PRODUCTIVITY IMPROVEMENT THROUGH MONITORING OF HUMAN RESOURCES COMPETENCE LEVEL

Tauno OTTO, Jyri RIIVES, Kaia LÕUN

Abstract: *Online resource databases allow production enterprises to cooperate effectively. The elaborated system concept supports the strategic planning of technology transfer, it also could be used as a basis for the industrial enterprises in elaborating co-operation networks and developing towards extended enterprises. Description and evaluation of innovation capacity through human resources development is a novel solution taken into consideration in the building of the model. Results at this phase are used to develop the technological and human resources database test version.*

The workshop productivity increasingly depends on skills and knowledge of whole workshop team. Different equipment and competencies are needed depending on complexity of production. The humans' impact on productivity and the methods for enhancing the productivity and efficiency of work in the machinery workshop environment are described in this paper. The data covering 75 Estonian metalworking and machinery companies has been analyzed. A novel expert tool is introduced, where during the evaluation guess values are assigned onto machinery, products, and staff members of the workshop, reflecting existing and needed levels of competence and machinery, thus helping further process planning.

Key words: *Network monitoring, e-manufacturing, resource allocation, databases.*

1. Introduction

¶Productivity is one of the key factors affecting the overall competitiveness of a company. Productivity can be managed in different levels – on national, sector or enterprise level. In the enterprise level there are also different possibilities for productivity management, e.g. different measures of productivity can be used or different levels regarded. At a cluster level, knowing the real-time functionality expectations and evaluating the experience on speed performance and limits of data interaction amount of commercial solutions drive the cluster to build up a new system (Viharos, 2003). In similar manufacturing situations and with similar equipment results can be different depending on competence of workforce. The most erroneous part of technological systems – human resource – is analysed on the basis of competence, thus making it possible to elaborate a methodology for evaluation and development of the database model for adding innovation capacity of labour force and entrepreneurs of the metal engineering, machinery and apparatus sector. As to the human resource evaluation only most widely known engineering professions of the machinery sector have been studied. Skills/knowledge to be evaluated are grouped according to professional standards. A professional standard is a paper, defining requirements of professional qualification for knowledge, skills, experience, values and personal qualities.

In practice prescription of professional requirements is substantial. Professional requirements are divided into four groups beginning with more general skills and ending with specific personal qualities essential for working in a profession. The general principles of professional requirements are as follows:

general skills – requirements for general skills and knowledge originating from economic affairs;

basic skills – special professional requirements for skills and knowledge;

extra skills – special professional requirements for skills and knowledge, characterised in narrow specialisation and/or necessity for executing additional assignments at current position;

personal qualities – expected personal identities and abilities required in a certain profession (Riives, 2006).

The definition of specific skills/knowledge depends on the field of activity of an enterprise. The definition process should be started in every particular case from job descriptions of a current enterprise.

Before the system was implemented vocational training courses were organised independently by tailor-made course plans. The new monitoring system makes it possible to support organisational work by adding value through different queries, statistical calculations and prediction mechanisms. In previous researches the difference between enterprises was not taken into account; however in current approach an added expert system enables fast estimation of needed competencies for management, engineering and workers levels.

2. Basis for Productivity

2.1 Organization's structure and management

A company is a technologically and legally independent organizational system that uses labour and equipment for manufacturing products or rendering services that respond to special demands. This organizational system is the best described by its structure. The company's structure has to be expedient for realizing business chain in the company. Business chain realizes through the organization's structure. The company's strategy determines the essence of the realization of the business chain and therefore, the company's structure. Business chain is general chain of functions. Business chain associates links supporting, assuring, and realizing production. These links are primarily marketing, market research, product development, product realization, storage and distribution of products, maintenance and repair of machinery, servicing. Company's strategy and policy determine what functions of business chain are realized in the company and this is the basis for formation of the company's structure. In other words, the company's structure is formed taking into account the activities the company realizes.

Whatever chain is strong only when its entire links are unbroken and strong enough.

Essence of business chain is determined by business strategy elaborated by the organization's management, or shareholders. Business strategy realizes through strategic management that is the process of determining, evaluating, and adapting the aims, or mission, of an organization and the patterns of decisions that guide the achievement of those aims in the long-term.

2.2 Organization as a system

According to the system approach, system may be defined in a following way:

- System is a whole that is constitutive of many components (parts);
- System (sub-system) has definable objective;
- Every part of the system contributes to the achievement of the system's objective, but none of the parts is capable to achieve this objective unwittingly or separately;
- Every part has its own objective, but affecting the total system, it depends on other parts. Thus, the parts of the system are mutually dependent;
- It is possible to understand or evaluate single part by its suitability to the system as a whole. But we cannot understand the system by exploring all its parts separately, without forming a whole of them;

- Study about the co-operation of the parts could help us understand, how the system works, but to understand, why this system exists, we have to look outwards the system;
- To understand the system, we have to understand its objective and mechanisms of mutual impacts and relations of the parts;
- Looking at the organization, we look at complex social, as well as technical system.

