14

The Advanced Technologies Development Trends for the Raw Material Extraction and Treatment Area

Ján Spišak, PhD. and Miroslav Zelko, PhD.
Development and realisation workplace of raw materials gaining and treatment,
Faculty of Mining, Ecology, The Technical University of Košice
Slovakia

1. Introduction

Mining organizations operating in today's market face many complex challenges. The continuing globalization of the mining industry means both increased demand and increased competition. This increased demand and strong commodity prices mean that improving productivity of processes is essential, while at the same time needing to control costs and maintain an effective cost profile for the future. To be effective and to keep productivity at optimum levels, the organization's logistics function is crucial. Ensuring continuity of the in-bound supply chain, maintaining service levels, maximize efficiency of outbound logistics, reducing inventory and increasing inventory turns are all essential to maintaining productivity and minimizing costs. In addition to the productivity and logistical challenges, the mining industry is increasingly the focus of public attention with regard to its health and safety and environmental performance. In order to survive and thrive in this dynamic environment, mining companies need powerful and flexible strategies and tools to enhance the way they operate.

The **EU minerals industry** provides vital inputs to Europe's economy and social well-being – it is not only an important supplier to the EU economy, it is also a world leader supplier of services, technology, engineering, consultancy, finance and equipment. Because of the high environmental standards and the often challenging geological conditions prevailing in Europe, European extractive technology has a leading position and holds about 50% of the relevant world market. To sustain this position and to ensure next development sustainability an intensive research and development on advanced technologies and high-tech products based on raw materials is needed. In 2008 the European Commission published its new strategic initiative "The raw materials initiative — meeting our critical needs for growth and jobs in Europe". Raw materials are essential for the sustainable functioning of all societies, so this platform could be a decisive priority for next EU development.

The requirement to realize a society development in intension of permanent technological sustainability resulted in many concepts and strategic documents or platforms, among others to **The European Technology Platform on Sustainable Mineral Resources** (ETP SMR). ETP-SMR unites hundreds of stakeholders from industry, the research community, public authorities, the financial community, regulators, consumers and civil society around the major technological challenges to the sector, in order to jointly develop a common vision. The platform will contribute to strengthening one of the fundamental pillars of the European economy and society: the European minerals industries. These include oil, gas, coal, metal ores, industrial minerals, ornamental stones, aggregates, smelters as well as technology suppliers and engineering companies. The ETP SMR has the following objectives: securing the future supply of/access to European raw materials; supporting the revival of exploration of Europe's mineral potential; developing innovative and sustainable production technologies; implementing best practices; reuse, recovery and recycling as well as new product applications; creating European added value through RTD-based technology leadership, education and training.

2. The importance and overview of advanced technologies

Currently there has been no shared understanding within the EU on exactly what should be considered as key advanced technologies. There is no coherent strategy on European level on how these technologies can be better brought to industrial deployment at a European level. Generally, the advanced technologies are knowledge intensive and associated with high R&D intensity, rapid innovation cycles, high capital expenditure and highly-skilled employment. They enable process, goods and service innovation throughout the economy and are of systemic relevance. They are multidisciplinary, cutting across many technology areas with a trend towards convergence and integration.

The advanced technologies and materials are the basis of the future priority to improve European industrial competitiveness. The top-ranking technologies are the part of ***advanced manufacturing*** *systems* leading to improvements in terms of new product properties, production speed, cost, energy and materials consumption, operating precision, waste and pollution management. The advanced technologies in mining industry will be based on marketable knowledge-based systems and the related services (e.g. simulation of automated robotics, extraction and finishing lines). Advanced technologies can be applied in all manufacturing industries and form an important element in the supply chain of many high value manufacturing businesses. They make up some 10.5% of EU industrial productions and provide some 2.2 million jobs and account for 19% of EU exports and over 40% of EU private sector R&D expenditure (ETP-SMR, 2009).

2.1 World-wide key concepts for the raw material extraction and treatment area

a. CSIR (RSA) „FutureMine" project - continuation of „DEEPMINE" in the area of occupational health and ergonomics, issues for deep mining mechanisation, automation, communication and sensors, http://www.csir.co.za/index.html. The Council for Scientific and Industrial Research (CSIR) in South Africa is one of the leading scientific and technology research, development and implementation organisations in Africa. It undertakes directed research and development for socio-economic growth.
b. CSIRO Exploration & Mining (Australia), main issues: Sustainable Mining Systems, Mining Automation, Mining Geoscience, Next Generation Mineral Mapping, http://www.em.csiro.au/about/about.htm. CSIRO, the Commonwealth Scientific and Industrial Research Organisation, is Australia's national science agency and one of the largest and most diverse research agencies in the world.
c. DMRC (Canada) Deep Mining Research Consortium – current DMRC projects are defined by the current challenges of deep mining in Canada,

http://www.deepminingresearch.org/Projects.htm. The DMRC provides a forum for members to fund research to improve or develop new technologies for mining at depth. The DMRC membership includes seven mining companies, the City of Greater Sudbury and CANMET-MMSL.

2.2 European concepts for the raw material extraction and treatment area

1. **Intelligent Mine** - the concept of Helsinki University of Technology.

According to this concept, it is a mine that monitors its entire operation in real time, with each process feeding relevant data to the successor process for action, as well as to the predecessor process for feedback. (Mining Congress, Katowice, Sept. 2008). The concept is based on the Production Management System and Data visualization and real-time production control system (Särkkä, 2008).

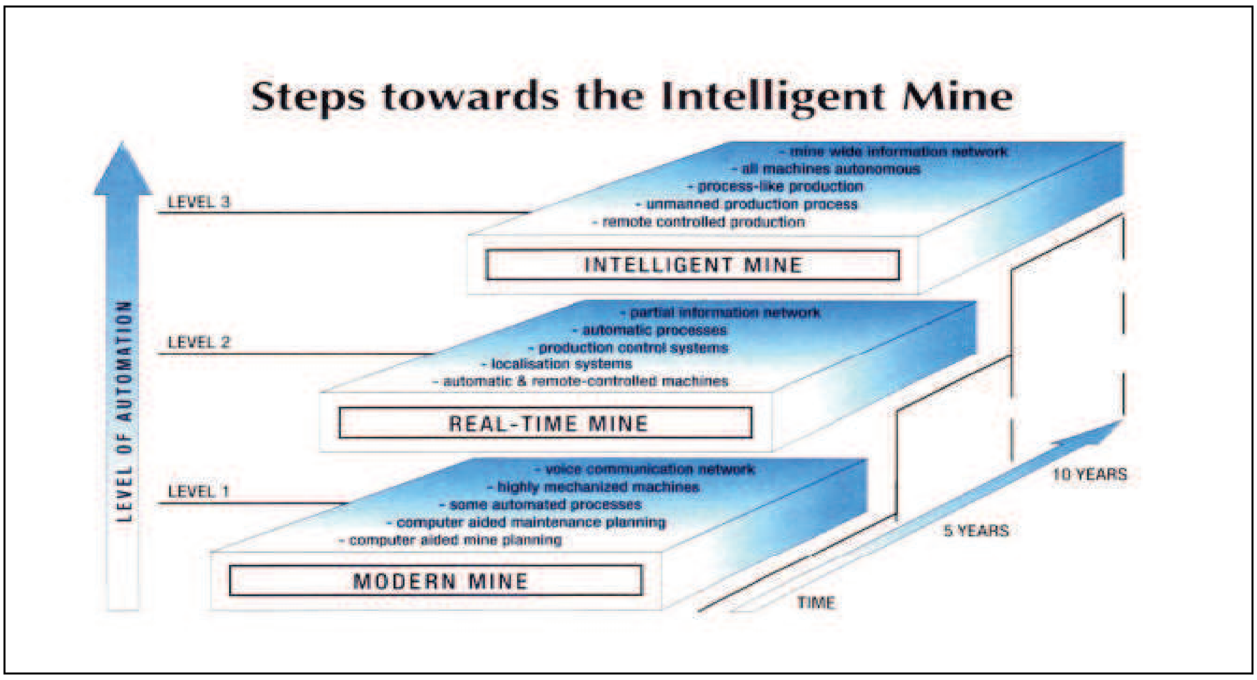

Fig. 1. Intelligent Mine concept

Production Management System (PMS) - is a real time control and monitoring system concerning the whole production chain of a mine starting from geological data ending to delivered concentrates. In the system all the needed applications should be integrated to use the one and the same database. The system should allow manage all the information needed in daily operation. Usually such a system consists of:

