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BASIC PRODUCTION SCHEDULING CONCEPT SOFTWARE APPLICATION IN A DETERMINISTIC MECHANICAL PRODUCTION ENVIRONMENT

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Keywords: Production Scheduling, Permutation Flowshop, Deterministic Mechanical Production, software
Abstract: This paper deals with production scheduling in a deterministic mechanical production environment. We focus on minimizing the objective function makespan using local search. Our aim is to present developed software solution with implemented basic scheduling concepts and our approach to scheduling in deterministic mechanical production environment on the simple case of 4 jobs and 5 machines. The outputs of solution are presented in the figures and they gives reasonable results. As we want to use combinatorial optimization we have implemented a heuristic approach. This heuristic is known as a Local Search Method. This method is commonly used in scheduling.

1 Introduction

This paper deals with production scheduling in a deterministic environment of mechanical production where there are different components processed on different kinds of machines in variable batches according to received orders. Our aim is to find the order of the jobs which has the minimal flowtime of production. In other words we focus on minimizing the makespan. The makespan, defined as max (C1,......,Cn), is equivalent to the completion time of the last job to leave the system. In the first part of the paper we are concerned with basic concepts of cheduling and permutation flowshops. As we want to use combinatorial optimization we have implemented a heuristic approach. This heuristic is known as a Local Search Method. This method is commonly used in scheduling.

Local search is based on the idea that the current solution can be improved by making a small change. With every single improvement of the solution we are trying to find a better solution. Each of the combinatorial – optimization problems which we solve consist of a certain number of specific elements which describe or define the problem. There are: objective function (optimization criteria) f: $\Pi \rightarrow R$, simple rule generating transition from one solution to another solution and a space of $\prod$ solutions which is determined by some constraints. Sometimes the set of elements can be named the configuration of the problem. It is our aim to find optimal solution π^* where $f(\pi^*) \leq f(\pi)$ for each π Π (see e.g. [6]).

In basic local search we move to the best neighbour if it improves the objective value, and if no neighbour is better than the current solution, we terminate the search. The problem with this strategy is that the search is easily trapped in a local minimum.

2 Basic concepts of scheduling

Fundamental notations in the scheduling problems are machine, operation and job.

Operation o is a basic technological action which can not be divided into more particular actions.

Job J is an operation sequence {o1, o2,...., og} which must be done within one order.

Machine M is a piece of equipment with the ability to carry out one or more operations. In some literature we can find the notion processor instead.

By scheduling problems we need to determine for each operation oij of each job Ji from given set of jobs J= {J1, J2,…., Jn} and machine Mj from set of machine M = {M1, M2,…., Mm} which carry out the operation oij and the time interval of that operation (or more time intervals if the preemption is allowed) (see e.g. [1]).

We assume two elementary conditions in most of the scheduling models [1]:

1. Each machine can carry out only one operation in one time interval,
2. In one time interval it is not possible to carry out two or more operations of one job.

From a scheduling point of view the operation is not preemtable. Some of the models allow the preemption and then continuing in this operation. In most of the models the operation continues where it had been interrupted. There are some models where we need to start from the beginning. Machines from the set of machines M can be universal or specialized. Universal machines can process any operation of any job. Individual machines of set M can process these operations with different processing times. A part of the solution of the scheduling problem can be assigning of machines to the operations. Specialised machines are determined to process only certain operations – each of the operations has been assigned the machine. The machine does not need to be available at anytime. As a result of changing the shifts, regular maintenance or other industrial matters there can be some periods when a machine can not carry out any operations. A very important characteristic of each machine is a time of its availability. We assume job J = {o1, o2,….,ok}. There are some scheduling problems where it does not depend what the order of the operations is. On the other hand there are scheduling problems where the order of the operations must be kept because of technology of production. We can define it by using the precedence relations between the individual operations. When operation y can start after operation x is finished then we will say that operation x prevents the operation y and denote it $x \prec y$. Relation $\prec$ is transitive, i.e. if $x \prec y$ and $y \prec z$ then $x \prec z$. We will assume that operation x directly prevents operation y if $x \prec y$ and there is no such operation z that $x \prec z \prec y$. This fact will be denoted as $x \prec\prec y$. There are several jobs given by the scheduling problem. These jobs are denoted as follows J1, J2,...., Jn. Each of the jobs consists of certain number of operations oi1, oi2,....., oigi. Further there is given the set of machines M= {M1, M2,....., Mm}. For each operation oij of any job i it is given time period p(oij) and machine $\mu ij \in M$ which can process this operation [1].

To create the schedule J1, J2,....., Jn where job Ji consists of operations oi1, oi2,.... , oigi means that one (in case when preemption of operations is not allowed) or more (in case when preemption is allowed) time intervals (b1x,c1x), (b2x,c2x),...., (bqxx,cqxx) must be determined for each operation oij = x where $bix \le cix$ (in which the operation x will be processed on the given machine) and that [1]:

1. $\sum i$ (cix - bix) $\ge$ p(x) - sum of partial time periods of processed operation x is $\ge$ as its length,
2. If x, y are two operations where for $x \prec y$ then $c1x \le b1y$ – when operation x prevents operation y then processing of operation y will not start earlier than x is finished,
3. Each of intervals (bix, cix) will be from the available machine interval.

We consider the scheduling problem to be given as [1]:

1) Set of machines M= {M1, M2,…., Mm},

2) Set of jobs J = {J1, J2,…..,Jn} and for each job Ji there is assigned an operation sequence oi1, oi2,…., oigi and function F which assigns a certain machine to each operation to carry out this operation

3) Precedence relation $\prec$ on a set of operations,

4) Criterion function of the schedule.

Output data from the scheduling criteria [1]:

From a given schedule the following parameters can be computed for each job Ji:

- Ci completion time of job Ji,
- Fi time period of job Ji in the system ,
- Wi total period of job´s Ji waiting in the system,
- Li = Ci - di time deviation of planned time of finished job Ji,
- Ti = max{0, Li = Ci – di} tardiness of job Ji,
- Ei = max{0, - Li} earliness of job Ji,
- Ui = 0, if $Ci \le di$, or Ui = 1. Penalty unit per job Ji

We can see that parameters Li, Ti, Ei, Ui are defined as a function of the completion time Ci. The period Fi of job Ji in the system can be described as follows Fi = Ci - ri where ri is a time of job Ji entering the system. If pi is a period of processing of the job Ji then its total period of waiting in the system is Wi = Fi - pi = Ci - ri- pi. All the above mentioned output parameters are functions of the parameter Ci [1].

3 Permutation flowshop

Where can we encounter the flowshop environment? How can we define it? The flowshop scheduling problem is a very active field of research which is almost 55 years old. When each job has to undergo a series of operations in many manufacturing and assembly facilities then we consider it to be the flowshop. These operations have to be done on all jobs in the same order and the jobs have to follow the same route. Buffers are considered to be very important elements in the real production scheduling. We can regard the buffer as a place where we need to keep some of the components for a while or a longer time. Sometimes the storage or buffer space in between successive machines may have for all practical purposes virtually unlimited capacity. When the products that are being processed are physically small, making it relatively easy to store large quantities between machines then it is unlimited. On the other hand, when we consider physically large components then the buffer space in between two successive machines may be limited, then the blocking should be taken into account. Blocking is considered when the buffer is full and the upstream machine is not allowed to release a job into the buffer after completing its processing. Having buffers of zero capacity, a job i just finishing on machine r cannot advance to machine r + 1 if this machine is still processing job its predecessor in the job sequence. The job i must remain at machine r. We can consider thus temporarily denying machine r job its successor in the job sequence until job i can advance to machine r + 1. Abadi and Sriskandarajah (1995) described the blocking flowshop problem as „the flowshop has no intermediate buffer therefore a job cannot leave a machine until the next machine downstream is free" [3].

