Analysis of Sustainability Assessment in Carbonate Rock Quarries

JULIJA ŠOMMET

TALLINN UNIVERSITY OF TECHNOLOGY
Faculty of Power Engineering
Department of Mining

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Supervisor:
Associate Professor Jüri-Rivaldo Pastarus,
Department of Mining
Faculty of Power Engineering
Tallinn University of Technology

Co-supervisor:
Dr Sergei Sabanov, CEng MIMMM
Senior Consultant (Mining Engineering)
SRK Consulting (UK)

Opponents:

Tarmo Tohver
Doctor of Technical Science, Ph.D.
Chief specialist at Eesti Energia Kaevandused AS. Estonia

Murat Mustafin
Doctor of Technical Science, professor
National Mineral Resources University „Mining". Russia, Saint-Petersburg

The defence of the thesis: May 22, 2014, 9:00 at Tallinn University of Technology, Ehitajate tee 5, Tallinn, Estonia.

Declaration:
Hereby I declare that this doctoral thesis, my original investigation and achievement, submitted for the doctoral degree at the Tallinn University of Technology, has not been submitted to any institution for any academic degree.

Julija Šommet

Karbonaatkivimite karjääride jätkusuutlikkuse analüüs

JULIJA ŠOMMET

ABBREVIATIONS

MS_i – Mining Sustainability Index

TI_{SUM} – Summarized trading income of a mining company

EAP – Economical activity profit of a mining company

FP_{EST} – National (here Estonian) standardized measure of ecological footprint value in gha/pers

RL_{ENav} – An average value of environmental indicators

RL_{EN} –Risk level for environment

ΣTD_n – Average age of machinery

BEES ─ Building for Environmental and Economic Sustainability

ASM ─ Artisanal and small-scale mining in African countries

LCA – Life Cycle Analysis

EMAS – Eco-Management and Audit Scheme

LIST OF ORIGINAL PUBLICATIONS

PAPER I   Šommet, J.; Pastarus, J.-R (2012). Comparison of Dolostone and Limestone Assessment Methods for Estonian Deposits. The 1st Congress of World Engineers and Riga Polytechnical Institute / RTU Alumni, 35-39

PAPER II Šommet, J.; Pastarus, J.-R. (2011). The nature of destruction of paste fills massive (in Russian). Проблемы Недропользования. National Mineral Resources University (Mining University), 191, 188 - 190.

PAPER III   Šommet, J.; Sabanov, S.; Pastarus, J.-R. (2010). Analyses of crushed limestone quality developed by different methods for conditions of sustainable mining (in Russian). Проблемы Недропользования. National Mineral Resources University (Mining University), 189, 133 - 135.

PAPER IV   Sabanov, S.; Pastarus, J.-R.; Šommet, J. (2011). Sustainability assessment methods in oil shale mine closure. Vita Ansone (Ed.). Environment. Technology. Resources: Environmental Protection and Monitoring. (271 - 275). Rezekne: Rezekne Augstskola Izdevnieciba

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PAPER VI Sabanov, S.; Šommet, J.; Milaševski, I.; Bashkite, V.; Gulevitš, J.; Beldjaev, V.; Robam, K. (2010). Sustainability assessment methods for developing advanced mining technologies. In: 9th International Symposium Pärnu 2010 "Topical Problems in the Field of Electrical and Power Engineering" and "Doctoral School of Energy and Geotechnology II", Pärnu, Estonia, June 14 - 19, 2010: Tallinn University of Technology, 2010, 69 - 74.

PAPER VII Šommet, J. (2013). Sustainability assessment of Estonian oil shale mining. Oil Shale, 30(2S), 363 - 370.

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CONTENTS

1. INTRODUCTION

1.1. Background

Actuality: The Estonian market of construction materials is in need of high-quality materials (limestone and dolostone aggregates, sand, gravel) in order to cope with everyday demand. It is essential to develop a multi-use assessment method for measuring the sustainability of mining activities in aggregate quarries in case of resource depletion.

Basis of research: Currently existing and well-known methodologies, such as life-cycle assessment approach specified in the International Standards Organization ISO 14004 "Environmental management systems", EMAS Easy system[1], Waste water Exergia analysis and Occupational Risk Assessment by British Standard BS 18001 „Occupational health and safety management systems" are using different data, which is strictly directed only to one field of this investigation, not including all necessary aspects (economics, environmental, technical feasibility, socio-cultural indicators).

Research hypothesis: It is possible to develop a multi-use sustainability assessment method for construction material quarries taking into account standards, methodologies and previous research.

Research methodology: This study is based on a complex synthesis method, which is based on theoretical research, experimental work in quarries and computer modelling. The results are also scrutinized and analysed for confirming their adequacy.

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[1] The interest in the environmental performance of organisations is continually increasing. It has become almost impossible for any organisation to operate without taking into account environmental consequences of their actions. Organisations with a proactive approach to environmental challenges look for ways to continually improve their environmental performance. EMAS is a first-class environmental management tool to achieve this. It leads to enhanced performance, credibility and transparency of registered organisations. Currently, more than 4,500 organisations and approximately 7,800 sites are EMAS registered.[4]

1.2.   Objectives

The aim of this study is to carry out analysis of international standards and norms for management systems, which are in use in mining industry and to develop a sustainability assessment method as a paradigm based on obtained results. The new methodology will be a synthesis, in the form of a multi-use and co-operative evaluation method, which takes into account the most important factors of requirements.

1.3.   Contribution

Originality of this research: This is the first time when complex sustainability assessment has been designed for constructing material quarries, based on a new sustainability assessment method. This method is applicable in other construction materials quarries with similar geological conditions.

Practical importance: For the first time, a novel complex sustainability assessment method is used in construction material quarries in order to estimate sustainable well-being of a mining company, environmental and social impacts. The method provides means for monitoring in real time the status of a company, thus allowing optimal and adequate decision-making. This methodology can be expected to be of interest and a helpful tool for mining specialists in Estonia, as well as in other European countries and for developed countries outside Europe.

Adequacy of research: the study material and detailed developed methodology have been presented in international conferences in the form of oral presentations and in research articles published in peer-reviewed international research journals and proceedings, such as Environmental and Climate Technologies 2012, Fuelling the Future: Advances in Science and Technologies for Energy Generation 2012 at The Energy & Materials Research Conference (EMR2012), 8th International Scientific Practical Conference "Environment. Technology. Resources", also in the 13th, 12th, 11th, 10th, 9th, 8th International Symposia "Topical Problems in the Field of Electrical and Power Engineering", MPES2012 and others.

Obtained analysis results and used experimental data were estimated using theoretical work and expert opinions.

Scientific result: This methodology was initially developed in the Tondi-Väo limestone quarry, where promising results were achieved. With scientific approach of sustainability assessment method for construction material quarries, a solution was found for an important problem, and a new method was designed. The methodology was originally constructed on the basis of two quarries, one

mining limestone and the other one dolostone. However, the results are clearly applicable in other quarries producing carbonate rock construction materials in Estonia and also in other countries with similar geological conditions. This methodology provides sophisticated means for making sustainability assessment and finding weakest or strongest aspects in running a company. It is a helpful tool for decision-making for several interested parties: company administration, purchaser, as well as branch administration.

2. PREVIOUS STUDIES AND A CASE STUDY

For developing new sustainability assessment method, different methodologies were considered, which are used or approved in different countries of Europe. All such methodologies use different risk systems, which are adjusted to necessary activities and specific research fields by approbated theoretical models.

P. Slovic states in a risk research review that the concept of risk was invented to help people to understand and cope with the dangers and uncertainties of life. While these dangers are real, there is no such thing as real risk or objective risk. Even the simplest risk assessment is based on theoretical models, whose structure is subjective and whose inputs are dependent upon judgment. [29]

A Review of Values, Concepts, and Methodological Approaches of Sustainability also shows that since sustainable development became the catchword in international discussions, several approaches to Sustainability Assessment have been developed. In order to measure or predict sustainability of a land use system or a society, one must consider the inherent problems of analysis and its complex systems. Appropriate scales and time horizons must be chosen; preconditions and requirements for operationalization and quantification of sustainability must be defined. There is a need to develop criteria that can be used to indicate to what degree strategies and policies contribute to sustainable development [2].

2.1.   State-level development plans and sustainability

For example, the Estonian National Strategy on Sustainable Development, *Sustainable Estonia 21*, was approved by the Parliament of Estonia in 1995, and according to the plans of sustainable development some main ideas should be elaborated in many sectors. This material consists of theoretical assumptions and is estimated using theoretical values. Also, it does not have a focus on mining, but builds a strategy for the next years of wellbeing of the country. [6]

Otherwise analytical publication, Indicators of Sustainable Development, presents over sixty different fields. Fields to follow: land use, biological diversity, structure of economy, environmental economy. Data on other countries have been also presented for comparison. The indicators are presented in accordance with the list of United Nation Commission of Sustainable Development and the Statistical Office of the European Communities. Most recent data are for the years 2003 or 2004. An important precondition for achieving success in carrying out the sustainable development strategy is sustaining the self-renewal capacity of renewable resources and using non-renewable resources according to clear rules and at as low rate as possible, foreseeing possibilities for replacement in the future. [7]

2.2. Development and sustainability of oil shale mining

A study on Estonian oil shale mining by E. Reinsalu can be useful as an appropriate example of Economy Analysis in Estonian conditions. It allows to measure a lifetime of a company, also to make an costs analysis calculations, as well as price calculations. With this research it is possible to make measurements of the predicted mining capability, minimal output of production, mining capability of excavation of reserves, mining capability necessary investments for machine purchases. Oil shale quality analyses are too specific and are not directly applicable for mining of carbonate rock, but they suit for fossil fuel extraction. The main idea of this research is that mining capability of a company depends on productivity.[5]

Another study of Risk Assessment Methods in Estonian Oil Shale Mining Industry helps quickly and qualitatively to solve, operate and find optimum variants for existing problems, also to predict and avoid the subsequent problems with minimal expenses during the project stage. The methodology is based on statistical analysis and consists of three general approaches depending on the type and quality of available data, involving main problems: stability of a mining block, loading, transportation and their influence on the environment. Risk assessment can be used for different purposes and at different levels: as a basis for decision-making when selecting among different remedial actions for a mined out area within certain time and financial restraints; to relate ground surface subsidence risk levels to acceptable risk levels established by the society for other activities. [21]

However can be that development is not measurable and immediately understandable, because it depends on particularly of the resources, scope of applications, efficiency of use, factors of consumption, environmental safety, etc. Nevertheless, when analysing sustainability, additional parameters should be

taken into account: Economy, Environment, Socio-cultural and Technology. As a result, proposals for improving the management were offered.

2.3. Construction materials sustainability

Another useful tool used in United States of America for building construction is Building for Environmental and Economic Sustainability (BEES). BEES allows to measure the environmental capacity of building products by using the life-cycle assessment approach specified in the ISO 14040 series of standards. All stages in the life of a product are analysed in life-cycle assessment: raw material acquisition, manufacturing, transportation, installation, use, and recycling and waste management as well. Economic performance for BEES is measured using the ASTM standard life-cycle cost method, which covers the costs of initial investment, replacement, operation, maintenance and repair, and disposal. [8]

2.4. Small-scale mining sustainability

A modern Toolkit for ASM (artisanal and small-scale mining) systems has been created for African countries (Uganda, Tanzania, Mozambique, Lao PDR etc). It can lead to improved policies, extension of services, interactions between large-scale mining companies and artisanal miners, to improve development impact for men, women, and artisanal mining communities. This is a very important tool for improving the situation potential to help people out of poverty when conducted in an informed and responsible way. Different techniques are used in different communities, also, men and women share different activities of labour, risks, and opportunities. Understanding the social, economic, and environmental aspects of ASM is essential for governments, non-governmental organizations, mining companies, and researchers in order to be able to contribute in positive socioeconomic and environmental outcomes from this sector. This Toolkit—including the detailed analytical framework and instructional modules—is a unique instrument for guiding research and researchers to ask the right questions and come to a gender-sensitive understanding of ASM activities.[22]

2.5. Occupational health sustainability

Using BS 8800 normative it can be defined, that Risk Matrix is a tool used in the risk assessment process which allows the severity of the risk of an event occurring to be determined. As can be seen at the Table 1 it gives a risk level by categorizing the likelihood of the harm and the potential severity of harm and then plotting these two risk determining factors against each other. This

methodology does not require extensive knowledge of analysis theory and it has detailed descriptions of the concequences of concern for each.[30]

	Severity		
Likelihood	Slightly harmful	Harmful	Extremely harmful
Highly unlikely	Trivial risk I	Tolerable risk II	Moderate risk III
Unlikely, but possible	Tolerable risk II	Moderate risk III	Substantial risk IV
Likely	Modetare risk III	Substantial risk IV	Intolerable risk V

Table 1 Risks types descriptions by BS8800. [30]

A practical guide to basic risk management brings up Australian research experience, where a system ambivalent to BS8800 is in use. The system is intended to help businesses manage risks to health and safety — to find any hazards they may have in their workplace, judge how dangerous such hazards are and rank them in priority order so that something can be done to eliminate or control them, as required by the legislation. Highest priority risk means extreme importance of the event and the maximum value is six.[31]

An alternative to the traditional systems by J.M. Woodruff was approved in United Kindom. The risk matrix in it was built using a special equation to rework existing risk estimation methodology. Instead of using an explicit value of the risk level, it is suggested that in lower risk industrial and commercial sectors it is sufficient to set up the risk, which will be likely to fall within only in three classes: intolerable, tolerable or acceptable. It is argued that this methodology has significant advantages over others risk estimation approaches presently used in UK.[33]

2.6.   Safety management

The practise by The Center for Safety Management and Engineering of the Tampere University of Technology, Finland, offers a five-point scale for risk determination to eliminate the causes of accidents, environmental emissions and

health hazards to improve the reliability of a system in such a way that fewer injuries and less damage occur. [32]

2.7.   Environmental assessment

For instance, an ecomapping tool can be very useful for this research, because it helps to scan environmental impact, problems and practices as shown in Figure 1 highlighting most serious problems of the company environmental management. The system allows gathering systematically useful environmental information in every company by observation of everyday practices and procedures as well as through reference to legislative requirements and good practice. It is a systematic method that builds up a picture of key environmental information by using symbols. The visual approach makes ecomapping very easy to understand. It is a useful support tool for raising employees' and stakeholders' awareness of the environmental impact of an organisation's activities. It also makes it possible to get more people involved at an early stage without needing a considerable amount of specialist understanding.[30] As a fact, ecomapping method can be used to simplify sustainability assessment method in environmental matrix assessment. Not only annual reports could be used for quick and easy environmental analysis, but also the mapping idea by ecomapping EMAS Easy system. Ecomapping system is advising to use maps of whole territory of the quarries and main buildings, aquifers and mining allotment areas.

2.8.   Conclusions on previous research

An extensive examination of previous studies shows that sustainability paradigm cannot be created with only the existing methodologies and current complex of problems cannot be solved with existing experiences, which were described below – used data is limited and as the fact they are oblige and not suitable for mining companies and carbonate stone quarries, but a five-point risk matrix is simple to understand and define. None of the approaches indexes the whole status of the company and does not check the achieved results by formulas. The literature study shows that there is no other worldwide experience of sustainability assessment method, which consist of module analysis within the mining sector [5][6][7][8][21][22], but for example, a patented methodologies have been developed: Sustainability Capital Planning Tool [27], System for quality Assessment of Psychological Signals [26], Product Sustainability Assessment [25] and Environmental Performance Assessment [24] as well.

To provide optimal assessment of the sustainability assessment capacities, a new one, specialised on mining methodology was required to be developed,

basing on market needs, where it is possible to adjust the basis of the economic assessment of mining and destruction, crushing process for the choice of best technology. This thesis consists of both theoretical and practical scientific work.
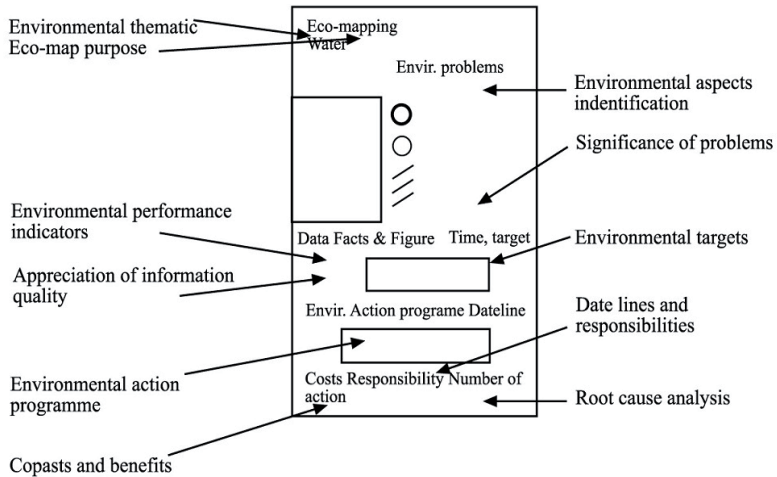
Key:

Hatched lines: small problem – (Area to be monitored, problem to be studied)

Circle: large problem – (Stop, corrective action)

The most serious problem is the thicker the circle

Source: Ecomapping (2006)

Figure 1. An example of ecomapping with explanations [34]

3. DEVELOPMENT OF THE SUSTAINABILITY ASSESSMENT METHODOLOGY

The developed methodology is a multi-use and co-operative evaluation method, which takes into account the most important factors of requirements and helps to identify weakest or strongest aspects of the carbonate rock quarries and facilitate the management of mining. It also shows main failures in the mining management process.

3.1.   Methodology

A sustainability assessment method for Estonian dolostone and limestone quarries was developed for the investigation. In this case, a module analysis was elaborated by the author of this thesis to measure and compare different parameters using previous research experience. The whole process of sustainability assessment method is illustrated in Figure 2. Principles of sustainability assessment method. The main selected parameters for the analysis can be followed in Figure 3, which contains a matrix of influenced parameters, where the final product was considered as a process and divided in four main parts: economic, environmental, technical feasibility and social – cultural. All parameters are considered and associated to each indicator by the local Estonian normative or legislation regulations and law. Most of them are based on European Union standards (at least 39 normatives: Mining Law, Water Statute, Waste Statute, Waste Oil Management Requirements, Municipal Waste Sorting Procedures, Fire Safety Requirements, Occupational Health and Safety Acts, etc). Parameter descriptions and overview of indicators used in the module analysis are shown in Figure 3, where it can be seen that Sustainability Assessment method is divided in four main modules. Each of them contains a selection of sustainability assessment indicators or parameters. Main economic indicators from Income Statement should be added, data from environmental reports should be analysed, socio-cultural values of the company should be evaluated and technical durability of the machinery park should be analysed as well. They can be added in need on removed as well.

Economic viability demonstrates if the company's wellbeing is at a maximum; is it possible to ensure efficient use of all resources, natural and otherwise, by maximizing or minimizing economical taxes; help to seek or identify and internalize environmental and social costs; maintain and enhance the conditions for viable enterprise, ensure a fair distribution of the costs and benefits of development. [PAPER IV] Economic indicators contain a part of the balance of the mining remnant stock and analyze data of unused material. Unused material volume shows a risk of mining exhaustion and a numerical overview of trading income, also operating expenses. In assessing the

summarized incoming risk, the Pareto principle 80/20 was taken as a basis. [8] For both analyses, all economical indicator data applied was real and taken from the accounting records program HansaWorld; summarized income statements were evaluated to percentage and compared between branches and all company. The mining company Väo Paas LTD hasv the Kareda dolostone deposit and the Tondi – Väo limestone mining branch.
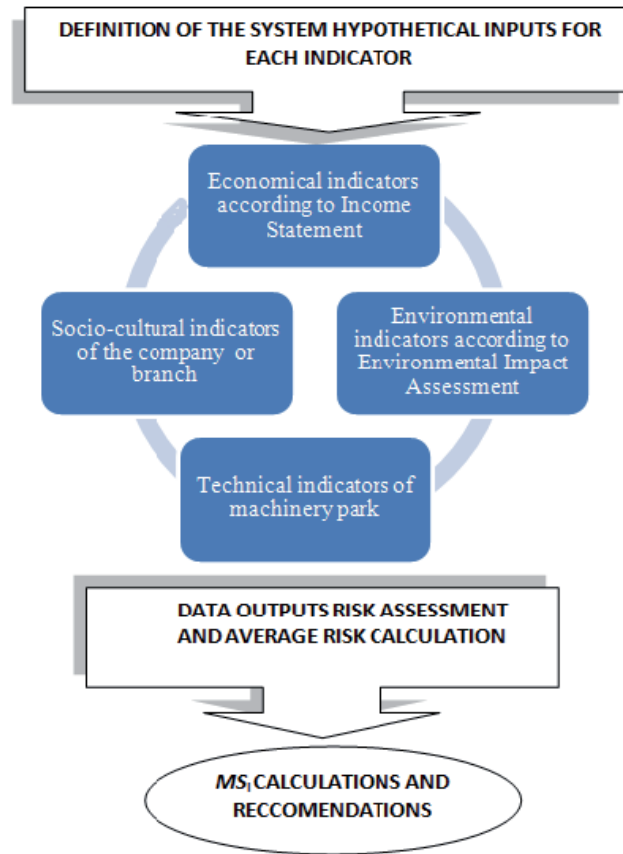
Figure 2. Principles of sustainability assessment method.

The environmental part contributes in preventing environmental collapses and hazards related to them (land contamination, subversive activity, flooding etc.), emissions into the atmosphere (by used energy costs and consumed fuel amount) and pumped quarry water to aquifers (petroleum content in the water, temperature, oxygen content, water pH, suspended solids and electro conductivity). Conditions for sustainable mining in densely populated regions allows transforming large areas of mined-out areas to suitable farmland or building areas. Mine water could be used for drinking water after self–cleaning. Mine closure is the period of time when the extracting activities of a mine have

ceased, and final decommissioning and mine reclamation are being completed. It is generally associated with reduced employment levels, which can have a significant negative impact on local society economies. It is also the period when the majority of mine reclamation is completed, making the land safe and useful again. [PAPER VI]

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                    ┌─────────────────────────┐
                    │ Sustainability Assessment Method │
                    │          Module          │
                    └─────────────────────────┘
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Economical Indicators	Environmental Indicators	Socio-Cultural Indicators	Technical Durability Indicators
Trading Income Operating Expenses Labour costs Depreciation Economical Activity Profit Loss The presence risk of competitors	Water pollution Dust contamination Noise level Vibration level Water pumping influence The energy cost Average petroleum use Unused materials Risk of exhaustion Soil contamination Max annual rate Mining allotment area Mining clime area Residues Wastes Chemicals in use Closure project Validity of permissions New extractions	Awareness Participation in tenders Competence Information requirements Safety Manuals Web activity Qality requirements Labor accidents Work Safety Risk Assessment Reclamations	Durability Ease of construction/ low tech Endure shock loads/ seasonal effects Flexibility/ adaptability Maintenance Reliability/security

Figure 3. Sustainability Assessment method for carbonate rock quarries

Technical parameters are estimated by sustainability of machinery park, where is considered quantity and the age of the machines.

In the sustainability assessment, the socio-cultural indicators pertaining to awareness and participating in tenders were divided into two separate parts. These two components are important, because they provide an effective promotion for the company and help the company to become widely known among local residents. The next new significant indicator is the labour middle age (average age of the staff), which was calculated by the average value for all company employees (the overall number of employees at the time of the analysis

was 41 persons); the nearest approximate quantity was 50. According to the Estonian requirements, the Work Safety Risk Assessment should be archived 55 years since its first measurement, mostly because of the workers' average life expectancy. While the middle labour age of workers was 50, risk was estimated as acceptable upon condition of an annual health check monitoring at the expense of the corporation. Another indicator "participation in tenders" shows how profitably a company can sell their goods and how successfully they use an opportunity offered by the state or other local companies. In that case risk value "5" could mean absolute inaction.

3.2. Risk Assessment of the Indicators

For the limestone deposit parameters gradation, a three-level risk matrix scale was used, adapted from the British Standard BS 18001 „Occupational health and safety management systems" (Table 2) and for dolostone a simple scale (simply using periodic numbers as in Table 3) was used, where the value zero "0" was included and five "5" was the maximum value. Two different parameter scales have been used to compare limestone and dolostone quarries to find out which one is more convenient. Results showed that three-level risk matrix scale usage is more comfortable and taken by default.