- Mine planning
- Production monitoring
- Production management
- Maintenance management
- Real-time condition monitoring and fault diagnostics
- Process automation
- Remote control tele operation

The production control part includes both the work planning and the real-time data collection from the production chain as the feedback to the scheduling. In addition to conventional daily or monthly production reports the key performance indicators can be followed in any timescale desired. The condition control part supports the maintenance work planning updating the information associated with the production equipment and adapting services into the production plan. Furthermore such a system gives the tools for the general management of maintenance.

Data visualization and real-time production control

The structure of the PMS is usually open. The data management system manages the visualizations, simulations, optimizations and production processes, resources location and automated equipments on the other side. The browser-type user interface is generally tailored according to expectations of the mine personnel. The user interface contains very easy-to-use search, assorting and linking features. All the information saved in PMS, dealing with geology, mining, milling, maintenance, cost control all the way to the system administration, should be managed with the same user interface.

2. **Mine of the Future (MIFU)**

The Swedish Initiative – Mine of the Future for years of 2009 – 2010, leader: Nordic Rock Tech Centre AB (RTC) established a consortium for the conceptual study "Mine of the Future" (MIFU) to develop a common vision for future deep mining (depth 1,500-2,000 m). The MIFU main tasks within a Strategic Research, Development and Innovation Agenda 2011- 2020 is research and development of new production processes and technologies and to conceptualise new objectives: the Attractive Workplace, lean and Green Mining and Mineral Processing and new Production Processes and Technologies.

MIFU is the result of growing social order, which emerged from the following facts:

- Extraction is realized from deeper mines and with lower ore grade;
- Stiffer environmental regulations (less energy, less CO_2, less water – necessary);
- Difficult to attract young people for a life in remote locations;
- Challenging safety standards in deep mine conditions;
- Market need for metals will increase;
- Big mines get bigger, smaller mines get smaller and more selective;
- Only the big mining companies have the resources and capabilities to develop and operate on global scale;
- Challenges and the changes are so large and numerous that a comprehensive international cooperation is needed both within and outside the industry in order to succeed.

3. **Intelligent Production Systems for a Sustainable Supply and Use of Mineral Resources (EU-IPSUM)**

Leader is prof. Nicolai Martens, Ludger Rattmann, Institute for Mining Engineering RWTH Aachen University. Intelligent Production Systems (EU-IPSUM) idea consists of:

- **Intelligent mass movement** (transport systems, logistics, process control and automation, ...)
- **Innovative rock breaking technologies** (cutting technologies, SMART IT-controlled blasting systems)
- **Intelligent mineral processing** (near to face processing, multi mineral processing, bio-processes)
- **Intelligent mobile production systems** (keyhole mining, sustainable industrial small scale mining)
- **New geo-resources** (geothermal energy, mining oilfields, water, ...)

- **Information Technologies** (sensors, RFIDs, process control, ...)

Common features of next advanced technology built concept are:

- **Production Management System –** mine planning, production monitoring, maintenance monitoring
- **Real-time condition monitoring and fault diagnostics** – localization systems,
- **Informatization and digitalization** - data visualization, simulation and optimization, virtual reality principles
- **Real-time production control –** technological logistics, RFID systems, sensors
- **Process automation –** SMART factory principles, automatic and remote-controlled machines
- **Intelligent mine** – unmanned production processes, autonomous machines, mine-wide information network

3. Innovative megatrends – basis for the design of advanced technologies

Each period is characterized by basic directions of development, which are determined by existing terms and conditions. Its early tracing allows to obtain a better position of the existing industry resp. companies in this sector through the increased productivity, quality production and cost reduction. In these directions should be developed main innovative activities in the future. In the present, the main lines of development are in the field of technology, logistics and information. In terms of exploitation and processing of raw materials we consider these trends for the most important:

- informatization and digitalization,
- using virtual reality,
- technological logistics,
- advanced control of processes,
- process approach, modeling and simulation,
- results from the research and development of technologies for the raw material extraction and treatment,
- customer oriented production – pull system of material flows,
- ecology and safety.

3.1 The informatization and digitalization

Basis for the **informatization** is process approach and its main aim is to obtain adequate information about realized resp. designed processes. The main source of information about processes are operational measurments, physical and mathematical models. Operational measurments provide empirical information. For obtaining a categorial information we need model experiments. Mathematical models have unique advantage. Their main attibutes must be adequacy and speed of medelling processes. One way how to achieve these requirements is the creation of models based on physical principles and creation of the simplified – replacing models. Simplified patterns must be created for each specific problem. To make creation of models more effective it is useful to apply an appropriate support system. Creation of such systems is very actual. We can consider a development of process models as a dominant factor of their computerization. A second key factor is process analysis, which task is to obtain relevant information needed for the further knowledge.

Closely related with the informatization is also internet and using of advanced communication and identification systems particulary in the logistic processes. One example of advanced technologies for the identification is system RFID. Its use in the extraction and processing of raw materials allows a precise identification of individual doses and following automated process control. For example For example. after arriving into the supply bin, chip RFID gives an impulse, by which provides us with an information about the quality, size of the dose, planned mode of processing etc.

Digitalization enables to increase the quality and at the same time expedite all works related to production preparation, primary production and following services in the total product life cycle. The concept of digitalization represents through its ICT integrated environment in which the reality is substitute by virtual computer models. These virtual solutions enable optimal preparation for the practical realization of production. In this environment digital models are dominated. Real company model creation is and the following it's processing is not a simple matter. It requires top prepared people, corporate processes knowledge, needed software and hardware support, but also patience and purposefulness. The Digital Factory concept is the internationally renowned marketplace, with special emphasis on solutions for product development, production and integrated business processes. Hot topics are product development (PLM/CAD), production and process planning (ERP, PPC), visualization/simulation, manufacturing/automation (MES), process integration, order processing and technical sales/service (CRM). This concept can be also seen as an enterprise and information strategy managing and collaborating processes of factories in global networks. It offers methods and application solutions for product and portfolio planning, digital product development, digital manufacturing, sales and support that deliver faster time-to-value.

The digitalization approach means a general digital support of planning following the process chain from development over process and product planning to production by using virtual working techniques. It follows that the whole process of developing a new product with its associated production equipment has to be completely simulated before starting any realisation. That calls for the integration of heterogeneous processes and a reorganisation of the whole platform´s work. The thread of all process modelling and optimisation is the virtual factory life cycle support till routine operation of real production process. The digital factory approach using simulation for operative production planning and control extends the one for plant design and optimisation.

3.2 Virtual reality

Visual communiation is the most effective tool of human contact with the outside world. For analysis and decision making its necessary to generate not only pictures, which contain necessary information, but with appropriate modification achieve appropriate visibility of relevant information. Another important requirement is to see the existing context. **Virtual reality** fulfils these atributes the best. Its conceptual contribution is the 3D and 4D display and enabling a dynamic communication with the virtual world. Visual support in the virtual reality environment is much wider and more efficient than conventional systems.