Without determining the objective of the system, it is not possible to determine whether the system functions well, poorly or not at all. System is a method whereby the result is achieved.
Being supported on the before said, we may determine features in a company that characterize a system:

- A company has its interests, objective and mutually dependent and co-operating parts;
- A company represents only one mutually dependent and co-operating part inside more larger systems (e.g. industry, economic union, state, world);
- Inside a company there act mutually dependent parts that also influence each other (e.g. branches, departments, teams, individuals). Every one of them has its interests and objectives that may have positive or negative influence on the company's ability to achieve its objective;
- Social interaction complex as communication, teamwork, collaboration, co-operation, etc. is added to technical and mechanical impacts in the company.

Therefore analysing the company, we may use main standpoints of the system approach.
Company with its fixed structure, departments and management schemes fulfils established objectives in the process of transforming inputs to outputs in effective and efficient way. As presented in Fig.1, transformation processes proceed by fixed operating processes that take places in different departments (Lõun, Tammoja, 2004).
As shown in figure below, the system can be thought of as a transformation T on inputs I which produces outputs O, this input-output relationship is expressed symbolically by means of the following equation (1):

$$T(I) = O \quad \text{or} \quad T : I \rightarrow O \tag{1}$$

where T – transformation;
I – input;
O – output.

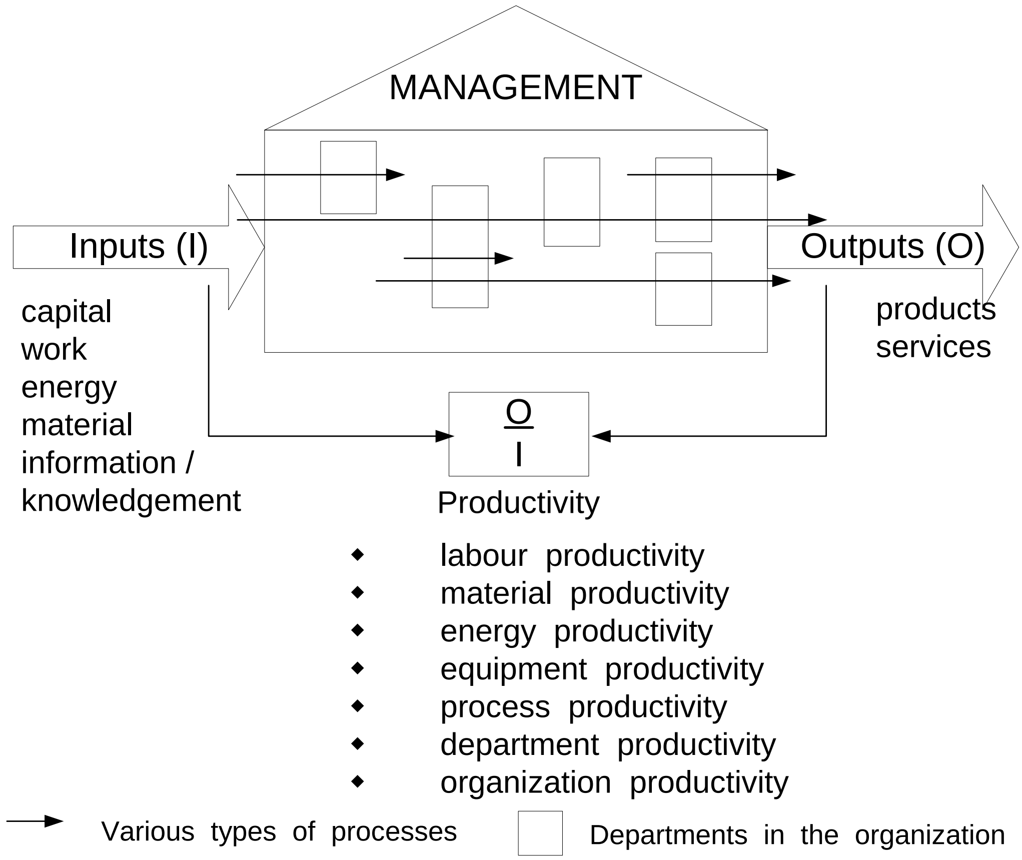

Fig.1. Organization as a system with measurable value

Focusing on this equation (1), questions concerning a system usually fall into one of the following categories:

a) System analysis: Clarify contents of T, I, and O;
b) System operation: Given T and I, find O;
c) System inversion: Given T and O, find I;
d) System synthesis or identification: Given I and O, determine a suitable T;
e) System optimisation: Pick I, O, or T so that a specified evaluation criterion is optimised (Hitachi, p.11).