Flowshops that do not allow sequence changes between machines are called permutation flow shops. In these flow shops the same sequence or permutation of jobs is maintained throughout. In another words order of machines is fixed and only the jobs are allowed to change the order because of permutations. Unlike the classical flowshop problem where the computional problem is $(n!)^m$, permutation flowshop problem is in that case only n!. We are not able to solve big instances by searching

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each permutation in any case. It would not be sensible. For many optimization problems there are very simple methods of scheduling problems. [4]

Given a permutation schedule j1,....,jn for an m machine flowshop, the completion time of job jk at machine i can be computed easily through a set of recursive equations (see e.g. [1]).

We can also consider another approach to evaluation of the makespan. It can be computed under a given permutation schedule by determining the critical path in a directed graph that corresponds to the schedule [5].

4 Our approach and software application

For the simplest algorithm of the production scheduling of mechanical production we can use as an input of jobs Si, $i \in \{1,\dots,m\}$ according to the order in which they come to the production system and on which machines VZj, $j \in \{1,\dots,n\}$ are assigned (its priority in the system is assigned by the principle of FIFO (First In – First Out) from the assigning matrix and for calculation is strictly given) [2].

We start in time zero with the assignment of jobs to the machines whereby the algorithm works iteratively. We store the shortest production time of the particular operations in each iteration and in the end we sum up all the “the shortest production times” $\sum_f T_k \rangle \max$; $f \in k \ \forall k_{S_i}$ and this represents the makespan [2].

We can see from the figure 1 below how the original algorithm works. We have 5 jobs and 4 machines in the production system. We do not consider a limited buffer in this example so we use an unlimited buffer for each machine [2].

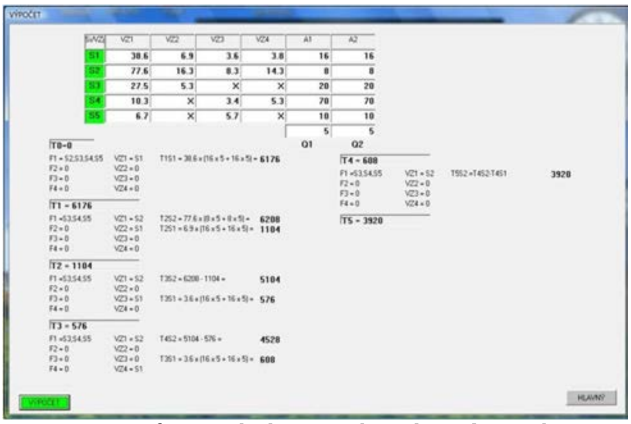

Figure 1 Softvare calculation with 5 jobs and 4 machines

In the figure 2 and the following we can notice particular steps in a software application which has been developed for testing scheduling and optimization techniques.

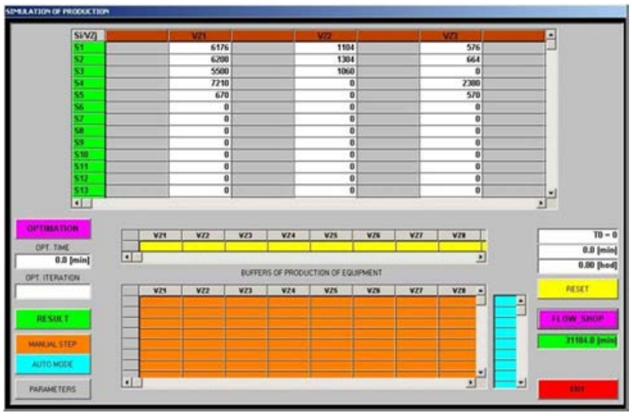

Figure 2 Aplication of permutation flowshop with local search

In the figure 3 we can see a demonstration of permutation flowshop with local search heuristic. There is only the small example with 5 jobs. In this application it is possible to use manual mode where we can see step by step what is going on inside the system. This manual mode uses the original algorithm which works on the principle i.e. „time jumps“ which is very similar to jobshop problem.

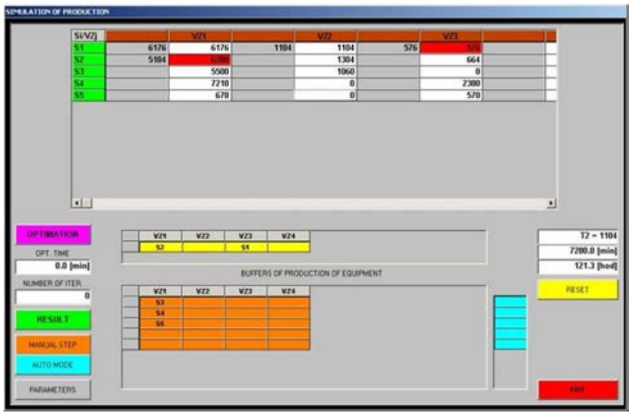

Figure 3 Aplication of permutation flowshop with local search (manul mode)

In the figure 5 we can see evaluation of the results within local search. We have demonstrated it with 10 jobs and can compare it to brute force which is 10! with its 3 628 800 permutations. It is clear it would not be sensible to compute it without using combinatorial optimization.

By using combinatorial optimization we have solved only 45 neighbourhoods from defined neighbourhoods within the first iteration with starting sequence of jobs.

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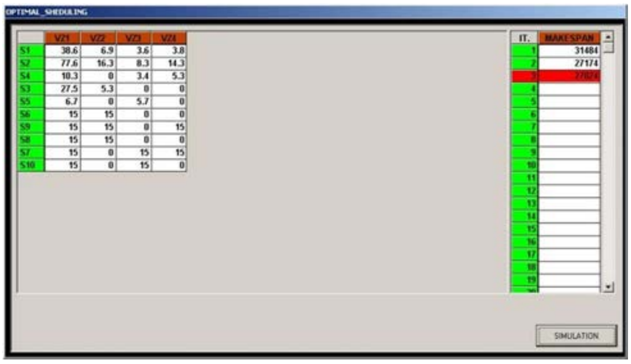

Figure 3 Aplication of permutation flowshop with local search (results)

Conslusion

A survey in conventional mechanical enterprises in Slovakia and abroad has shown that there are opportunities by managing of the production gaps in the practical and user friendly application software which would be used in practise.

On the base of standard scheduling concept and with the notion of real production constrains we have developed the software and test our approach of makespan minimization on simple cases (e.g. of 5 jobs and 4 machines). The outputs of solution are presented in the figures and they gives reasonable results. In more coplex test of software solution with 100 jobs and 100 machines it takes 45 minutes to find the optimum. It is important to mention that the searching time is obviously related to the methods used, but is also dependent on the hardware of used computers.

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UTILIZATION OF THE SOFTWARE PRODUCT TECNOMATIX JACK IN OPTIMIZING OF WORKING ACTIVITIES

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Keywords: ergonomics, worker, workplace, method, design
Abstract: The article deals with the issue of ergonomics in the workplace in the environment of simulation program Tecnomatix Jack. Ergonomics deals with a complex design of work environment and environment, also deals with projection of work tools, machinery construction and with the principles of occupational health in order to reduce human effort while increasing worker productivity and efficiency of its work. The benefits related to the use of simulation programs are verifiable mainly in avoided costs that would be necessary to invest in case of direct application the proposals into practice. Designing of ergonomically optimal workplace is based on fundamental principles that take into account the adaptation of work for each employee and for each job role.

1 Introduction

Designing of ergonomic workplaces is engaged in standard DIN 334,000. Objectives within the ergonomic design of workplaces are to create a work space with its equipment, lighting, microclimate that corresponds to the quality requirements for the work of man [9], [10]. Thus designed ergonomic workplace is one of the most important prerequisites for achieving the highest performance of personnel, ensuring its security and promoting its work motivation, which ultimately helps to increase productivity [1], [3]. Designing of ergonomically optimal workplace is based on fundamental principles that take into account the adaptation of work for each employee and for each job role [2], [4].

