CARPATHIAN LOGISTICS CONGRESS CLC´2011

6th International Conference LOGISTICS & TRANSPORT 2011, LOADO´2011
7th International Conference Financial and Logistics Management 2011, FLM´2011
Logistics Conference TOTAL LOGISTIC MANAGEMENT 2011, TLM´2011

TECHNOLOGICAL LOGISTICS PRINCIPLES AS THE KEY ELEMENT OF NEW INNOVATIVE TECHNOLOGIES AND SOLUTIONS FOR SUSTAINABLE RAW MATERIALS SUPPLY.

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Key words: Technological Logistics, Advanced Technologies, Innovative Strategies, Advanced Process Manipulation, Knowledge Triangle

Abstract: The EU strategic goal of innovation process in the area of raw material resources extraction and treatment is the sustainable development. Innovative approaches address all aspects of the value chain including mineral exploration, mining, beneficiation, metallurgy, recycling. The European Commission is fully aware of this importance and integrates the raw material resources within the ground pillar of European industry sustainable development and those are becoming an integral component of new EC approach for European innovation partnership (EIP) creation. The strategic goal of innovative approach filling in the area of raw material processing by the form of advanced technologies is also a target of the IntelliMine consortium. The technological logistics principles were accepted as a new approach to advanced technology strategy and implementations creation for European mines of the future. These principles are the subject of this contribution.

1 INTRODUCTION

The EU strategic goal of innovation process in the area of raw material resources extraction and treatment is the sustainable development. The European Commission is fully aware of this importance and integrates the raw material resources within the ground pillar of European industry sustainable development and those are becoming an integral component of new EC approach for European innovation partnership (EIP) creation. The strategic goal of innovative approach filling in the area of raw material processing by the form of advanced technologies is also a target of the 7FP project called IntelliMine, where TUKE represented by VRP is one of the three important partners, as far as the scope and budget is concerned. The technological logistics principles were accepted as a new approach to advanced technology strategy and implementations creation for European mines of the future. Innovative approaches address all aspects of the value chain including mineral exploration, mining, beneficiation, metallurgy, recycling. The filling of this strategic target is possible to reach by securing database and knowledge, by aggregates and components research and development with the aim of scale minimization scale, securing an effective functionality, applying technological logistics principles and the concept of advanced process manipulation APM (5).

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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 raw material resources area will be based on marketable knowledge-based systems and the related high-tech 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 (3).

2 NEW INNOVATIVE TECHNOLOGIES AND SOLUTIONS FOR SUSTAINABLE RAW MATERIALS RESOURCES.

Sustainable raw materials supply comes from two different, but complementary, sources:

- **primary raw materials**, or raw materials originating from a mining process, complemented as appropriate by ore beneficiation and metallurgical processes, of which the complexity depends on the mineral substance/ metal to be produced and its required specifications, for instance in terms of needed purity;
- **secondary raw materials**, that can either derived from recycling of material that is from waste and scraps occurring in the initial mining, beneficiation, metallurgical or fabrication process (" primary waste") or from end of life products and waste ("secondary waste").

Innovative approaches shall address all aspects of the value chain including mineral exploration, mining, beneficiation, metallurgy, recycling. Moreover complementary efforts are needed to reduce the amount of mineral raw materials needed to provide specific product functionalities and to design products planning for their later recycling, based on the **3R principle (Reduce, Re-use and Recycle)**. Research and development is needed to further economically competitive, safe and environmentally friendly extraction, processing of primary raw materials as well as the safe and environmental friendly extraction of mining waste heaps and recycling of secondary raw materials in order to improve the quality and quantity of recyclates. The reduction of energy and water use, as well as the reduction of use of toxic chemicals, of problematic emissions to air, soils or water shall serve as a guiding principle to design research projects.

With respect to raw materials and reach the targets EU needs to incorporate the full knowledge triangle (Fig.1), encompassing research, education and innovation to solve the grand challenge of future raw material supply. The research represents new knowledge, education with problem-solving within/beyond current practice and innovations that represents "fresh thinking that creates value" in the form of knowledge transformation into financial profit.

With innovation we here understand "innovative ideas can be turned into products and services that create growth and jobs." (4). While some innovations are related to research, we must understand that many innovations/ideas are not evolving from basic nor applied research. Such an examples are e.g. IKEA (flat pack furniture), DELL (supply chain), Google (business models), Facebook (social innovation).