Organization is as a system that has to be managed capably and effectively for attaining its objectives. System is expressed via organization's structure. One example of departments of typical small- or average-sized manufacturing company. Departments are the most important elements of the company's structure. Departments are bearers of the processes that take place in the organization. Effectiveness and efficiency of processes is expressed via productivity indicators (e.g. in case of production number of pieces produced in certain time). Departments have concrete objectives and carry certain tasks in a company and these tasks and objectives have to contribute to achieving the company's overall objectives. Departments may be comprised of some subunits. For example, various workshops may belong under manufacturing department. These subunits usually have different functional tasks; workshops may have different technological capabilities and automation level. Manufacturing department or subunit (workplace, workshop) that uses numerical control machine tools and large number of automated auxiliary devices for transport and mounting of details is called automated manufacturing system.

As in case of all manufacturing systems, also well automated manufacturing systems have three main phases in their life-cycle (see also Fig.2):

- creation of the system;
- operation of the system;
- essential rebuilding or extermination of the system.

Companies are influenced by and forced to make changes by growing competition in the global market. Automated manufacturing systems are usually very complicated and expensive. Therefore they have to be very productive.

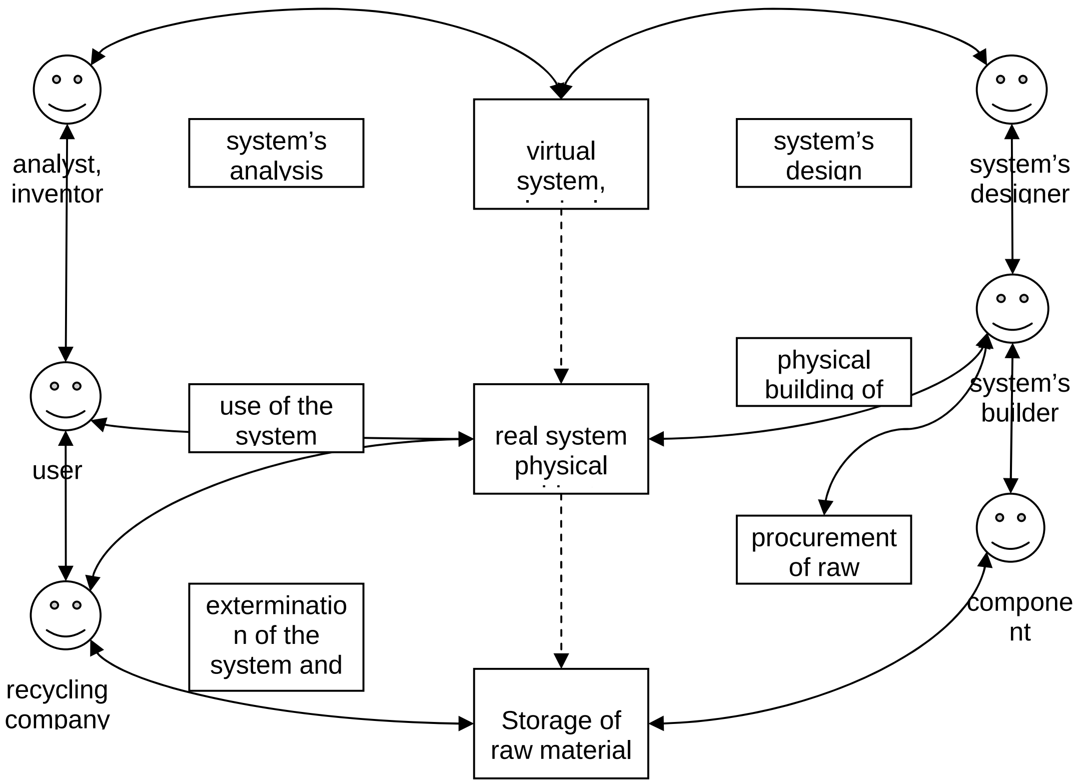

Fig.2. Human's roles and activities in system creation, operation and maintenance

3. Productivity on Workshop Level

Productivity on workshop level is largely influenced by following three factors:

1) machine tools used;

2) work organization and management in the workshop and in the company;
3) human resources, employees performing certain tasks.

As follows, we take a look how these factors influence productivity on workshop level.

Although the term "productivity" is often used nowadays, it is often misused and sometimes confused with the term "production". Many people think that the greater the production, the greater the productivity. This is not necessarily true.

In spite of the various perceptions of productivity, it is universally recognised that most organizations – including firms and non-profit organizations – are input-output systems. This is true also in the case of subsystems in an organization, since any process can be seen as an input-output system. For any process regardless of the scale, inputs i.e., resources are needed to produce the outputs. Most productivity models and definitions for productivity aim to consider the efficiency of these systems either directly or indirectly. In this paper, productivity is defined as follows:

"Productivity is a relationship (usually a ratio or an index) between output (goods and/or services) produced by a given organizational system and quantities of input (resources) utilized by the system to produce that output." (Sink, 1983).

Based on the above-said, productivity can be shortly defined as follows (equation 2):

$$P = \frac{O}{I} \tag{2}$$

where P – productivity.

Productivity is concerned with the effective and efficient utilization of resources (inputs) in producing goods and/or services (output) (Sumanth 1984, p.4).