The ergonomic design of work is based on the following principles:

- anthropometry/industrial anthropometry - the source of the dimensions, mobility and possibilities of load individual parts of the human body such as body weight, height it is part of the scientific discipline of anthropology [11], [12],
- somatography - graphical representation of the human figure in the technical, resp. other documentation in addressing the dimensional relationship of man and his workplace.
- perimeter - measure the size of the visual field with pinpointing of its borders, physiologically field is an area that can be seen without moving eye.

Simulation support for the ergonomic solution:

- **CAD systems -** allows you to simulate human labour and to design jobs so as to meet the ergonomic requirements in order to minimize the burden of man while maintaining health and safety at work [6], [8]. Some integrated systems provide simple tools for simulation and analysis of the human body, for example Human Builder, Human Measurement Editor, Human Posture Analysis and Human Activity Analysis (features and capabilities of these internal modules are limited), CATIA (allows you to use static analysis of the human body, but dynamic analysis however is not available).
- **Tecnomatix Jack -** complex 3D simulation tool for evaluating the behaviour of man at work, this is the instrument through which it is possible in the virtual environment to design workplace and simulate various solutions that meet ergonomic standards without investing in equipment and technology [13]. Digital

human model in this program is a real biomechanical properties of natural motion and joint range (taken from NASA studies). Human model is composed of 71 segments and 69 joints, some with more priority and more degrees of freedom, a total of 135 degrees of freedom.

2 Ergonomic analysis in software Tecnomatix Jack

The aim of implementing or enforcing ergonomic principles should be [5], [7]:

- layout of workplaces and processes to meet requirements for a person's health, safety and comfort do the job,
- maintaining human health and sustainable deploy ability of all employees,
- prevention of overloading staff,
- provide improved satisfaction of workers,
- increase efficiency through ergonomic workplace layout.

Overview of the most commonly used methods:

- Low Back Analysis - evaluates the forces exerted from the spine to the lower back on the virtual human model in every position and in every man's load.
- Static Strength Prediction - detects the percentage of workers who have the power to carry out the work activity.
- NIOSH - a tool for the evaluation of symmetrical and asymmetrical lifting the load.
- Metabolic Energy - the analysis of metabolic energy expenditure - calculated energy consumption of a particular work activity.
- Fatigue Recovery - recovery and fatigue analysis helps us to assess whether the work activity comprising sufficient time to prevent the recovery of the fatigue of the worker.
- Ovako Working Posture Analysis (Owas) Tool - assesses the relative discomfort of man in the working position, emphasis on the position of the back, patio and legs, determines the urgency of remedial action. The method is suitable for analysing posture by performance of work tasks. Assesses the relative discomfort of working position from the position of back, hands, feet and load levels, to the work posture is assigned a number which indicates the urgency to carry out corrective measurement. This measurement is performed to reduce the potential risk of injury to workers.
- Rapid Upper Limb Assessment (RULA) - analysis of the upper limbs, evaluates the working position in terms of diseases of the upper extremities. Rula "is a survey method for the investigation of work-related upper limb disorders," Applied Ergonomics, 1993
- Manual Handling Limits - it is used for the evaluation of manual handling, helping to reduce the risk associated with back pain, even during lifting, lowering, pushing, pulling and carrying loads.
- Predetermined Time - the time needed to carry out the work activity with distribution of the workload to file motions.

Choosing a suitable method for analysing the optimality of job positions is governed by the results explanatory power from their implementation with regard to potential and real health and safety risks during work (Table 1) [14]. Validating the methods ergonomics intervention selection process is on the figure 1.

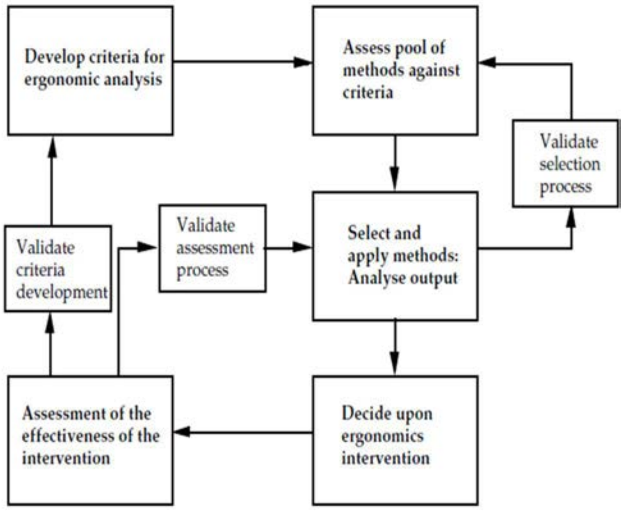

Figure 1 Validating the methods selection ergonomics intervention process. (Adapted from Stanton, N.A. and Young, M.S. [1999], A Guide to Methodology in Ergonomics, Taylor & Francis, London. With permission.)

Below is created a simple workplace in the simulation program TX Jack and are applied methods OWAS and RULA, which help to analyse optimal working postures with an emphasis on upper body (Figures 2-9). These are the most commonly used analysis. This is a load detection of worker by translating the object from the floor to the machine. After the realization of simulation and subsequent completion of the analysis it is clear that the working conditions are not suitable for the protection and safety. Therefore, corrective measures were taken, which consist in the proposal by the conveyor, which significantly reduces the burden on workers at the workplace. This is evident from the realized simulation and subsequent carried out analysis Rula and Owas.

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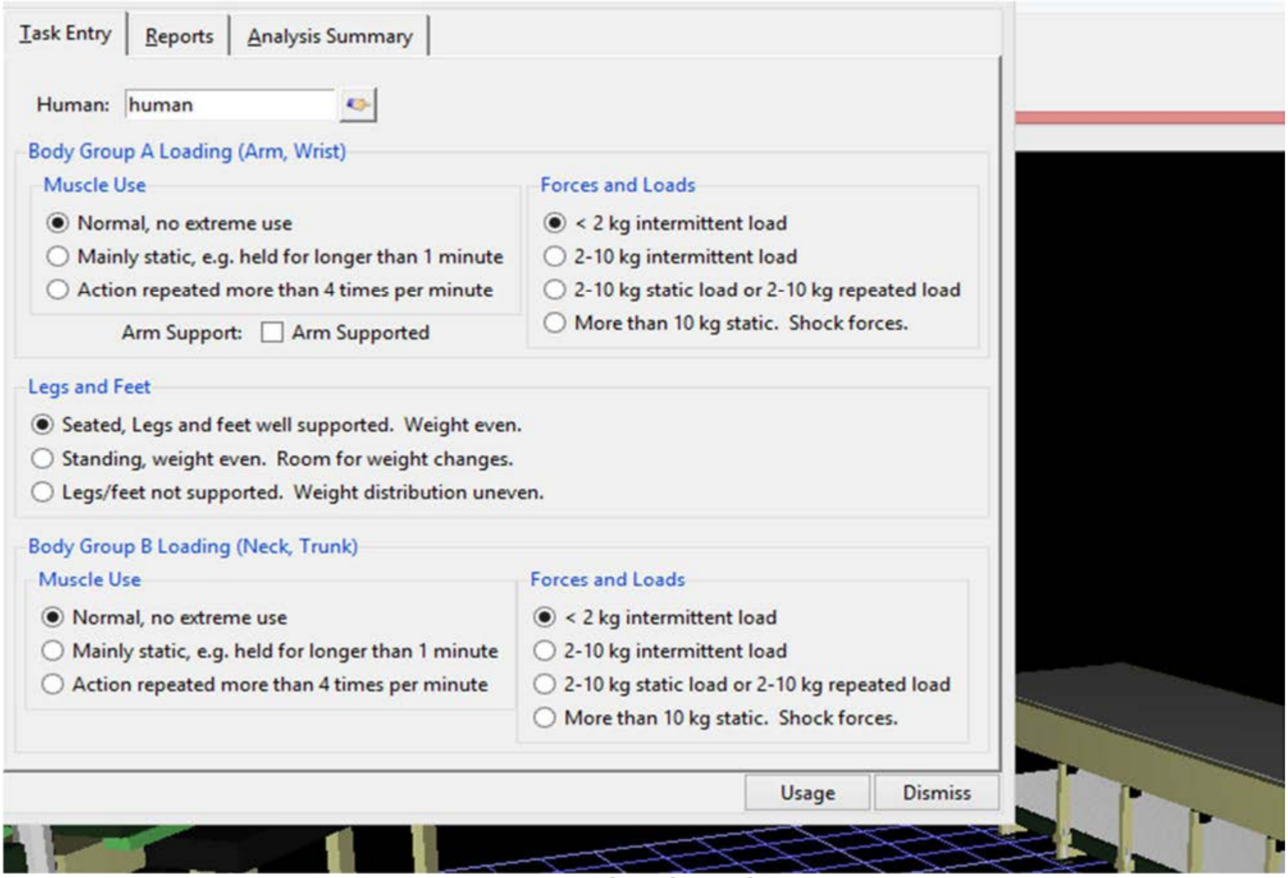