The main focus in the development of virtual reality in terms of research and development of raw material should be conceptual and technical management of static and dynamic visualization of processes to solve specific problems. The first step is their handling in the laboratory conditions and following operational verification. Real appear two main directions: using virtual reality for design support and using virtual reality for the management support. An example of virtual reality utilization is a creation of 3D models of technological equipment and their connection into the virtual manufacturing processes during the design, resp. presentations to investors. A good example of using advanced virtual reality in the management process is virtual support of managing technological aggregate, by which we can scan and identify possible errors on aggregate during the maintenance and running of the operation, etc.

3.3 Technological logistics

In terms of theory of processes and systems, we can generally devide processes into the three basic types. **Transformation** (processing and installation) represents technological operation and objective of its management is to provide planned (programmed) running of transformation. **Transmision** (transfer) and **cumulation** (storage) represent logistical operations and objective of their management are flows. From a systemic point of view, technological operations present system components and logistic operations system relations. System organization, it means that interlinking of components is objective of organization.

Technological logistics is part of logistics focused on field of technological processes. It creates the lowest level from the hierarchical point of view. Logistical processes which form a part of technological processes are running in the technological aggregate. Currenty, is technological logistics developed only as supplementary component of technological processes and does not have systemic theoretical ground. Its systemic integration into the logistics took place only recently. Logistical processes provide processes change-transformation and allow their optimal implementation. From that reason they include important innovative potential. As an example we can present logistical processes in the field of processing the granular materials. In the case of magnesite processing there are following transformation processes: processes of drying, calcination and sintering. Logistical processes are focused on the coordination and management of flows and in these field we can devide them on processes **rheological** (material flow), **hydromechanical** (medium flow) and **thermodynamical** (thermal flow).

Rheological processes characterize such movement of granular material in the compact layer. Thickness of layer represents the accumulation component and movement of the layer represents transmission component of the process. The movement can be vertical or horizontal and takes place thanks to gravitational forces, pressure forces and centrifugal forcces. Thickness and the type of movement of the layer and material in the layer decisively influence transformation processes and recently have been subject to the significant innovation. Based on this principe was designed new type of thermal aggregate working in the thin compact layer and significant contribution also was increase in the layer thickness in the rotary furnace (Dorcak&Spisak, 2004).

Hydromechanical processes ensure the movement of gaseous and liquid media through the compact layer, resp. process is performed by flux in the fluidized layer.

Thermodynamical processes include heat and material transfer as well as their accumulation. By increasing the intensity of transmission we can decrease equipment sizes, resp. increase their effectivness.

The main contribution of technological logistics is fact, that is seeking a solution to the problem directly in physical, executive field, wchich forms the essence of the process.

Solutions at the higher hierarchical levels can be optimized only based on the output from the technological area. The benefits achieved by the solutions in the domain of technological logistics can reach up to tenth percent of the process cost, which confirms that this area has great potential for the innovation. Its use mainly depends on the professional handling of the task, therefore education of the professionals and systemic research of the topic must be regarded as decisive factors.

An example of difference in the nature of technological and logistical innovation can be arrangements leading to the same change on the level of the technological process. This is achieved by decreasing a temperature of caustization with the same fuel saving for the caustization. Technological measure (change in transformation) depends on adding appropriate chemical reagent to decrease the temperature of decomposition (for example NaCl) into the burden. Negative is change of the final chemical composition of the product, which disables its use for some applications, as well as the costs of the reagent.

The same can be ensured by applying the principles of the technological logistics. Specifically, by synchronizing thickness of the layer, heigth of the zone with hydraulic and thermodynamic processes, which is expressed by longer stay of the material in the detention zone. This causes that the same degree of magnesite caustization will be achieved indeed for a longer period, but at lower temperature and significantly lower costs without affecting quality of the product and composition of the product.

In terms of using advanced technology in the logistics, new concept should be based on the PULL system, it means on the tensile principle and should meet following logistical requirements:

- eliminate the need for processes, flows, supply bins,
- integration of processes and equipment
- flow of supply bins,
- balancing capacity of resources in the supply bins,
- harmonizing production and transfer doses in the manufacturing process,
- minimalization, directness, uniformity and fluency of the material flows.

Ideal in terms of optimalization of resources would be a manufacturing process, which would work **without need of supply bins**, it means that everything would be running by system JIT (just in time – right in time). This state presents technological-organizational optimum. However to reach this kind of state in the mining company is probably not possible. Despite of that the elimination of the suplly bins need in the limited scale is real and possible to perform by harmonization of performances and capacities of the machines and equipments. And mainly through the integration of the manufacturing operations and processes into the one technological aggregate, which eliminates a need for the maintaining processes and equipments between them. As an example we can use new integrated thermal aggregate, in which we integrate supply bin, drying, dedusting of combustion gases, pre-heating, calcination, cooling, windy classification and deplacement of the product. Another option how to eliminate the need for the supply bin we can use transfer as well as mobile supply bin.

If it is not possible to remove suplly bins completely, the possibility for more effective system of extracting and processing of the raw material we can use - FIFO (first in/first out) supply bins with piston flow of material in them. In these supply bins does not occur mixing of raw materials of different quality from different doses which moving one after other. Flow supply bins work on the principle of gravity, they are simple in design and enable to create self-organizational systems. In terms of maintenance and operation they are not so demanding. The harmonization of the stock volume in the supply bins means determining the optimal storage capacity of supply bins and estimation of the optimal level of the stock volume in them based on the needs of technological process. For this purpose i tis appropriate to use simulation and balancing models of manufacturing process. On one side resources are linked with financial issues, on the other side they are inevitable for the optimal functioning of some technological processes. They are inevitable mainly in front of narrow place, resp. in front of continuously operating aggregates, for example in front of rotary and pit furnace.

To ensure effective and smooth running of the manufacturing process, the condition is to define optimal size of production and transfer dose. Mining process is characterized by conherently-discrete material flow, conherently-discrete running manufacturing processes and till now also by variable size of manufacturing and transfer dose. Mining dose is given by extraction method and sizes of mining block, transfer dose by capacity of transferring equipment and mineral adjustment is running mostly continuously. Dose difference causes mixing of raw material different qualities. Consequently arise problems with sustainment of the productoin quality by unstable avails adjustment, capacity utilization and uneven loading of manitenance equipment. New concept of extraction and adaptation, which is based on PULL principle, requires to revaluate existing system and not only to synchronize manufacturing and transfer doses in the production, but also to adapt them to the customer requirements. The basic criteria for the optimal material flow are his **length, directness, uniformity and fluency**. Placement and organization of the process and directness influence length of material flow, uniformity and fluency is affected by level of its use. All mentioned qualities of the material flow influence its economic situation. Fulfilling the requirements for minimization, directness, uniformity and fluency during design it is possible to decrease investment costs and during the process running dut down operational costs, specificaly costs on transfer and manipulation, costs resulting from the decrease of resources volume and production in progress and also costs for maintenance etc.

3.4 Concept of Advanced Process Manipulation

Concept of **Advanced Process Manipulation** (APM) is based on procedural principle, where all handling activities are focused on optimal running of the process. This approach brings significant changes into the handling of the processes. In the present the most of solutions in some way take the process into the account., although real proces oriented approach is mostly an exception than rule. Existing individual solutions show conceptual advantages of this approach. Classical approaches can exist only in certain connection with these new conceptions. While using external manipulation, subject is dominating over an object. Object is passive and is waiting for the intervention. When using internal manipulation, object is active and requires a minimum of the external forces. Manipulation is made by transformation, mutation and adaptation. Manipulation process can be physical or logical and can run on the following manipulating levels: structura, organizational, operational and physical (Hughs&Grigg, 2008).