Productivity is an essential factor affecting the profitability and overall competitiveness of a firm. Improving productivity, or any other important factor, is difficult without knowing the impact of the decisions taken. This is why we need to measure productivity (Hannula 1999, p.1).

Technological capabilities of automated manufacturing system evolve on the basis of technological capabilities of machinery (machine tools, presses, casting equipment etc). Technological capabilities can be defined as set of characteristics $\{TB_{TP}\}$ where entities (b_1, b_2… b_m) represent both in qualitative and quantitative way the functional characteristics of this machine tool. The range of production to be manufactured, complexity and quality of products are general measures of technological capabilities. This can be defined as set of technological capabilities needed for processing the details $\{TB_D\}$. This means that, as a rule, for manufacturing simple and uniform products it is not rational to use too complicated machinery (see equation 3). The adequate situation is presented in Fig.5.

$$\overline{TB} = TB_{TP} - TB_D \tag{3}$$

As illustratively presented in Fig.3, the unrealized technological possibilities may take quite a big part if manufacturing simple product using complicated machinery. Consequently, use of complex machine tool for manufacturing a simple detail is uneconomic.

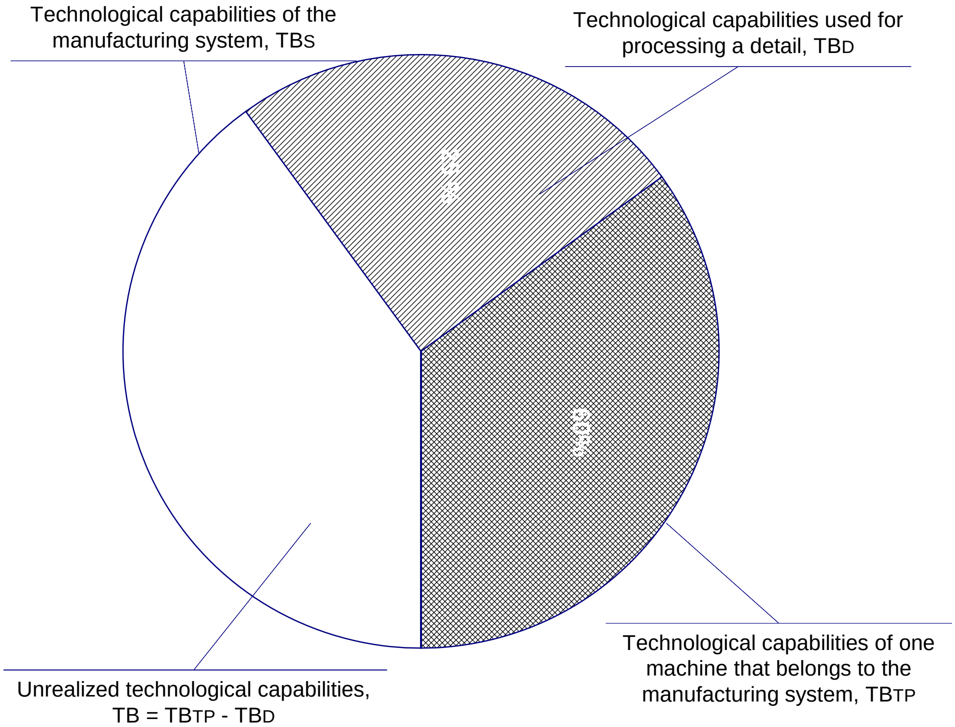

Fig.3. Technological capabilities of the machine tool belonging into technological system and their use

Set of technological possibilities of the machine is determined by analysis of the machine's structure (construction) and parameters characterizing that machine. Therefore, technological capabilities are determined for each machine separately and on the basis of technological possibilities of separate machines belonging into system are formed possibilities of the whole system. General technological possibilities $\{TB^U\}$ represent potential of the manufacturing system, i.e. what kinds of works are feasible to perform in the system. One can say that the greater are technological possibilities of devices belonging to the system, the greater is also technological potential of the whole system. Guaranteed technological possibilities $\{TB^G\}$ express this part of characteristics of industrial devices that are common for all devices of the system. Large intersection area permits to organise the production in the system in more flexible way. The above-described situation is presented in Fig.4.
In accordance with technological capabilities of machine tools, from the viewpoint of production process production systems may be categorized into following groups:

a) single-staged;

b) multi-staged.