Periodicity of the events means that: likely – typically experienced at least once every six months; unlikely, but possible – typically experienced at least once every five years by an individual; highly unlikely – typically experienced once during the working lifetime of an individual. There are five types of risks, what are clearly determined: trivial risk is considered as acceptable and no further actions and documentation needed; tolerable risk – no additional control are required unless they can be implemented at low costs and actions to further reduce these risks are assigned low priority; moderate risk – consideration should be given as to whether risks can be lowered where applicable and the risk reduction measures should be implemented within a defined time period, usually within up to six months; substantial risk – some efforts should be made to reduce risk and it should be done urgently within a defined time period (preferably one month) or it might be necessary to consider restricting the activity; intolerable risk – means unacceptable risk, improvements in risk controls are strongly reccomended, so that the risk is reduced to a tolerable or acceptable level and in that case the work activity should be halted until risk controls are implemented.[30]

DAMAGE	MINOR	DANGEROUS OR HARMFUL	VERY INSECURE
UNLIKELY	NON-EXISTENT RISK (I)	MINOR RISK (II)	ACCEPTABLE RISK (III)
LIKELY	MINOR RISK (II)	ACCEPTABLE RISK (III)	ACCEPTABLE RISK WITH MONITORING (IV)
VERY LIKELY	ACCEPTABLE RISK (III)	ACCEPTABLE RISK WITH MONITORING (IV)	UNWARRANTED RISK (V)

Table 2. The effects of assessment consequences[30].

When possibility of the event is certain, then risk level will be high, if possibility of the event is low, then risk is also low as it is show at the describing Table 3.

Risk level	Possibility
5	Certain
4	Near certain
3	Very likely
2	Frequent
1	Seldom
0	Impossible

Table 3. Damage possibility and probability of event.

A three-level risk matrix scale was used to measure highlighted indicators for sustainability assessment in limestone mining. It is a three-level risk matrix scale (descriptions are shown in Table 2 and Table 3), where minimal risk level is graded as "I" and grade "IV" means that risk is very high. Risk evaluation means that a non-existent risk (I) is minimal risk and can be ignored, but it is necessary to ensure that this remains stable in the future; very low risk is minor risk (II) – it is not necessary to apply measures, but the aim is to find a better solution that does not create additional expenses; acceptable risk (III) - necessary measures should be taken to reduce risks, such as informing the staff about risks, analyzing the situation and applying additional supporting measurements; acceptable risk with monitoring (IV) – immediate actions should be taken to reduce the risk, increasing staff awareness of the risk level, training on measures to reduce this risk; unwarranted risk – very high risk, shows that measures to

eliminate this risk must be implemented swiftly in order to remedy the situation. [2]

The next risk descriptions were used only for economic risks assessment: for summarized trading income and economic activity according to Pareto rule was used in Figure 4.A. risk scheme. To measure risk levels of operating expenses (such as goods, commodities, aggregate, service, office miscellaneous operating expenses, labour costs), depreciation, average fuel use and energy cost were used in Figure 4. C. scheme, where all data from income statement was compared between all company data and transferred to percentage value. To measure labour amount risks were used in Figure 4. B. scheme, which is based on EU Commission Regulation No 70/2001. For maximal annual rate (in thousands tonnes) and residues amount risk determination was used in Figure 4. D. data, which is based on Estonian quarries common annual rates. Residues shows annual storage amounts, which are calculated every quarter of the year or usually at the end of the year.

Calculated %	Risk Level		Calculated %	Risk Level		Calculated %	Risk Level		Thousands m^3	Risk Level
100...80	1		10	1		80...100	5		700...	5
60...80	2		10...20	2		60...80	4		500...700	4
40...60	3		20...50	3		40...60	3		300...500	3
20...40	4		50...100	4		20...40	2		250...300	2
...20	5		100...	5		...20	1		0...249	1
A			B			C			D	

Figure 4. Risk Descriptions for Economic Indicators.

3.3.   Control of the Analysis

The Sustainability Assessment Method steps can be followed in Figure 5, where it is shown that after all risks definitions, an average risk of whole analysis must be calculated. Analysis results can be controlled and after that an Indexation of the company could be done. Indexation value leads to achievements of goals and helps to specificity the solutions for sustainability improvement. Sustainability Assessment method should be held by introduced module indicators, which are fold to tables and control of the results can be achieved using the following equations.

For economic indicators it is valid that summarized trading income cannot be approximately equal to economical activity profit (as equation 1 shows) and summarized trading income should be greater than its economical activity profit (as equation 2 shows). If a company is divided to different branches, then

additional economic control should be calculated for them, in that case branch summarized trading income should be greater than 20% (as equation 3 shows).

$$TI_{SUM} \neq EAP \qquad (1)$$

$$and\ TI_{SUM} > EAP \qquad (2)$$

where TI_{SUM} is summarized trading income and EAP is economical activity profit. Additional control of economic parameters in comparison with all company data should be done for branches analysis.

$$TI_{SUM} > 20\% \qquad (3)$$

Control of Technical indicators and Feasibility should be calculated for Average Technical Durability as equation (4) shows, where summarized years of machines divided to its amount *n* should not be larger than seven years, in other cases the risk is graded higher than 2.

$$\Sigma TD_n : n \leq 7 \qquad (4)$$

Subsequently, the company status Indexation consists of data analysis. The last step of sustainable assessment is solution specification for achievement of main goals.
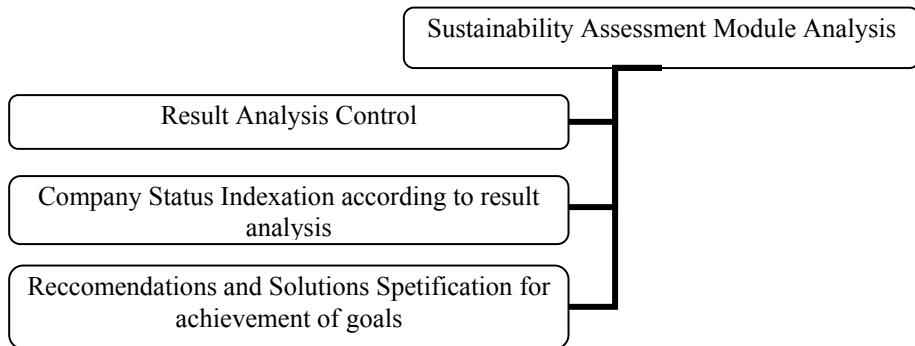

Figure 5. Sustainability Assessment Analysis Steps

Gradation of company wellness could be estimated by the average arithmetical mean of all Sustainable Assessment indicator values as (equation 5) shows, where Ec_i – is the average value of Sustainable Assessment of Economic Indicators, En_i – is the average value of Sustainable Assessment of Environmental Indicators and SC_i – is the average value of Socio-Cultural Indicators of Sustainable Assessment and T_i – is the average value of Technical Indicators. Thereafter Mining Sustainability Index (MS_i) is always a whole number and can by estimated using five basic grades:

- Five points „V" means, that Company is Sustainably Developed
- Four points „IV" – Successful Company
- Three points „III" A quite Successful Company, but additional activities should be carried out to improve the situation
- Two points „II" – The company needs more positive activity, special attention needed to reducing the risks
- Zero to one point "I" – no outcome activity [5].

$$MS_i = 5 : [(Ec_i + En_i + SC_i + T_i)/4] \qquad (5)$$

Mining Sustainability Index (MS_i) also shows a possible price range of a mining company in the case when the enterprise is being purchased. The higher the index is the more successful the company is - accordingly the price should be also higher. The lower the index is the more improvement should be done.

It is possible to increase the Mining Sustainability Index (MS_i) after a sustainability analysis has been done, it requires investments making to the weakest aspects and performing future suggestions, which are described in the next paragraph.

4. APPLICATION OF THE SUSTAINABILITY ASSESSMENT METHOD

The results of the investigation are presented graphically (Figure 10 and Figure 11), where an overview of necessary indicators for sustainability assessment method is described and shown step- by-step for the Tondi-Väo limestone quarry and the Kareda dolostone quarry in Estonia. In that case results can be perceived visually as shown below.

Sustainability assessment method for carbonate rocks has an analogy with the Safety Risk Assessment Method and Life Cycle Assessment (LCA) by its evaluation system or the currently popular environmental EMAS Easy system by its sets of measured components.

Both Sustainability Assessment matrixes (a three-level risk matrix scale and a simple scale matrix) analyses are based on general characteristics of carbonate rock quarries. Nevertheless, both analyses are easy to compare and in fact have an analogy with the workplace safety risk estimation. It is recommended to make an analysis at least once per year. If a company is larger than a micro company (<10) in accordance to the number of employees by EU Commission Regulation No 70/2001, it is advised to divide the analysis of the business into several

branches and compare economic parameters by total company percentage. These sustainable assessment module analyses were composed in tables in the spreadsheet application Excel, for more information, see an overview of dolostone analysis and limestone analysis below. The analyses provide a qualified image for the end-user and company owners. One of the two modules analysis table systems should work better and provide better results with more accurate data than the other.

For example, the environmental parameters module in Figure 10 shows unwarranted risk for volume of unused material and risk of exhaustion, because only 325 m^3 of a total amount of 3049 m^3 was left to excavate and it is less than 10,7 %. Then extraction permission risk is also unwarranted considering that it was left only one month for permission and new permission was not available yet.

For the long period overview analysis data was taken for both deposits (Tondi-Väo limestone deposit and Kareda dolostone deposit) over the period March 2011, October 2011, March 2012, October 2012 and March 2013 as can be seen below in Figure 6. Annual data of eeconomic Indicators Risk Assessment graphical observation. It can be seen, that in spring some time risks are very high and at the autumn they decrease: economic activity loss and operating expenses are marked in different risk levels, but most of them are in a maximum level. Operating Expenses needs to be revised in both branches.

According to the 80/20 Pareto principle, mathematically, where something is shared among a sufficiently large set of participants, there must be a number "k" between 50 and 100. There is nothing special about the number 80% mathematically, but many real systems have somewhere around this region of intermediate imbalance in distribution.[9] For example, Figure 10 and Figure 11 show summarized trading income for a whole company or for a certain deposit, different operating expenses and activity profit or loss. All data should be real and is easily followed by accounting records program. Total values are shown in percentage. The deposit–branch economical parameters depend on total economic aspects of the company. If employees' percentage in a branch of the company is 15 %, it means that other parameters in the economical overview table should not be less than 15, in other case the risk is critical for the branch and production should be suspended. [3]
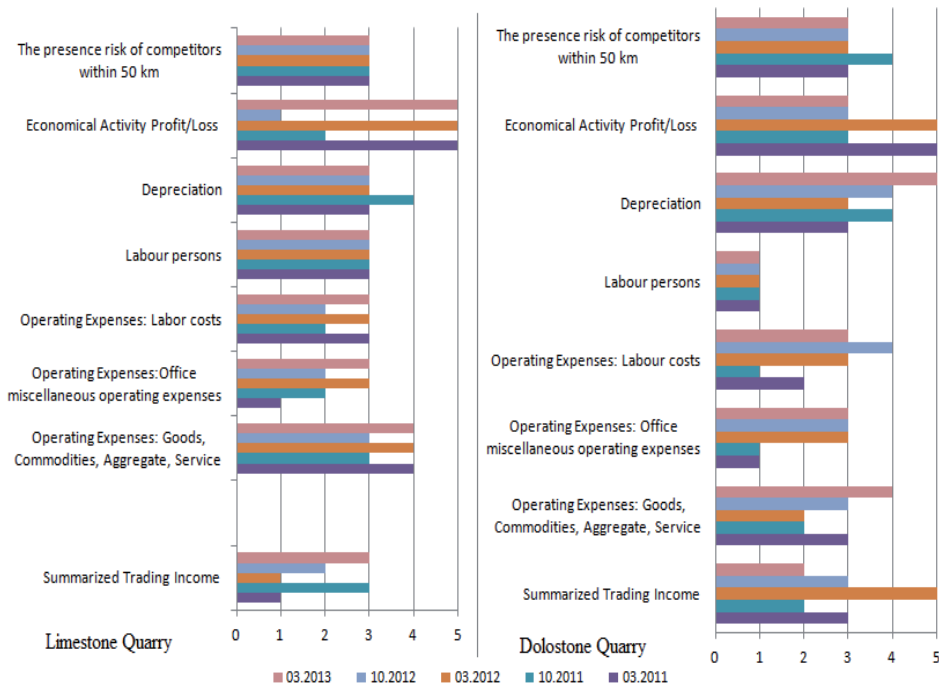
Figure 6. Annual data of economic Indicators Risk Assessment graphical observation

Periodical observation over the period 03.2011-03.2013 of environmental indicators of both branches can be followed in Figure 8. Existence of mining closure project and existence of environmental handbook are most important on risk reducing for Kareda branch, average petroleum use risk could also be reduced by using alternative methods of energy sources (electricity or diesel fuel, petroleum). Regarding to Figure 8 analysis data for Tondi-Väo branch most important influence have existence of mining closure project and environmental handbook, also validity of extraction permission and as the fact the risk of exhaustion; water pumping to aquifer risk increases with rainfalls and high water period. For example, in the Kareda deposit there is no groundwater coming info quarry area, thus there is no such a process as "water pumping to the aquifer".

In order to develop the sustainability assessment method, environmental annual reports of both branches were used to describe the part of environmental indicators. Validity of extraction permission should be compatible with the assessment date. Some new environmental indicators were added in the limestone analysis, such as the existence of an Environmental Management Handbook, where the environmental aspects, goals, missions, actions and needs to protect and improve environmental conditions in and around the facilities are clearly demonstrated. In such a case when a Handbook does not exist, the risk is

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very high (value "5"). When a Handbook is completed and approved by the company board member, then the risk is minimal ("1"). In between the risk level varies according to the stage of a draft handbook. For this limestone deposit analysis, risk value was graded as "3", because ecological mapping was done, responsible personnel was trained, but a final confirmation on a Handbook was not yet completed. At the moment, the existence of a handbook in not strictly required in Estonia, but rather recommended by the standards. The grade "3" means that risk is acceptable, but some additional activities are recommended in order to improve the average sustainability of the mining company.

Observation of the technical indicators is shown in Figure 9. As can be seen for both branches technical indicators parameters is mostly in high risk, because of average ages of machines and its maintenance, owing to works closure during the winter period.

Socio-cultural indicators overview can be followed in Figure 7. Socio-cultural risk determinations showed that more attention should be given for commercial promotions in this area. Web activity was increased considerably. Unfortunately, the number of accidents increases with works volume increment. Other parameters remain stable over the long period.
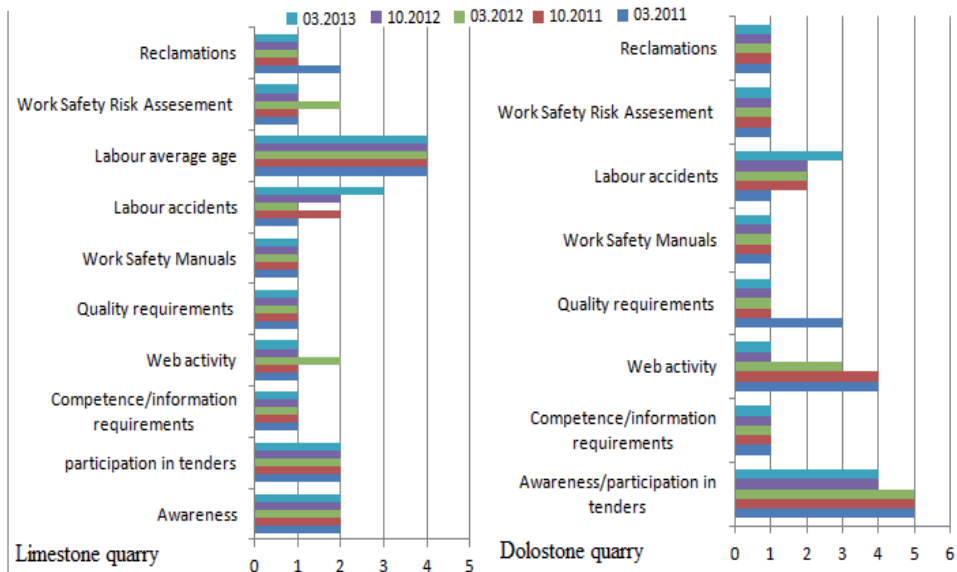

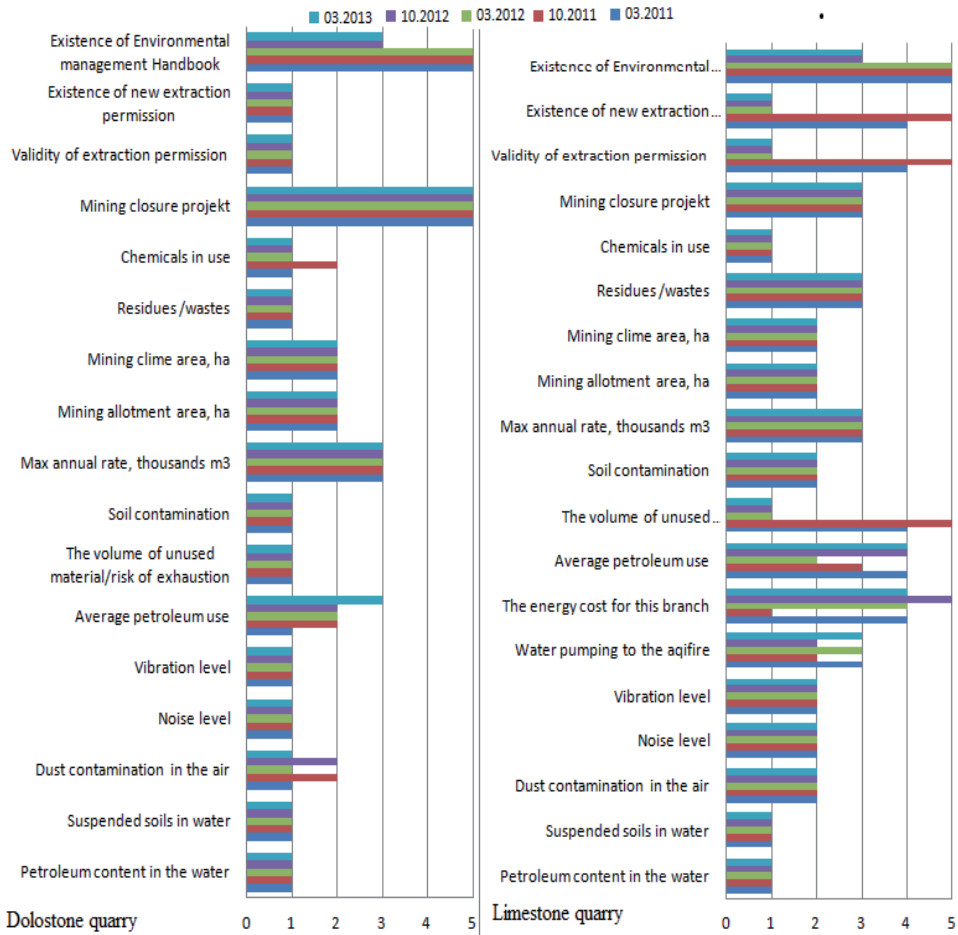*Figure 7. Annual data of socio-cultural indicators risks evaluation for both quarries*

Figure 8. Annual data of environmental indicators observation both quarries
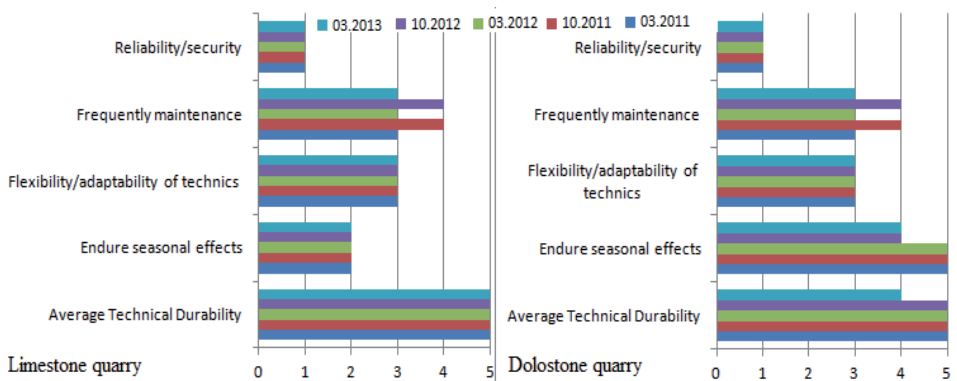

Figure 9. Annual data of technical indicators risks parameters for both quarries

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The expected result of this study was to explore a multi-use analyzing methodology for sustainable assessment in mining management. In case the total risk of an analysis is valid or more than the average (if the grade "5" was estimated as maximum, then "2.5" is an average), then supporting measures should be taken in these area of the company's activity. The sustainability assessment method develop the scientific output of the optimal activity analysis, to ensure the practical output of the company's competitiveness in Estonia on the basis of the consumer's wishes and needs and to provide an optimal assessment of the capacities of different groups based on the company needs. The urgency of the research consists in management efficiency in the current market conditions. It is a necessary requirement of the activity improvement and company development for competitive advantages. [3]

4.1.   Results of the Analysis

When using modern technologies, extraction of a mineral resource of construction material is accompanied by many technological processes each of which has distinctive conditions and its own impact on the mining environment. Sustainability Assessment Method was used for determination and elaboration of safety parameters for mining advanced technology efficiency and for defining environmental impacts resulting from different mining processes, and also proposes key challenges and opportunities to economic growth of company and environmental management and sustainable mining technologies. (PAPER VI)

In Estonia, there is increased demand for high-quality carbonate rock aggregates of limestone and dolostone. This investigation was carried out in co-operation with the Estonian company Väo Paas LTD (is a main branch in Estonia of Germany and Finland subsidiary company), Eesti Põlevkivi LTD company ash sales department in OSAMAT LIFE+ 09/ENV/EE/227 project frame, road building company Matthaei Ehitus LTD and Department of Mining, Tallinn University of Technology. Different deposits and geological conditions in different parts of the country were taken into account. Two Estonian quarries with different conditions were considered: Kareda dolostone (77.6 ha) quarry in central Estonia and Tondi-Väo limestone quarry (48 ha) in north Estonia. These quarries are located in densely populated areas. In the Väo quarry, limestone is being excavated using drilling blasting. Selective excavation is not applied at the moment. Obtained fractions are derived from limestone by rotor crusher and then sieved. The same excavation processes were followed in the Kareda dolostone quarry. Output aggregates are consumed in road, railway and building construction, concrete aggregates and concrete mixtures stuffing, and also for composing unbound mixtures. Each area of usage is followed by the EN (European Normative) standards. Used standards are valid throughout the European Union. Test results received in this study are applicable also for

research in other EU countries. The foundation was to find solutions to improve the mining sustainability situation in different companies.

The aim was to develop the scientific output of the optimal mining under specific circumstances for different geological conditions and the ballast testing methodology, based on the particular intended use. The aim was as well to ensure practical output of the company's competitiveness in Estonia on the basis of the sustainability, to consider consumer's wishes and needs (material and environmental quality) to the maximal extent. The use of a sustainability module analysis was proposed for organizing an optimal analysis for both deposits.

There are following possibilities within the scope of this study for finding solutions for improving sustainability of mining and quality of carbonate aggregates:

1. Background study of excavated carbonate rock, amount and quality of stockpiled product, investigation of environmental impacts, reuse or recycling activities (landfill technologies).

2. Cost-benefit analysis for mining management, where the Pareto principle 80/20 was taken as a basis. The 80/20 rule shows that in any considered topic, a small proportion (20 percent) is vital while a large proportion (80 percent) is trivial. Pareto Principle, the 80/20 rule, can serve as a daily reminder for focusing 80 percent of your time and energy on the 20 percent of your work that is really important. [20]

3. Review of entrepreneurship stimulation measures and other (structural, socio-economic) factors that have an impact on growth and stability of the mining operations, environmental and social strategy (selective extraction, carrying out constant tests for aggregates, optimal crushing technology selection on the basis of market demand).

4. Analyzing approaches to have the potential to be commercially viable activities, recognizing the state of the art in existing methods and technologies as well as up-and-coming innovation research. The problem is aggravated by the fact that, in the future it is planned to replace the use of low quality dolostone and limestone with granite aggregate. A complex approach is needed for solving the above-mentioned problems.

5. Approbation of different systems for Sustainability Assessment elaboration. For the limestone parameters gradation a three-level risk matrix scale was used to measure and compare the results. For dolostone, a simple scale (simply using periodic numbers) was used, where a zero point "0" (no activity)

was included and five points "5" (maximally unlikely activity) was the maximum value.

6. The second step after the Sustainability Assessment module analysis was the indexation of the company. To implement this, a Mining Sustainability Index (MS_i) should be determined. It will help to index mining company success, wellbeing and sustainability; it can show possible price range of an enterprise in cases of purchasing and determines the volume of next necessary measures to improve the sustainability of the company. The lower the index is, the more improvement should be done.

7. It is necessary to develop systematic monitoring of the result control. A complex of equations can be elaborated for adequate data and results.