Figure 2 Rula Dialog window

Table 1 Risk category

Risk category	Effects on the musculoskeletal system	Corrective measures
1.	position, which has no harmful effects on the musculoskeletal system	there is no action required
2.	position with the potential to cause damage to the musculoskeletal system	corrective actions are required in the near future
3.	position with harmful effects on the musculoskeletal system	corrective measures are needed as soon as possible
4.	burden caused by this position has an extremely harmful effect on the musculoskeletal system	the need for immediate corrective action

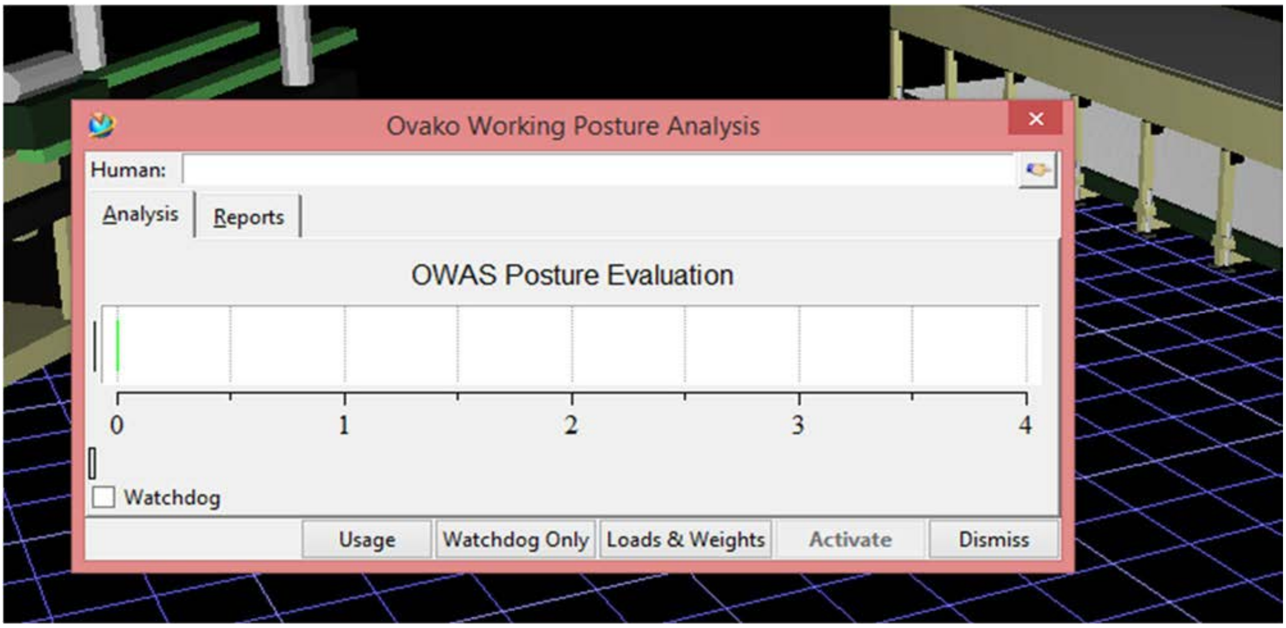

Figure 3 Working Posture Analysis Dialog window

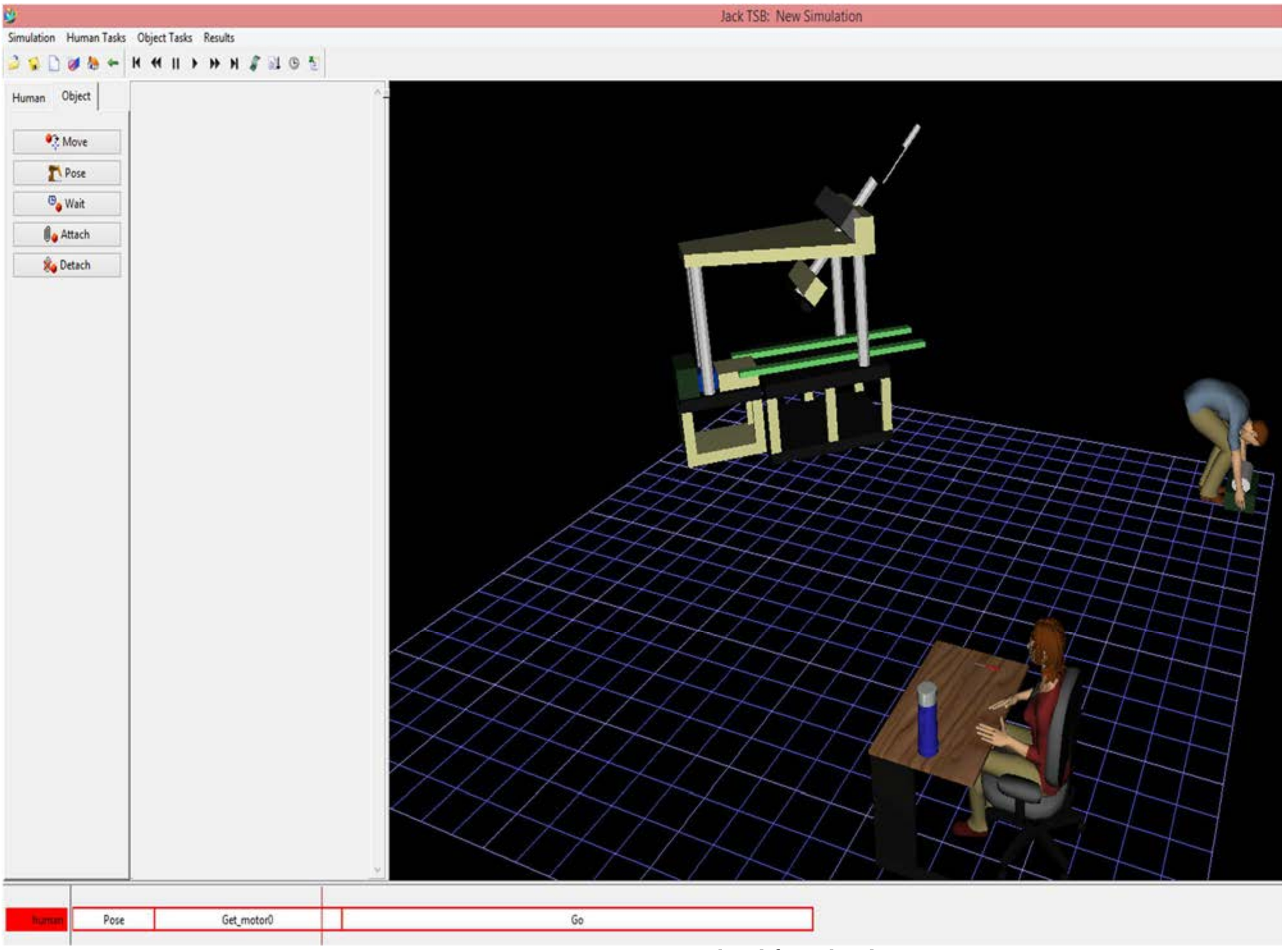

Figure 4 Operating position when lifting the object

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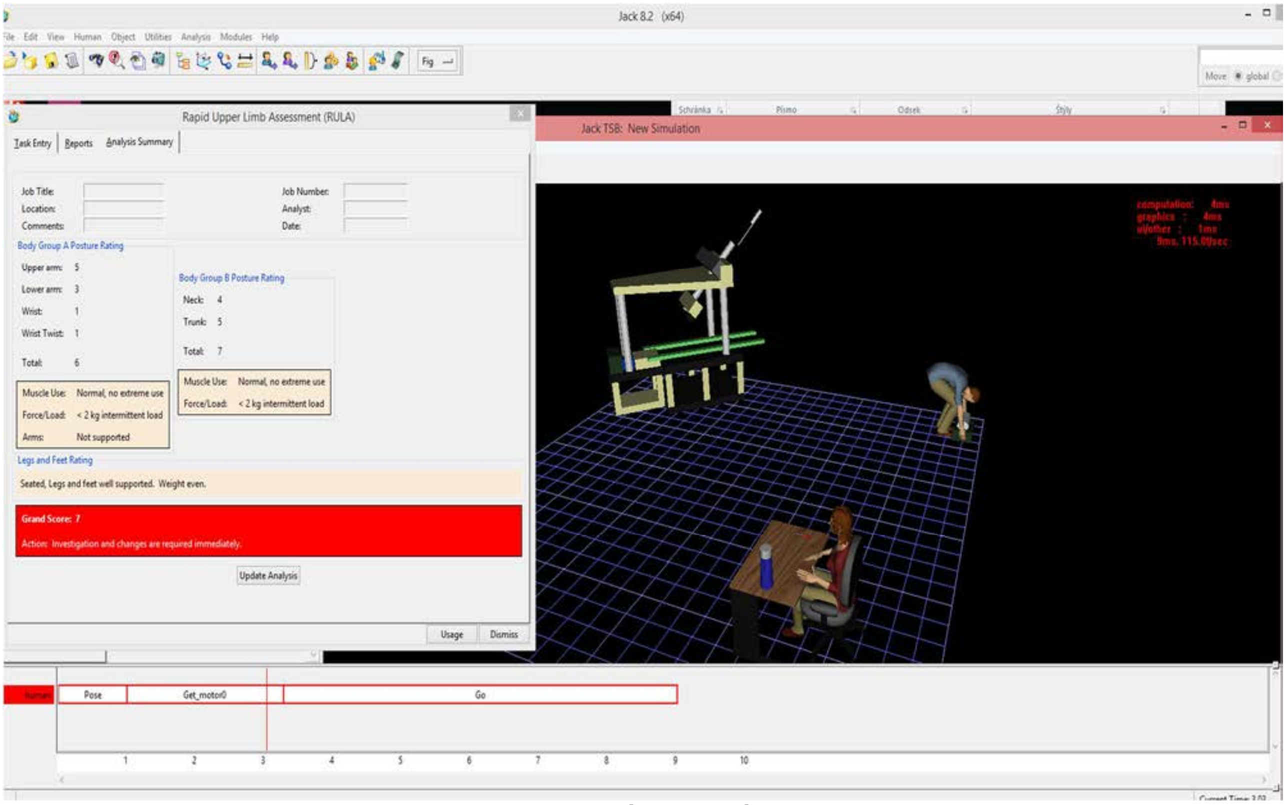