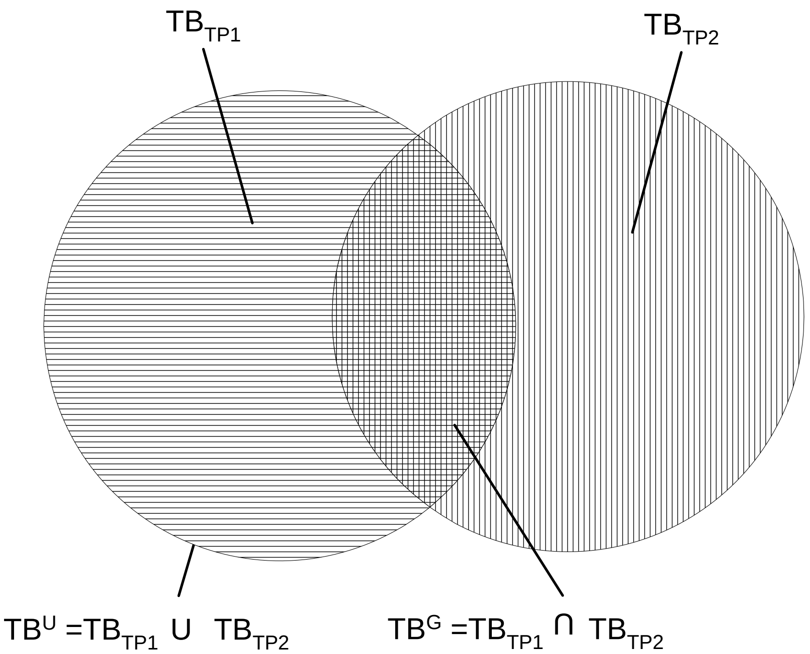

Fig.4. Interpretations of technological capabilities

Manufacturing systems with single-staged production process usually consist of poly-functional machine tools (processing centers, flexible manufacturing modules) that can replace each other by their technological capabilities. In this case, technological possibilities of the machines belonging to the system are wide-ranging and by use of these machines it is possible to perform large amount of main operations (milling, turning, boring etc) that are needed for processing the detail.

Majority of manufacturing systems are with multi-staged production process. Such production systems are realized by use of mono-functional machine tools (e.g. drilling machines, boring lathes, grinding machines, milling machine tools etc). Mono-functional machine tools are complementing each other, for total processing of the detail several operations have to be performed and the detail processed passes several processing positions in its technological route.

Thus, technological possibilities play important role in designing operational and route technologies but also in management of whole production process.

To be effective and efficient, nowadays production systems have to turn attention to continual improvement. There are different methods for continual improvement. Companies having longer lifetimes, face mainly the problem of changing the customs. Often many employees of the company are not interested of changes, because this requires additional efforts, changing the traditions and creates some uncertainty. Meanwhile, standstill leads to stagnation in the company. Companies, that are flexible and able to introduce changes, are more efficient and viable. Owing to the previouslysaid, it would be important to create flexible system of processes in the company that is able to cope with improvement changes and enables to realize the changes efficiently. The basis for this is implementation of ISO 9001:2000 standard-based quality management system. To establish objectives and measure results (BSC), it is important to know business chain and the organization. Main process of manufacturing company is production process that realization's efficiency determines the organization's efficiency and competitiveness. To assure competitiveness, it is essential to raise productivity continually. Useful tools for that is The Theory of Constraints that enables to improve performance of the manufacturing company by identifying and eliminating the bottle-necks. Very important is human capital, employees, who carry out these processes. Supportive tool is Lean Manufacturing and "House rules" that help employees, especially the new ones. When the organization is achieved its highest level, always it is possible to smooth the results and for that it would be reasonable to use 6-sigma theory (Riives, 2007). All above said is presented in the system development model in Fig.5.