8. In the last step of the research, recommendations and suggestions approved by practise for future improvements should be given, which can help to make significant improvements in mining operations, environmental and social influences and its management.

Deposit matrix analysis results are shown graphically in Figure 10 and Figure 11, where it can be seen that in the Kareda dolostone deposit technical and socio-cultural risks are dominating and in the Tondi-Väo limestone deposit environmental and technical risks prevail.
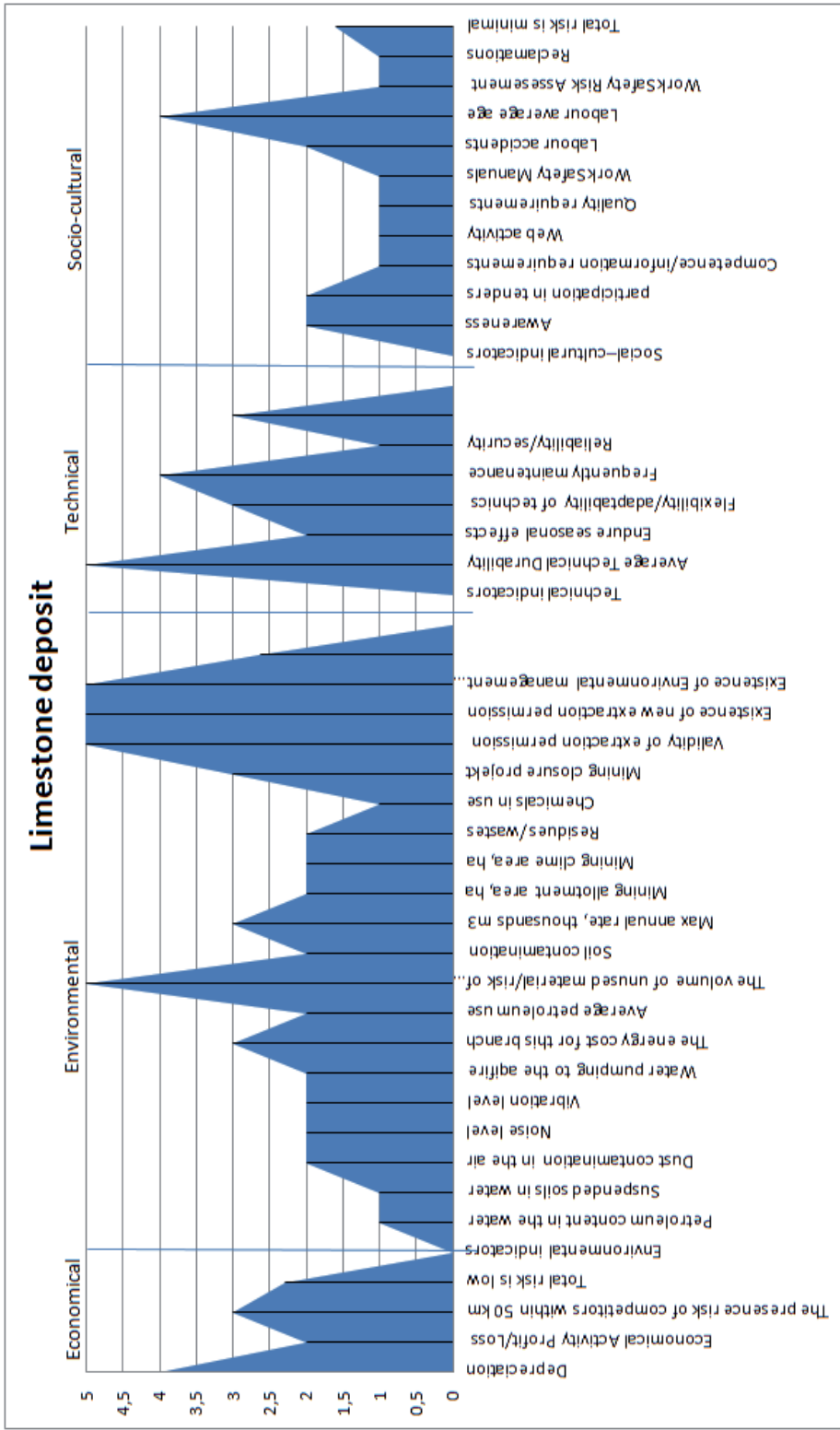
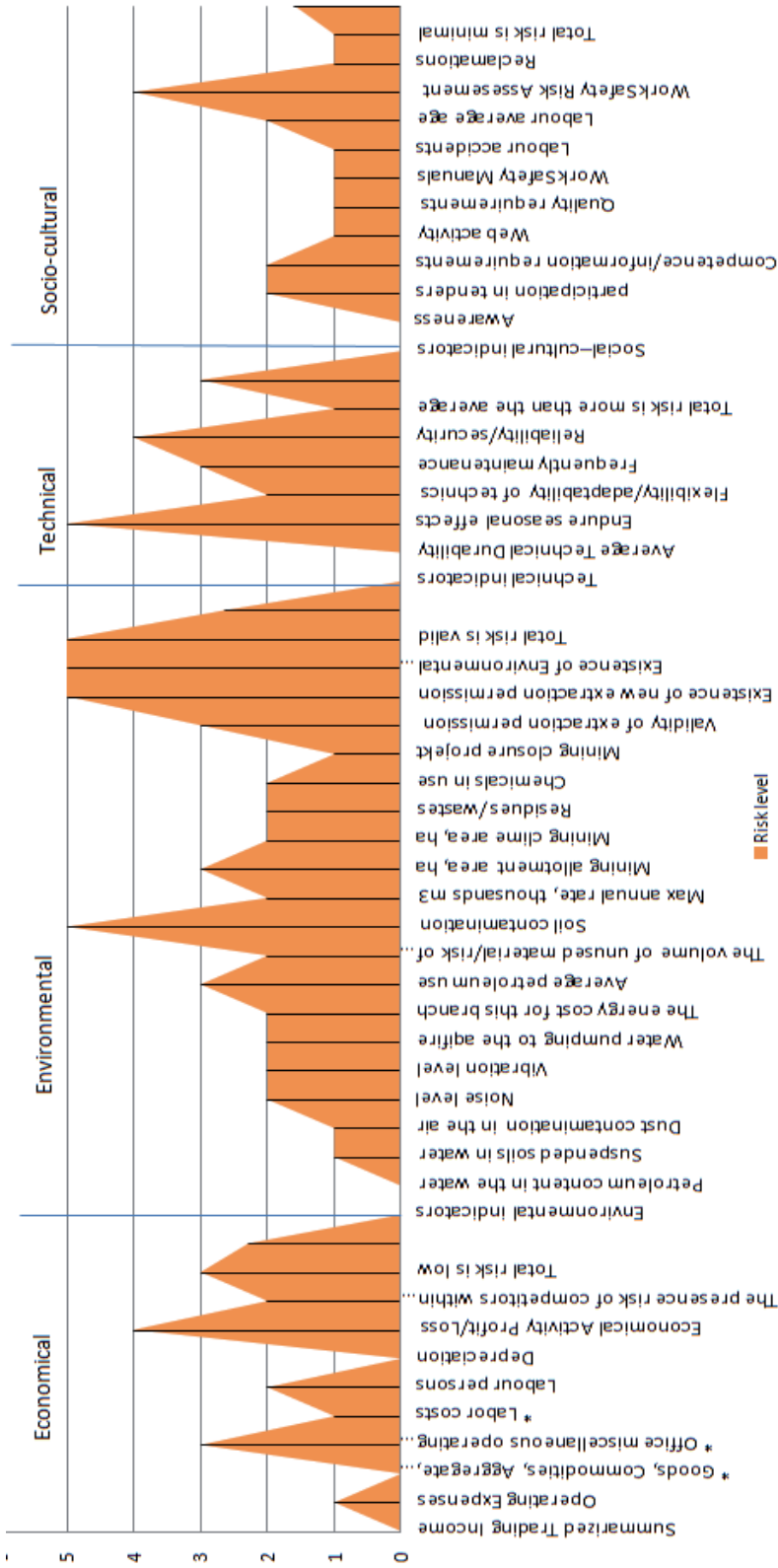*Figure 10. Overview of Indicators Used in the Limestone Sustainability Assessment*

Figure 11. Overview of Indicators Used in the Dolostone Sustainability Assessment

5. RESULTS OF THE STUDY AND CONCLUSIONS

There was no other methodology experience for making decisions and managing operations with sustainability assessment in Estonia or other European countries. The task of the research was to develop a multi-use sustainability assessment method for construction material quarries taking into account different geological conditions and all main European legislations.

This study determined optimal Sustainability Assessment by module analysis for carbonate rock quarries in Estonian and European mining conditions, taking into account all risks of activities (in environmental, economic, socio-cultural, technical feasibility). A Sustainability Assessment method was created, which helps to assess mining management quickly and adequately. The methodology also provides better understanding of mining processes and has an impact on different fields, diminishes the risk of accidents and casualties in quarries, contributes in preventing undesired hazards, and gives modern interpretation of results for new mining technologies.

This research helps to support company management and shows new development directions. A complex set of equations were developed for adequate data and results control. This allows to control the achieved results in a manner, which is impossible to perform using other currently applied methods.

Sustainability Assessment is inseparably paired with company indexation by Mining Sustainability Index (MS_i). The conception of Mining Sustainability Assessment method was determined in this study and it allows to index mining company success, wellbeing and sustainability; it shows possible price range for a mining company in case of purchasing and determines the volume of next necessary measures to improve the sustainability of the company. The lower the index is the more improvements should be done. Main recommendations, which will be given for future improvements in technology and management are approved by practice. It can help to make significant improvement in the sustainability of the company.

The results of research in this thesis can be used in practise in different construction materials quarries. Methodology was approbated in two quarries in north and central Estonia quarries taking into account different mining conditions. The research was performed in cooperation with the Tallinn University of Technology and other companies. The analysed dataset is extensive and for better handling it is preferred to divide company by branches or parent company. In a full version, analysis should be done using four scale

matrix and for reduced three scale matrix, where selected parameters are equal. Economic, environmental, socio-cultural and technical feasibility can be assessed using a five-point scale and with the help of BS 18001 „Occupational health and safety management systems". Results can be seen in a table form or in reduced version also graphically. Some examples are also given, which can be used for improving sustainability.

Re-evaluation of before used aspects and new methodological modelling have an important role in this study. The result allows to increase the company's liquidity, profitability, and hence competitiveness.

The analysis showed rather high risk levels in both branches and with different parameters. An important part in this situation is the period, which is under review: the end and beginning of the season, during the crisis. Therefore was decided to make an analysis annually in one time with compulsory annual economic analysis.

Methodologies for Sustainability Assessment were used for determining and developing safety factors and parameters for mining advanced technology efficiency and for defining environmental impacts resulting from different mining processes. Sustainability Assessment methods can be used for different purposes and at different levels: as a basis for decision-making when selecting among different remedial actions for a mined out area with temporal and financial constraints as a decision support model; to relate ground surface subsidence risk levels to acceptable risk levels established by the society for other activities. Particular attention will be paid to issues of current waste production and storage, old mining waste landfills, waste handling procedures, development of the framework for waste management. [5]

5.1. Recommendations for further study on sustainable development

Based on results of this study it is recommended to undertake a review using the sustainability assessment method in a mining company at least once a year. According to results for companies, where Mining Sustainability Index (MS_i) is lower than 4, it has been shown that after performing the analysis, future proposed work could be given for sustainable development. If Sustainability Index remains stable at 4, additional actions should be followed by the matrix analysis table. This research indicates that most advantageous solutions could be:

- Right choice of technique and its influence to extracted material. Obviously, for hard rock material blasting is still the best way to get raw material,

because it allows achieving maximum quality of produced aggregate. The quality of produced raw material and aggregate depends on both, as well as production technology and also geotechnical properties of the rock deposit (especially of compressive strength). The coarser the raw material is the better will be quality of production and aggregate properties, because the grain size becomes smaller only in latest progress stadiums. (PAPER V)

- Development of new generation equipment has given good results. For example, the new generation of cone crushers is not working only on pressing method, but also the impacts are added into process, what makes mining process more efficient. (PAPER VI)

- Control of the process by using special sensors can give certain results in improving material quality. If it keeps the cone feeding rate in the same level of about 80%, material pieces will not be crushed by each other. It will reduce the percentage of waste material. (PAPER VI)

- Correct choice of electrical drives increases efficiency and sustainability of mining. As mining machines work in hazardous conditions e.g. high humidity, dust etc., it has considerable influence on their lifetime and productivity. Many used electrical drives and their control systems are out of date. Hence they have low reliability and require more maintenance. (PAPER VI)

- Sales increment and search for new customers should be done; also additional quality control of aggregates (PAPER III), additional unbound mixtures specifications by macadam hydraulic conductivity [15] [23] and market opening up for fill technology using residue materials should be applied (PAPER II). A wide assortment of fill materials is available in the Estonian mining industry. It required careful selection of aggregates as a component part in fill mixture. Usable investigation methods and achieved results are applicable for different aggregates as a component part in fill mixture.[11] [14] [17] [18] (PAPER II) Conversion of industrial waste into valuable and environmentally friendly products is highly important at the moment in the EU as well as worldwide. In general, this will address the challenges of the European policies and legislation concerning waste and promote waste recovery and sustainable recycling with a focus on life-cycle thinking and the development of recycling markets.[14]

- Working actively with the staff, training and increasing competence among the employees of all ranks.

- Attracting new investors or sponsors and participating in different tenders and improving standards [16].

- Occupational risk assessment should be done carefully and safety manuals and their checkups should be done correctly in time by carrying out a systematic operational audit, informing employees about working environment risk factors, organizing health check-ups for employees, carrying out the elementary - introductory instruction for an employee starting to work for the enterprise. If necessary, supplementary instruction should be carried out.

- Implementation of environmental management systems will be very useful. An environmental management system (EMS) should be a part of the management system of mining companies. This means controlling, decreasing and preventing environmental impact resulting from the activities of the organisation and, thus, improving its competitiveness. Organisations in Estonia can choose between two EMS's: the international environmental standard ISO 14001 and EMAS or the European Union Eco-Management and Audit Scheme. ISO 14001:2004 and ISO 14004:2004 focus on environmental management systems. Other standards in the family focus on specific environmental aspects such as life cycle analysis, communication and environmental auditing.[15]

- Process optimisation by minimising costs, minimising waste productions, minimising energy use and land area, clean water, maximise the score of qualitative sustainability indicators is necessary.; [19]

ACKNOWLEDGEMENTS

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KOKKUVÕTE

KARBONAATKIVIMITE KARJÄÄRIDE JÄTKUSUUTLIKKUSE ANALÜÜS

Siiani ei ole olnud töösturitel ja auditeerijatel piisavat metoodilist kogemust jätkusuutlikkuse määratlemiseks ja vastavate piirmäärade seadmiseks ja probleemide lahendamiseks, mida saaks kasutada Eestis ja kõikjal Euroopas. Üks keerulisematest ettevõtluse probleemidest tänapäeval on ettevõte säästva ehk jätkusuutliku arengu programmi väljatöötamine, kuna Eesti lubjakivitööstus vajab ikka rohkem ja rohkem kvaliteetset materjali, ning pidevat keskkonna kontrolli. Selle probleemi lahendamiseks nn võimalik koostada kompleksne hindamismeetod ehitusmaterjalide karjääride jätkusuutlikkuse hindamiseks, lähtudes varem läbiviidud uuringutest ja kasutusel olevatest metoodikatest ning standarditest.

Käesoleva doktoritöö ülesandeks oli uurida kaevandamise jätkusuutlikuse probleeme – kaevandamisprotsesside mõju keskkonnale, ettevõte majandusele ja inimestele Eesti riigi tingimustes ning töötada välja vastav optimaalne hindamisprogramm, või siis arendada uus, seni kasutamata jätkusuutlikuse hindamise metoodika arvestades Euroopa ja maailma kogemust. Kogutud eelinfo ja taustauuringu abil sai sünteesitud kriitilise analüüsi metoodika. Väljatöötatud jätkusuutlikkuse moodul analüüs karbonaatsete ehitusmaterjalide jaoks osutus täpseks, kiireks ja kokkuvõtlikuks meetodiks, mis tagab konkreetse tulemuse ja arvestab tähtsamaid mõjufaktoreid: aitab välja selgitada ettevõte tugevamaid ja nõrgemaid sõlmed, keskkonnamõju ja toime majandusele ning sotsiaalsfäärile. Metoodika on kasulik nii ettevõte omanikele, töötajatele, kui ka potentsiaalsetele ostjatele, kuna annab hea ülevaade kõikidest toimuvatest protsessidest karjäärides karbonaatsete kivimite kaevandamisel.

Antud uurimisteema toetab ettevõtete arendustegevust, toob sisse uudse vaatenurga ja loob soodsama keskkonna innovaatiliste lahenduste tekkeks, arvestades, et toimunud muudatused majanduses nõuavad teadmisi majanduse arengu perspektiividest nii riigis tervikuna kui ka tööstusettevõtetes. Selletõttu tekkis vajadus põhjalikumalt uurida jätkusuutliku arengu probleeme, kaasa arvatud ka tööstusettevõtete jätkusuutliku arengu võimalusi.

Jätkusuutlikkuse hindamise on lahutamatult seotud ka firma indekseerimisega *Mining Sustainability Index*'iga (MS_i). Indeksi idee ja väärtuslikkus olid väljatöötatud antud töö käigus ning see võimaldab hinnata ettevõtte ekukust ja jätkusuutlikkust, selle järgi saab defineerida ka hinnaklassi ettevõtte müügi korral, samuti määrab tööde mahtu jätkusuutlikkuse tõstmiseks.

Mida vähem on indeks, seda rohkem tegevust on seotud olukorra parandamisega.

Antud doktoritöö väljund on teadusuuring, mille tulemused on rakenduslikku suunaga ja kasutatavad praktikas, mis on kohane konkreetsete ettevõtete oludele. Metoodika on katsetatud nii Põhja- ja Kesk-Eesti karjäärides arvestades nende erinevaid geoloogilisi tingimusi. Teadustöö viidi läbi tihedas koostöös mitme ettevõtega ja ülikooliga. Kuna analüüsi andmed on väga mahukad, siis töö näitlikustamiseks, ühe ettevõte hindamiseks on otstarbekas jagada ettevõte filiaalideks ehk osakondadeks. Analüüs toimub nelja valdkonna või nn maatriksite abil üheaegselt, kus selekteeritud ja modifitseeritud parameetrid on võrdväärdsed. Majanduslikud, keskkonna, tehnilised ja sotsiaal-kultuurilised valdkonnad hinnatakse viiepallilise süsteemi abil ja selle hindamiseks on kasutatud kolmeastmelist riskimaatriksit Briti standardi BS 18801 „Occupational health and safety management systems" järgi. Hindamise peamaatriks on esitatud tabeli kujul, kuid lihtsustatud analüüsi saab kujundada ka graafiliselt, mis võimaldab veelgi lihtsamalt analüüsida tulemusi. Peale parameetrite hindamist ettevõtte edukust identsifiteeritakse väljatöötatud *Mining Sustainability Index*'i abil ja valemite kompleksi abil tulemusi kontrollitakse; samuti on töös toodud mõningad näpunäited jätkusuutliku olukorra parandamiseks, mis praktilises ja igapäevases töös näitasid häid tulemusi.

Oluline roll uuringus on varasemate aspektide ümberhindamine ja uute metodoloogiliste mudelite loomine. Tulemus võimaldab suurendada ettevõtte likviidsust, kasumlikkust ja sellest tulenevalt konkurentsivõimet.

Doktoritöö on seotud järgmiste uuringutega: Euroopa projekti uuring MIN-NOVATION; ETF grandid "Backfilling and waste management in Estonian oil shale industry" No ETF8123 ja "Conditions of sustainable mining" No ETF7499, samuti interdistsiplinaarse uuringu doktorikooli projekt DAR8130 "Sustainable mining".

ABSTRACT

ANALYSIS OF SUSTAINABILITY ASSESSMENT IN CARBONATE
ROCK QUARRIES

One of the most complicated business problems nowadays is designing a sustainable development program for a company. Sustainability Assessment and Sustainable Development for Estonian Carbonate Quarries is a comparative study. This investigation has been performed in collaboration with several local Estonian mining companies and institutions. Scientific work determined the Sustainability Assessment Method using module analysis in conditions of Estonian and European mining taking into account all risks of activities.

The expected result of the study is to explore a novel analyzing methodology for Sustainability Assessment in mining management. A specific monitoring tool and indicators were developed in order to access each branch of mining (Economical, Environmental and Technical Feasibility and Socio-cultural indicators). Sustainability Assessment consists of a module analysis. For adequate data and result monitoring, a complex of equations were developed, which allows to control achieved results. It, is impossible to perform an alike procedure using other current methods. Subsequently, some main recommendations and suggestions were made to improve sustainability of mining company.

Sustainability Assessment for Estonian Carbonate quarries helps to identify, manage and corporate with different risks and weakest aspects associated with mining company services, business operations and products. Assessment serves as an advisor for best development and future company wellness. It will thus make it possible for company personnel to monitor and contribute into the process, while the past evaluations were in luck of necessary information and are not committed with data of carbonate rock quarries. This research highlights all aspects needed for sustainable development and it is pioneering and unique methodology, tailor-made for quarries. The analysis involves quarterly monitoring of economic, environmental, technical and social performance. The methodology is very useful and defines itself by used methods and relevance for developing future well being and usefulness of outputs: such as comprehensive training model and technique tool. Sustainability Assessment indicates appropriated future strategies for dealing with in mining management. The research problem is relevant and of significance to mining companies in Estonia and other European countries in varying geological conditions.

ELULOOKIRJELDUS

Nimi   Julija Šommet
Sünniaeg   24.08.1983
Kodakondsus   Eesti
E-posti aadress   ohutu.tk@gmail.com

Haridustee ja teaduskraadi info:
2009 - ...TTÜ, Energeetikateaduskond, Mäeinstituut, doktoriõpe, doktorant
2006 - 2009 TTÜ, Energeetikateaduskond, Mäeinstituut, magistrikraad
2002 - 2006 TTÜ, Energeetikateaduskond, Mäeinstituut, bakalaureuse kraad

Keelteoskus
Inglise keel   kõrgtase
Eesti keel   kõrgtase
Vene keel   emakeel

Erialane enesetäiendus:
07.2011 Töötervishoid ja tööohutus, TK Haldus (Eesti)
01-05.2011 EMAS easy Keskkonnajuhtimis süsteemide koolitus, KIK (Eesti)
28.-29.01.2010 Maapõue kasutamise uus kontseptsioon, TTÜ, mäeinstituut
01.2008 Töötervishoid ja tööohutus, TK Haldus (Eesti)
10.2007 Ohutusnõuded ja seadusandlus väikekarjäärides, TTÜ, mäeinstituut
05.2007 Töötervishoid ja tööohutus, PTB koolitus (Eesti)
05.2007 Esmaabiandjate väljaõpe kursus, PTB koolitus (Eesti)
04.2007 Maavarade kaevandamise sõlmprobleemid, TTÜ, mäeinstituut (Eesti)

Teenistuskäik

2011- ...	Jätkusuutlikkuse ja riskihindamise keskus, OÜ Ohutu TK, juhatuse liige
2009 - ...	Tallinna Tehnikaülikool, Energeetikateaduskond, Mäeinstituut, Maavarade kaevandamise õppetool; doktorant (0.00)
2006 - ...	OÜ Väo Paas; kvaliteedijuht, töökeskkonnaspetsialist, laborant (0,7)

Teaduspreemiad ja- tunnustused   2012, Julija Šommet; Best Presenter Award Certificate in Mining session in 12th International Symposium Kuressaare 2012 "Topical Problems In The Field Of Electrical And Power Engineering"

Publikatsioonid

1.1. - 1 publikatsiooni

Šommet, J. (2013). Sustainability assessement of Estonian oil shale mining. Oil Shale, 30(2S), 363 - 370.