Figure 5 RULA Analysis - Initial Situation

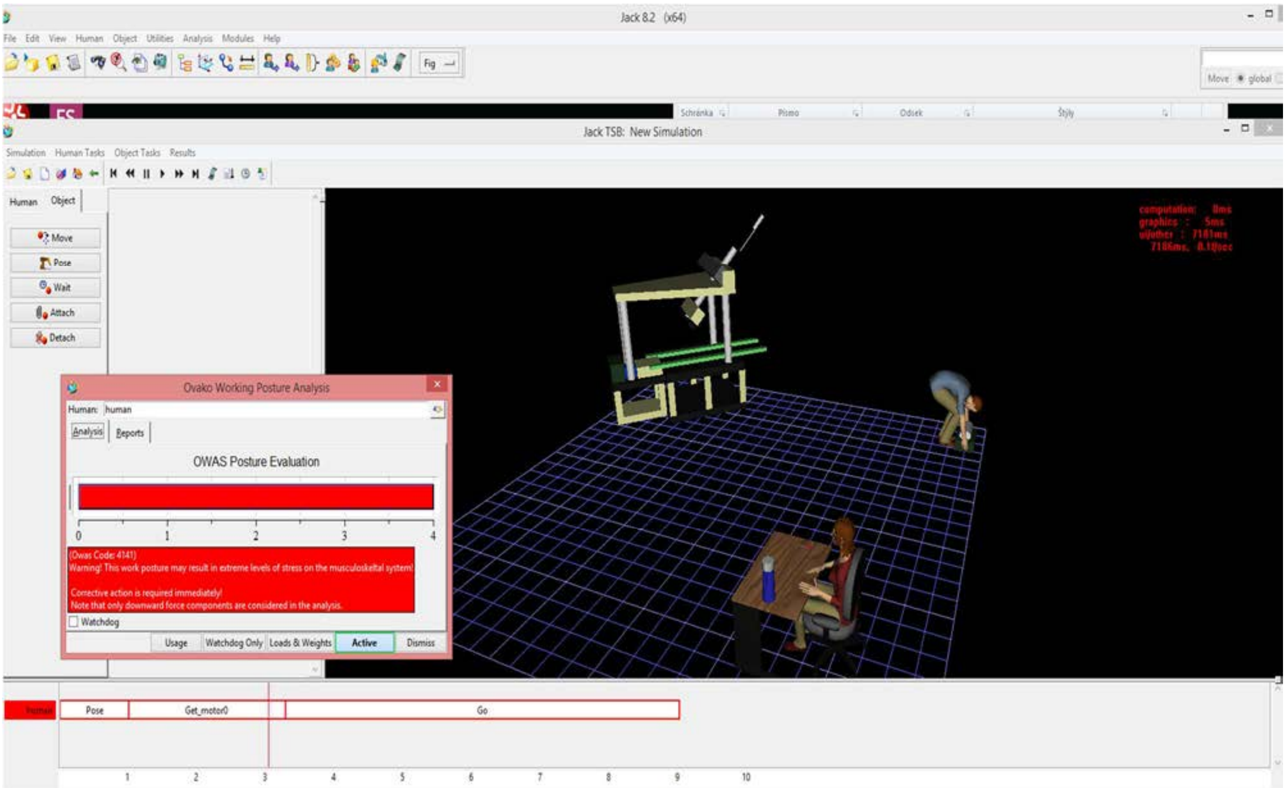

Figure 6 OWAS Analysis - Initial Situation

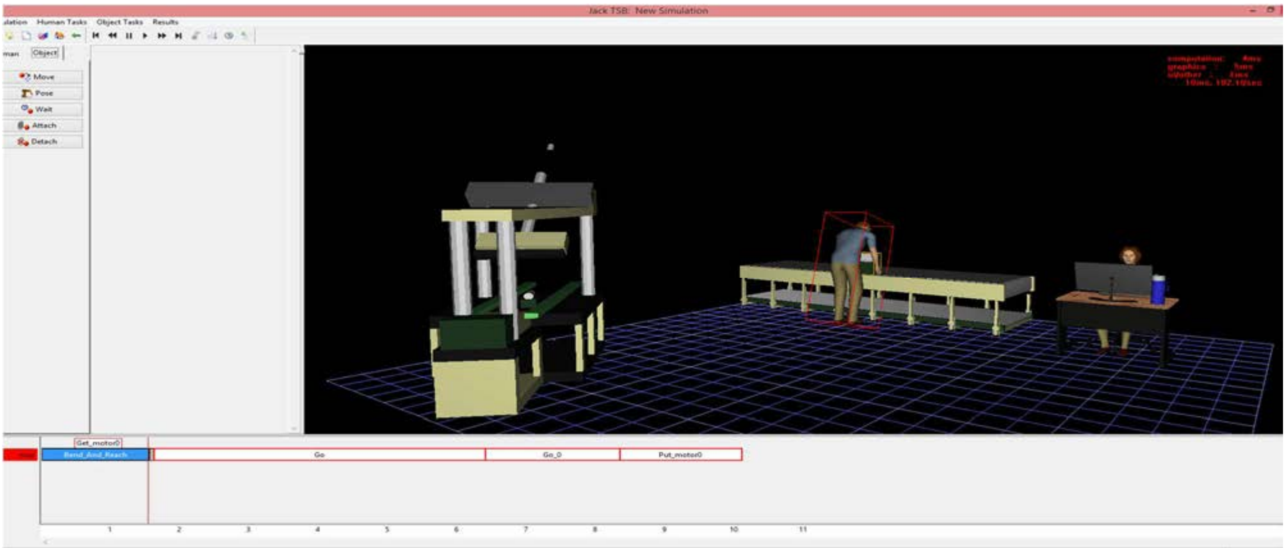

Figure 7 Corrective action in the form of a conveyor

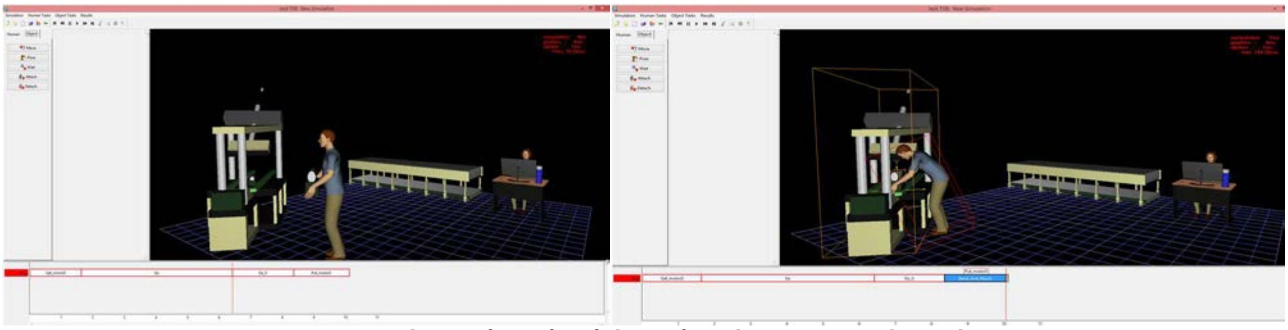

Figure 8 Simulation of transfer of objects from the conveyor to the machine

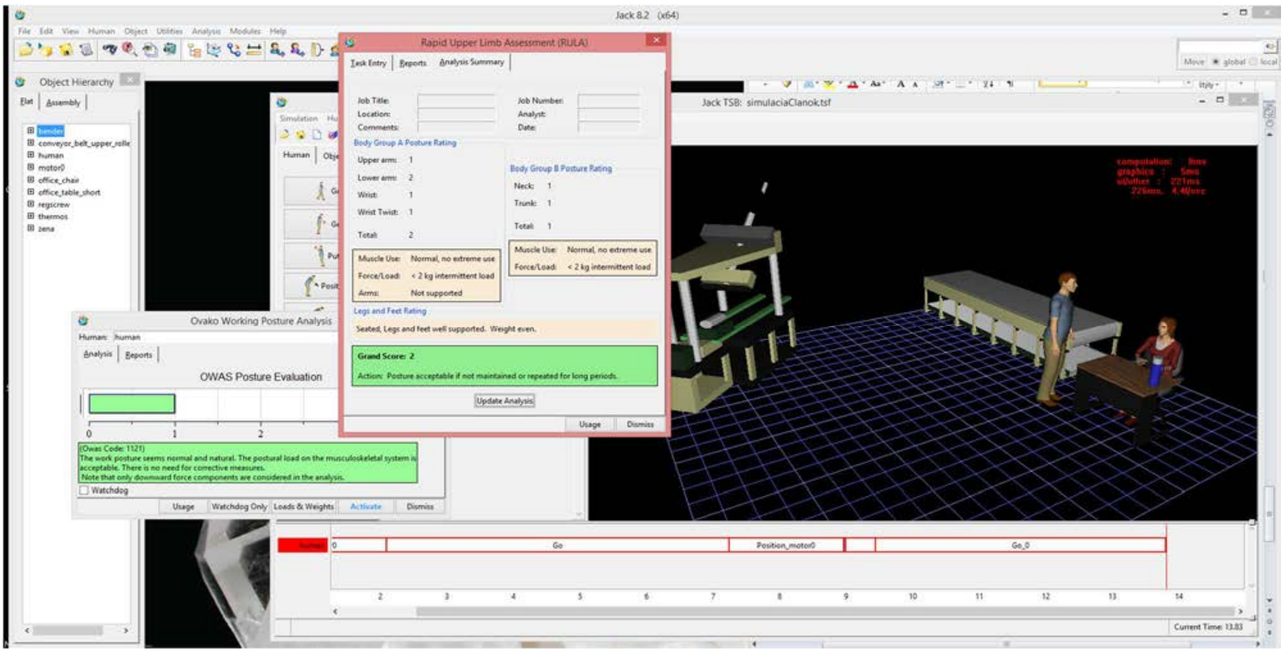

Figure 9 RULA and OWAS Analysis - after the implementation of corrective measures

Conclusion

The simulation program Tecnomaix Jack is a tool that helps to define the factors that affect job performance and helps to verification of corrective actions in virtual reality. Application of software support creates conditions for experimental verification of various proposals for solutions in a virtual environment. The implementations of measures emanating from the experiment as optimal are easier.

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NUMERICAL SIMULATION OF STEEL PLOUGHSHARE

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Keywords: FEM, Blade, Critical force, Yield Strength
Abstract: The text presents information about the sphere of a steel ploughshare structural design. Blade is designed as a part of the fire–recovery track vehicles. Main advantage is a general range of application in various severe conditions. The article explains the basic principles of a design proposal that are subsequently verified by a numerical simulation. The authors made two types of simulations. The first one is a calculation, when the ploughshare is under standard load created by working conditions. Second case is, when the ploughshare is under critical load. The main message of the text is present basic know-how, how to design the steel ploughshare and evaluate the plastic zone at blade, which was created by under critical load.