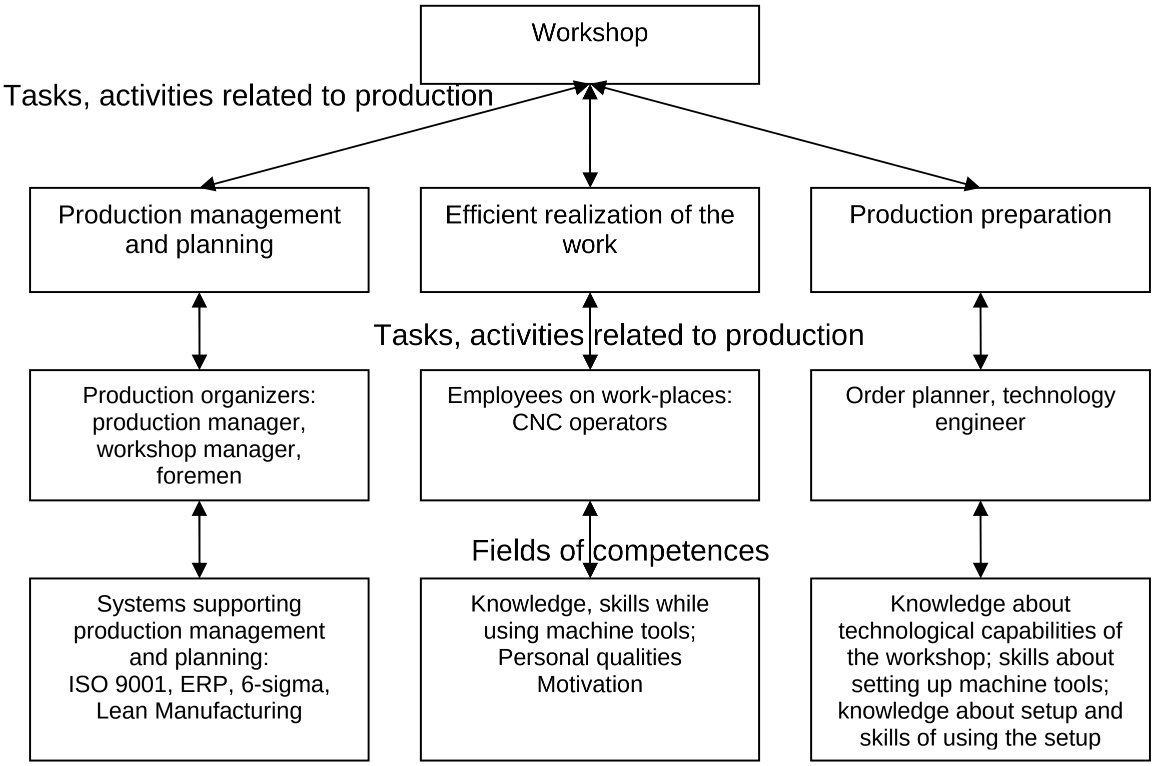

Fig.5. Development of productivity and competitiveness in workshop

Main value of modern production system is human resource. The humans' impact on productivity and the methods for increasing the productivity and efficiency of work through determining and estimating the competencies of the employees in the certain working environment are described subsequently.

The human's skills, knowledge, experiences, motivation and desire to apply them in a team influence how many pieces he/she could produce during a certain time period using a certain machine with certain technological capabilities. Therefore, using the same machine and applying the same organizational methods, one employee could produce much more details than another during the same time. Influence of human factor to productivity is larger when the process is less automated. That's why development of human resources is with essential importance and hence the need to evaluate existing and required competencies of employees.
Human resource development process in an organization is presented in Fig.6. Basis for human resource development is the organization's strategic tasks and operative actions. The most important that determine how well an employee performs his/her tasks and how productive he/she could be, are levels of skills and knowledge (competences) of performing everyday tasks.