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3.2. - 13 publikatsiooni

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3.4. - 3 publikatsiooni

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5.2. - 1 publikatsioon

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Kaitstud lõputööde loetelu

2006 - 2009 TTÜ, Energeetikateaduskond, Mäeinstituut, magistri õppe, magistrikraad, 2009, (juh) Ingo Valgma, Lubjakivikillustiku toormaterjali kvaliteedi sõltuvus raimamistehnoloogiast, Tallinna Tehnikaülikool, Energeetikateaduskond, Mäeinstituut

2002 - 2006 TTÜ, Energeetikateaduskond, Mäeinstituut, bakalaureuse õppe, bakalaureuse kraad, 2006, (juh) Tõnis Kattel, Nabala lubjakivi maardla teise plokki hüdrogeoloogilised tingimused, Tallinna Tehnikaülikool, Energeetikateaduskond, Mäeinstituut

Teadustöö põhisuunad

4. Loodusteadused ja tehnika, 4.14. Tootmistehnika ja tootmisjuhtimine (T340 Kaevandamine/mäendus)

4.2. Maateadused(P430 Maavarad, P470 Hüdrogeoloogia, geoplaneering ja ehitusgeoloogia, T250 Maastikukujundus, T270 Keskkonnatehnoloogia, reostuskontroll)

4.17. Energeetikaalased uuringud, T140 Energeetika (jätkusuutlikkus, jäätkusuutlik areng)

Jooksvad projektid

Täitmine ja jääkide (jäätmete) haldamine Eesti põlevkivitööstuses
Põlevkivi kadudeta ja keskkonnasäästlik kaevandamine

CURRICULUM VITAE

Name: Julija Šommet
Date of birth: 24 August 1983
Citizenship: Estonia
E-mail: ohutu.tk@gmail.com

Education history
I earned my degree of Master of Science in Geotechnology from Tallinn University of Technology in Estonia, at June 2009. In September 2009, I started to work on my doctoral thesis "Sustainable Development in Estonian Mining Industry" which consists of a unique sustainability evaluation system. A Module Risk Analyse is applied to measure the mining influence on the scope activities. It is a convenient and quick analysis, which helps to find optimum decisions for existing problems in different mining stages. This analysis is easily compared and has an analogy with the Safety Risks estimation.

Theses at Tallinn University of Technology:

- **2006 – 2009**: M.Sc. Geotechnology „ Influence of rock extraction technology on the quality of mined limestone", supervisor professor Ingo Valgma

- **2002 – 2006**: B.Sc. Geotechnology „Hydro – geological conditions of the Nabala second block limestone deposit", supervisor Tõnis Kattel

Career objective
I spent six years participating in grant projects and programs in mining engineering research and teaching in Tallinn University of Technology, Department of Mining. I also work at a Mining Company as a Quality Manager and Safety Expert and I am a board member at the Risk Assessment and Sustainability Centre in Tallinn; combining my work with my PhD studies at the University Mining Department. Since 2008, I have actively participated in international conferences with oral presentations on the results of this research and have also written journal articles and conference proceedings.

Language competence
English language   fluent
Estonian language   fluent
Russian language   mother tongue

Experience Details and Professional Employment:

2011 – to present, job title: Board Member
Employer: Risk Assessment and Sustainability Centre (Ohutu TK Ltd), Estonia
2006 – to present, job title: Quality Manager and Laboratory Technician
Employer: Limestone and Dolostone Mining Company (Väo Paas Ltd), Estonia
2007 – to present, job title: Safety Risk Expert
Employer: Limestone and Dolostone Mining Company (Väo Paas Ltd), Estonia

2009 – 2013, job title: Teaching Assistant at Tallinn University of Technology, Department of Mining, Estonia

Scientific Work
Honours & Awards
- In July 2012, as PhD student; Award for the Best Presenter in Mining session in 12th International Symposium, in Kuressaare town at the conference "Topical Problems In The Field Of Electrical And Power Engineering"

Publications

1.1. - 1 publication

Šommet, J. (2013). Sustainability assessement of Estonian oil shale mining. Oil Shale, 30(2S), 363 - 370.

1.2. - 4 publications

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5.2. - 1 publications

Pastarus, J-R.; Sõstra, Ü.; Valgma, I.; Väizene, V.; Väli, E.; Tohver, T.; Šommet, J. (2013). Prospects for application of waste rock aggregates as filling

material in Estonian underground mines. International Oil Shale Symposium Tallinn, Estonia, 10.-13.06.2013 (35 - 36). Tallinn: Enefit

SKILLS
- Production Quality Control and Management
- Occupational Risk Assessment and Safety Manuals composing
- Oral Presentations, Writing Articles and Teaching Assistant

Current research topics

4. Natural Sciences and Engineering, 4.14. Industrial Engineering and Management(T340 Mining)

4. Natural Sciences and Engineering, 4.2. Geosciences (P430 Mineral deposits, economic geology, P470 Hydrogeology, geographical and geological engineering, T250 Landscape design, T270 Environmental technology, pollution control, T340 Mining)

4. Natural Sciences and Engineering, 4.17. Energetic Research, T140 Energy research: Sustainability, Sustainable Development

Other research projects

Backfilling and waste management in Estonian oil shale industry

Sustainable and environmentally acceptable Oil shale mining

APPENDIXES

| PAPER I | Šommet, J.; Pastarus, J.-R (2012). Comparison of Dolostone and Limestone Assessment Methods for Estonian Deposits. The 1st Congress of World Engineers and Riga Polytechnical Institute / RTU Alumni, 35-39 |

Comparison of Dolostone and Limestone Assessment Methods for Estonian Deposits

Julija Sommet[1], Juri - Rivaldo Pastarus[2], [1]*Department of Mining TUT, Tallinn University of Technology; Sustainability and Risk Assessment Center, OÜ OHUTU TK*, [2]*Department of Mining TUT, Tallinn University of Technology*

Abstract – **The goal of this study was to elaborate a methodology of sustainability assessment for developing advanced mining technologies. Last year sustainability assessment methods were conducted for Estonian deposits of dolostone and limestone. The elaborated sustainability assessment methods have shown that a three - level risk matrix monitoring scale gives a structured analysis results. The paper introduces with comparison of new Module Analysis (three - level risk matrix) and earlier used Module Analysis (simplest risk scale).**

Keywords – **Sustainability Assessment Method, Module Analyze, carbonate aggregates**

I. INTRODUCTION

The mining industries worldwide are changing their mining practices by developing and implementing a variety of technologies and mining methods compatible with the principles of sustainable development. Adoption of the principles of sustainable development by the mining industry comes at a cost and requires major changes to current mining practices. Relating the different approaches to sustainable development across disciplines and against the background of the conceptual framework allows us to appraise their relative potentials and limitations. [1]

This paper deals with the introduction and comparison of sustainable assessment method for Estonian dolostone and limestone mining's. The sustainable method was developed for Estonian deposits last year for a mining company OÜ Väo Paas. In this case, a module analyze is in use to measure and compare different parameters. For the limestone parameters gradation a three-level risk matrix scale was used from the British Standard BS 8800 „Occupational health and safety management systems"[1] and for the dolostone a simple scale (simply using periodic numbers) was used, where a zero point "0" was included and five "5" point was the maximum measurement. Two different parameter scales have been used to compare limestone and dolostone to find out which one is more convenient.

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[1] Written with the help of industry, safety practitioners and the Health and Safety Executive (HSE), this British Standard will help organizations develop a framework for managing OH&S so employees and others, whose health and safety might be affected by the organization's activities, are adequately protected. The guidelines in BS 8800:2004 are based on general principles of good management and are designed to enable the integration of OH&S management within an overall management system. [7]

The aim of the work was to evaluate the practical output of mining companies' competitiveness in Estonia on the basis of the consumer's wishes and needs, because sustainability depends at least on the environment, socio-cultural parameters and also on the technological level. This paper will also give a more convenient method for the gradation and sustainable assessment analysis of non-metallic aggregates developed on Estonian deposits.

Reference [2] shows that, since sustainable development became the catchword in international discussions, several approaches to sustainability assessment have been developed. In order to measure or predict the sustainability of a land use system or a society, one must consider the inherent problems of analysis and its complex systems. Appropriate scales and time horizons must be chosen; the preconditions and requirements for operationalization and quantification of sustainability must be defined; and the philosophy and value system behind this concept and its translation into policies must be made explicit. On the other hand, the ethical and political convictions behind the multitude of policy recommendations made under the umbrella of sustainable development often remain obscure. There is a need to develop criteria that can be used to indicate to what degree strategies and policies contribute to sustainable development.

II. THE METHODOLOGY OF ANALYSIS

To organize an optimal analysis for both deposits it was proposed to use a module analyze table with a matrix of influence risks values, where the final product was considered as a process and divided to four main parts: economic, environmental, technical feasibility and social – cultural.

Economic viability demonstrates if the company's well being is at a maximum; is it possible to ensure efficient use of all resources, natural and otherwise, by maximizing or minimizing economical rents; help to seek or identify and internalize environmental and social costs; maintain and enhance the conditions for viable enterprise, ensure a fair distribution of the costs and benefits of development. [1]

The environmental quality part contributes in preventing undesired collapses and hazards related to them, emissions to atmosphere and aquifer. Conditions for sustainable mining in densely populated regions allows transforming large areas of mined areas to suitable farmland or building areas. Mine–water could be used for drinking water after self–cleaning. Mine closure is the period of time when the extracting activities of a mine have ceased, and final decommissioning

and mine reclamation are being completed. It is generally associated with reduced employment levels, which can have a significant negative impact on local economies. It is also the period when the majority of mine reclamation is completed, making the land safe and useful again. [1]

Technical feasibility and the technological scheme depend on extraction methods. For this reason, there is a great variety of possible combinations of processes in the excavation field. For carbonate rock materials, the analysis table is given below (at Table II and Table III). [4]

Socio–cultural well–being includes respect and a reinforcement of the fundamental rights of human beings, including civil and political liberties, cultural autonomy, social and economic freedoms, and personal security. Any company should seek to sustain improvements over time; ensure that the depletion of natural resources will not deprive future generations through the replacement with other forms of capital. [1]

A specific large–scale monitoring tool and indicators were developed in order to access each branch of mining, because on a small–scale this is not very effective and illustrative; it does not include the technical indicators part, which is important.

For the analysis of dolostone mining aspects, were used a 5-point scale including the zero point value ("0" – very minimal or no impact, "1" – minimal impact, "2" – medium impact, "3" – considerable impact, "4" – very important impact and "5" – no positive outcome activity, impact is gross). [3]

A different scale was used for limestone mining: three-level risk matrix scale (descriptions are shown at the Table I), where minimal risk level is "1" point and point "5" means that risk is very high. Risk evaluation on Table I is based on the British Standard BS 8800 „Occupational health and safety management systems" and it means that a non-existent risk (I) is minimal risk and can be ignored, but it is necessary to ensure that this remains stable in the future; very low risk is insufficient risk (II) - not necessarily to apply measures, aim is to find a better solution that does not create additional expenses; acceptable risk (III) - necessary measures should be taken to reduce risks, such as staff informing about risks, situation analyze and applying additional supporting measurements; acceptable risk with monitoring (IV) - immediately steps should be taken to reduce the risk, increasing staff awareness of risk level, training on measures to reduce this risk; unwarranted risk – very high risk, shows that measures to eliminate this risk must be implemented swiftly to remedy the situation. [7] For example, the environmental parameters module in Table II shows unwarranted risk for volume of unused material/risk of exhaustion, because it was left only 325 m^3 to excavate of a total amount of 3049 m^3. Validity of extraction permission risk is also unwarranted considering that it was left only one month for permission and new permission was not available yet.

Both analyses are based on general characteristics of carbonate rock mining. The new methodology has an analogy with the Safety Risk Assessment Method by its evaluation

system. Nevertheless both analyses are easy to compare and as the fact have an analogy with the workplace safety risks estimation, life cycle assessment (LCA) or the nowadays-popularized environmental EMAS Easy[2] system by its sets of measured components. It is recommended to make analyze at least once every three months. If company is larger than micro company (<10) in accordance to the number of employees by EU Commission Regulation No 70/2001, than it is advised to divide the analysis of the business by several branches. These module analyze tables (Table I and Table II) were composed in the Excel program. For more information see an overview of dolostone analyze Table II below and Table III of limestone analyze.

Analyze should provide a qualified image for the end user and company owners. One of two modules analyze table systems should work better than the other and provide more accurate data. For both analyzes all economical indicators data was real and taken from the accounting records program; summarized income statements and evaluations percentage shown for 1 worker of the total income of Väo Paas OÜ mining company Kareda dolostone deposit and Tondi – Väo limestone mining branch over October, 2011. The economical indicators contain a part of the balance of the mining remnant stock and analyze data of unused material, its volume which shows a risk of mining exhaustion, and a numerical overview of trading income and operating expenses. In assessing the summarized incoming risk, the V. Pareto principle 80/20 was taken as a basis.

TABLE I

RISKS DESCRIPTIONS

The Effects of Consequences			
INJURY	INSUFFICIENT	DANGEROUS OR HARMFUL	VERY INSECURE
UNLIKELY	NON-EXISTENT RISK (I)	INSUFFICIENT RISK (II)	ACCEPTABLE RISK (III)
LIKELY	INSUFFICIENT RISK (II)	ACCEPTABLE RISK (III)	ACCEPTABLE RISK WITH MONITORING (IV)
VERY LIKELY	ACCEPTABLE RISK (III)	ACCEPTABLE RISK WITH MONITORING (IV)	UNWARRANTED RISK (V)

The 80/20 Rule means that in anything a few (20 percent) are vital and many (80 percent) are trivial. The Pareto's "principle, the 80/20 Rule, should serve as a daily reminder to focus 80 percent of your time and energy on 20 percent of your work that is really important". [8]

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[2] Interest in the environmental performance of organisations is continually increasing. Operating without taking into account the environmental consequences of their actions becomes almost impossible for organisations. Organisations with a proactive approach to environmental challenges look for ways to continually improve their environmental performance. EMAS is the premium environmental management tool to achieve this. It leads to enhanced performance, credibility and transparency of registered organisations. Currently, more than 4,500 organisations and approximately 7,800 sites are EMAS registered. [6]

For example Table II below, shows summarized trading income for whole company or for certain deposit, different operating expenses and activity profit or loss. All data should be real and it is easy to follow by accounting records program. Total values are shown in Euro. The deposit–branch economical parameters depend on total economic aspects of the company. If employees' percentage in branch is 15 %, it means that other parameters in the overview table should not be less than 15, in other case the risk is critical for the filial and production should be suspended. [3]

TABLE II
OVERVIEW OF INDICATORS USED IN THE DOLOSTONE MODULE ANALYZE

Economical Indicators	Risk Level	Kareda Branch, %
Summarized Trading Income	2	19,7
Operating Expenses		
* Goods, Commodities, Aggregate, Service	2	20,9
* Office Miscellaneous Operating Expenses	1	17,9
* Labor costs	1	9,7
Employees	0	15,4
Depreciation	4	29,2
Economical Activity Profit/Loss	3	23,2
Presence of competitors within 50 km	4	
Total risk is less than the average	2	
Environmental indicators		
Petroleum content in the water	0	
Suspended soils in water	0	
Dust contamination in the air	0	
Noise level	0	
Vibration level	0	
Water pumping influence	0	
Energy cost	1	
Average petroleum use	5	
Volume of unused material/risk of exhaustion	0	
Soil contamination	1	
Max annual rate, thousands m^3	3	
Mining allotment area, ha	2	
Mining clime area, ha	2	
Residues /wastes	1	
Chemicals in use	2	
Mining closure project	5	
Validity of extraction permission	0	
Existence of new extraction permission	5	
Total risk is less than the average*	2	
Technical indicators		
Average Technical Durability	5	
Endure seasonal effects	5	
Flexibility/adaptability of techniques	3	
Frequently maintenance	4	
Reliability/security	1	
Total risk is more than the average, supporting measures should be taken**	4	
Social–cultural indicators		
Awareness/participation in tenders	0	
Competence/information requirements	0	
Web activity	0	
Quality requirements	0	
Work Safety Manuals	0	
Labor accidents	1	
Work Safety Risk Assessment	0	
Reclamations	0	
Total risk is minimal	0	

* average means the value of 2,5
* *too many techniques for such amount of labor/unused techniques
** techniques needs to be upgraded or replaced by new one to avoid maintenance [3]

In order to develop the sustainable analyze, the environmental annual reports of both branches were used to describe the environmental indicators part. Validity of extraction permission should be compatible with overview data time. Some new environmental indicators were added to limestone analyze, such as the existence of an Environmental Management Handbook, where the environmental aspects, goals, missions, actions and needs to protect and improve environmental conditions in and around the facilities are clearly demonstrated. In case if the Handbook does not exist, the risk is very high ("5" points), when the Handbook is completed and approved by the company board member, then the risk is minimal ("1" point); in other cases the risk level varies according to the stage of the draft handbook. For this limestone deposit analyze risk point value was measured like point "3", because ecological mapping was done, responsible personnel was trained, but Handbook confirmation of the finalization remained not completed. At this time in Estonia, the existence of a handbook in not strictly required, but rather recommended by the standards. Point "3" means that risk is acceptable, but some additional activities are recommended to improve the average sustainability of the mining company.

All parameters at the modules of Tables II and III are considered and associated to each indicator by the local Estonian normative or legislations regulations and law, most of them are based on European Union standards (at least 39 normative: Mining Law, Water Statute, Waste Statute, Waste Oil Management Requirements, Municipal Waste Sorting Procedures, Fire Safety Requirements, Occupational Health and Safety Acts, etc).

In the limestone sustainability assessment, the socio-cultural indicators pertaining to awareness and participating in tenders were divided into two separate parts. These two components are important, because they provide an effective promotion for the company and help the company to become widely known among local residents. The next new significant indicator is the labor middle age, which was calculated by the average value for all company employees (the overall number of employees at the time analyze was made was 41 persons); the nearest approximate quantity was 50. According to Estonian requirements, the Work Safety Risk Assessment should be archived 55 years since its first measurement, mostly because of the workers average life expectancy. Being that the middle labor age of workers were 50, risk was estimated like acceptable upon condition of an annual health check monitoring at the expense of the corporation.

Another indicator, like participation in tenders shows how felicitously company can sell their goods and how successfully they use an opportunity offered by the state or other local companies. In that case risk point "5" could mean absolute inaction.

The expected result of this study was to explore a better type of analyzing methodology for sustainable assessment in mining management. In case the total risk of an analyze is valid or more than the average (if point "5" was estimated as maximum, then "2,5" point will be average), then supporting measures should be taken in these area of the company's activity. The sustainable assessment develop the scientific output of the optimal activity analyze, to ensure the practical

output of the company's competitiveness in Estonia on the basis of the consumer's wishes and needs and to provide an optimal assessment of the capacities of different groups based on the company needs. The urgency of the research consists in management efficiency in the current market conditions. It is necessary requirement of the activity improvement and company development for competitive advantages. For more accurate data research should be continued. [3]

TABLE III

Overview of Indicators Used in the Limestone Module Analyze

Economical indicators	Risk level	Filial branch %	For 1 person %
Summarized Trading Income	1	53,0	100
Operating Expenses			
* Goods, Commodities, Aggregate, Service	3	42,6	33
* Office miscellaneous operating expenses	1	30,2	2
* Labor costs	2	35,7	16
Labor persons	-		-
Depreciation	4	58,7	15
Economical Activity Profit/Loss	2	83,0	28
The presence risk of competitors within 50 km	3		
Total risk is low	2		
Environmental indicators			
Petroleum content in the water	1		
Suspended soils in water	1		
Dust contamination in the air	2		
Noise level	2		
Vibration level	2		
Water pumping to the aquifer	2		
Energy cost for this branch	3		
Average petroleum use	2		
Volume of unused material/risk of exhaustion	5		
Soil contamination	2		
Max annual rate, thousands m3	3		
Mining allotment area, ha	2		
Mining clime area, ha	2		
Residues /wastes	2		
Chemicals in use	1		
Mining closure project	3		
Validity of extraction permission	5		
Existence of new extraction permission	5		
Existence of Environmental management Handbook	3		
Total risk is valid	3		
Technical indicators			
Average Technical Durability	5		
Endure seasonal effects	2		
Flexibility/adaptability of techniques	3		
Frequently maintenance	4		
Reliability/security	1		
Total risk is more than the average	3		
Social–cultural indicators			
Awareness	2		
Participation in tenders	2		
Competence/information requirements	1		
Web activity	1		
Quality requirements	1		
Work Safety Manuals	1		
Labor accidents	2		
Labor average age	4		
Work Safety Risk Assessment	1		
Reclamations	1		
Total risk is minimal	2		

The methodologies for sustainability assessment will be used to determinate and elaborate the safety factors and parameters for mining advanced technology efficiency and for defining environmental impacts resulting from different mining processes. The sustainability assessment methods can be used for different purposes and at different levels: as a basis for decision-making when selecting among different remedial actions for a mined out area with time and financial constraints; to relate ground surface subsidence risk levels to acceptable risk levels established by the society for other activities. Particular attention will be paid to issues of current waste production and storage, old mining waste landfills, waste handling procedures, development of the framework for waste management. [5]

III. CONCLUSION

The limestone and dolostone are most expressive examples of the analysis, which show that it can be applied to other carbonate rock mining. Two different parameter scales have been used to compare limestone and dolostone to find out which one is more convenient. The elaborated sustainability assessment methods have shown that a three-level risk matrix monitoring scale gives more structured analyze results and it is recommended to use British Standard BS 8800 for the aspects gradation. The sustainability assessment methods can be used for different purposes and at different levels, such as a basis for decision–making when selecting among different remedial actions for a mined out area with time and financial constraints.

For successful development of a company in the long–term, the detailed recognition of external and internal factors affecting the company's development is required: dynamics of demand of consumers, formations of corporate culture and negotiation of weak aspects by optimal and effective use of internal resources, in particular. [3]

To carry through the final study of sustainable assessment Module Analyze determinations and measurements of impacts should be made for all Estonian carbonate deposits for developing an overall assessment of the sustainability measurement scale. The next step in this research is the sustainable analysis of Estonian oil shale. The real limitation of both the analyses conducted is the considerable amount of time which is needed for the analyses process. To make the analysis easier and to save time in the future, a Module Analyzing computer program should be prepared with the three-level risk matrix scale, which will make it possible to analyze the data more quickly. The research shows that the three - level risk matrix scale provides more accurate data analysis and it could be used for all aggregates. The final step of this research and the main aim to continue will be the estimation and rating of a company's sustainability status and recommendations for improvements, if necessary.

In the event that monthly reports are used for the analysis, then it is recommended to make analyze at least once every three months, but in this case the results have a dependency on the seasons. To avoid such inaccuracy, alternatively one can

use bi-annual summary data reports, which allow carrying out the analysis infrequently and facilitates the application of the module analysis.

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Julia Shommet earned at Tallinn University of Technology Mining Department a B.Sc. Geotechnology at 2006, also M.Sc. Geotechnology degree in 2009 and now is taking third year of PhD study. Supervisor is Jüri-Rivaldo Pastarus and co-supervisor is Sergei Sabanov.
Is working for the OÜ Väo Paas company as the Quality Manager, Laboratory Technician at the testing laboratory and as a Safety Risk Expert as well as compiling all necessary documentation. Has substantial experience in all areas of macadam testing, risk safety manuals composing and safety risk assessment scheduling for Estonian Standards and requirements. Experience on this activity's is almost six years. Participating in teaching last two and a half years at Tallinn University of Technology Mining Department with the courses for bachelor students in Estonian language: Rock Mechanics, Rock Breaking and Processing, Marine Geotechnics and Elements of Engineering Geology.
E-mail: ohutu.tk@gmail.com

Juri - Rivaldo Pastarus has earned a Doctor's Degree in 1996 with the research "Large cavern stability in the Maardu granite deposit" at Tallinn University of Technology. Since 1985 and till present is Associate Professor of Tallinn University of Technology, Faculty of Power Engineering, Department of Mining, Chair of Mining Engineering. He is a member of Estonian Mining Society (EMS) and Head of Rock Mechanics Section; also member of World Business University Association (WBUA); Member of International Organizing Committee of International Conference "Environment. Technology. Resources."; Member of International Organizing Committee of International Symposium "Mine Planning and Equipment Selection" (MPES); Member of International Organizing Committee of International Symposium "Environmental Issues and Waste Management in Energy and Mineral Production" (SWEMP); since 2007 till present he is a Member of Educational Committee of Society of Mining Professors (SOMP); and also in other organizations.
E-mail: pastarus@cc.ttu.ee

PAPER II

Šommet, J.; Pastarus, J.-R. (2011). Характер разрушения закладочных массивов. Проблемы Недропользования. Санкт-Петербургский Государственный Горный Инс, 191, 189 - 190.

Шоммет Юлия Александровна, Пастарус Юри-Ривалдо Валдекович
Таллиннский Технический Университет, Кафедра горного дела. Эстония
Эхитаяте тее 5, Таллинн, 19086, Эстония

Характер разрушения закладочных массивов

Эстонская сланцевая промышленность является одним из ведущих отраслей в Эстонии. 95 % электроэнергии получают из горючего сланца. В настоящее время при подземных работах применяется камерная система разработки с буро-взрывными работами. Технологический процесс эффективен, но связан с большими проблемами, в том числе и с экологическими. При этом потери в целиках составляют примерно 30-40%. С другой стороны образуется много отходов обогатительных фабрик (известняк) и зола ТЕЦ. Они могут быть использованы в качестве закладки при подземных работах, а также в дорожном строительстве. При использовании отходов для закладки требуется исследовать характер разрушения закладочного массива, что определяет прочность массива.