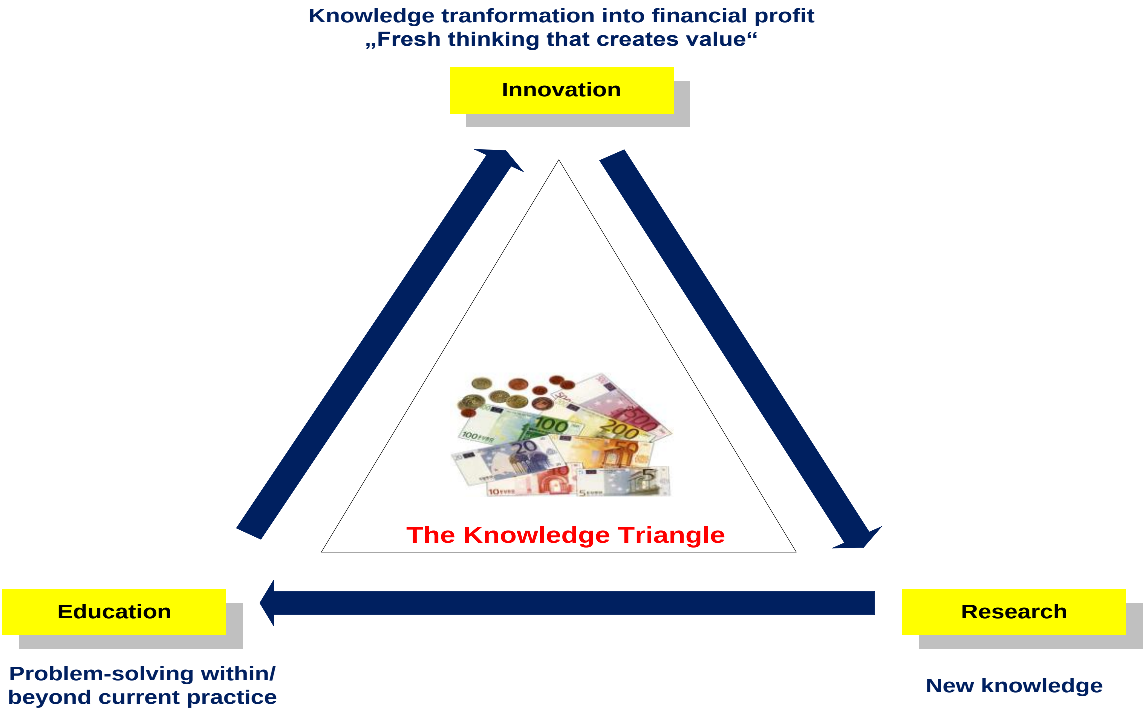

Figure 1 The knowledge triangle on the 3R principle

3 TECHNOLOGICAL LOGISTICS

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. Currently, 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, calcinations and sintering (2). Logistical processes are focused on the coordination and management of flows and in this field we can divide them on processes **rheological** (material flow), **hydromechanical** (medium flow) and **thermodynamical** (thermal flow).

3.1 Technological logistics as a part of innovation megatrends

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 or 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 (1). The key conception is the concept of process and aggregate informatization, digitalization and SMARTization. Implementation of latest science and research results in the development of new advanced materials treatment technology and its management system requires the use of adequate approaches to the analysis, design and management of business processes. 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.

System and process approach covers all the four basic characteristics of manufacturing processes including: quality, quantity, time and location. Production processes at all levels, from a system perspective may be divided into three main groups namely:

- transformation – processing, where there is a change in the quality, quantity and time,
- transmission - transport, there occurs a change in location and time,
- accumulation - storage, there is a change only time.

Transformation (processing and assembly) is a technological operation and under its management to ensure planned (programmed) during the transformation. **Transmission** (transport) and **accumulation** (storage) present logistical operations and subject of their control are flows. From a systemic point of view, technological operations present system elements and logistic operation of system link. Configuration of the system, i.e. interconnection of elements is the subject of the organization. To ensure the functioning (functionality) is the subject of management. Currently in production processes, dominant system of management is combined system, composed of the program, beforehand and feedback control.

While in technological processes prevails program-feedback control, in logistic processes it is program-forward control. Due to increasing competitive pressure and production quality requirements as well as system flexibility is needed to emphasise on the predictive component in the management. This is one of the causes to prefer logistics and process approach in the management today. To this trend are responding also in the present made structure designs of advanced management, which prefer **program-predicting management**, concept of process management including self-organization, self-regulation, computerization and digitization and the introduction of the principles of logistics to the lowest hierarchical level processes (technological logistics) and especially concept of **advanced process manipulation** (APM). It is based on process approach, where all manipulative activities are focused on optimal process assurance. This approach brings significant changes into the process manipulation. Currently, most solutions in some way take the process into the account, but the actual process-oriented approach is more an exception than the rule.