On the structural level is specified optimal working instrument. By structural arrangements we can approximate a process to the optimal. On the structural level is process influenced by structural components, by their interconnection and parameters. Structural component influences the process in the way that becomes its part and executes the activity on behalf of the targeted process. It is preferable to place manipulating components on the local level, which perform their operations spontaneously on behalf of running process. Simple exponents express the laws of self-organization of irreclaimable processes. Process running based on exponential laws requires a minimum of external interventions. Real processes are generally running in some restrictions. In these cases processes are expressed by more complicated relations including simple exponents. In case of restricted resources the process can be approximated by logistical curves. However these do not have that preferable qualities as simple exponents. That is why is necessary to execute process management based on optimal trajectory.

Organizational level is characterized by choice of organizational forms, determining working mode, which insures that process is running close to the optimal mode. For specified structural level is necessary to find the optimum, or its borders. Manipulation task is to find aggregate of process trajectories, which reflect starting state into the final state. This transformation is executed based on physical laws. All processes in given device are harmonized.

In the operational level is manipulation executed by handling, which reflects real state of trajectory into the desired trajectory. I tis not possible to run the process without disturbances. Disturbances are time functions. Process shoulg be running close to the chosen trajectory. Planned trajectory is stabilized by management. Handling parameters are process parameter and product parameter. Management system or operator determine handling parameters and execute control interventions. Optimal strategy on this level is stabilization of process trajectory. Optimal working mode is reached by control devices. Priority has prediction before correction. Minimalized external handling is necessary for the execution of the radical changes of the process.

On physical level is realized macroscopic process, which determines microscopic processes. By manipulation we understand a realization of operational interventions through the active physical items based on physical laws (power, movement), which functions as converters, accumulators, etc.

Optimalization represents qualitative jump in the processes improvement. Main task of optimalization is to find from the group of extremal curves the most preferable curve. This process is connected with principal and practical difficulties. Hierarchical mathematical model of the processes here plays the key role. Optimalization of the processes in context of advanced process manipulation can be devided into the following phases:

1. Technical optimalization (decrease in restrictions):
   - designing – optimal components of the process,
   - organization – optimal ties of the process.
2. Operational optimalization:
   - planning – optimal trajectory of the process,
   - performing – optimal running of the process.

3.5 Process approach, modelling and simulation

In the process approach is key attention devoted to the process needs, which enables to be pro-active. It is necessary to create a system which is able to react on process needs, with the appropriate technology, process organization and adequate management (Davenport& Prusak, 1998).

It means to have the appropriate process elements, their interlinking, quality sensors, by which we can detect the phase of the process as well as present and future trends. In this

manner a whole system, starting from the design of the process and ending by its realization, is more and more sensitive on what occucs in the process. Process takes place on various levels. On each level process should run in the optimal mode.
Process orientation can be devided into the two parts:

- first part (analysis) includes collecting data about the process and ability to understand the process
- second part (synthesis) forms an ability to use these information to influence the process

Sensor-based approach is a philosophy, which optimalize use of the process potential. Processional orientation may present significant benefits. One of the key factors of advanced process orientation is an understanding of the process essence, which has two basic aspects:

- However difficult is the process, it is necessary to understand it.
- Big amount of sophisticated and advanced tools exist existuje, which are available to those, who have already understood them and already knows how to use them.

Modelling and simulation

An example of available sophisticated and advanced tools is modeling and simulation, which are used for better understanding of the process laws, but also for the experimentatory use with different prepared advanced solutions resulting in the process development.
Symbolic models are the abstract representation of the real world. We talk about verbal or formalized description of modelled system, for example through the graphical or mathematical presentations. They are unchangeable and uncoverable experiment tool, because it is more simple to manipulate with models than with the real objects. Models allow to understand better a reality based on following the changes of chosen indicators. Simulating model by using simulations give the possibility to experiment effects of the prepared actions during the running of the processes. Analysis of simulation results offers a good orientation about o the extent and impact of planned measurments. In the present we use two models for the purposes of better effectivness of production and process management:

- First type form **models of production systems**, which serve on the simulation of functioning and behaviour of these systems as a whole. They are usable on the strategical level for defining technical-economical efectivness and impacts of prepared investments or racionalized actions, on tactical-operational level for planning and shcedulling of the production etc. An example of this type of model is blancing model of the manufacturing process.
- Second type of model represent **models of processes and devices**, which are used for solving certain types of cases, for example for design of thermal aggregates. As an example of this group serves model of thermal adjustment of magnesite in the rotary furnace.

By connecting both above defined model types we get an advanced hierarchical model system, which is based on hierarchical principles and allows directly study complicated processes and on this principle perform also their optimalization. Hierarchical nature of the processes is generally known and accepted. To each hierarchical leved corresponds its specific process, which includes elementary processes and their combinations. To every hierarchical level applies specific type of movement. Technological process are expressed by evolution degree in time. Process on certain level we may consider for an abstraction of complex process executed on various levels. Processes on the individual levels are reciprocally interconnected in that way that processes on the lower level perform processes on the higher level. This is reflected in the reciprocally corresponding parameters. Kinematic parameters on the lower levels correspond to the force functions on the higher levels. Processes on the higher levels determine processes on the lower levels (Prawel, 2007).

On each hierarchical level are internal ties and external ties between processes on the individual levels. Those can have different structure and different complexity. They can be hard or soft. Soft ties express an autnomy of the processes. Ties between lower and higher levels are securing and between higher and lower levels are controlling. Controlling and securing ties are also between the components on individual levels. Process innovation can take place on intro-level and between-level. Typical hierarchical levels of the processes are: **designing level, managing level and physical level**. On physical level are running material processes based on their own laws. On the management level is running controlling process, which provides process on physical level by determining operative parameters. On the design level is proposed executive (material) and managing process. Designing process has only free ties towards the proceses on the physical and operative level. Between physical and managing level are strong inter-level ties.

3.6 The results in the research and development of technologies used for the the raw material extraction and treatment

Dealing with the research and development of technologies used for the the raw material extraction and treatment is the content of ETP SMR Strategic Research Agenda (SRA) which shows the way the mineral industry should proceed in forthcoming decades if it is to serve European society in the way necessary. The structure is divided into the the 4 focus areas. The scope of the established focus areas relates directly to particular steps in the raw material value chain. The focus areas covers the whole life-time of a particular product, from exploration and extraction until reuse and recycling. It reaches processes from the exploration, the identification of valuable mineral resources to the sellable products. All steps of the supply and production chain for mineral resources are underlined with societal issues of various kinds.

- **Exploration, Extraction and Closure (**Towards Total Resource Utilisation, Energy efficient fragmentation technologies, Innovation for materials handling and logistics optimisation, Internal processing systems for re-use and recycle, Environmental footprint reduction using new processing systems, techniques (life cycle assessment), Knowledge building networks)
- **Reuse & Recycling (**Information network for mineral and metallurgical industry, Industrial network on waste prevention and recycling aiming at turning wastes into products, Prevention of waste by innovative processing - innovative processes turning waste into products, Feedstock recycling (plastic, waste wood, chemicals), Footprint free production - Recycling of materials and better use of mineral resources
- **Products & Materials (**Creating new mineral product functionality through an enhanced product and customer understanding and knowledge building, Finding new application areas for mineral products and designing the mineral products for tomorrow, More efficient management of innovation in the mineral industry and building new products development capabilities)

- **Mineral Economics and Societal Issues (**has identified research areas in close relation with other focus areas to detect and use cross-sectoral synergies.)

