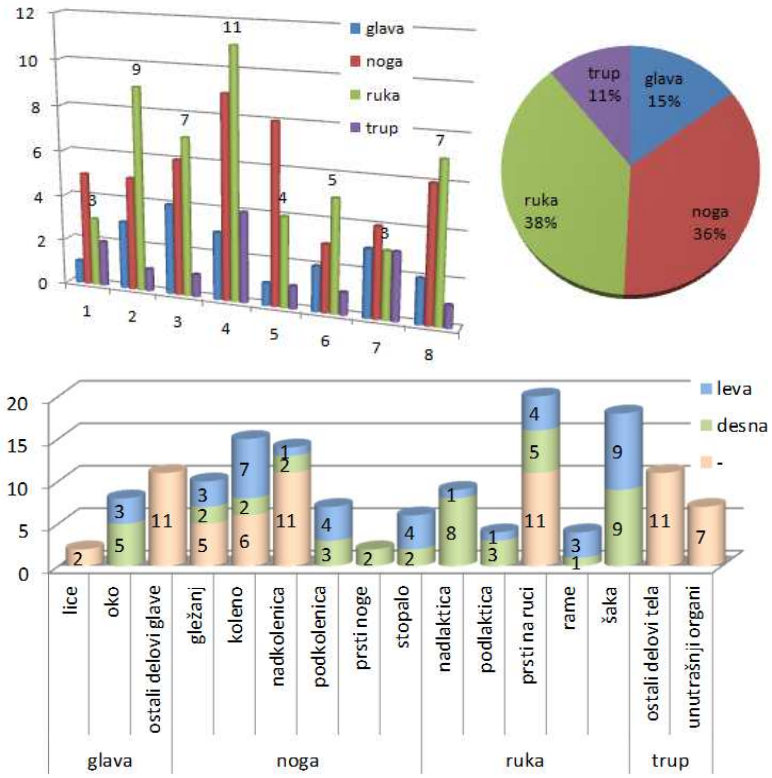


***Figure 2** The BI development environment*

Thus we can observe injuries on the arm, head, leg, or hull, or browse for a knee, feet or forearm injury within the leg category (Figure 3 right, Figure 3 down left). A time dimension can be also be added, and all this information can be viewed by months, trimesters, years, or within a limited time period. This information enables preventive action with the aim of raising the level of protection equipment for body parts that are most frequently injured.



Row Labels	-	desna	leva	Total
glava	**13**	**5**	**3**	**21**
lice	2			2
oko		5	3	8
ostali delovi glave	11			11
noga	**22**	**13**	**19**	**54**
gležanj	5	2	3	10
koleno	6	2	7	15
nadkolenica	11	2	1	14
podkolenica		3	4	7
prsti noge		2		2
stopalo		2	4	6
ruka	**11**	**26**	**18**	**55**
nadlaktica		8	1	9
podlaktica		3	1	4
prsti na ruci	11	5	4	20
rame		1	3	4
šaka		9	9	18
trup	**18**			**18**
ostali delovi tela	11			11
unutrašnji organi	7			7
Total	**64**	**44**	**40**	**148**

***Figure 3** Various OLAP presentations*

4. CONCLUSION

Both managers and employees in mine safety need to analyze the changing sets of information to improve and support their working tasks. Traditionally, available data is limited to queries or reports which have been predefined for them by IT experts. Business intelligence offers some novel approaches to presentation and analysis of business information. The field is expected to benefit from application of semantic technology, especially ontologies.

The tool developed for accident analysis in mines offers to the users an insight into large quantities of complex data. This insight can further be transformed into useful new knowledge which the management in a mine plant needs for decision making. Managements of mine plants that implement BI tools can make timely decisions of a higher quality thus improving the overall work safety of their employees.

In this paper we presented the use of an ontology-based tool in improvement of the analysis and reporting system with easy data access and query for users in mine safety area. We have demonstrated various possibilities that the use of such a business intelligence tool open, supported by a practical example of application of the tool for accident analysis in mines that brings considerable benefits to the mine safety.