При первичном подходе можно опираться на теорию прочности бетона при определении прочности закладочных материалов. При этом большой интерес представляет структурная теория прочности бетона. Экспериментами установлено, что
- Использование бетона с гравием (округлые частицы и зёрна) даёт меньшую прочность, чем бетон с щебнем (остроугольные частицы и зёрна)
- Определённый подбор зёрен по крупности повышает прочность бетона
- Высокая прочность заполнителей не оказывает влияния на прочность бетона
- Пониженная прочность заполнителей до некоторого предела даёт заметное снижение прочности бетона

Расчётным путём проф. Б.Г. Скрамтаев доказал, что при шарообразных заполнителях прочность бетона увеличивается в 1,1 раз, при наличии остроугольных заполнителей в 1,41 раза. Ступенчатая поверхность сдвига увеличивается при наличии остроугольных заполнителей, тем самым увеличивается прочность бетона. При этом крупность зёрен практически не играет роли, так как при увеличении или уменьшении диаметра зёрен ступенчатая поверхность остаётся постоянной. В.А. Черник, А.Л. Удовский и др. также в своих работах рассматривали вопросы о влиянии на прочность закладочного массива разных заполнителей.

Аналогичные исследования проведены в работах Ю.В. Пастаруса в условиях графитных месторождений, результаты которых приведены на рисунке 1.
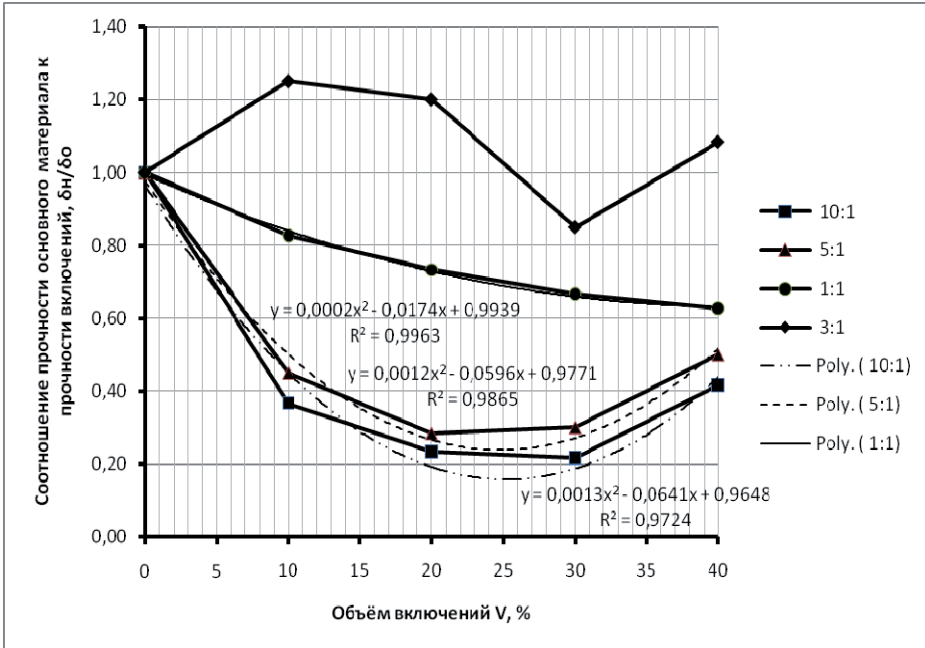

Рисунок 1. Зависимость прочности модели от количества включений при d/L=0,04.

Рассмотрим влияния включений на прочность неоднородного материала от процентного содержания включений. Исследования показали, что прочность неоднородного материала уменьшается, если объём включения менее 20-30%. Это объясняется концентрацией напряжений вокруг включений и разрушением материала в этой зоне. Если содержание больше 20-30%, то прочность материала увеличивается за счёт взаимного влияния включений. Плоскость сдвига при этом приобретает волнообразную поверхность. Если соотношение прочности основных материалов к прочности включения 3:1, то зависимость отличается от вышеуказанного. При содержании включений до 13-15% несущая способность неоднородного целика увеличивается примерно в 1,3 раза. Это явление связано с модулями упругости используемых материалов. С увеличением содержания включений от 15 до 28% уменьшается несущая способность модели неоднородных целиков. Дальнейшее увеличение содержания включений с 28% и более вновь увеличивает несущую способность целиков. Такое поведение требует дальнейших исследований.

Вторым важным фактором является соотношение прочностных свойств включений и основного материала. С увеличением прочности включений, несущая способность неоднородного образца уменьшается, что связано с концентрацией напряжений вокруг включений.

Третьим важным фактором является крупность включений. При увеличении крупности включений, прочность неоднородного материала увеличивается, но незначительно. Это соответствует результатам исследований проф. Б.Г. Скрамтаева.

В Таллиннском Техническом Университете были проведены лабораторные исследования прочности образцов из золы ТЕЦ и известняка. Прочность известняка колеблется в пределах от 50 до 80 МПа. Прочность золы пока точно не определена. По предварительным данным её прочность на сжатие менее 20 МПа. При этом зола имеет связывающий эффект и действует, как цементирующий материал. Результаты исследований преведены в таблице 1.

Таблица 1. Результаты лабораторных исследований.

Вид золы	Зола, %	Щебень, %	Прочность на сжатие, МПа
Зола блоков кипящего слоя сжигания	75	25	7,9
Зола блоков кипящего слоя сжигания	50	50	5,2
Зола блоков пылевидного сжигания	75	25	2,2
Зола блоков пылевидного сжигания	50	50	2,4

Исследования показали, что прочность бетона зависит от типа золы и её процентного содержания. Рекомендуется использовать золу из блоков кипящего слоя сжигания, так как это даёт большую прочность образцов. Это связано с процентным содержанием извести в золе, что увеличивает прочность бетона. Опыт использования этой смеси в реальных условиях пока отсутствует.

Данные результаты в общем виде подтверждаются вышеперечисленными данными. При этом надо учитывать необходимость дополнительных исследований в будущем.
Вышеуказанное исследование даёт исходные данные для проектирования закладного массива.
В заключение можно сказать, что теоретические исследования показали, что прочность закладочного массива зависит от упругих и прочностных свойств их компонентов. Кроме этого, большое значение имеет процентное содержание известняка. Крупность зёрен известняка имеет незначительное влияние на прочность закладочного массива. На основе лабораторных

исследований показано, что прочность образцов закладочного массива зависит от типа золы ТЕЦ. Процесс разрушения закладочного массива сложен и требует дальнейших исследований.

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АНАЛИЗ КАЧЕСТВА ИЗВЕСТНЯКОВОГО ЩЕБНЯ ПРИ РАЗЛИЧНЫХ МЕТОДАХ РАЗРАБОТКИ В УСЛОВИЯХ УСТОЙЧИВОГО РАЗВИТИЯ ГОРНОДОБЫВАЮЩИХ ПРЕДПРИЯТИЙ

Шоммет Юлия Александровна, Сабанов Сергей Михайлович, Пастарус Юрий Валдекович. Таллиннский Технический Университет, Горный институт. Эстония

Введение

Известняк широко добывается в Эстонии и используется в качестве строительного материала для производства бетона, заполнения в дорожном строительстве и для наполнения на строительных площадках. В зависимости от месторождения изменяются физико-механические свойства пород. Известняк добывают в основном с помощью буро-взрывных работ или механизированных средств. Наиболее важная задача производителя заключается в обеспечении последовательного высококачественного процесса производства, который, в свою очередь гарантирует конечный продукт отвечающий основным требованиям стандартов. Горнодобывающий сектор сталкивается с проблемами увеличения производства без технологических остатков и сведения к минимуму воздействия на окружающую среду горного производства.

Целью данного исследования является сравнение производства щебня и качество готового материала известняка, полученных разными методами добычи и в различных горно-геологических условиях (например, взрывные работы и фрез Vermeer Terrain-Leveler T1255 в Тонди-Вяо карьере, а также фрез Wirtgen 2500SM в Ида-Вирумаа, разрез Кивиыли на добыче известняка и горючего сланца).

Показатели качества полученного щебня провереного различными лабораторными испытаниями варьируются. Все показатели проверяются по европейским стандартам (European Norms-EN), что позволяет сравнивать результаты тестов из различных условий.

В процессе этой работы было сравнено качество готового щебня, который добывается буро-взрывним способом и при помощи фрезерных комбайнов.

Результаты лабораторных тестов

Все тесты были проведены в лаборатории предприятия «OÜ Väo Paas», где каждая фракция щебня была испытана по следующим параметрам: определение частиц по размеру просеиванием согласно EVS-EN 933-1, чистота содержания f (0,063 мм) по EVS-EN 933-1, определение формы частиц-индекс лещадности FI по EVS-EN 933-3 и индекс формы по EVS-EN 933-4, определение устойчивости к фрагментации методом Los Angeles (LA) по EVS -EN 1097-2. Колебания насыпной плотности по EVS-EN 1097-3 для щебня были минимальны.[2]

Результаты испытаний представлены в таблице 1.

Фракция, мм	Взорванный и дроблёный	Размолотый Vermeer-ом и дроблёный	Взорванный и дроблёный, среднее значение с '04-'09	Взорванный и дроблёный	Размолотый Vermeer-ом и дроблёный	Взорванный и дроблёный, среднее значение с '04-'09	Взорванный и дроблёный	Размолотый Vermeer-ом и дроблёный	Взорванный и дроблёный, среднее значение с '04-'09	Взорванный и дроблёный	Размолотый Vermeer-ом	Размолотый Wirtgen-ом
	0-4	0-4	0-4	4-16	4-16	4-16	16-32	16-32	16-32	0-45	не фракци-онирован-ные	
Содержание мелких частиц, f%	6,7	9,3	13,9	1,1	0,7	1,1	0,6	0,5	0,6	2,5	0,7	4,7
Коэффициент LosAngeles, LA	NR	NR	NR*	27	24	25	-	-	31	30	≤34	≤30
Коэффициент пластичнности, FI	NR	NR	NR	11	13	14	9	9	8	17	41	≤20
Сопротивление замораживанию и оттаиванию в воде F, %	NR	NR	NR	1,4	-	1,3	0,6	-	0,9	1,9	-	≤4

Таблица 1. Физико-механические свойства испытанных агрегатов (*NR-не предусмотрено).

Результаты испытаний

Большое преимущество фреза- способность производить фракционированный щебень с низким коэффициентом LA и низким содержанием мелких частиц, в случае извлекания материала с высокой прочностью на сжатие. Но полученный материал не подходит для использования в качестве нефракционного щебня, поскольку формы частиц слишком продолговатые и плоские-увеличивается индекс лещадности. Это видно даже визуально, а также по результатам испытаний. Хотя другие параметры удовлетворяют требования к качеству, необходимо додробить сырьё для достижения приемлемого индекса лещадности. В противном случае материал не может быть использован в строительстве, поскольку это даёт большую усадку готовых конструкций (дорог или зданий).

Сравнение методов

Исследование было основано на идее, что каждый дополнительный метод дробления изменяет свойства материала, чем больше прошёл он этапов дробления, тем меньше остается трещин и зерно становится все меньше, морозостойкость и коэффициент LA улучшаются (таблица 1). Таким образом, свойства агрегатов улучшаются при дополнительных процессах измельчения - фрезеровании или вращении 1000 раз на испытательной машине (таблица 1. Vermeer значение средних и 0/45). Кроме того, крупные фракции имеют меньшее содержания мелких частиц, индекс лещадности FI значительно понижается, когда материал становится крупнее-это показывает последствия воздействия. Это позволяет значительно уменьшить количество технологических остатков, улучшив качество готового продукта. Сопротивление замораживанию и оттаиванию в воде больше зависит от прочности на сжатие и образа дробления, чем от вида извлечения.

Преимущества и перспективы используемых технологий

Лабораторные испытания показали, что качество зависит от методов получения сырья, и в некоторых случаях оно существенно меняется.

Взрывные работы могут вызывать трещиноватость и расслоенность материала. Это можно избежать путем точного расчета количества взрывчатых веществ, в этом случае влияние на качество конечного продукта легко поправимо правильным подбором сит и мощности рабочего режима. Кроме того, важным преимуществом взрывных работ является доступная цена.

Недостатком фрезового материала является непригодность для использования в строительстве без дополнительного дробления, т.к. материал даёт большую усадку готовых конструкций (дорог или зданий).[1] Кроме того, расходы при использовании фреза (лизинг, ремонт, необходимое дополнительное измельчение), являются слишком высокими, и по-этому более подходит использование взрывных работ.

Недостаток использования фреза при добыче в условиях с низким пределом прочности на сжатие-сравнительно высокое образование мелких частиц, что в свою очередь увеличивает образование технологических отходов (см. таблицу 1 результаты теста Wirtgen). В этом случае содержание более чем 3% мелких частиц требует еженедельного контроля концентрации метиленового синего вещества по EVS-EN 933-9. Тем не менее, путем корректировки размеров сит и дробилок могут быть устранены перечисленные недостатки. Данный вид продукции, безусловно, требует непрерывного, по крайней мере раз в неделю, мониторинга, контроля и испытаний.

Заключение

В ходе испытаний выяснилось, что для более твёрдых пород взрывные работы по-прежнему являются подходящим способом для получения сырьевого материала, позволяя получать максимально лучшее качество. Качество производимого сырья и щебня зависит от технологии производства, а также от свойств месторождения. Чем крупнее сырьё, тем лучше будет совокупность свойств, так как зерно становится меньше, только в последних стадия обработки.

Результаты испытаний показали, что каждые дополнительные средства обработки и эксплуатации сырья с высокой прочностью на сжатие улучшают качество по различным параметрам (лещадность и форма индекса, содержание мелких частиц, устойчивостью к дроблению LA). Параметры изменяются в соответствии с методами разработки и уменьшают образование технологических отходов.

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SUSTAINABILITY ASSESSMENT METHODS IN OIL SHALE MINE CLOSURE

Sergei Sabanov, Jyri-Rivaldo Pastarus, Julia Shommet
Tallinn University of Technology, Department of Mining
5 Ehitajate tee St, Tallinn, 19086, Estonia
e-mail: sergei.sabanov@ttu.ee, pastarus@cc.ttu.ee, julia.shommet@hotmail.com

Abstract. *The post mining processes impacts on the environment, economy and people, whilst there may be positive contributions to the economy and social progress through mining there may also are negative impacts to the environment. The aim of this study is to elaborate sustainability assessment methodologies suitable for mine closure life cycle stage which allows defining hazardous influences on environment, society and economic dimensions, and helps quickly, conveniently and qualitatively solve, operate, find optimum variants for existing problems. The sustainability assessment methods will provides best decisions on the technological and post technological processes of a mining industry and can be used in the exploration, planning, exploitation and closure stages*

Keywords: *sustainable mining, waste management, risk assessment.*

Introduction

The extraction of oil shale is a temporary land use. Once mining has finished the land can be 'recycled' or reused through restoration. In many cases, restoration involves returning the land to its original use. However, this is not always feasible. Through creative restoration planning, oil shale extraction offers the opportunity to improve the environment in and around mine sites or to create new land uses [1,2,3,4]. Various processes in oil shale mining industry often become dominating in the most dangerous post-technological process, which can pose a hazard to people, cause economic damage and environmental interventions. Providing of favourable conditions for oil shale mine closure in conformity with technological and ecological safety defines the necessity of elaboration the sustainability assessment methods. The reason is related to absence of suitable criteria, skills and methodology of using oil shale resources that is suitable for all parties. The aim of this study is to elaborate sustainability assessment methodologies suitable for mine closure life cycle stage which allows defining hazardous influences on environment, society and economic dimensions, and helps quickly, conveniently and qualitatively solve, operate, find optimum variants for existing problems and optimize usage of mineral resources. Important tasks are analysing a ground surface long-term stability

under usage backfill method and determination opportunities to economic of mining waste management.

Sustainability assessment methods
Sustainability assessment is a comprehensive, integrated and far-sighted approach to decision making. Its basic demand is that all significant undertakings must make a positive contribution to sustainability. The mining industries worldwide are changing their mining practices by developing and implementing a variety of technologies and mining methods are compatible with the principles of sustainable development. Adoption of the principles of sustainable development by the mining industry comes at a cost and requires major changes to current mining practices. Relating the different approaches to sustainability assessment across disciplines and against the background of the conceptual framework allows us to appraise their relative potentials and limitations. The constraints to scientific operationalisation of sustainability and to its translation into policy measures, which are revealed by this reference system, highlight the necessity for continued integrated systems research [1,2,3,4].

Closure planning is an activity that continues throughout the life of a mine, starting with conceptual closure plans prior to production, periodic updates throughout the life of the mine, and a final decommissioning plan. At most mines, progressive reclamation over the life of the mine is used to reduce the reclamation burden at closure.

Environmental Quality
The environmental impacts associated with oil shale preparation and productions are subsequently variable, as the mining methods used to extract oil shale by open and underground methods result in different environmental impacts [7]. The objective is to include all activities that usually take place around a mining site. In this study, the Life Cycle Assessment (LCA) tool is used to analyze and assess the environmental impact of oil shale mining. The inputs and outputs identified for all the technological chains of mines and open casts under investigation [7,8].
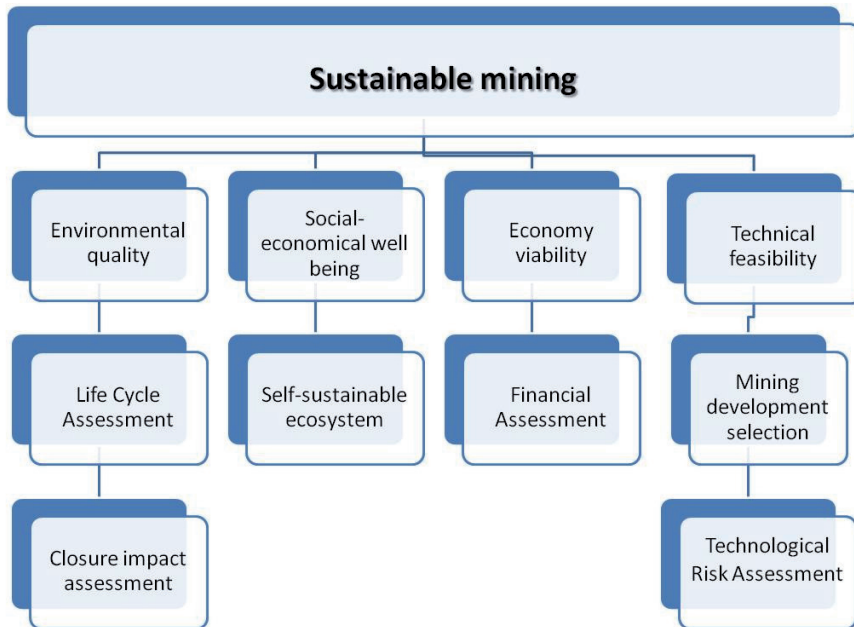
Fig.1. Sustainability assessment methods

This part contributes in preventing undesired collapses and hazards related to them, emission to atmosphere and aquifer. Conditions for sustainable mining in densely populated regions allows changing large areas of mined areas to suitable farmland or building areas. Mine-water could be used for drinking water after self-cleaning.

Economical viability
Economic sustainability is clearly identified information, integration, and participation as key building blocks to help countries achieve development that recognises these interdependent pillars. It emphasises that in sustainable development everyone is a user and provider of information. It stresses the need to change from old sector-centred ways of doing business to new approaches that involve cross-sectored co-ordination and the integration of environmental and social concerns into all development processes. Furthermore, broad public participation in decision making is a fundamental prerequisite for achieving sustainable development [1,4].

Maximize human well-being
• Ensure efficient use of all resources, natural and otherwise, by maximizing rents
• Seek to identify and internalize environmental and social costs

• Maintain and enhance the conditions for viable enterprise

Technical feasibility
Technical feasibility is one of the important parts of the sustainability assessment methods. Risk assessment techniques defined in its broadest sense, deals with the probability of any adverse event [6]. Various types of risk considered in the mine closure include the engineering risk, human health risk and ecological risk. Risk assessment is the process of deciding whether the existing risks are tolerable and risk control measures are adequate. It incorporates the phases of risk analysis and risk evaluation.

Mining includes separate stages of production with different destination and place of performance. The technological scheme characterizes processes and specifies the order of works performance in time, the mode of their carrying out and means of their realization. The technological scheme depends on extraction methods. For this reason, there is a great variety of possible combinations of processes in the excavation field [13,14].

Social-economical well-being
This part provides diminishes the risk of accidents and casualties in mining, low emissions technologies. Socio-efficiency describes the relation between a firm's value added and its social impact. Both eco-efficiency and socio-efficiency are concerned primarily with increasing economic sustainability. The business case alone will not be sufficient to realise sustainable development [2,3,4,13,14].

• Ensure a fair distribution of the costs and benefits of development for all those alive today.
• Respect and reinforce the fundamental rights of human beings, including civil and political liberties, cultural autonomy, social and economic freedoms, and personal security.
• Seek to sustain improvements over time; ensure that depletion of natural resources will not deprive future generations through replacement with other forms of capital.

The social upheaval and inequitable distribution of benefits and costs within communities can also create social tension. Ensuring that improved health and education or economic activity will endure after mines close requires a level of planning that has too often not been achieved. [1,3,11,12,14].
Mine closure is the period of time when the extracting activities of a mine have ceased, and final decommissioning and mine reclamation are being completed. It is generally associated with reduced employment levels, which can have a significant negative impact on local economies. It is also the period when the

majority of mine reclamation is completed, making the land safe and useful again.

The methodology techniques

Designing mine closure systems for surface and underground mines. Determining the elements for mine closure infrastructure. Integrating life-cycle models of oil shale and energy commodities to describe global geologic occurrences, genetic processes, present and future uses, recycling potential, possible substitutions, disposal strategies, and associated environmental effects. Investigation of bedrock hydrological and mineral-related elements, slope stability, soil formation, and sediment transport and deposition is aid in understanding the structure and function of natural ecosystems. Assessing geologic and geotechnical risks influencing on subsurface displacement and subsidence. Defining technogenic deformation processes by geotechnical monitoring. Identification of the opportunities to economic mining waste management.

Predicting the long-term stability behaviour of underground oil shale mines and the attenuation or degradation of rock wastes requires an improved understanding of the rheological processes controlling the changes of physical-mechanical properties. In backfill technologies past fill of underground goaf (using mixture of limestone rock and ash from power plant) are preferred. Effect of backfilling will serve for minimization of surface movement; improvement of safety in mining (high rock pressure, water outflow, etc.; facilitation of mining operations; increase of extraction ratio; binding mobile elements). The methodology helps revealing behaviour of backfill material in-situ conditions and definition physics-mechanical characteristics and rheological properties for various structures of backfill components. Risk estimation will be used for calculation probability of a ground surface subsidence and displacement. Particular attention must go to issues of waste production and storage, old mining waste landfills, waste handling procedures, entrepreneurship development and the legal framework for waste management. Environmental and social assessment tools should be combined to enable a transition to integrated impact assessment. This will be used for future projects consultation with the community to identify local concerns.

Conclusions

The sustainability assessment methods can be used for different purposes and at different levels: as a basis for decision-making when selecting among different remedial actions for a mined out area within time and financial restraints; to relate ground surface subsidence risk levels to acceptable risk levels established by the society for other activities, predicting the long-term hydrologic behaviour of aquifers and aquitards and the attenuation or degradation of toxic wastes, methodologies on management of mining wastes. The methods is able to give

opportunity to find better way for mine closure planning in according with environmental performances and socio-economical well-being.
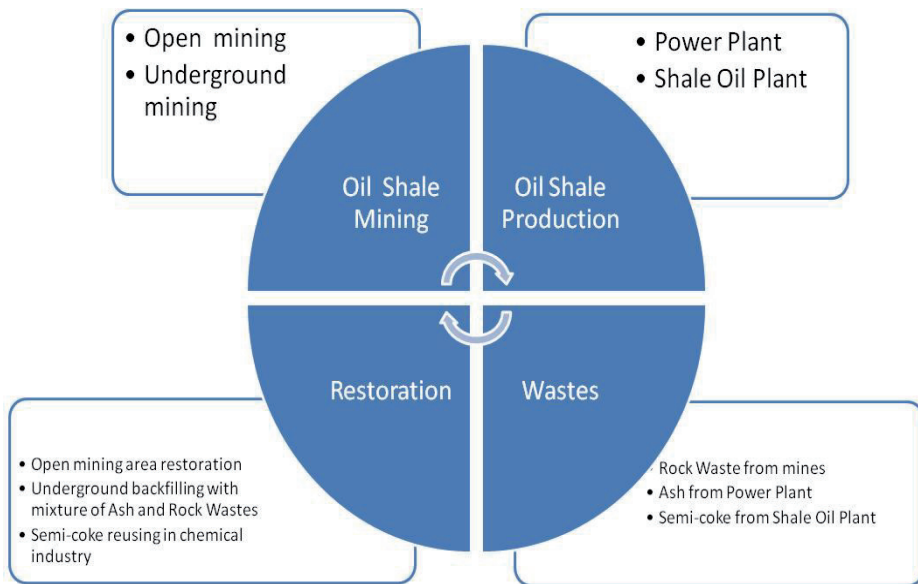

Fig. 2. Shale Life Cycle stages alternatives.