3.7 Customer oriented production – pull system of material flows

For the management of the manufacturing process in general exist only two philosophies. Principle of the first pressure philosophy is to push the fastest and most effectively all resources, material, semi-product through the whole manufacturing chain and through that gain the most of the product not regardless following business activities, mainly consumption (production on stock). Sometimes we call this procedure the push method. Simply we can say, that type of systems „Push" are those manufacturing systems, in which is production managed with a stiff plan (production on stock). Here the priority play business objectives (for example maximalization of using company resources, minimalization of company costs etc). Methods of push management can be various, they always depend on centralized monitoring and influencing of individual activities. This method is characteristical for the first-fabricated industried, it means industries with the uniform manufacturing process. Typical example of these processes are processes of exploitation and processing of the raw material.

Second method is puulling, based on the opposite principle. Using this method - **„pull" method** impulse for the production-logistic chain comes from the customer (custom made). In the moment, when the final process is requested by customer for the delivery of the product, he will turn to the previous process with the request for delivery of the necessary inputs, this process requests previous, etc. This method i sused as an advantage not only in the production and delivery of the cars, but also computers and other goods, which are configured based on customer requirements. For those are parts, semi-products mainly „pulled" by flow, than pushed in the fron in big amounts according to planned directives. Management of the material flow gets more simplified.

Both philosophies have their advantages and disadvantages. Manufacturing processes and conditions of their functioning predict form of a management and by that also choice for one of these philosophies. Till now in the mining processes was typical to use PUSH system, which corresponded to the character of the manufacturing process and conditions of its functioning. The problem is, that conditions have currently and significantly changed, customer is not waiting passively for the delivery of the ordered product, suppliers of the input into the mining company are also following market rules. Meanwhile also the technologies used in the mining industry are changing lately and are adapting to the energic, technological, ecological and social requirements. By that way they create conditions for the implementation of more economical PULL system of the management also in the mining industry. While most industries have undergone, resp. proceeds on the more effective energic, material, personal (PULL) system of operating manufacturing processes, mining industry (partly with a reason – natural conditions, technology of extraction and adaptation etc) is using only classic (PUSH) system. If the concept *extract - adapt - sell – to dispatch* changes on *sell- extract- adapt- to dispatch* It will make signigicant changes in the companies management, which would bring new possibilities of increase business competitivness, targeted exploitation and targeted processing of extracted material and it will significantly improve customere service.

Application of PULL system in the planning and managing of the mining activies opens new possibilities in optimalization and better effectivness of the business processes.

Utilization of this new system in the original structure of business activities is not possible, resp. it would enforce significant corrections, which would seriously restricted its innovative potential. For this reason it is inevitable before application of new system of management execute radical (reengineering) changes in organization of existing corporate logistic systems of mining companies.

All known mining production processes as well as the majority of homogeneous manufacturing processes is organized by PUSH system, it means based on manufacturing process and mainly its narrow place and is not based on customer needs, which are in this system on the second place. Main features of this type of organization of the production process are:

- Maximalization of production volume by PUSH system of management of manufacturing process (output restricted only by transmittance of narrow place),
- Minimalizaton of unit product cost by decreasing fraction of fixed component,
- High costs for storage and manipulation given by creation of between-operational resources,
- Advantages connected with the forcus on one, resp. narrow selection of goods,
- Possibility of flexible and immediate product withdrawal from the shipping stock by customer,
- There must be fullfilled the requirement for tzv. limitless withdrawal (resp. stock), it means that is necessary company´s ability to sell all what was produced. This is possible only with a permanent dominance of demand over the offer,
- Problematic enlargment of production range,
- Simple and stereotype system of producton planning and managing,
- Feedback of quality control of manufactured production,
- High degree of using labour force, high labor productivity

PULL system is based on the opposite philosophy. Needs of customer are dominant and manufacturing process must be organized in that way, that i tis able to fulfil customer needs in flexible and meanwhile effective manner. Basic characteristics of this system are:

1. maximalization in fulfilling customer requirement – hard focus on the customer,
2. ensuring production flexibility and ability to react the fastest way on changing requirements of the customers (changes in production selection and amount of whitrawed production),
3. Pull work organization, by which are parts „pulled" by manufacturing process based on need to finalize customer orders,
4. Management of fluency of material flow and its synchronization allow to have quite better overview opposite to classical PUSH system about material flows and stocks,
5. Minimalization of running times of production by choosing the extent of production doses in that way, that there will be minimal between-operational times, mainly times for preseting the machines and downtimes,
6. In building of quality control into the manufacturing process and its consistent exercitation, quality is not controlled because is produced,
7. Minimalization of between-operational stocks by synchronization of produced doses in accordance with requirements of purchasers will allow cost decrease for storage,
8. Decreasing variable costs caused by decrease of measurment of production in-process,
9. Increasing fixed costs because of not even loaded process capacity,
10. Decreasing of oversized work pace using creative potential of human labor and team work,

11. Information support of processes and transparent information flow.

Based on comparing basic features of PUSH and PULL system is possible to say, that in regard to changed market conditions, application of PULL system in the specific conditions of mining industry can bring not only significant decrease in total production expenses, but it can be the way to ensure its permanent maintainable prosperity.

3.8 Ecology and safety

Dealing with the research and development of technologies used for the the raw material extraction and treatment is the content of many European project ideas using advanced technologies to reach the objective are listed following:

- New technologies for management of gases which are rich in SO2 aiming to produce by-products, e.g. gypsum directly from gases
- Environmental footprint reductions by developing new technologies and applications: water treatment, gas streams handling, etc.
- Radical changes and innovations in mineral and metallurgical processes to improve efficiency and decrease environmental negative impacts
- Clean processes (hydro, bio, pyro) for treatment of complex ores and wastes aiming to reduce environmental impact
- Materials and chemicals to reduce environmental footprint
- Monitoring tools and sustainability environmental management standards, indicators
- Innovative methods for disposal of tailings
- Technological and administrative tools for reduction of mining waste
- Management and disposal of wastes in mining operations
- Assessment of the environmental impact of mining activities on groundwater and soils - evaluation of the current knowledge base, mitigation or remediation technologies
- Rehabilitation and chemical and biochemical processes for extraction, sequestering or stabilisation of pollutants from contaminated land
- New technologies preparing shafts for filling; old shafts, excavations, shallow deep mining activities
- Remote sensing technologies for assessment and monitoring reclamation process
- Pro-active policies of the mineral industry implantation in developing countries to improve and sustain regional development

4. The 21st century mining corporation concept

"The 21st Century mining corporation" concept presents a complex objective created and target-oriented solution for mining industry, making provision for all relevant innovative megatrends, integrating latest results of research and development in the form of progressive technology, system processes into **the integrated holistic solution** flexibly adaptable on the conditions of factual mining corporation.

This integrated holistic solution (Fig. 2) incorporates the full raw material value chain - raw material sources searching, their extraction, primary and secondary processing, up to the product finalization. It makes provision for the product re-use and recycling on basis of minerals, territory revitalization after mining activities, but also an information support of mining enterprising, system control and mining corporation logistics, including all necessary utility and corporate processes (maintenance, transport, etc.) and socio-economic aspects.