1 Introduction of steel construction

A method of designing a steel structure is a difficult process that may be affecting a number of factors. Primary instances which must be considered at the beginning of the proposal are:

- manufacturability,
- ability for long-term operations,
- easy maintenance for a construction elements,
- economical aspects,
- safety for users [5].

The primary effort is to develop steel construction of low-weight and high load capacity. This leads to, that a shape, a dimensions and a load conditions allow a loss of the primary stable equilibrium position (fixed), what is in terms of functional ability of the structure unacceptable. The loss of stability and shapes exists, when the conditions are created for transition from a stable equilibrium position to a unstable equilibrium position. This transition is characterized by changing the shape of the body. A loss of stability of elastic bodies occurs most frequently in the case of long thin rods, thin-walled construction a wherever at last one dimension of the body is very small in relation to other [4].

Design in order to determine the optimal solution is a complex process and consisting of determining the operating conditions of construction, rational selection of active scheme shape structural materials and components that ensure the efficiency of construction with regard to price and technology [6]. For more information about buckling problem and theory about design the steel structures see the publications [2], [4], [5], [7] and [8].

1.1 Introduction of ploughshare

Ploughshare is universal working tool applied for pushing, moving and storing the material on construction site. They paramount technical parameters are:

- geometrical characteristics,
- angle setting of the working mode,
- angle of blade cutting edge.