Acknowledgements

The research outlined in this paper was supported by the Serbian Ministry of Education and Science grant # TR 33039.

REFERENCES

[1] Albani, A. Dietz, JLG.: The Benefit of Enterprise Ontology in Identifying Business Components. In The Past and Future of Information Systems: 1976–2006 and Beyond, *IFIP International Federation for Information Processing (Avison D, Elliot S, Krogstie J, Pries-Heje J, Eds)*, Santiago, Chile, August 21-23, 2006, pp. 214, pp. 243-254., ISBN 0387347321, 9780387347325

[2] Cheng, H., Lu, YC., Sheu, C: An ontology-based business intelligence application in a financial knowledge. *Expert Systems with Applications*, Volume 36 Issue 2, March, 2009., pp. 3614-3622, doi>10.1016/j.eswa.2008.02.047

[3] Danihelka, P.: Safety and Security Research and its Relation to VŠB-TU Ostrava. *Transactions of the VSB-Technical University of Ostrava Safety Engineering Series*, 2012., Number 2, 2012., Volume VII, pp., 1-5, ISSN 1801-1764 (printed version)

[4] Dhillon, BS: Engineering Safety: Fundamentals, Techniques, and Applications. *World Scientific Publishing Co. Pte. Ltd*, Singapore, 2003., ISBN: 978-981-238-221-*4*

[5] Gagné, C., Lazure, L., Ledoux, É., Ouellet, S., & Fournier, P. S.: Knowledge Management in the Quebec Mining Industry: A Framework of Practice to Ensure Evidence-Based Knowledge Translation. *In Proceedings of the 12th European Conference on Knowledge Management*, University od Passau, Germany, 1-2. September 2011, pp. 315-321. ISBN 978-1-908272-106-5

[6] Galatescu, A., Alexandru, A.: Ontology-based Modeling and Inference for Occupational Risk Prevention. In SEMAPRO 2010: *The Fourth International Conference on Advances in Semantic Processing (Popescu M, Ed)*, International Academy, Research, and Industry Association (IARIA), 2010., pp 205-212, ISBN: 978-1-61208-104-5

[7] Glowacki, A.F.: Development of a Taxonomy for Indexing Web-Based Mining Safety and Health Research. *In The First International Future Mining Conference*, Sydney, 2008., http://www.cdc.gov/niosh/mining/userfiles/works/pdfs/doatf.pdf.

[8] Grimaldi, J.V., Simonds, R.H.: Safety Management. Richard D. Irwin, Chicago. 1989., ISBN 978-1-84996-114-1

[9] Joel, R.: Health Information Systems: Concepts, Methodologies, Tools, and Applications. Vol. 1. IGI Global, 2009., ISBN-13: 978-1605669885, ISBN-10: 1605669881

[10] Kolonja, B., Stanković, R., Vuković, F. and Obradović, I.: An Approach to Management Decision Support: The Coal Mine Pljevlja Management Information System. *In Proceedings of the*

Fifteenth International Symposium on Mine Planning and Equipment Selection, Vol. 1 (Cardu M, Ed), Torino, Italy, 20-22. September 2006, pp. 436-441. ISBN 88 901342 4 0

[11] Stanković, R., Obradović, I., Kitanović, O., Kolonja, Lj.: Towards a Mining Equipment Ontology. *In Proceedings of the 12th International Conference "Research and Development in Mechanical Industry"*, RaDMI 2012 (Dašić P, Ed), Vrnjačka Banja, Serbia ,14 - 17. September 2012, pp 108-118. ISBN 978-86-6075-036-7

[12] Vaught, C., Mallett, L., Brnich, M. J., Reinke, D., Kowalski-Trakofler, K., & Cole, H.: Knowledge management and transfer for mine emergency response. *International Journal of Emergency Management*, Volume 3, Issue 2-3, 2006., pp. 178-191, DOI: 10.1504/IJEM.2006.011167