The solution rises from the fundamental dividing of extraction and raw material processing value chain into the five basic research areas according to European Technology Platform for the raw material extraction and treatment. that details, fills up and target orientates goals for filling the concept vision of intelligent, complex and effective raw material extraction and treatment by an advanced technology into the new products with higher added value, all allocated underground – that is „Invisible Mine" vision – an vision of not only underground extraction, but also underground mineral processing. This vision presents the mining and processing industry plants, that can be "invisible" not only from the reason of their underground location, but mainly from the point of absence of their unhealthy impact against environment, miniaturization and smartization, minimizing consumption of energy, an advanced system control based on the principles of APM (process self-steering, self-regulation and self-organization), complex non-waste extracted raw material processing into the products according to customer requirements. To create such a solution it is needed to obtain the critical amount of information and knowledge.

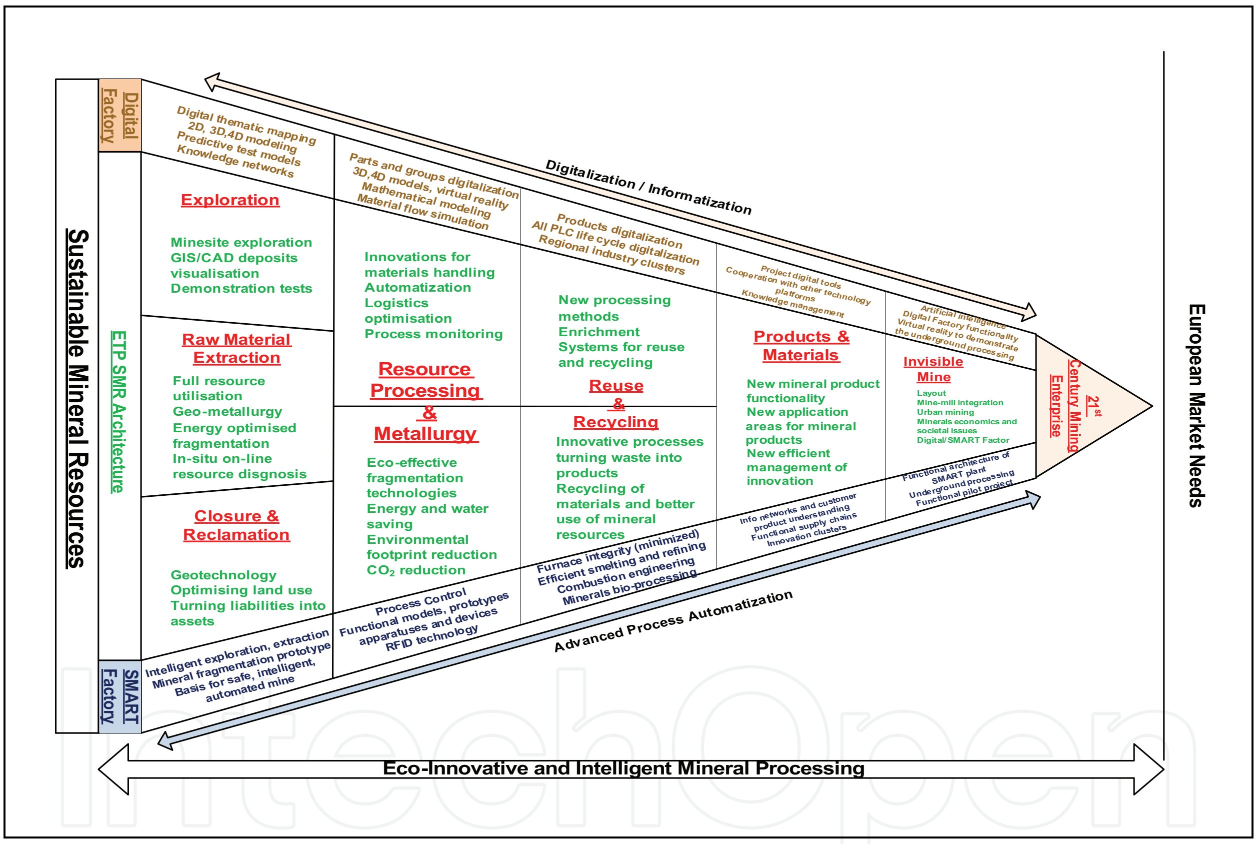

Fig. 2. The scope of the 21st Century mining corporation concept

The task to use advanced technologies in mining industry links together more economical and effective utilization of accessible raw materials with emphasis on the environmental safekeeping at the same time. This complex problem demands to optimally realize wide scale of activities, starting with geological exploration, extraction, raw material treatment – up to the product finalization in two reciprocally influencing levels – in real level (physically) and in virtual level (digital). From that reason the 21st Century mining corporation concept is within digital world represented by Digital factory concept and within a physical appearance by the SMART Factory concept. The diagram (Fig.3) presents the mutual interconnection of these two worlds.

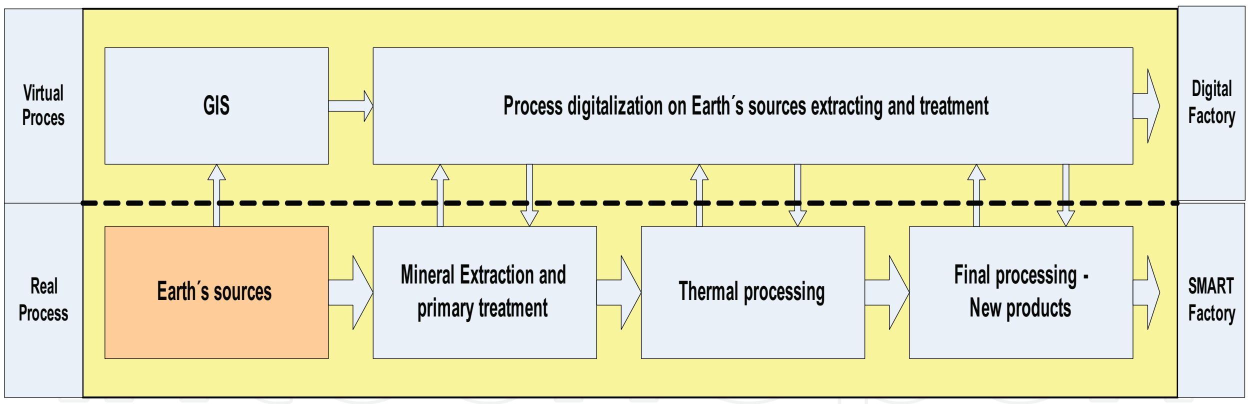

Fig. 3. The basic diagram of the 21st Century mining corporation

4.1 The Digital Factory

The Digital Factory (DF) is an advanced technology of a real production virtual picture, which shows the production process at virtual environs. The Digital factory concept serves first of all to plan, simulation, management and production optimization. Informatization, digitalization and virtual reality create the fundamental prerequisites for the digital factory creation (Kuehn, 2008).

To create the complete digital factory in the area of raw material extraction and treatment it is needed to digitize processes gradually, which digitalization would enable to reach important benefits and these can be gradually enlarged and integrated. From this point of view the digitalization of two corporate processes is actual: specifically corporate processes aggregating scheduling within logistics and key technological aggregates (e.g. thermal aggregates) within technology. These processes present a suitable basis for the progressive digitalization of others referring processes. The key technological (e.g. thermal) processes digitalization within the raw material modification enable to utilize a predictive approach in their control and based on the mathematical simulation models it enables to use a virtual techniques in their control. These processes represent from technological point of view bottlenecks, in most cases. The modelling and consequently also operational harmonization and integration is performed by progressive foregoing and consecutive process models linking into the thermal process models.

The final digitalization objective is to create **the whole technological process model** vertically integrated with **superior advanced corporate planning and control system**, which integrates into the one system all corporate processes on the tactic-operative level. Thereby we can reach the corporate process integration – the foundation-stone of Digital Factory concept.