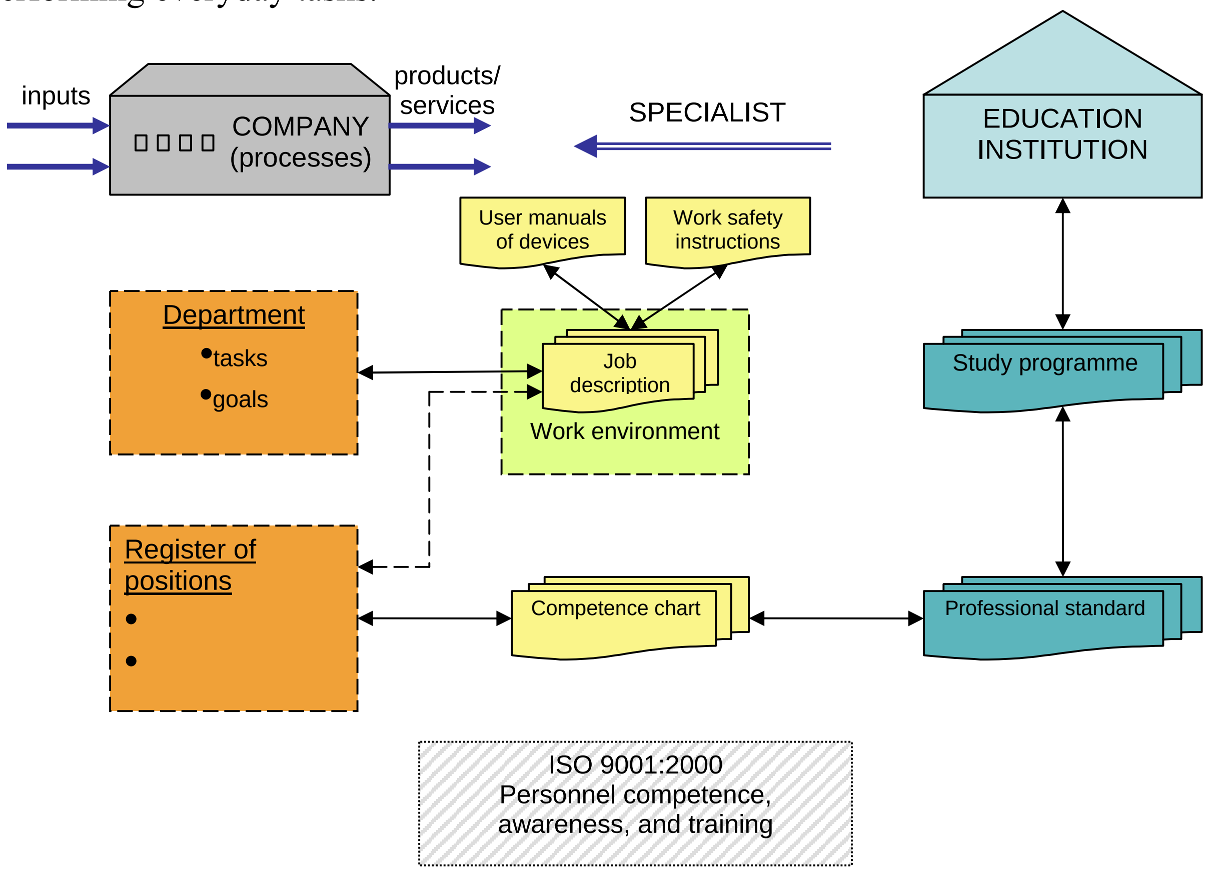

Fig.6. Human resources development process

In Estonia, expert tool for evaluating employees' existing and needed competence level is introduced (INNOMET system). Data about employees' existing and needed levels of competence was gathered and analysed in case of 75 machine-building, metalworking and apparatus industry companies. The processes of INNOMET are:

- ☐ Determination of the Human Resources (HR) competence and the training needs in the company, taking into consideration the strategy of the company and operating needs.
- ☐ Matching the training needs with the possibilities and carrying out the real courses through the system.
- ☐ Fixing the needs for professional examinations and developing the national professional award system in the field of machine building and apparatus industry

In the first stage of the process are determined training needs according to competency charts of the company. Competency charts are filled personally for each employee or vocation (e.g., CAD engineer, CNC operator, welder, etc.). The competency charts can be filled through Internet in every enterprise, whereas sensitive information of enterprise will remain undisclosed. The analysis is based on average indicators of vocations, industrial fields (toolmaking, machine-building, etc.) or on regional basis. The existing (EL) and needed levels (NL) are estimated in scale 0-5, where 0 means "the skill has no importance" and 5 means "the skill is has high importance". In case the EL<NL, there exists need for additional training. For general professions special standard templates have been created, e.g. results of queries concerning Production Manager in 18 Estonian enterprises are depicted in Fig. 7. On the template competences are divided into four groups: general, basic, special, and personal.

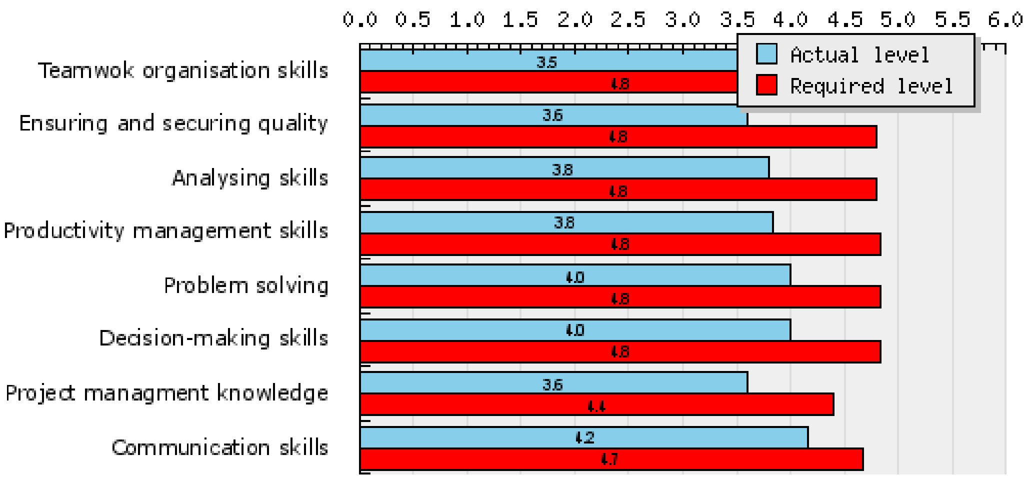

Figure 7. Overview of special skill values: Existing (EL) and needed (NL) competences of Production Manager in Estonian enterprises

The second stage includes arrangement of training courses according to the mapped needs. The input is obtained from analysis of all Estonian educational organisations of

the sector. The training activities are organised based on unified training calendar and corresponding documentation.
When returning to Fig. 7, on that information educational institutions can draw conclusions and offer corresponding training courses e.g., course of teamwork organisation skills could be advantageous, at the same time course of project management has less potential).
Before the Innomet system implementation the vocational training courses were organised independently by tailor-made course plans. New monitoring system enables to support organisational work by adding value through different queries, statistical calculations and prediction mechanisms.
The basis for evaluating employees' existing and needed level of competence is competence chart. Competence charts were drawn up based on the jobs of the company. Standard competence charts have been developed during INNOMET project and available to users, so companies have it easier to draw up their own competence charts. In the INNOMET system the user can directly use standard competence charts or draw up individual competence charts with regard to a specific job or person in the company. Competence charts are not some absolutely permanent documents, but are based on the strategic needs of the company and the requirements established to the specific job.
The required level of competence shows primarily how extensive the skills and knowledge of people holding the respective position should be in various fields of competence.
From the point of view of clear limitation of the relationship between the employer and the employee it would be wise to specify the required levels of skills and knowledge as precisely as possible. High requirements of the needed level also require specific training and finding education opportunities by employers.
The main objectives of evaluation of the existing level of knowledge and skills of the personnel are:

- to identify strengths and weaknesses of each employee;
- to identify the need and areas for training and development;
- to collect information for further planning;
- to take existing resources into account and use them skilfully.