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Influence of extraction methods on the raw material physicomechanical properties of fillers

Julija Shommet

ABSTRACT: The paper deals with the assessment of limestone macadam quality in limestone mining sector in Estonia. It provides test results on various raw materials with different mining-geological conditions, and obtained by surface miners Wirtgen 2500SM, Vermeer Terrain-Leveler T1255 and blasting operations. The tests results have shown that every additional processing and operating of a raw material improves its quality by different parameters: flakiness and shape index, fines content, resistance to fragmentation by Los Angeles method and resistance to freezing and thawing. While many of the parametres improve, some parameters change for the worse.

INTRODUCTION

Limestone is extensively mined in Estonia for the use as a materials used for construction. Limestone aggregates are used for producing concrete, filling in road construction and for subsoil filling at construction sites. Limestone in Estionia is distributed widely and is considered as a national stone. They have variation in geological condition and rock mechanics properties (Lüütre et al. 1971). Limestone is mined generally from surface quarries by using mechanized means (i.e. surface miners) or explosion blast.

The aim of this research is to compare manufactured macadam quality and raw material property of the limestone obtained by different mining methods and in different mining-geological conditions (e.g., blasting in Tondi-Väo and cutting by Vermeer Terrain-Leveler T1255 in Tallinn Tondi-Väo limestone mining; surface miner Wirtgen 2500SM in Ida-Virumaa Kiviõli limestone and oil-shale mining). Quality of the limestone raw materials and macadam assessed by laboratory tests are varying and quite dependable the mining-geological conditions of the rocks.

All quality indicators are assigned by European Standards (EN), what allows to compare test results from different conditions (for more information see paragraph Existing tests).

Examined Mining Solutions
At this work process was compared a number of different limestone raw materials and manufactured macadam quality, which are extracted by three different methods. Short description and technology overview of minig machines and methods can be found in next paragraphs.

Surface miner Vermeer Terrain-Leveler T1255TL

A raw material was cut in Tondi-Väo limestone mining by innovative surface miner Vermeer Terrain Leveler T1255TL, which was complicated in America; it allows to penetrate the rock through the use of top down cutting.

Top down cutting is a technique that allows the cutter teeth to gain penetration without using the machine's tractive effort to drive the teeth into the rock. As the unit travels forward and the drum rotates, the teeth on top of the drum are advancing over the top of the rock surface. As the teeth come down toward the rock surface, they make contact by impacting the rock. The first benefit - more horsepower goes into cutting rock and less into movement of the machine.

The second benefit is material sizing. There are several factors that control product size, one of which is tooth penetration. Increased tooth penetration increases the material size and decreased tooth penetration reduces the material size. This can be done by changing the drum depth.

As the drum depth decreases, tractor speed increases resulting in deeper tooth penetration. As the drum depth increases, tractor speed decreases resulting in less tooth penetration. (Vermeer 2009).

Weight of the machine is 111,1 t (cutting depth 0 to 69 cm, cutting width 3.7 m, Caterpillar C18 ACERT Tier III diesel engine power of 447.4 kW or 600 hp). Productivity was tested for the Tondi-Väo geological conditions of the deposit in July and September 2007, at the average it was 350 tons per hour (4808.5 t of raw material mining time was 13 hours and 36 minutes). This surface miner has a trencher control TEC 2000.2, which allows regulate the working tilt and offers flexibility at the job.

The extracted limestone dry compressive strength was 85-142 MPa, wet compressive strength 80,0-140,0 MPa and resistance to freezing and thawing 50 cycles.

Surface Miner Wirtgen 2500SM

In some mining's in Estonia like Narva and Kiviõli is also used surface miner for selective extraction of limestone layers. High-throughput surface miner Wirtgen 2500 SM has 1000 horsepower to avoid dust and noise, as well as possible to dispense with blasting operations. The aim of use is not only selective mining of the rock material, but also the landscape design. Surface miner carries out three operations in the world at one time, it was complicated in Germany. Similarly, the Narva oil - shale opencast mining used for the modernization of Wirtgen surface miner to combine the work of a number of machines: cutters, dashes, and downloads. For Narva opencast conditions the material extraction productivity is 440 t / h by average, which is a very good indicator, in which certainly affects limestone layers relatively low compressive strength 40-80 MPa, in some cases up to 100 MPa. It can safely be assumed that the surface miner Vermeer Terrain Leveler could also work well in such minig - geological conditions.

Wirtgen surface miner is used for limestone mining in Narva opencast since January 2007 (Nikitin et al. 2007).

Blasting method
It is usual method to extract raw material for Tondi-Väo limestone deposit. Current technology service is purchased from a company which deals with blasting.A raw material was separated by blasting method with a large trace array network charges 3,0*3,0 m or 2,8*3,0 m.

Laboratory Tests
Existing tests
All aggregate tests were held in the company laboratory, where each macadam fraction and also raw material was tested by the following parameters: determination of particle size distribution by sieving method according to EVS-EN 933-1, purity - fines content (0,063 mm) according to EVS-EN 933-1, determination of particle shape - flakiness index according to EVS-EN 933-3 and shape index according to EVS-EN 933-4, determination of resistance to fragmentation by the Los Angeles test method according to EVS-EN 1097-2. Loose bulk density according to EVS-EN 1097-3 was not determinate for the milled material and for tested macadam the fluctuations were minimal. The test results might be seen in Table 1.

Table 1. Physical-mechanical properties of tested aggregates (* NR-no required)

	Aggregate fraction, mm	Fines content f, %	Los Angeles coefficient, LA	Flakiness index, FI	Resistance to freezing and thawing in water F, %
Blasted&crushed	0-4	6,7	NR	NR	NR
Milled by Vermeer	0-4	9,3	NR	NR	NR
Blasted&crushed-average `04-`09	0-4	13,9	NR	NR	NR
Blasted&crushed	4-16	1,1	27	11	1,4
Milled by Vermeer	4-16	0,7	24	13	-
Blasted&crushed-average `04-`09	4-16	1,1	25	14	1,3
Blasted&crushed	16-32	0,6	-	9	0,6
Milled by Vermeer	16-32	0,5	-	9	-
Blasted&crushed-average `04-`09	16-32	0,6	31	8	0,9
Blasted&sieved	0-45	2,5	30	17	1,9
Milled by Vermeer	All-in	0,7	≤34	41	-
Milled by Wirtgen	All-in	4,7	≤30	≤20	≤4

Test results

The most advantage of Vermeer surface miner extraction is that manufactured macadam fractions low LA coefficient and fines content in raw material is low as it was expected, in a case is extracted a material with high compressive strength.

A raw material extracted by surface miners is not suitable for use in non fractionated sieved aggregates, because particle shape changes - crushed grains are too oblong and flat, it also increase flakiness index and needle category of final production. This can be seen even visually and also in the test results. Although the other parameters of the test results satisfy the quality requirements, it is still necessary to crush raw material to achieve an acceptable index of flakiness. Otherwise material could not be used in construction, because it gives a great shrinkage of the finished constructions (roads/buildings).

Test considerations

The research was based on idea, that every additional crushing changes material properties, the more it is crushed, the less cracks remains and the grain becomes smaller, thereby the frost resistance and the LA index improves (see Table 1) in different extraction kinds, however, aggregates properties improves in the additional crushing processes - by milling or rotating 1000 times at test machine (for comparison see Table 1 Vermeer Terrain Leveler LA average values and 0/45). Also, the coarser crushed aggregate fraction has less fines content, the flakiness index improves when aggregate material becomes coarser - shows the effects on impact and consequently the coarse fractions are less sensitive to the effects of crushing impact, shape index should also improve. Resistance to freezing and thawing in water depends more on compressive strength and crushing way not on the extraction kind.

The advantages and perspectives of used technologies

Laboratory test has shown that quality depends on methods of obtaining the raw material and in some cases it become significally different.

With blasting may be occurred addional cracks and salmonids. This can be avoided by the correct calculation of the quantities of explosive materials. Impact on the quality of the final product of the process is inevitable. Also the important advantage of blasting is an obtainable price.

Milled material disadvantage is not suitability for use in construction- it gives a great shrinkage of the finished constructions (roads/buildings).

Also surface miner use costs (leasing, mainte-nance, repairing, needful additional crushing) are too high and consequently it is more appropriate to use blasting.

Insufficiency surface miner use and extraction in conditions with low compressive strength of the deposit provides relatively high fines content (see Table 1 Wirtgen surface miner test results).

More than 3% of the fines content in the limestone macadam fraction requires a weekly methylene blue control of the substance concen-tration according to EVS-EN 933-9. However, by adjusting the crusher sieves sizes may be eliminated and grade aggregates to the more purer fractions. This kind of production certainly calls for continuous, at least once a week monitoring, controlling and testing.

Conclusion

Obviously for the hard rock materials blasting is still the best way to get raw material, because it allows getting maximum better quality. The quality of produced raw material and macadam depends on both, as well as production technology and also deposit properties (especially of compressive strength). The coarser is raw material the better will be aggregate properties, because the grain becomes smaller only in latest progress stadiums.

The manufacturer's most important task is to ensure a consistent and high quality manufacturing process, which in turn guarantees a final product with the essential requirements of product standards.

Mining sector faces challenges to increase the output of mines and to minimize the environmental impact of mining at the same time. Continuous mining and milling techniques for the hard rock industry are unfortunately limited by the hardness of rock material. The application limits for the future technique will be placed above the limits of bucket wheel excavating systems with a diggability of normal up to 10 MPa of uniaxial compressive strength (UCS). This can be expanded with special designed excavators for frozen hard coal or soft limestone.(Nikitin et al. 2007).
Overall it does not allow to get best quality, except for the Los Angeles values using additional crushing.

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Sustainability assessment methods for developing advanced mining technologies

Sergei Sabanov, Julia Šommet, Irena Milaševski, Viktoria Bashkite, Julia Gulevitš,
Viktor Beldjaev, Karin Robam

Tallinn University of Technology

sergei.sabanov@ttu.ee, julia.shommet@hotmail.com, renamilashevski@gmail.com,
viktoria_bashkite@yahoo.com, julia@warren.ee, beldjajev@hot.ee,
karin.robam@ttu.ee

Abstract
Nowadays under using modern technologies, the extraction of a mineral resource is accompanied by many technological processes each of which has distinctive conditions and its own disturbance on the mining environment. The goal of the study is to elaborate methodology of sustainability assessment for developing advanced mining technologies. The methodologies for sustainability assessment will be used for determination and elaboration safety parameters for mining advanced technology efficiency and for defining environmental impacts resulting from different mining processes, and also key challenges and opportunities to economic growth of mining waste management and innovative mining technologies.

Keywords Sustainability assessment, advanced mining, waste management

Introduction
Various processes in mining industry often become dominating in the most dangerous technological and geotechnical factors, which can pose a hazard to people and their work, stop the production, cause economic damage to the enterprise and environmental. Providing of favorable conditions for the mining enterprises in conformity with technological and ecological safety defines the necessity of sustainability assessment. Nowadays under using new equipment, the extraction of a mineral resource is accompanied by many technological processes each of which has distinctive conditions and its own disturbance on the mining environment.

Sustainable development is a comprehensive, integrated and far-sighted approach to decision making. Its basic demand is that all significant undertakings must make a positive contribution to sustainability. The mining industries worldwide are changing their mining practices by developing and implementing a variety of technologies and mining methods are compatible with the principles of sustainable development. Adoption of the principles of sustainable development by the mining industry comes at a cost and requires major changes to current mining practices. Relating the different approaches to Sustainable development

across disciplines and against the background of the conceptual framework allows us to appraise their relative potentials and limitations. The constraints to scientific operationalization of sustainability and to its translation into policy measures, which are revealed by this reference system, highlight the necessity for continued integrated systems research [1,2,3]. The most important condition is the modification of existing or developing of new mining methods that are compatible with sustainable development [4,5]. The important aspects are ground surface stability, decreasing of losses of mineral resources, reusing of accompanied breed in construction industry and safety, environmentally friendly technologies. On the bases of the data received from mining industry it is necessary to work out conception of the suitable model for sustainable development of various mining processes and problems that cannot be decided by means of other methods [6].

The goal of the study is to elaborate methodology of sustainability assessment for developing advanced mining technologies. The methodologies for sustainability assessment will be used for determination and elaboration of safety factors and parameters for mining advanced technology efficiency and for defining environmental impacts resulting from different mining processes. The sustainability assessment methods can be used for different purposes and at different levels: as a basis for decision-making when selecting among different remedial actions for a mined out area within time and financial restraints; to relate ground surface subsidence risk levels to acceptable risk levels established by the society for other activities. Particular attention will go to issues of current waste production and storage, old mining waste landfills, waste handling procedures, development of the framework for waste management.

This study will be done with cooperation of different institutions at Tallinn University of Technology. The Department of Mining, the Department of Electrical Drives and Power Electronics and the Department of Machinery which will represents own contribution in this research. The main idea of this collaboration is how to use optimal technological solutions in order to achieve the results best in sustainable mining.

1. The research methodology

The technique of researches will be made by measurements and tests in laboratory and mining conditions. The methodology will include simulation and modeling of the several technological, environmental and economic indicators to assess their performance in sustainable development of mining. The research will be done with help of Sustainability Assessment (Figure 1), Risk Assessment, Strategic Impact Assessment, Life Cycle Analysis methodologies.
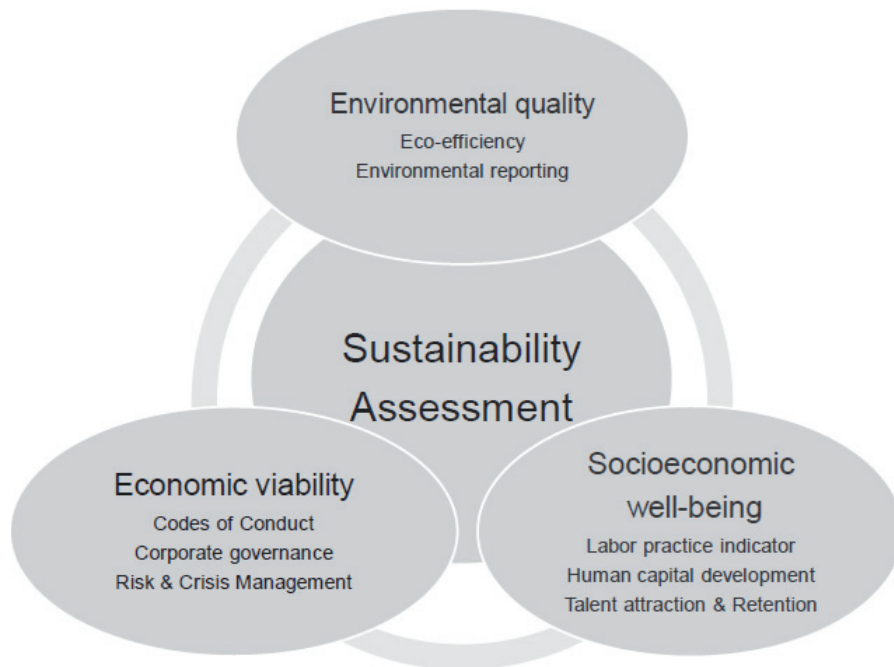
Figure 1. Sustainability Assessment

2. Complex approach for mining waste management

Department of Mining is plane to work out the suitable methodology for waste management. Waste rock dumps are located in huge amounts near the area of abandoned mines. The solution will help bring down the scale of unused waste rock by offering up a technological process for the production of aggregate for structural concrete and for other types of construction material. Co-products of oil shale mining is a large amount of neutral (limestone) and products of processing hazardous (oil shale ash) waste is generated on the ground surface. Complex approach is needed for solving these complicated problems. This study will contributes in saving financial resources in mining and reusing of wastes, diminishes the risk of accidents and casualties in mining, low emissions technologies, emission to atmosphere and aquifer.

The research topic „Sustainable Mining: key challenges and opportunities to economic growth of mining waste management and innovative mining technologies" will include the follows tasks:
- Background study of mining waste flow/amount of waste generated, investigation of environmental impacts of waste disposal/storage/re-use/recycling activities;
- Cost-benefit analysis of different strategies for mining waste management;

- Analyzing approaches to waste re-use and recycling that have the potential to be commercially viable activities, recognizing the state of the art in existing methods/technologies as well as up-and coming innovation research.

3. Combination for equipment selection

Department of Machinery will study how to produce right combination for equipment selection which gives certain advantages in contrast with old techniques for quality excavation of mineral resources.
The tasks of this study are:
- To find the optimal machinery modification for crushing – sorting complex in order to get better and more qualitative material;

- To reduce equipment maintenance and exploitation cost by integration of e-maintenance technologies;

- To develop new methodologies for more efficient and sustainable use of mining machinery.

The total electrification of all crushing-sorting complex equipment assemblies and development of e-maintenance techniques can solve the high maintenance and exploitation costs. The new material processing techniques development by modification of used equipment. Development of new generation equipment has given good results. For example, the new generation of cone crushers is not working only on pressing method, but also the impacts are added into process.
Control of the process by using special sensors can give certain results for material quality improvement. If we keep the cone feeding rate on the same level about 80%, the material pieces will not be crushed by each other. It will reduce the % of waste.
The practical importance of the research is to find the optimal and efficient technological solution and the way of local materials treatment. New updated equipment – stable work of crushing – sorting complex (sensors, automation), better material; E-Maintenance system – less exploitation and maintenance costs and fully controlled system;
The expected result is to define the most sustainable technological solution for every kind of material excavation. The right combination of equipment has to give certain advantages in contrast with old techniques for material quality, shape and production leftovers. The best improvement of new technology will be the possibility to integrate the system into local crushing – sorting complex.

4. The electrical drives and power electronic converters'

Department of Electrical Drives and Power Electronics will study the electrical drives and power electronic converters' that are used as actuators in the mining

machines. Correct choice of electrical drives increases efficiency and sustainability of mining. As mining machines work in hazardous conditions e.g. higher humidity, dust etc that has an enormous influence on their lifetime and productivity.

Many used electrical drives and their control systems are out of date. Hence they have low reliability and require more maintenance. The control technology has made a rapid increase in today's industry, allowing exact control of electrical drives. The main problem is to implement new electrical drives and their control systems in order to increase sustainability of mining.

Before selecting new systems an analysis of necessary functionalities and operations has to be carried out. Nowadays electrical drives vary by power, type, control etc. Depending on function, an appropriate drive can be selected. For example, for positioning control servo drives can be used and for heavy machines frequency controlled induction machines.

Electrical drives are one of the most important parts of any industrial branch. New positioning and control technology can help to increase capability of mining equipment. It is expected, that innovative drive system will improve the efficiency and reliability of mining.

5. Improving standards of illumination and visibility and, hence, standards of health and safety

Also the Department of Electrical Drives and Power Electronics draw out the idea to produce general guidance and recommendations for a wide range of underground mining locations and activities, to assist mine operators in improving standards of illumination and visibility and, hence, standards of health and safety. Studies on a wide range of underground machines and workplaces identified critical visual task requirements, and recommendations were formulated on standards for the improvement of both illumination and visibility under specific conditions. The study also will make recommendations on improving the visual environment to reduce specifically identified hazards, and produced guidance for the selection, sating and maintenance of lighting equipment.

Other object of the research is to determine if there are visual performance improvements when using solid-state cap lamps with light-emitting diodes (LEDs) as compared to incandescent light bulbs commonly used in miner cap lamps. The result of the research should to improve the design of the future cam lamps and should positively affect the safety of employees in the underground mining industry.

Conclusion

Sustainability assessment methods allows defining hazardous influences on environment, society and economic dimensions, and helps quickly, conveniently

and qualitatively solve, operate, find optimum variants for existing problems and optimize usage of mineral resources. This study contributes for saving mineral resources, improvement of mining safety, reusing of oil shale production wastes in accordance with preserving environment for future generations. The results will be useful in country's development plans, mining designs and in teaching and scientific work.

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SUSTAINABILITY ASSESSMENT OF ESTONIAN OIL SHALE MINING

JULIJA ŠOMMET[*]

Department of Mining
Tallinn University of Technology
Ehitajate tee 5, 19086 Tallinn, Estonia

Abstract. *The global importance of and demand for oil shale are currently rapidly growing. Deposits of oil shale are widespread around the world. All this necessitates assessment of the sustainability of existing open-pit and underground mining technologies to improve oil shale mining management.*

The aim of the present study is to elaborate a method for assessment of the sustainability of oil shale mining to develop advanced mining technologies on this basis. Sustainability assessment has earlier been applied to two exploited Estonian carbonate rock deposits – dolostone and limestone. It was shown that a three-level matrix monitoring scale gives structured results. This paper considers the applicability of a sustainability assessment matrix to Estonian oil shale mining.

Keywords: *Sustainability Assessment Method, Module Analysis, carbonate rock aggregates, oil shale mining.*

1. Introduction

In Estonia, oil shale has been used for over 90 years mainly for production of electricity and oil, with the generated waste ash being used for cement and light brick production. Oil shale usage has always been dependent on available mining and processing technologies on the one hand and world oil and petroleum prices on the other. This also holds true today when new technologies are being applied at a power or oil processing plant. For example, the separation plants built in Estonian new and reconstructed underground mines and Aidu surface mine allowed employment of oil shale finishing hand mining techniques and hand sorting, which increased production [1].

Since sustainable development has become a catchword in international discussions, several approaches to sustainability assessment have been worked out. In order to measure or predict the sustainability of a land use system or a society, one must consider the inherent problems of analysis and

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[*] Corresponding author: e-mail *ohutu.tk@gmail.com*

its complex systems. Appropriate scales and time horizons must be chosen; preconditions and requirements for operationalization and quantification of sustainability must be defined; and the philosophy and value system behind this concept and its translation into policies must be made explicit.

On the other hand, ethical and political convictions behind the multitude of policy recommendations made under the umbrella of sustainable development often remain obscure. There is a need to develop criteria that can be used to indicate to what degree strategies and policies contribute to sustainable development [2].

The current paper considers the possibility of applying a sustainability assessment method to Estonian oil shale mining. The method was developed during a doctoral study and approbated for Estonian carbonate stones deposits. In this work, Module Analysis is used to measure and compare different parameters – economic, environmental and socio-cultural. For gradation of specially selected indicators and parameters a three-level risk matrix scale from British Standard BS OHSAS 18800 „Occupational health and safety management systems" was adopted to consider how often each hazard is likely to occur. In this standard, a minimal risk level is considered as "I" and "V" means a very high risk. Risk evaluation following Table 1 indicates that non-existent risk (I) could be ignored, because its effect is insignificant. However, one must ensure that it will remain stable in the future. Slight risk (II) suggests that it may not be necessary to apply measures. However, the aim is to find a better solution that would not bring about additional expenses. In the case of acceptable risk (III) necessary measures should be taken to reduce risks, including also informing the staff. Acceptable risk with monitoring (IV) requires immediate steps to be taken to reduce the risk, informing the staff as well. In the case of unwarranted risk (V) swift actions must be implemented to remedy the situation. The Sustainability Assessment method uses the evaluation system which is similar to that of the Safety Risk Assessment Method [3].

Usually risk analysis is used to assess the safety of different technical systems. So far it has not been applied to the sustainability assessment of mining. Many authors [2, 4, 5, 6] have described the sequential steps of the risk analysis of technical systems. Most researchers are in general agreement on the basic elements the risk analysis should include. Description of the system, and the scope and expectations of the risk analysis should be defined at the start. An iterative approach should be adopted with qualitative

Table 1. Risk evaluation and damage occurrence

Dangerous	Insufficient damage	Dangerous or harmful	Very insecure damage
Unlikely	Non-existent risk (I)	Slight risk (II)	Acceptable risk (III)
Likely	Slight risk (II)	Acceptable risk (III)	Acceptable risk with monitoring (IV)
Very likely	Acceptable risk (III)	Acceptable risk with monitoring (IV)	Unwarranted risk (V)

methods being employed at the early stages of the process. If more information becomes available, use of quantitative analysis will be necessary.

Risk identification is the process of determining what can go wrong, why and how. Failure can be described on many different levels. Conceptualization of different possible failure modes for a technical system is an important part of risk identification. One should first take into account as many types of failures as possible. The initial list can then be reduced by eliminating those types of failures considered implausible.