The advanced corporate planning and control system is based on the deposit Geographic Information System utilization, the Hierarchical mathematic-simulation model of the raw material extraction and treatment process and the aggregate planning system, which creates the superstructure above the former two models. Such a system makes it possible a mining operation functioning in new effective mode, fully respecting customer needs, the possibilities of raw material treatment and processing, as well as the extraction possibilities and constraints. On the following diagram (FIG.4.) it is displayed the interconnection among an individual parts of the proposed system.

Each from the sub-models is able to work independently, what may bring a considerable contribution, but only en bloc it can reach and fetch all consequential synergistic effects. The scope of the Aggregate Planning System (APS) is to process customer-tailored requirements and creates a suitable custom-made fulfilment for production process regarding its constraints. Through the right harmonization of all activities, the APS can provide production processes from material input to their outputs - products. Through the APs interconnection to the Hierarchical Model of Production Process (HMVP) and Geographic Information System (GIS) by reciprocal information flow the system can ensure more perfect and effective control for full mining production processes.

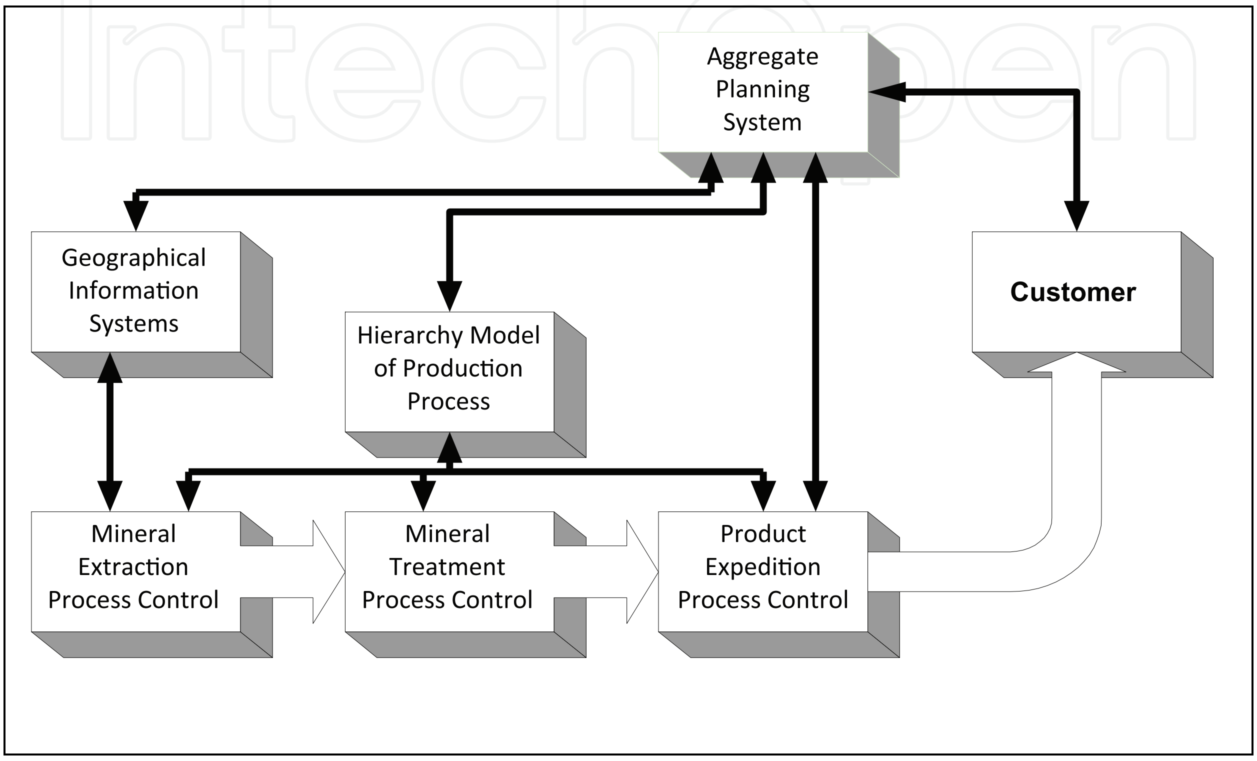

Fig. 4. Advanced corporate planning and control system

4.2 The SMART factory

The target of so-called **SMARTization** is to create an intelligent and sophisticated factory in area of the raw material extraction and treatment and to ensure its functions within full life-cycle, which comprise a designing support, planning of operation-service activities. Physically version concept realization of „invisible and intelligent" factory - mine will be realized in order to fulfil requirement to be up to standard of **4e**: must be effective, economic, energetic unassuming and ecologic.

Smartization decreases constraints lying on a process and ensures their realization by natural style with the outer control intervention minimization and full elimination. Performed processes run over the surrounding of their technological optimum. At the same time it is possible to simplify technology, equipment and process organization. Hierarchical approach makes it possible to perform process optimization independently of structural, organizational, operating and physical levels. The structural level task is to decrease constraints on process in order to run over maximally freely with the maximum internal feedbacks, which meet ideal technology. At the most processes it is possible sort of to come near to this stage, which we can denoted as technologically optimal process. Technologically optimal process is able to be a measure for the individual alternatives. The optimization goal is not only to find optimal output of the process, but also optimal course of the process. On the organizational level we can designate an optimal trajectory of the process for specified conditions of the process within the frame of its possibilities. Operational level ensures the course of the process nearby an optimal trajectory. Under the optimization from the point of the scope we understand not only finding of the total optimum, but also relative process improvement.

Application of SMARTization to the raw material extraction and treatment processes will designates a meaningful upgrade of technology. We reach benefits in operating costs decreasing, mostly in energy savings and in the higher raw material assessing. It will be created a possibility to develop new products this way or to increase the add-on value of existing ones. The increased contribution is estimating on 25-50%. The master impact will be on the potentialities of transition from standard production into high-tech category.

SMART factory concept is created gradually, based on the advanced technology ensuring the real semi-operational and operating activity. The realization of complex SMART technology implementation within the frame of full corporate processes spectrum needs to create partial solutions alternatively innovated technological islands and integrates then consequently into the total and functional solutions. So-called SMARTization will comprise the modifications of real and virtual objects (mathematical models), database and visual communication on the level of a partial operations and components through the machines and aggregates up to a complex operating technology.

1. **Partial operations and component parts** – development of intelligent partial operation – equipment component part, aggregate or technology with elements of sophisticated autonomous operations, e.g. autogenous grinder component.
2. **Equipments** – represent development of autonomous equipments built from Smart type of component.
3. **Aggregates** – represent development of bigger unit as are individual equipments and dealing with integration them into the aggregates, e.g. windy separation integration into the swing-hammer crusher.
4. **Technology** – represents development of the biggest unit, components and aggregates integration into the sophisticated complex, which represent the technology for factual technological process or nodal point, e.g. technology of thermal processing in thin layer.
   In this manner the created advanced technology will designate the transition from automated equipment supported by control system to high intelligent autonomous self-steering system equipments without assistance of control system! The final stage is to establish the integrated and smartized technology complex of raw material processing.

The strategic goal of smartization is to reach sustainable development in area of raw material treatment. It can be reached by securing the database and knowledge for all life-cycle phases by the process and aggregate research and development, with the aim of to minimize dimension, technical efficiency, by the technological logistics (TL) and the Advanced Process Manipulation APM principles applying. The solution is based on the research and development of advanced technology within raw material extraction and treatment within the approach of Invisible/Intelligent Mine and on virtual designed functional verification of advanced technology for the raw material extraction and treatment process application.