The blade shape is intended by operating condition and types of blades are illustrated in Figure 1.We can assume, that our proposed ploughshare will be used in hard working conditions. That means, the base of soil is formed by stones, sand, root age system and along with the peat. Therefore is design intentionally oversizers according to rigid construction in positive way (increase a tool lifetime).Now is time for question: how is increase the weight of the ploughshare if we increased its own stiffness??? Good outcomes provide us the mathematical optimization methods. Where can user with reliable and desired mathematical approaches to get a very accurate usable result [1].

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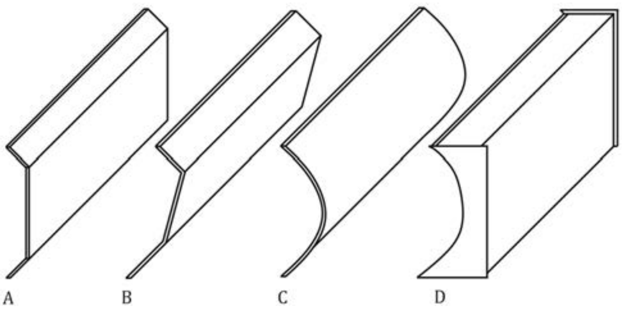

Figure 1 Ploughshare shapes

Introduction of ploughshares typology:

- A - type for small dozers,
- B - type for medium dozers,
- C - type for large dozers,
- D - thin-walled ploughshare.

1.2 Determination of working load

Consider the theory of cutting the soil, which was written by author [1]. It is assumed, that the separated material will be clipped from soil with blades part of ploughshare. Thus released material, which is pushed in vertical direction along ploughshare, is marked by number 1 in Figure 2. If the rising current reached some height level, than coherence of the soil is decreased and clipped materials starts falling down front of the ploughshare. This status is marked by number 2 in Figure 2.

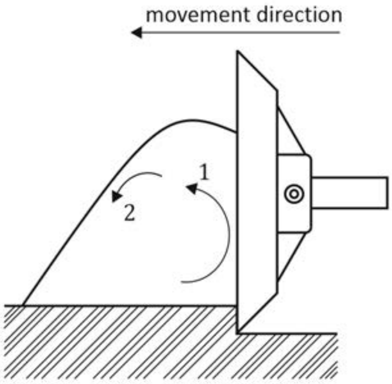

Figure 2 Working condition

So, it is possible to envisage composition of forces, which are redistributed in ploughshare during the working cycle. Based on this a forces redistribution, it can be calculate a working force and next step, according to this working force, is make a dimensioning construction, strength calculation and others operations, which are necessary for correct proposal. Redistribution of forces is in Figure 3.

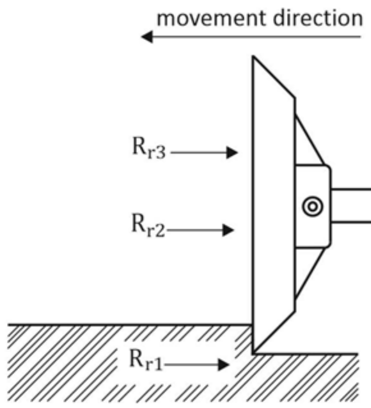

Figure 3 Redistribution of forces

Introduction:

- R_{r1} - cutting resistance of soil,
- R_{r2} - pushing resistance of soil,
- R_{r3} - friction resistance of soil.

A rigorous mathematical treatment for working force R_{rc} is given below:

$$R_{rc} = a.b.K + G_z.f_{zp} + G_z.f_{zr}.cos^2\gamma \qquad (1)$$

Introduction:

- a - depth of cutting (m),
- b - width of cutting (m),
- K - the nominal resistance against cutting (kPa),
- G_z - gravity of pushing soil (N),
- f_{zp} - coefficient of friction of cutted material on the soil (-),
- f_{zr} - coefficient of friction of soil on the ploughshare (-),
- γ - inclination angle of the ploughshare (°).

Our determined of the R_{rc} value is R_{rc}= 34,9 kN.

2 Finite element method

The basic idea of the finite elements method is very simple. Mathematical functions, which we are looking at a particular area, we are interpolated so, that the region divide into sub-areas called finite elements. Within each analyse with finite element function is approximated appropriately chosen function clearly defined values in the fixed function and selected points called nodes. Instead of search function is a complex task with practically impossible, we are looking for now only a value in the nodes. The problem is thus discretized, the task is now to find it just a set of numbers. In classical mechanics of rigid bodies, this procedure leads to solving the system of linear algebraic equations of the type:

$$\boldsymbol{K}\,\boldsymbol{d} = \boldsymbol{R} \qquad (2)$$

Introduction:

- ***K***- stiffness matrix,
- ***d***- is a column matrix containing the searched values shifts in nodes,
- ***R*** - column matrix containing the external forces applied to the body [8].

2.1 Numerical simulations

For a numerical calculation was used Solidworks 2012 software. For a first necessary step we have set the correct boundary conditions at 3D model and a simplified mathematical model. It means that all 3D components of ploughshare that are not necessary for the correct calculation are removed and replaced with boundary conditions that reflect reality. This step is dramatically reducing the number of equations entering to the calculating. Advantages of this step are, reducing time used for solving equations. Thus, we have created a mathematical description of the areas to simplify the blade itself without arms (we assume, that a pushing arms are super rigid), bolts, and other structural members. Our monitored parameters for the simulation have the following values. Maximum tension generated in the material caused by working load force R_{rc} is σ_{max} = 190 MPa and for deformation δ_{max} = 3,84 mm. We have used a classical construction material with yield strength R_e =275 MPa. Redistribution of induced stress at ploughshare is in Figure 4 and Figure 5.

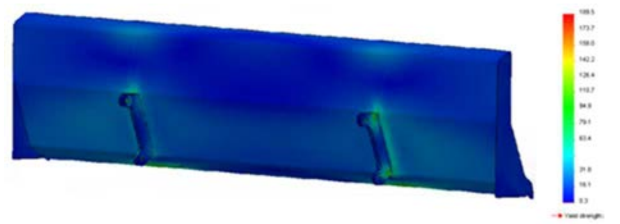

Figure 4 Redistribution of induced stress

It can be seen, that stress is created and manifests itself only at areas with the ploughshare handles. As was previously mentioned, the initial proposal blade is intended oversizers due to blade life time. The simulation No. 2 explores, what would happen if the ploughshare is overloaded. The blade is subjected by critical force. Information about this type of the simulation is in chapter bellow.

Figure 5 Redistribution of induced stress

2.2 Calculation with critical force

For this type of task, we have used a nonlinear calculation, the same steel material and the critical load is R_{rc2} = 50 kN. The maximum induced stress is σ_{max} = 277,5 MPa and induced deformations are δ_{max} = 5,51 mm. As can be seen, the watched value of the yield strength, have been exceeded about 22.5 MPa. This excess of yield strength causes a created plastic material in critical areas. After unloading, it is a state, when the blade ceases to operate the critical loads and system is returned to equilibrium state position, areas with a plastic materials have a same positions and what is only changing is a induced stress from σ_{max} = 277,5 MPa to σ_{odl} = 12,8 MPa (Figure 6).

Thus, it is possible to make a conclusion. If a critical load value reached maximum (σ_{max} = 277,5 MPa), the ploughshare is not seriously damaged due to a permanent plastic deformations created in areas, which are not affected the main design nodes and residual stress has a minimum value (σ_{odl} = 12,8 MPa).