The system also includes expert tool for deciding the needed competence level. In principle, the scales can be combined by own experience, by using the opinion of technical consultant or by integrated expert system. The expert system tool is based upon short questionnaire concerning production and management data. The estimation can be given for engineering staff, management staff or workpeople. In principle, the scales can be combined by own experience, by using the opinion of technical consultant or by integrated expert system. The expert system tool is based upon short questionnaire concerning production and management data. The estimation can be given for engineering staff, management staff or workpeople. There are always three options to choose, total number of questions should not exceed ten. The average expert value AVERAGE is calculated as follows:

$$AVERAGE = \frac{\sum_{i=1}^{k} E_i}{k} \tag{3}$$

where k – number of questions, E – expert estimation for the question i.

Exemplary expert tool for estimation needed level of competence depending seven main parameters is described in Fig. 8.

WELDING ENGINEER			
Situation description			
1	Number of various production processes		
	1-3	4-7	over 7
	1-2	3-4	5
2	Average number of operations in the process		
	less than 5	5-12	over 12
	1-2	3-4	5
3	Average number of workers in the production area		
	less than 50	51-150	over 150
	1-2	3-4	5
4	Average durability of the machinery in use		
	More than 10 years	5-10 years	Less than 5 years
	1-2	3-4	5
5	Number of different assemblies/products per year		
	Less than 20	21-50	Over 50
	1-2	3-4	5
6	Annual turnover (million EUR)		
	Less than 2	3-7	Over 7
	1-2	3-4	5
7	Materials to be welded		
	Construction steels with good weldability	Stainless steels and other steels with limited weldability	Other materials (e.g. Al) in addition to steels.
	1-2	3-4	5
8	Different welding processes		
	1-2	3-4	Over 4
	1-2	3-4	5
9	Quality regulations for welding joints		
	Quality control of	Simple requirements	High requirements or 100%

	welds is not required	or random control	control of welds
	1-2	3-4	5

Figure 8. Expert estimation tool for production management, where
BSC - Balanced Scorecard; ERP - Enterprise Resource Planning; PPS - Production Planning System; 6σ - Six Sigma; LM - Lean Manufacturing

The INNOMET system is realized by database system for monitoring human resources capacity for machinery sector, enabling estimation of existing workforce through web-based interface.
The processes that database of INNOMET system enables are:

1) Determination of the Human Resources (HR) competence and the training needs in the company, taking into consideration the strategy of the company and operating needs.
2) Matching the training needs with the possibilities and carrying out the real courses through the system.
3) Fixing the needs for professional examinations and developing the national professional award system in the field of machine building and apparatus industry.

INNOMET is considered as an e-manufacturing tool.
With the INNOMET as a transparent and integrated system it is possible to compare and value skills and qualifications both in the industry and in education programmes in all different levels and therefore enable transfer of competencies among countries, regions and also among industrial sectors in long term.

6. Conclusions

All above-discussed factors – equipment, work organization tools, and human resources – should be viewed and taken into consideration all together and in balance. Numerical control machine tools have wide range of technological capabilities and are very productive, but they are very expensive that influences the price of the products. Therefore, management and organizational methods suitable for the company’s development level should be used. Nevertheless, to achieve high productivity, expensive and productive machine tools and organizational methods exploited to some extent are not enough when they are not exploited reasonably and efficiently. Efficiency of exploitation of machine tools and organizational methods depends very much on employees’ skills and knowledge – competences. Therefore the authors have turned much attention to elaboration and implementation of employees’ competence evaluation and development system (INNOMET).

The system results can support the strategic planning of technology transfer; it also could be used as a basis for the industrial enterprises in elaborating co-operation networks and developing towards extended enterprises.

The proposed model is capable of monitoring the quality and quantity of technological resources in machine-building enterprises of the network. Influence of human resources can be evaluated successfully when using proper taxonomy and expert estimations. The described methodology of human resources development has been thoroughly tested in five institutions: in enterprises of diverse type (specialising in machinery, tools engineering, metal engineering and road engineering), and Tallinn University of Technology. Testing results turned to be successful and the system elaborated has proved its place as a carrier of competence development.

Results at this phase are used to revise and develop a test version of the human resource database. However, in a long perspective when a critical mass of companies are involved in the system the results could be used as a basis for educational institutions to elaborate complementary study and training programmes and modify the existing ones.

The current solution is focused on the sector of metalworking, machinery and apparatus engineering. The proposed model can be transferred also to other industrial sectors (wood processing, chemical industry, construction materials industry, etc).

The developed database solutions were tested in a restricted area, having common cultural and language basis. Development at a multicultural level needs additional research of common understanding – development of ontology for building automated libraries assuring similar knowledge-based input from different languages.

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