The application of up-to-date science research results in the form of production technology and logistics area SMARTization demands to apply adequate approaches to control corporate processes in the concept design. The systemic and process approach will cover all four main production process characteristics: *quality, quantity, time and position*. Production process on all levels will be divided into three main groups namely:

- transformation – processing, which causes the quality, quantity and time change,
- transfer - transport, this causes the position and time changes,
- cumulation - storage, which causes only a time

At present time the dominant control system is **the combined system** in production processes, built-up from program, forward and feedback control (Lipsett et al., 1998).
While in technological processes dominate programming-feed-back control, in logistics processes dominate programming-forward control. The progressive competitive tension impact and requirements on quality production, as well as on system flexibility we need to put the accent on predicting component within the control. This is one of the reasons to prefer logistics and process approach within the control on the present. Upon this trend also the managerial structure proposal for the new concept of the raw material extraction and treatment process with using of advanced technology is responding, which prefer the programming-predicting control, an advanced manipulation process concept (self-organization, self-regulation, self-steering), the control informatization a digitalization and the logistical principle into lowest hierarchical process levels implementation (technological logistics).

5. Methodology for the accelarated transfer of advanced technologies into the practice

In order to accelerate a transfer of advanced technologies and processes into the practice was designed original organization approach towards research and development activities at our working place. It is built on the expansion of research space towards implementing activities and replaces classic activities before realization (project preparation, test operation, start up of the operation) by advanced tools (virtual reality) allowing greatly speed up the innovation process and ultimately reduces investment and operational costs of modern technology. This methodology is schematically shown in the picture below Fig. 5.
Proposed methodology is designed in regard to the up to now results of realized applied research, resulting in the creation and development of advanced technological processes and technology in the science field of exploitation and processing of raw material applied in

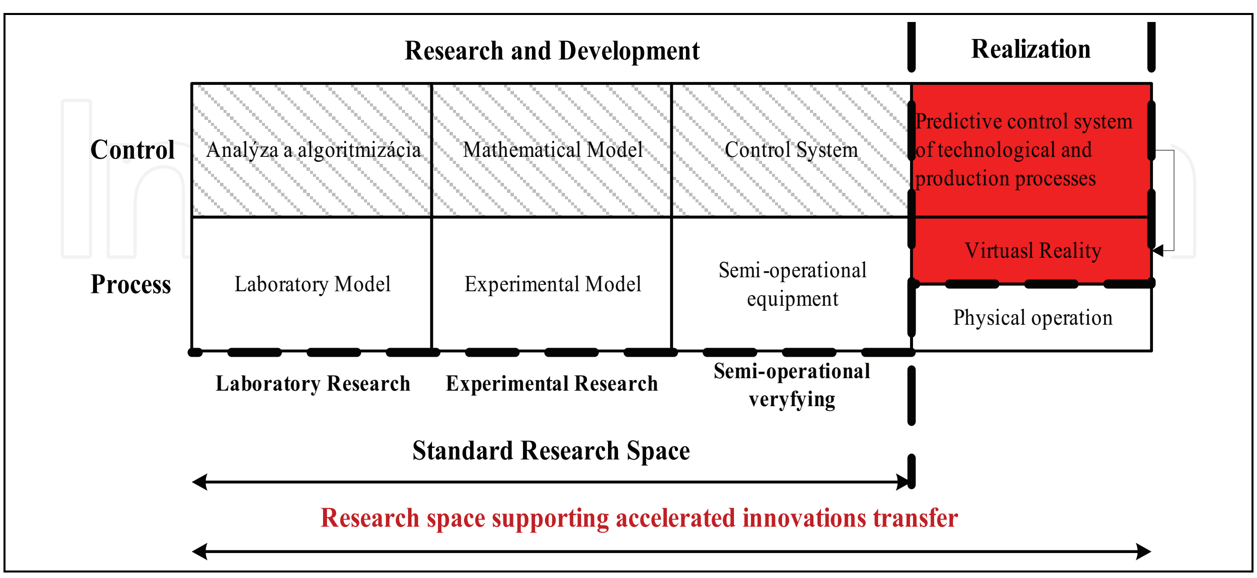

Fig. 5. Concept of extending the research area which supports accelerated transfer of the technologies.

new **extraction and complex magnesite processing technology** pilot project . Purpose of this concept is integration and finalization of up to know partially solved research tasks focused on innovation of processes and tools for acquisition and processing of raw materials to the functional and half-operational verified scheme of complex high-tech technology processing of magnesite.

In the context of the above mentioned approach towards applied research linked with a transfer of new knowledge into the practice is particularity of draft concept for **complex semi operational verifying of new technology functionality without the need of its physical construction**, which brings very significant cost and time savings. Concept will be handled locally in a semi-operational environment also the functionality of particular technological processes and their compatibility with partial mathematical models of processes and aggregates. Consequently on complex mathematical model created in virtual reality environment will be verified whole production process together with created intelligent monitoring system, predictive control system of technological and manufacturing process and the proposed business logistics system.

The advantage of this methodology compared to classical concept of access to research and development is:

- half operational verification of individual technological processes (thermal and finishing) in physical form, at local scale and not depending on time
- verification of the proposed logistics processes in the operating conditions only in virtual reality
- predictive control system of individual technological processes integrated in hierarchical management system of manufacturing process will be verified in operating scale in virtual reality
- verified links and optimal allocation of technology and logistics operations in the new technology prior to its construction
- defined the precise techno-economical parameters of future operation

6. Conclusion

The target of this contribution has been to analyze complexly the potention of advanced technology application and innovative trends for making the raw material extraction and treatment process more effectively and to ensure the competitiveness and sustainable growth of mining corporations. The solution of presented goal suggests the innovative solution application in specific and exacting conditions of mining production processes, the complex appraisal of their contributions and the generalization of gain experience from its application. From the aspect of innovation character were appraised technological, logistical and economic-organizational innovations.

The results from an analysed impacts of suggested innovation arrangements, as well as the present experience from its applications in practice were utilized for a model method definition to support innovative process, starting-point and principles on innovation arrangements proposal with the highest level of changes, to the conceptual model proposal of new advanced technology on raw material extraction and treatment area – **the 21st Century mining corporation concept**. This concept is the generalization of developed and progressively applied concept of a complex magnesite ore processing that contains the proposal of new productivity-technological, logistic and organizational–control system. The proposal of production-technological system come out from new technology of raw material thermal processing possibilities (ITA technology, micro-fluidic high-speed rotary furnace) as well as new extraction and finishing solutions. The logistics system proposal is based on an application of PULL system for controlling corporate processes, possibilities of address extraction and processing according to customer-tailored requirements, which come out from aggregate system planning concept, possibilities to utilize mathematical modelling and technological logistics. At the proposal of organizational–control system were utilized the forward control principle in maximum measure, process informatization and digitalization and virtual reality. Cross-sectional approach was used at new raw material extraction and treatment proposal and the philosophy of advanced process manipulation.

Submitted concept of the advanced technology application on the raw material extraction and treatment area comes out from our experience of factual own innovation applications on various level and various areas of corporate processes. On levels from process parameters change, through their restructuring, radical reengineering changes pending the proposal of new complex technology. Most listed examples were already realized in practice, or in the near future time the realization is prepared. The application of suggested solutions and concepts in corporate practice will enable corporations the greater orientation on customers, permit an effective exploitation of mineral resources, or enables on qualitatively higher level to operate with corporate sources. Significant solution benefit represents also possibility to allocate a fact, that concept results after verification in practice would be immediately integrated into educational process. Implementation of a verified knowledge about raw material extraction and treatment innovation process contributes towards an enhancement of educational-training activities predominantly at close phase gradual study a post-gradual study. The student preparation like specialist – professionals for innovation enterprising is decisive for securing sustainable development of corporation functioning in raw material extraction and treatment area.

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