Risk estimation entails the assignment of probabilities to the events and responses identified under risk identification. Assessment of appropriate probability estimates is one of the most difficult tasks of the entire process. Probability estimation can be grouped into three general approaches depending on the type and quality of available data:

1. analytical approach uses logical models for calculating probabilities;
2. empirical approach uses existing databases to generate probability;
3. judgmental approach uses experience of practicing engineers in guiding the estimation of probabilities.

Attaining an exact value of probability for technical systems and processes is not a realistic expectation. Component event probabilities may be assessed using a subjective degree-of-belief approach [3].

2. Sustainability assessment method for oil shale deposits development

In order to carry out an optimal analysis of the sustainability of an oil shale deposit a module analysis should be used [3]. This analysis uses a matrix table containing influence risk values, where the final product considered as a process and overall matrix is divided into modules or parts: Economic, Environmental and Socio-Cultural (Fig. 1).

For assessment of the economic sustainability of oil shale, different parameters should be used, taking Pareto principle as a basis. Pareto principle, or the 80/20 Rule, means that in many events, the few (20%) is important and majority (80%) is trivial. Pareto principle, the 80/20 Rule, serves as an everyday reminder to focus 80% of one's time and energy on the 20% of work that really is important [3].

For an additional Economic Indicators analysis it is recommended to use SWOT, PESTLE or Ratio analysis.

SWOT analysis (also SLOT analysis) is a strategic planning method used to evaluate the Strengths, Weaknesses/ Limitations, Opportunities, and Threats involved in a project or in a business venture. It involves specifying the objective of the business venture or project and identifying internal and external factors that are favorable or unfavorable for achieving that objective. The technique is credited to Albert Humphrey, who led a convention at the Stanford Research Institute [8].
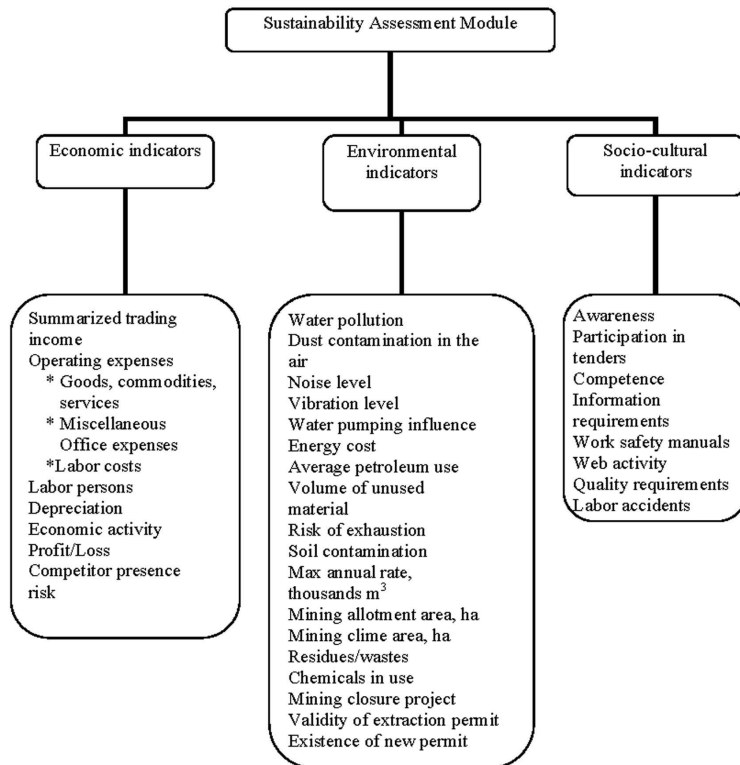
Fig. 1. Indicators used in Module Analysis.

PESTLE stands for business analysis including Political, Economic, Social, Technological, Legal and Environmental analysis. The term PESTLE has been used regularly during the last 10 years and its true history is difficult to establish. PESTLE analysis is particularly popular in introductory marketing courses in the United Kingdom. PESTLE analysis is in effect an audit of an organization's environmental influences with the purpose of using this information to guide strategic decision-making. The assumption is that if the organization is able to audit its current environment and assess potential changes, it will be better placed than its competitors to respond to changes [8].

Ratio analysis is a tool used by individuals to conduct a quantitative analysis of information in a company's financial statements. Ratios are calculated from current year numbers (evaluate a company's present performance and its possible future performance) and are then compared to previous years, other companies, the industry, or even the economy to judge

the performance of the company. Ratio analysis is predominately used by proponents of fundamental analysis. There are many ratios that can be calculated from the financial statements pertaining to a company's performance, activity, financing and liquidity. Some common ratios include the price-earnings ratio, debt-equity ratio and earnings per share, asset turnover and working capital [9].

Financial sustainability is a reflection of stable predomination of income over expenses and provides broad manipulation of financial assets of companies by their effective and smooth process of oil shale development and oil products realization. The Financial assessment examines viability of oil market and the economic value of land use. It incorporates Economic Growth, Research and Development, Codes of Conduct, Compliance, Corporate Governance, Risk and Crisis Management techniques [10].

Environmental indicators should be based on Environmental annual reports of the company to protect and improve environmental conditions in and around facilities. Good environmental practices prevent undesired phenomena from occurring, such as ground and surface subsidence and hazards related to them and emissions to sensitive receptors. Sustainable mining in densely populated regions requires rehabilitation of mined areas to accommodate leisure, agricultural or industrial facilities [10]. Influence of geological parameters and features on mining efficiency and environmental protection is significant. In underground mining, stability of the immediate roof by a mining face or stope is determined by geological features. The presence or vicinity of karst, joints or fissures, and an aquifer in the overburden rock at the face in the mines Estonia and Viru determines the stability of the immediate roof. These factors, in general, have been determined for the Estonian oil shale deposit and are cartographically mapped. To a great extent, karst and joints inside a mining block area are undetermined, because it is practically impossible to determine. Risk management and assessment methods allow solving these complicated problems. Seismic activity in Estonia is at such a low level, practically negligible, that it has been considered in this study only to a limited extent [11].

Socio-cultural well-being indicators describe the relationship between appropriate technology of mining activities and assessment of its social impact and incorporate Standard of Living and Basic Human Needs, Community and Equal Opportunities [12].

There are a number of other indicators and methods which may be used for assessment of mining sustainability. However, most of them are still in the developing stage. There have been a few tests carried out to develop the technological level assessment of a mining company during the study. The tests have been primarily induced by economic or legal problems, such as search for a new investor, promotion for selling the company, etc. However, it is mostly taxation, penalties and business reputation that guide the choice of indicators. There are organisations or individuals who have other motivators [14].

The parameters used in the module analysis are determined by Estonian legal acts and standards. Being mostly based on European Union standards, directives and regulations, these include the Mining Law, the Water Statute, the Waste Statute, the Waste Oil Management Requirements, the Municipal Waste Sorting Procedures, the Fire Safety Requirements, the Occupational Health and Safety Act, etc., 39 in total [3].

Gradation of company wellness could be estimated by the average of all Sustainability Assessment indicator values as equation 1 shows, where Ec_i is the average value of economic indicators of sustainability assessment, En_i is the average value of environmental indicators of sustainability assessment and SC_i is the average value of socio-cultural indicators of sustainability assessment:

$$MS_i = (Ec_i + En_i + SC_i)/3 \qquad (1)$$

Thereafter Mining Sustainability Index (MS_i) can be estimated by five basic grades: V means that the Company is Sustainably Developed, IV denotes Successful Company, III stands for Quite Successful Company, but additional actions should be taken in order to improve the situation, II designates no positive activity, I signifies no outcome activity.

3. Sustainability assessment techniques

The module analysis used for sustainability assessment of oil shale deposits differs from that applied to carbonate rock deposits in resource charac-terisation techniques and quality indicators. The techniques of sustainability assessment of oil shale mining (open pit and underground) in terms of resource characterisation (product quality) and mining profitability can be summarized as follows:

- application of numerical quality indicators corresponds to the techniques and methods of mining (crushers selection, sieving process regulation, selective mining and excavation, blasting, etc.);
- conducting of mineralogical, chemical and oil yield studies of oil shale;
- scheduling of oil shale production in a plan that applies appropriate capital and operating costs to determine economic viability;
- design of systems and technology for surface mining, underground mining, modified in-situ retorting, true in-situ retorting and determining requirements for infrastructure;
- in-situ process thermal and chemical reactions modeling, kerogen oil recovery modeling, geomechanics reservoir simulation;
- investigation of bedrock hydrological and mineral-related elements, soil formation, sediment transport and deposition aids in understand-ing of the structure and function of natural ecosystems:

- definition of in-situ stress regime through geotechnical monitoring;
- geotechnical assessment of open and underground mining and the stability of in-situ retorted areas;
- identification of opportunities for economic mine waste management;
- integration of life-cycle models of oil shale and energy commodities to describe global geologic occurrences, genetic processes, present and future use, recycling potential, possible substitutions, disposal strategies and associated environmental effects:
    1. identification of the impact of ecosystem loss or damage on local flora and fauna;
    2. long-term environmental monitoring of the leaching process ("spent" shale-co-product of in-situ retorting) and its influence on water quality; land use and reclamation [10].

4. Conclusion

This study treats of the sustainability assessment of oil shale mining in Estonian conditions, taking into account oil shale characteristics and mining parameters. The sustainability assessment used earlier for Estonian carbonate rocks served as a basis. Although the sustainability assessment of oil shale differs from that employed for carbonate rock in some of the techniques and parameters used, module analysis can be applied to both cases to grade company wellbeing and to improve mining management, as well as to find out weaknesses of operations.

Acknowledgement

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PAPER VIII   Pastarus, J.-R.; Šommet, J.; Valgma, I.; Väizene, V.; Karu, V.,(2013). Paste fills technology in condition of Estonian oil shale mine. Vita Ansone (Ed.). Environment. Technology. Resources: Environmental Protection and Monitoring. (182 - 185). Rezekne: Rezekne Augstskola Izdevnieciba

Paste fills technology in condition of Estonian oil shale mine

Jyri-Rivaldo Pastarus, *Tallinn University of Technology, Department of Mining, Estonia*, Julija Shommet, *Tallinn University of Technology, Department of Mining, Estonia,* Ingo Valgma, *Tallinn University of Technology, Department of Mining, Estonia*, Viivika Väizene*, Tallinn University of Technology, Department of Mining, Estonia,* Veiko Karu*, Tallinn University of Technology, Department of Mining, Estonia*

Abstract – **Oil shale mining and processing industry in Estonia produce a wide assortment of waste could be considered as available fill materials. Waste rock which is not usable in civil engineering and road building may be used for backfilling underground mines. Paste fills technology, which has several benefits, requires careful selection of oil shale waste rock aggregates and other carbonate stones. The laboratory tests and theoretical investigations were made for determination the applicability of limestone and dolostone aggregates as backfill material. It enables to determine the feasible parameters of aggregates from oil shale mining waste rock. Analysis showed that limestone aggregates of Estonian oil shale mines suit best for backfill technology in conditions.**

Keywords – oil shale industry, backfill technology, paste fill, fill materials, limestone and dolostone aggregate, geometrical parameters of aggregates.

1.   INTRODUCTION

The oil shale industry of Estonia provides a significant contribution to the country's economy, but causes a large number of different problems 1516. Oil shale is used as a fuel for producing energy and shale oil 1910. The mining sector faces challenges to increase the output of mines and at the same time to minimize the environmental impact of mining. Limestone and dolostone companies, where material is excavated by blasting and crushing technology, are in need of fillers distribution also.

Underground oil shale mining is performed by using a room-and-pillar method with blasting 161711. It is cheap, highly productive and easily mechanized. Unfortunately, if the depth of excavation is over 60 m (mine Estonia) the loss in pillars increases up to 40%. On the other hand, there are problems of use or bury the waste in landfill due to large amount of neutral (limestone) and hazardous (ash) waste generated by oil shale industry. A complex approach is needed for solving the above mentioned problems. Backfill technology would have a significant impact on the mining practice in Estonian oil shale industry 148179 .

Backfilling in mining operations is in wide use in all over the world. Nowadays attention has been focused on the use of combustion and mining by-products as filling materials. Separation of limestone from the raw oil shale generates large amount of waste, which proportion is approximately 40%.

Waste rock which is not usable in civil engineering and road building may be used for backfilling already mined areas.

In modern backfill technologies paste fills are preferred 4. It requires careful selection of fill materials, including limestone aggregates. Past fills method has several benefits,

most of them are crucial for the usefulness of backfill technology. On the same time there is lack in data characterizing the above mentioned waste filling materials. The choice of a proper backfill material is essential in the control of fill costs and backfill properties after placement. The main aim of these investigations was to determine the applicability of waste rock aggregates as backfill material in condition of Estonian oil shale mines.

2. GEOLOGICAL SITUATION

The Estonian oil shale deposit is located in the north-eastern part of the country. The oil shale bed has a form of a flat bed slightly inclined (2 – 3 m per km) southward. The commercial oil shale bed and its immediate roof consist of oil shale and limestone seams. The main roof consists of carbonate rocks of varying thickness. Characteristics of the individual oil shale and limestone seams are rather different. The strength of the rocks increases southward. The underground mining works are going at deepness 35-65 m, but at the southern border of deposit mining deepness will grow up to 120-130 m, notable increases overburden and its pressure to pillars [8][11][16]. The thickness of commercial oil shale seam is about 2.8 m. The waste rock separated from run of mine, which proportion is approximately 40%, is suitable for production of construction and backfill material [13].

Limestone companies are mostly located in Harjumaa County. It is in the northwestern Estonia, on the southern shore of the Finnish Gulf, about 80km to south from Helsinki, Finland. Geologically this area belongs to the southern slope of the Fennoscandian shield, where the Precambrian Early Proterozoic crystalline rocks of age 2.0-1.3Ga are covered by sequence of the Ediacaran and Paleozoic sedimentary rocks with age between 600Ma and 359Ma in Estonia. In the Harjumaa County there are being registered 16 carbonate stone deposits, four of them: Vasalemma, Harku, Nabala, and Väo are listed as deposits of all-country importance [20].

3. BACKFILL TECHNOLOGY

Backfilling in mining operations is in widely used in all over the world. Nowadays attention has been focused on the use of combustion and mining by-products as filling materials. In Estonian oil shale industry a wide assortment of fill materials is available in Table 4. The whole processing of oil shale from mining up to energy and oil generates large amount of different waste:

1. Separation of limestone from the raw oil shale generates large amounts of waste, which consists in 82...94 % of limestone and 6...18 % of oil shale residues. These are stockpiled in form of cones (55 m height) and total area of these piles is about 3.5 km2. Limestone production is about 6.5 Mt per year.
2. The Estonian Thermal Power Plants use two different oil shale combustion technologies: pulverized firing (PF) and circulating fluidized bed combustion (CFBC) technology. The compositional and morphological variation between PF and CFBC ashes [3] are principally controlled by firing temperature differences between combustion technologies, and by grain size difference of oil shale fuel. From the point of chemistry ash from oil shale combustion is very similar to cement (with exception in alkalinity) and there is no significant difference between the

potential environmental impacts from the side of oil shale ash. About 4 km2 of the landfill are occupied with ash ponds. Annual production is about 5 Mt. The determination of different ashes parameters demands supplementary investigations and is under construction.

In modern backfill technologies paste fills are preferred 45. It requires carefully selected grain-size distribution of solid particles and is able to flow without sedimentation in pipes by low water content (10...30 %). In this case backfill slurry has several benefits:

- Mixtures are able to set with lower or without presence of additional binders.
- Shorter binding times and better mechanical properties.
- Drainage and processing of bleed water eliminated.

Consequently, at a first approximation the limestone aggregates properties determine the behavior of backfill. Oil shale waste rock (limestone) is produced during extraction as reject material from separation plant and material from crushing and sizing operations in aggregate production. It became clear that production of aggregate produces large amount of non-commercial aggregate [13].

4. GEOMETRICAL PARAMETERS OF AGGREGATES

The porosity of fill material consists of the void spaces between solid fragments. If the fragments are solid spheres of equal diameters the cubic and rhombohedral pacing is possible (see Fig. 1) 1.
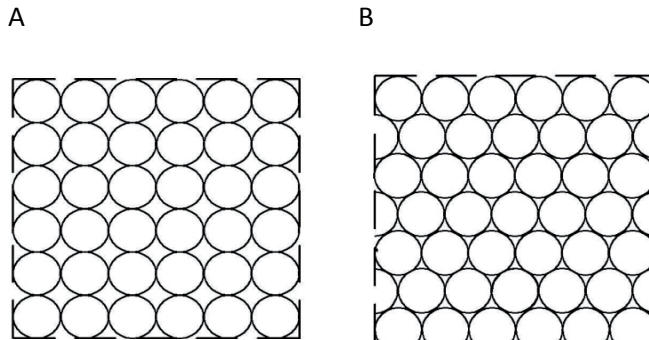
A   B

Fig. 12. Packing of the solid fragments 1, A – cubic packing; B – rhombohedal packing

These two configurations represent the extremes of porosity for arrangements of equidimensional sphere with each sphere touching all neighboring spheres. The porosity of well-rounded backfill materials, which have been sorted so that they are all about the same size, is independent of the particle size and falls in the range of about 25.95% to 47.65%, depending upon the packing 1. If a backfill contains a mixture of grain sizes, the porosity will be lowered. In this case the smaller particles can fill the void spaces between the larger ones. The wider the range of grain sizes, the lower the resulting porosity.

In addition to grain-size sorting, the porosity of material is affected by the shape of the grains 1. Well-rounded grains may be almost perfect spheres, but many grains are very irregular. Sphere-shaped grains will pack more tightly and have less porosity than particles of other shapes. The orientation of the particles, if they are not spheres, also influence porosity.

This phenomenon determines the bearing capacity of backfill/pillar. Conformation of getting theoretical result demands supplementary investigations of in situ conditions.

a. Uniformity Coefficient

The uniformity coefficient of a material is a measure of how well or poorly sorted it is. It is presented by following formula1:

$$C_u = d_{60} / d_{10} \tag{1}$$

where C_u – uniformity coefficient; d_{60} – grain size that is 60% finer by weight; d_{10} – the grain size that is 10% finer by weight.

A sample with a uniformity coefficient less than 4 is well sorted, if it is more than 6 it is poorly sorted 1.

The grain-size distribution curve and uniformity coefficients for aggregate sizes 4/16, 16/32 and 32/63 mm have been determined. Fig. 13 demonstrates the grain-size distribution curve for aggregate size 16/32 mm, mine Estonia.
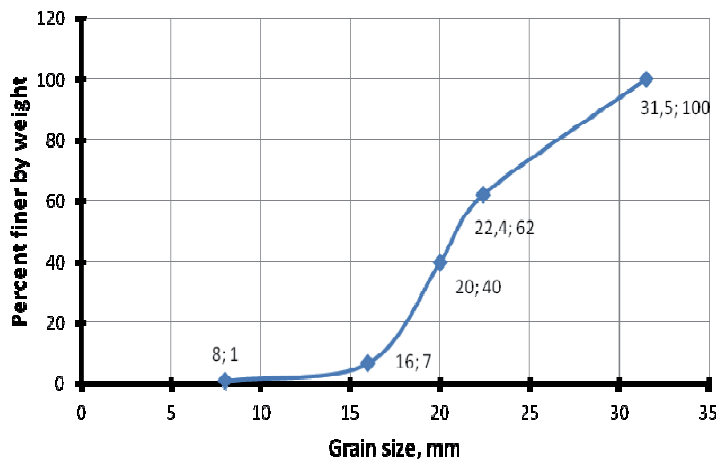

Fig. 13. Grain-size distribution curve. Aggregate size 16/32 mm, mine Estonia

Investigation showed that uniformity coefficient for all aggregate sizes is less than 4. For limestone and dolostone uniformity coefficient is less than 3. Consequently, the above mentioned aggregates are well sorted and they satisfy the paste fills requirement.

b. Shape of the Coarse Aggregate

Flakiness Index is the percentage by weight of particles in it, whose least dimension is less than 0.6 of its mean dimension. Flaky particles may have adverse effect on concrete

mix. For instance, flaky particles tend to lower the workability of concrete mix which may impair the long-term durability. The results of flakiness index investigation in Estonian oil shale mines and open casts are presented in Table 4.

<div align="center">

TABLE 4
FLAKINESS INDEX OF WASTE ROCK AGGREGATE
*produced and tested aggregate 8/16 mm

Aggregate size, mm	Flakiness index Fl (average), %			
	Mine Estonia	Open cast Aidu	Tondi-Väo limestone deposit	Kareda dolostone deposit
4/16	9	6	11	5*
16/32	6	3	7	4
32/63	4	2	10	10

</div>

Investigation showed that the flakiness index depends on aggregate size for limestone aggregates of Estonian oil shale mines. If the aggregate size increases, the flakiness index decreases. In general, the flakiness index of produced aggregates does not exceed 35% and that depends on type of crushers and number of crushing stages [12]. If the flakiness index is less than 50% the negative influence on the strength parameters of backfill is negligible.

5. AGGREGATE PARAMETERS FOR BACKFILLING

A complex method, including laboratory tests and theoretical investigations, were made for determination of the applicability of limestone aggregates as backfill material. The results of investigations are presented in Table 5.

<div align="center">

TABLE 5
OIL SHALE WASTE ROCK (AGGREGATES) PARAMETERS

Parameter	Measured values	Recommended values
Porosity of fill material, %	40 - 50	26 -48
Uniformity coefficient	1 - 2	<4, well sorted
Flakiness index, %	2 - 11	<35

</div>

In conclusion, it is visible that the aggregates from oil shale mining waste rock can be used as a material for backfilling the underground mined area. As long as Estonian oil shale mines are located near to the backfill requited areas, other aggregates of limestone and dolostone not suitable because of the location.

6. RESULTS

In Estonian oil shale industry a wide assortment of fill materials is available. In modern backfill technologies paste fills are preferred. It required careful selection of limestone aggregates as a component part in fill mixture. A complex of geometrical

parameters of limestone aggregates is presented, which determines the quality of fill mixtures and backfill properties after placement.

Analysis showed that limestone aggregates suit best for backfill technology in conditions of Estonian oil shale mines. Usable investigation methods and getting results are applicable for different aggregates as a component part in fill mixture.

7. ACKNOWLEDGEMENTS

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PAPER IX   Šommet, J. (2013). Sustainable Development in Estonian Mining. Environmental and Climate Technologies, Volume 11, p. 34-40

Sustainable Development in Estonian Mining

Julija Šommet, *Tallinn University of Technology*

Abstract – **Importance and demand of high qualified mining material (carbonate rocks, oil shale) are growing nowadays. Deposits are widespread around the world. Is it possible to create the sustainability paradigm, that helps to manage quarries adequately to improve overall effectiveness of the company in total? This study focuses especially on the mining industry. This paper will introduce modern systems and a new one, that allows to make an indexation of the company by mining sustainability index and gradation of the company by its wellness; also brings several benefits for future sustainable development.**

Keywords – **Sustainability Assessment, carbonate aggregates, oil shale mining**

I. INTRODUCTION

Estonia has an increasing demand for carbonate rock aggregates of very high quality. The investigation in this research paper was carried out in the conditions of the Estonian company Väo Paas LTD (Germany and Finland subsidiary company), Eesti Põlevkivi LTD company ash sales department in OSAMAT LIFE+ 09/ENV/EE/227 project frame, road building company Matthaei Ehitus LTD and in cooperation with the Tallinn Technical University Department of Mining. The research is based on different deposits and geological conditions in different parts of the country, as well as central Estonia Kareda dolostone (77,6 ha) quarry and north Estonia Tondi Väo limestone quarry (48 ha). Quarries are located in high populated areas. In Väo quarry drilling blasting excavates limestone deposit rock. Selective excavation is not currently applied. Derived from limestone by rotor crusher and then sieved to obtain different fractions of the aggregates. The same excavation processes were followed at the Kareda dolostone quarry. Output aggregates go to road, railway and building construction, concrete aggregates and concrete mixtures stuffing, also for unbound mixtures composition. Each area of usage is followed by EN (European Normative) standards which are valid throughout the European Union. The results of the current thesis topic test may also be used for research in other EU countries. The basis of this research is to find solutions to improve the situation in the mining industry today.

The most important locations for mining in Estonia are the Ida-Virumaa County with its oil shale mining for electric power stations (about 15 million tons annually), and the Harjumaa County, which holds second place in total mining and the first in raw building material mining. In Harjumaa County in 2008,1746 000m^3 carbonate raw materials 1746 000m^3 and 49 800m^3 of pure limestone were extracted for technological use [1].