3.2 New advanced technological logistics concept

The principal contribution of technological logistics is the fact that is looking for the problem solution straight at physical, productive area, which creates the subsistence of the process. Solutions on higher hierarchical levels can be optimized only based on the basis from technological area. Assets achieved by the solution in technological logistics area can reach a few tenths of percents of process cost, which confirms, that this area has a great innovation potential. In terms of using advanced technology in the logistics, new concept should be based on the PULL system (1), it means on the tensile principle and should meet following logistical requirements:

- the need for processes, flows, supply bins elimination,
- processes and equipments integration,
- supply bins flowing,
- capacity of resources in the supply bins balancing,
- production and transfer batches in the manufacturing process harmonization,
- minimization, directness, uniformity and fluency of the material flows.

Ideal in terms of optimization 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 supply 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, de-dusting of combustion gases, pre-heating, calcination, cooling, windy classification and displacement of the product. Another option how to eliminate the need for the supply bin we can use transfer as well as mobile supply bin (6).

If it is not possible to remove supply 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 flowing 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 balancing 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 it is 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, possibly 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 batch. Mining process is characterized by coherently-discrete material flow, coherently-discrete running manufacturing processes and till now also by variable size of manufacturing and transfer dose. Mining batch is given by extraction method and sizes of mining block, transfer dose by capacity of transferring equipment and mineral adjustment is running mostly continuously. Batch difference causes mixing of raw material different qualities. Consequently problems arise with sustainment of the production quality by unstable avails adjustment, capacity utilization and uneven loading of maintenance equipment. New concept of extraction and adaptation, which is based on the 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 cut down operational costs, specifically costs on transfer and manipulation, costs resulting from the decrease of resources volume and production in progress and also costs for maintenance etc.

4 METHODOLOGY FOR THE ACCELARATED TRANSFER OF ADVANCED INNOVATIVE TECHNOLOGIES INTO THE PRACTICE

In order to accelerate a transfer of advanced innovative technologies and processes into the practice was designed original organization approach towards research and development activities at VRP 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 innovative 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. 2).

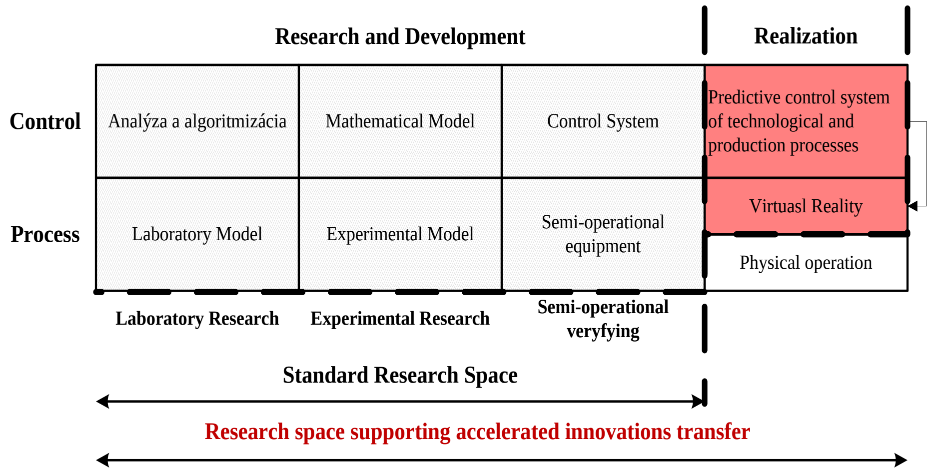

Figure 2 Concept of extending the research area which supports accelerated transfer of the advanced technologies.

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 innovative technology in the science field of exploitation and processing of raw material applied in new extraction and complex magnesite processing technology pilot projects: used in project **Advanced technologies for the mining company of the 21st. century**. Purpose of this concept or framework 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 magnesite high-tech technology processing.

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 (1) 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 innovative 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 advanced technology and innovative logistics operations in the new technology prior to its construction,
- defined the precise techno-economical parameters of future advanced operation

5 CONCLUSIONS

The VRP´s “Advanced technologies for the mining company of the 21st. century” concept and project 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 advanced technology, system processes into the integrated holistic solution flexibly adaptable on the conditions of factual mining corporation. The results from an analyzed 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 advanced technologies for the mining company of the 21st. century 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 systems.

„This work was supported by the Slovak Research and Development Agency under the contract No. SUSPP-0005-09"

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