The Estonian oil shale deposit is located in the north-eastern part of the country. The oil shale bed has a form of a flat bed slightly inclined (2 – 3 m per km) southward. The commercial oil shale bed and its immediate roof consist of oil shale and limestone seams. The main roof consists of carbonate rocks of varying thickness. Characteristics of the individual oil shale and limestone seams are rather different. The strength of the rocks increases southward. The underground mining works are conducted at a depth 35-65 m, but at the southern border of deposit mining the depth will increase up to 120-130 m, notable increases overburden and its pressure to pillars [21]. The thickness of the commercial oil shale seam is about 2.8 m. The waste rock separated from run of mine, the proportion of which is approximately 40%, is suitable for production of construction and backfill material [22].

In Estonia, oil shale has been used for over 90 years mainly for production of electricity and oil, with the generated ash, which has been used for light brick production and cement. Oil shale usage has always been related on available mining and processing technologies on the one hand and world oil and petroleum prices on the other. This also holds true today when new technologies are being applied at power or oil processing plant [2].

Limestone companies in Estonia are mostly located in Harjumaa County which is located in northwestern Estonia, on the southern shore of the Gulf of Finland, about 80 km south of Helsinki. Geologically this area belongs to the southern slope of the Fennoscandian shield, where the Precambrian Early Proterozoic crystalline rocks of age 2.0-1.3 Ga are covered by sequence of the Ediacaran and Paleozoic sedimentary rocks with age between 600 Ma and 359 Ma in Estonia. In the Harjumaa County there are being registered 16 carbonate stone deposits, four of them: Vasalemma, Harku, Nabala, and Väo are listed as deposits of country-wide importance [10].

To develop advanced mining technologies and to evaluate the practical output of mining companies' competitiveness in Estonia on the basis of the consumer's wishes and needs, sustainable development should consist of obtained data modernization with the unique system, which can be useful also in the country's development plans, mining designs and in teaching and scientific work.

Sustainability Assessment helps to identify the weakest or the strongest company aspects, which determine sustainability: economics, environment, technical feasibility, socio-cultural aspects. Sustainability Assessment can be used with large-scale matrix methodology in carbonate stone quarries and with small-scale for oil shale mining. Sustainability Assessment is useful for company owners, administration, staff and potential purchaser.

II. PREVIOUS STUDY

In the frame of this research a review was made of the sustainability field of existing researches in different countries. They confirm the necessity of the new sustainable assessment for mining in module system.

The Estonian National Strategy on Sustainable Development, Sustainable Estonia 21, was approved by the Parliament of Estonia in 1995 and, accordingly, long-term plans of sustainable development are to be elaborated in the energy, transport, agriculture, forestry, tourism, chemical industry, building materials industry and food industry sectors. These plans consist of theoretical assumptions and are estimated by theoretical estimations and not focusing on the mining as well only stratifying the next years of country wellbeing [3].

The analytical publication of Indicators of Sustainable Development presents over 60 social, environmental, economic and institutional indicators in the following fields: equality, health, education, living conditions, security, welfare, atmosphere, land use, coastal areas, freshwater, biological diversity, structure of economy, pattern of consumption and production, environmental economy, institutional capacity. The data of other countries and the European Union data have been presented for comparison. The indicators are presented in accordance with the list of the United Nation Commission of Sustainable Development and the Statistical Office of the European Communities. Most recent data is for the years 2003 or 2004. The regional dimension is also presented where possible. Indicators are supplemented with definitions and comments on data. Information has been provided in overviews, tables, diagrams and thematic maps. Materials are addressed to the users more interested in the subject history. The important precondition for achieving success in carrying out the sustainable development strategy is the sustaining of the self-renewal capacity of renewable resources and using non-renewable resources according to clear rules and at as low rate as possible, foreseeing the possibilities for replacements in the future [4].

Enno Reinsalu's research for oil shale mining can be useful as a good example of economic analysis in conditions of mining in Estonia and to help in determination of the company wellbeing, because it allows to measure such a parameter like a company's possible lifetime and also to make an outlay analysis, its calculation and price calculations. Results are shown in the table and graphically also for quick illustrative purposes. The data used in the economic analysis has some similar aspects. Oil shale quality analyses are too specific and cannot be applied for carbonate stone mining, only for the energy materials. Sustainability is not measurable and understandable immediately; it depends on the resources of the universality, scope of application, the efficiency of use, the consumption gain factors, environmental safety, etc.

In research for oil shale mining it is possible to measure predicted mining capability, minimal output production, mining capability reserve and deficit, mining capability boost, necessary investments for machine purchases (medium or large sized). Economic activity balance and consumption forecasts were done for the next years, price modelling were calculated also. As a result, proposals to improve the management were offered. Mining costs increase due to high prices of purchased materials, especially explosion and metallic prices, also salary increase. The main idea is that the company mining capability depends on productivity [5].

Another useful research Building for Environmental and Economic Sustainability (BEES) is used in the United States of America for building constructions. BEES is an elaborated computer program and it measures the environmental performance of civil engineering products. For measurements it uses the life-cycle assessment approach specified in the standards of ISO 14000. All stages of construction engineering are analyzed: raw material purchasing, manufacture process, transportation, installation and construction as well as waste management and recycling. Economic performance is measured with the help of American Standards, which cover all costs [6].

Risk Assessment Methods in Estonian Oil Shale Mining Industry research is related to the mining industry, there are various conventional methods available; however, methodology shows the greatest promise for defining hazardous influences. It allows to develop methods for avoiding or reducing negative factors. The method helps to solve quickly, conveniently and qualitatively operate, find optimum variants for existing problems in oil shale mining industry, to predict with the minimal expenses during the project stage how to flexibly avoid the subsequent problems. The method is based on statistical analysis and consists of three general approaches depending on the type and quality of the assailable data. Method involves the following problems: stability of a mining block, application of advanced mining technology; extraction of mineral resources, loading, transportation and their influence on the environment. The risk assessment can be used for different purposes and at different levels: as a basis for decision-making while selecting among the different remedial actions for a mined out area within time and financial restraints; to relate ground surface subsidence risk levels to acceptable risk levels established by the society for other activities. The results of the risk assessment are of particular interest for practical purposes. Risk assessment methods are applicable in various fields of Oil Shale mining production [14].

For the southern countries and African countries (Uganda, Tanzania, Mozambique, Lao PDR etc) a Toolkit is created by ASM (artisanal and small-scale mining) system that can lead to improve policies, extension services, interactions between the large-scale mining companies and the artisanal miners—and ultimately, to improve development impacts for men, women, and artisanal mining communities. This is a very important tool to improve the situation in those countries. Whether newly begun or long established, ASM has the potential to help men and women out of poverty when conducted in an informed and responsible way. In different communities, different techniques are used, and men and women share different divisions of labor, risks, and opportunities.

Understanding the social, economic, and environmental aspects of ASM is essential for governments, nongovernmental organizations, mining companies, and researchers to be able to contribute to positive socioeconomic and environmental outcomes from this sector. This Toolkit—including the detailed analytical framework and instructional modules—is a unique instrument to guide research and researchers to ask the right questions and come to a gender-sensitive understanding of ASM activities [15].

The appearance of the "sustainable development" is a responsibility concept in the mining of natural resources, which allows to make corporations useful by applying a long-term environmental management. For this purpose a Sustainable Development Model (SDM) framework was created to illustrate the integration sustainable development into the "whole" ecosystem. The ecosystem approach is a framework that covers the natural environment opportune futures and enforcements. This management model system uses four main components that determe resource development for products that require disposal into the environment: use of land, water, and atmospheric resources and an outcome assessment process. Quality of the processes is governed by standards, permits and limitations; it helps to measure the ecosystem productivity. The main idea of Sustainable Development is to achieve whole ecosystem sustainability [19]. This framework also provides a four matrix system as a decision support model.

Nowadays existing and popularized methodologies, like life-cycle assessment approach, specified in the International Standards Organization ISO 14004 "Environmental management systems", EMAS Easy system, Waste water Exergia analyze and Occupational Risk Assessment by British Standard OHSAS BS 18801 „Occupational health and safety management systems" are using different data, which is strictly directed to separate fields of this investigation not absorbing all necessary ones (economics, technical feasibility, socio-cultural indicators).

Interest in the environmental capacity of organizations is growing incessantly. Working and operating without taking into account the environmental investigations and importance of company activities becomes almost impossible. Different companies with a professional activity accession to environmental challenges look for new methodologies to improve their environmental performance. EMAS is the premium environmental management system which can help to achieve this. This system helps to promote productivity, credibility and transparency of companies. At the present time, more than 4,500 organizations and almost 7,800 sites all over the world are using EMAS system [4].

A solution to the sustainability paradigm problem cannot be solved with existing trials – they are circumstantial and oblique for mining. Sustainability Assessment, helps to identify the weakest or the strongest company aspects of the four, which determine sustainability: economics, environment, technical feasibility, socio-cultural. Assessment can be used in the full version for carbonate rock quarries and in an abbreviated version for oil shale mining. A brief version of the analysis could be also done without any economic calculations. In that case, the results can be observed graphically and can be more easily perceived visually than tables (Fig. 1 and Fig. 2).

III. ANALYSIS METHODOLOGY

This research gives a convenient method for the gradation and sustainable assessment analysis of carbonate aggregates excavated on Estonian quarries and deposits, also brings future suggestions for the sustainable development. Investigation has shown that no one nowadays used approach does not indicate the company and does not check the achieved results by formulas. The Sustainability Assessment methodology will be demonstrated in detail in the next paragraph.

Research is focused on working out an analysis, which consists of a unique evaluation system. In order to carry out an optimal analysis of sustainability, a Module Analysis should be used. This analysis uses a matrix table containing influence risk values, where the final product considered as a process and overall matrix is divided usually into four modules or parts: Economical, Environmental, Technical and Social–Cultural. There are a number of indicators in each module, which are used for assessment of mining sustainability (described on Fig. 1. and Fig. 2). The indicators used in the module analysis are determined by Estonian legal acts and standards. Being mostly based on European Union standards, directives and regulations, these include the Mining Law, Water Statute, Waste Statute, Waste Oil Management Requirements, Municipal Waste Sorting Procedures, Fire Safety Requirements, Occupational Health and Safety Acts, etc., 39 in total [16].

Sustainable Assessment consists of a four module system, each module is divided into different indicators; which are considered as a process and measured by risk level (Table I).

Economical and environmental part of this methodology consists of a selective analysis of the annual reports and obtained data modernization. For assessment of economical sustainability different parameters should be used, taking Pareto principle as a basis. Sustainability supposes that all parameters and processes are important and should be equal [6].

For quick and easy environmental analyze could be used not only annual reports but also mapping idea by ecomapping EMAS Easy system, it is advised to use a map of the whole territory of the open-pit mining with aquifers and mining allotment area as it is shown in the example (Fig.4).

Ecomapping is an easy technique to note different environmental impacts and problems. The most important environmental information of the company is gathered systematically and is followed by local legislatives and standards requirements. This systematic method builds up a picture of environmental information on a map or plan of the site by using simple symbols. Ecomapping helps to very easily understand visually environmental impacts which are positive for company owners, employees and stakeholders. It also permits to get more people involved at the early stage of an environmental problem [17].

TABLE I
RISK CONTROL ACTION PLAN [13]

| Level of Risk	Action Plan
Invial	No actions required, no need to keep records
Tolerable	Existing controls are adequate, but monitor to ensure this is required
Moderate	Implement, with deadlines, measures to reduce risk. Take into account the cost of effectiveness of such measures.
Substantial	Stop work until risk is reduced, allocate sufficient resources to significally reduce the risk.
Intolerable	Stop work until risk has been reduced, this may necessitate the allocation of unlimited resources.
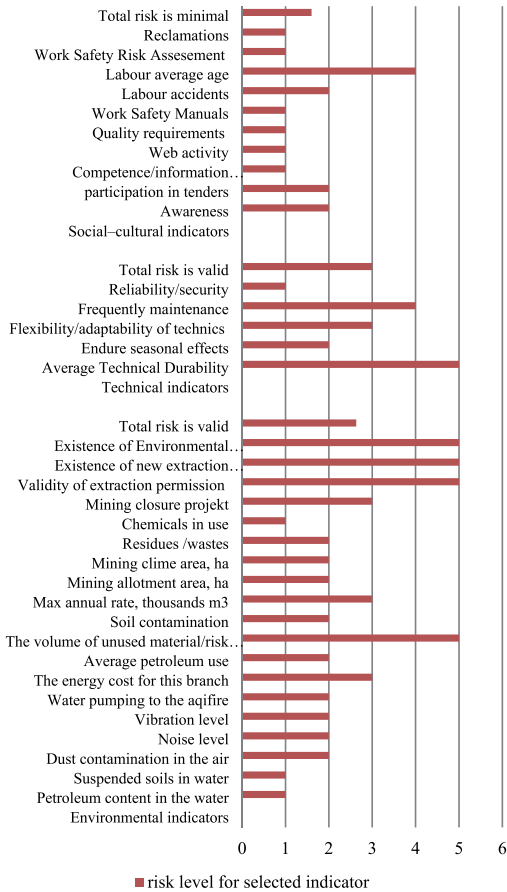
Fig. 1. Kareda dolostone- central Estonia quarry analysis results observation
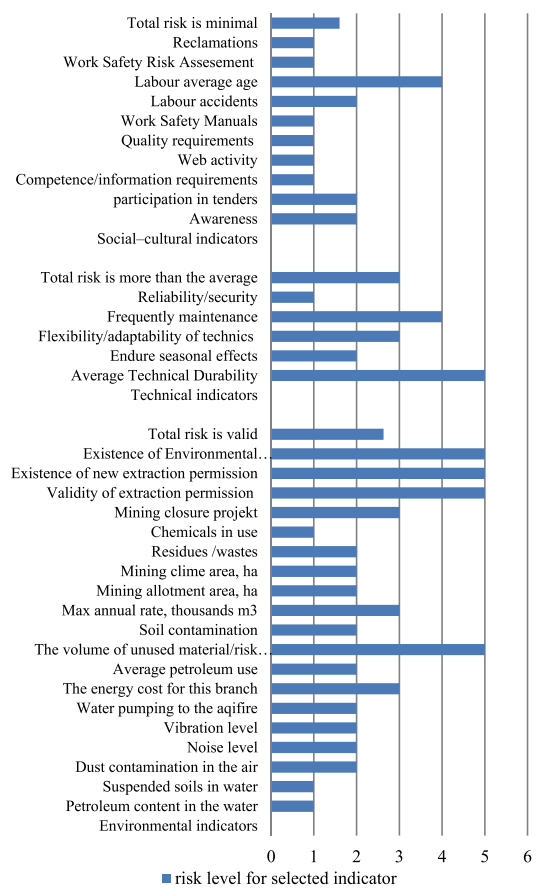

Fig. 2. Observation of north Estonia Tondi – Väo quarry analysis

Assessment steps can be easily followed by the Fig. 3, where it shows, that all the results should be controlled and only after that indexation of the company wellbeing and sustainability can be made. Indexation value leads to goals achievements and helps to specify the solutions for sustainability improvement. Sustainable Module analysis can be held by introduced module in Fig. 3.
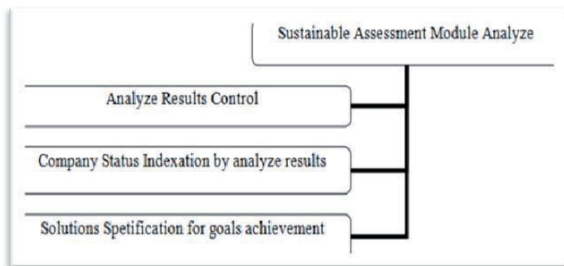

Fig. 3. Sustainable Assessment Analyze Steps

IV. RESULTS CONTROL

After each module parameter was measured by risk level, results control should be made by the following equations.

For economic indicators summarized trading income could not be approximately equal to economical activity profit (1) and summarized trading income should be greater than its economical activity profit (1). If the company is divided into different branches, then additional economic control should be calculated for branches in that case branch summarized trading income should be greater than 20% (3).

$$TI_{SUM} \neq EAP \qquad (1)$$

$$TI_{SUM} > EAP \qquad (2)$$

Where TI_{SUM} is summarized trading income and EAP is economic activity profit. Module analysis should be done also for branches using additional data control of economic parameters in comparison with all company data.

37

$$TI_{SUM} > 20\% \qquad (3)$$

Control of Environmental Indicators and risk data is available by the next equation, taking into account the country's (Estonia in this case) ecological footprint (FP_{EST}) in gha/pers if divided by an average value environmental indicators (RL_{ENav}), then risk levels for environment (RL_{EN}) should be alike if the data is correct. (4) is valid thru also for dolostone mining, and is improved by the research. For the other European countries should be used appropriate ecological footprint in gha/pers taking into account country location.

$$RL_{EN} = FP_{EST} : RL_{ENav} \qquad (4)$$

Control of Technical indicators and Feasibility should be calculated for Average Technical Durability as (5), where summarized years of machines divided to amount of the machines, this parameter should not be larger than 7 years, in other cases the risk is higher than 2 points.

$$\Sigma TDn : n \leq 7 \qquad (5)$$

After that the company status indexation should be made using analysis data and its results and next equation (6). Last step of the sustainable assessment is solutions specification and probably suggestions giving for main goals achievement. Obtained analyze results are estimated by theoretical work and experts opinion, also experimental data was controlled by different formulas in several research activities.

Key:

Hatched lines: small problem – (Area to be monitored, problem to be studied)

Circle: large problem – (Stop, corrective action)

The most serious problem is the thicker the circle

Source: Ecomapping (2006)

Fig. 4. Ecomapping example scheme with explanations

V. COMPANY STATUS INDEXATION

The gradation of company wellness could be estimated by the average of all Sustainable Assessment parameter values as

(6) shows, where Ec_i – is average value of Economic Indicators Sustainable Assessment, En_i – is average value of Environmental Indicators Sustainable Assessment and SC_i – is average value of Socio-Cultural Indicators Sustainable Assessment and T_i – is average value of Technical Indicators. Thereafter the Mining Sustainability Index (MS_i) is always a whole number and can by estimated by five basic grades:

Five points „V" - Company is Sustainably Developed

Four points „IV" – Successful Company

Three points „III"-Quite Successful Company, but additional activities should be taken to improve the situation

Two points „II" – no positive activity

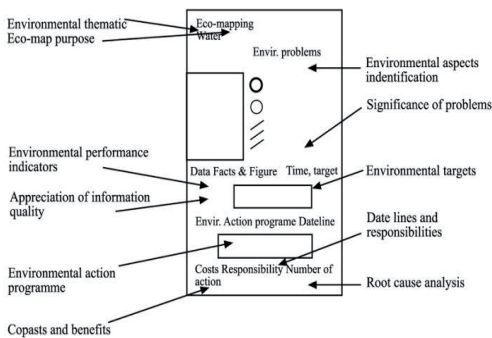*Zero till one point "I"* – no outcome activity [5].

$$MS_i = 5 : [(Ec_i + En_i + SC_i + T_i)/4] \qquad (6)$$

Mining Sustainability Index (MS_i) also shows a possible price range enterprise of mining company in case of purchasing this company. The higher the index, the more successful the company is - accordingly the price should also be higher. It is possible to increase the Mining Sustainability Index (MS_i) after sustainability analysis has been done; it requires investments to be made to the weakest aspects or suggestion improvements which will be described below.

VI. SUGGESTIONS FOR SUSTAINABLE DEVELOPMENT

After the analysis was held according to the results for companies, where the Mining Sustainability Index (MS_i) is lower than 4 future proposals could be given for sustainable development. If Sustainability Index remains stable at the point 4, additional actions should be followed only by the module analyse table. If Sustainability Index is less than 4 points, then most advantageous solutions could be:

• Right choice of technique and its influence to extracted material. Obviously for the hard rock materials blasting is still the best way to get raw material, because it allows getting maximum better quality. The quality of produced raw material and macadam depends on both, as well as production technology and also deposit properties (especially of compressive strength). The coarser the raw material, the better the aggregate properties will be, because the grain becomes smaller only in latest crushing progress stadiums [8].

• Development of new generation equipment has given good results. For example, the new generation of cone crushers is not working only on pressing method, but also the impacts are added into process.

• Control of the process by using special sensors can give certain results for material quality improvement. If we keep the cone feeding rate on the same level of about 80%, the material pieces will not be crushed by each other. It will reduce the percentage of waste.

• Correct choice of electrical drives increases efficiency and sustainability of mining. As mining machines work in hazardous conditions e.g. higher humidity, dust etc that has an enormous influence on their lifetime and productivity.

- Many used electrical drives and their control systems are out of date. Hence they have low reliability and require more maintenance [7].
- Sales increasement and new customers search with market opening up for fill materials technology using residue materials. In the Estonian mining industry, a wide assortment of fill materials is available. These materials require careful selection of aggregates as a component part in fill mixture. Usable investigation methods and getting results are applicable for different aggregates as a component part in fill mixture [10]. Conversion of industrial waste into valuable and environmentally friendly products is highly important at the moment in the EU as well as all over the world. In general this products will address the challenges of European policies and legislation concerning waste and promote waste recovery and sustainable recycling with a focus on life-cycle thinking and the development of recycling markets [11].
- A successful mining company should produce qualitative materials and aggregates, as the fact it is important to held and arrange particularly precise quality analysis. Previous research has shown, that the higher the percentage of fines content at the sieved raw material - the less fines content should be in other aggregates from the same crusher. If the fines content is consistently stable, then the content of other aggregate fractions should also be consistently stable. Otherwise, we can confident that this is some problems with the crushing process on the crusher itself [12].
- Working actively with the staff, training and competence rising of the employees of all ranks.
- Attracting new investors or sponsors and participating in different tenders.
- Occupational risk assessment defying , safety manuals and its check-up's, carrying out a systematic operational audit, informing employees about working environment risk factors, organizing health check-ups for employees, carrying out the elementary - introductory instruction for an employee starting to work for the enterprise. If necessary, carrying out a supplementary instruction.
- Realization of environmental management systems, which should also be an important part of the management system of the company: controlling, diminishing and preventing environmental problems from the activities of the company and as a result improving its competitiveness. In Estonia, companies have a choice between two systems: the international environmental standard ISO 14001 or EMAS (the European Union Eco-Management and Audit Scheme) [3].
- Process optimisation by minimising costs, minimising energy use and land area required, minimising waste productions; clean water, maximise the score of qualitative sustainability indicators [20].

VII. Conclusion

Sustainability Assessment and Sustainable Development for Estonian Carbonate Quarries is a comparative investigation. This research is collaboration between several local Estonian mining companies and institutions. Scientific work determined the sustainability assessment by module analysis in conditions of Estonian mining taking into account all risks of activities.

The expected result of the study is to explore a new analyzing methodology firstly for sustainability assessment in mining management. A specific monitoring tool and indicators were developed in order to access each branch of mining (Economical, Environmental and Technical Feasibility and Social–cultural indicators). Sustainability Assessment consists of module analysis. For the adequate data and results control were elaborated a complex of equations, which allows to control achieved results. Another nowadays used technologies do not propose a data check-up's with equations After that, some main recommendations and suggestions were made to improve sustainability of mining company.

Sustainability Assessment for Estonian Carbonate quarries helps to identify, manage and reduce different risks and weakest aspects associated with mining company services, business operations and products and it is a decision support model. Assessment serves as an advisor for best development and future company wellness. It gives a possibility for company personnel to monitor and contribute to the mining process, while the nowadays used researches are not committed with data of carbonate rock quarries or mining. Research highlights all aspects needed for sustainable development and it is first and unique methodology, which was developed for quarries.

Analysis involves the monitoring of economic, environmental, technical and social performances in every quarter of the year. The methodology is very useful and defines itself by used methods and relevance for developing future wellbeing program and usefulness of its outputs: like comprehensive training model and technique tool; it could be used by company owners and personnel, potential purchaser, foreign investors or consulting companies as well. Sustainability assessment indicates appropriated future strategies for mining management. The research question is the right one and matters to mining companies in Estonia and other European countries in different geological conditions.

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Julia Shommet earned at Tallinn University of Technology Mining Department a B.Sc. Geotechnology at 2006, also M.Sc. Geotechnology degree in 2009 and now is taking third year of PhD study. Supervisor is Jüri-Rivaldo Pastarus and co-supervisor is Sergei Sabanov.

J. Shommet is working for the OÜ Väo Paas company as the Quality Manager, Laboratory Technician at the testing laboratory and as a Safety Risk Expert as well as compiling all necessary documentation.

Has substantial experience in all areas of macadam testing, risk safety manuals composing and safety risk assessment scheduling for Estonian Standards and requirements. Experience on this activity's is seven years. Participating in teaching last three years at Tallinn University of Technology Mining Department with the courses for bachelor students in Estonian language: Rock Mechanics, Rock Breaking and Processing, Marine Geotechnics and Elements of Engineering Geology.

E-mail: ohutu.tk@gmail.com

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