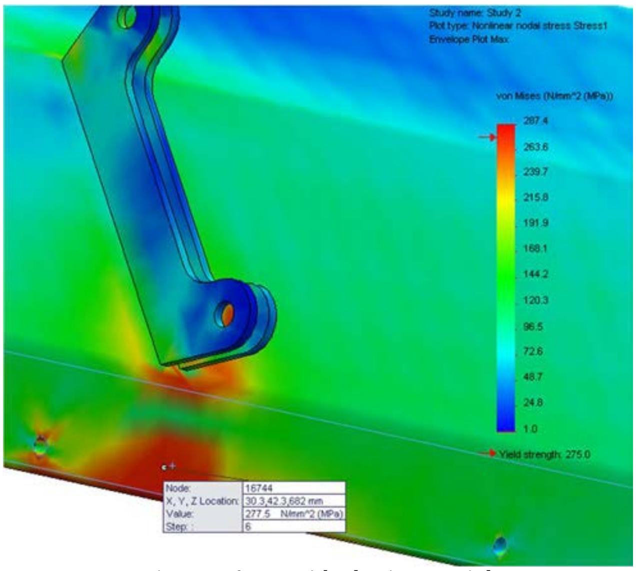

Figure 6 Areas with plastic material

It is appropriate to mention that such a state should be more thoroughly investigated and not to be really on the outcome of one simulation. For this reason, it has been made two independent simulations for confirmed the correctness of the first calculation with same results. Construction design of ploughshare is shown in Figure 7. The marks indicate the number of structural parts.

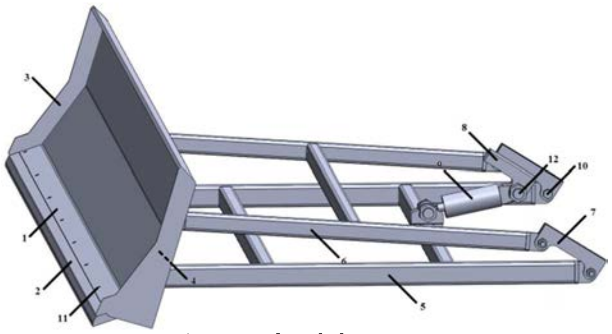

Figure 7 Ploughshare

Conclusion

Ploughshare is a tool for vehicles, which are used for working with soil. Developing process of a blade is very difficult in which the amount of unknown figures, which may negatively affect the reliability of the tool. We have presented the theoretical model of ploughshare to draw attention to areas of proposal, which have help to reader to understand this problematic.

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PERFORMANCE EVALUATION INDICATORS OF UNIVERSITY SPIN – OFF COMPANIES

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Keywords: university spin-off, companies, evaluation of innovation performance, innovation potential, evaluation methods
Abstract: Article deals with the performance of university spin-off companies. First step of this contribution is to evaluate the theoretical results of given problems and specifications of spin-off companies. The work evaluates and compares different and existing methodologies used in the scientific literature with the characteristics of used factors. On the basis of processed methodologies there have been create the list of factors needed for evaluation of innovative potential of university spin-off companies. It was processes by comparative method. The result is a proposal of concept evaluation of recommended methodology

1 Introduction

Universities in particular countries or regions often represent high level of support the local development of culture and science and research. All information that is situated on the academic, universities are trying to push into the consciousness by different ways. It is producing high-quality and educated workforce, or support by various projects. The increasingly important is however begins the commercialization of research results through the establishment of spin - off companies [1].

The main incentives leading to the creation of spin-off companies is:

- Relatively easy to enter the market.
- Probable profitability of the project.
- The possibility of obtaining a patent.
- Intellectual wealth.

Academic spin-offs companies are companies founded by an academic inventor aiming to exploit technological knowledge that originated within a University to develop products or services. These companies contribute to technology transfer in two stages: as first, they transfer technology from their parent organization to themselves and, secondly, they transfer the technology to customers.

The main task of university spin-off companies is to use technological expertise acquired by research and development activities of universities and their subsequent commercialization. Each technology transfer takes place from the parent company to spin-off and subsequently to customers. The contribution of university spin-off companies and their business is not just marketing, but also the linkage between university activities and practice. This link has at present a great social value because it offers many advantages for all parties involved such activities.

Interconnection to universities may have other benefits as well at the same time for spin-off and industrial start-up businesses in the form of access to new knowledge, human capital, training and other resources. Literature also focuses on the links between scientists in their breadth and diversity.

Spin-off and industrial start-up businesses may be linked to universities in many forms such as research projects, contract research for universities and outside the universities, sending employees to training for university, student internships in companies or maintaining informal relationships [1], [14].

Key success factors of spin-off companies

Generally, there are two key factors that are common to the success of spin-off companies focused on profit:

- employees with relevant experience,
- maintain management structure that is independent from the mother organization.

The most common business model for spin-off companies is: the subsidiary company is not just a property of a parent company, but pays to the parent company dividends based on its profitability. Whereas it is necessary to generate revenues through new business activities or investments, reduce taxable business income, maintain the exemption or restrict legal obligations, companies are increasingly returning to the creation of profit-oriented subsidiaries. Many spin-off companies started with venture capital or with finance provide by investment/business angels (individual investors who provide the initial capital of the company in order to start operations) [14].

2 Analysed methods

The aim of this article is to identify and propose, on the basis of literature review, a model of evaluation of the spin-off companies' performance. The need for evaluation of university spin-off companies is based on the efficiency of the linkage between university environments with practice. Assessment provides feedback in terms of use and commercialization of knowledge and skills by providing scientific-academic environment into practice.

Methodology of Maximilian Goethner and Uwe Cantner

The methodology is based on analysis of large number of university spin-off companies and non-university innovative start-up businesses. In this work, the authors deal with the issue of performance of university spin-off, compared to non-university ISTART-up companies, with factors that affect their performance and the fact whether the differences in performance are evident. The assessment is based on data which authors of works collected from 128 university spin-off and 128 non-university innovative start-up companies in Germany. [11]

The assessment includes 6 dependent and 11 independent parameters:

- 6 dependent parameters: increase in demand, increase in unemployment, business rescue, rating, patent and its application in practice and the probability of patenting.
- 11 independent parameters: previous experience of the founders of management, innovation, initial capital, degree of development of a new product or service, number of company founders, the objectives of growth and development, Indicator target market, market growth, market competition, PhD. team, natural sciences team.

Each of indicators is more precisely specified and has precisely defined values of individual parameters for realization the individual assessment.

Methodology of Manheim Foundation Panel

This methodology models the probability of "survival“ new companies in the field of industries that require a high degree of expertise. Factors that this model monitors and studies include: year founded of company, industry focus, ownership that a company holds in another company, the number of founders in company, credit rating, buildings and land property belonging to the company and the highest level of education achieved in society. On the base of this model there was also developed company's growth model, which relies on the characteristics and factors mentioned above [8].

This model uses three categories of variables.

The first of these represents characteristics of founding team:

1. Academic entrepreneur (AE) - current employee of University,
2. Research AE - if at least one of the academic entrepreneurs involved in university research during his time at university.
3. No-research AE - at least one academic entrepreneur who did not act in university research.
4. % of academic titles in team
5. The size of team

The second category is characteristics of company and external environment at the time of its formation.

1. Science - at least one of the academic entrepreneurs worked in the field of engineering.
2. Engineering / Mechanical engineering - at least one of academic entrepreneurs operated in the area of engineering.
3. Patent of company.
4. Research and development (cont.) internally and regularly on a continuous basis.
5. Research and development (OCC) internally, but only on an occasional basis.
6. Employees in the time of company formation.
7. Credit rating: Characterizes access to the borrowed capital.
8. Limited liability: fullness of law conditions relating to the legal form of company.

The third category is characteristics that relate to the environment. It deals with relationships with universities:

1. Interface with universities.
2. Branch of industry
3. Cohort: Represents annual categorical variables that characterize the year of company formation.

The method of assessment Research Centre of Science and Technology TEKPOL

This method comes from the work of authors Yelda ERDEN and Alp Eren YURTSEVEN who approached to each of the factors individually, whereby they scored each factor by comparative method of all 12 evaluated university spin-off companies. This methodology includes also informative but very interesting information about these companies, e.g.: barriers preventing or slowing down the innovation process, reasons which led the founders to establish spin-off, the motivation that leads them to cooperate with other actors on the market, etc. The main evaluative factors of this work consists of following 11 factors [10]: Year of establishment, number of founders, number of employees, sector in which company operates on the market, factor of researched and development activities, product innovation, process innovation factor, cost of innovation, cooperation factor - it describes profile of actors with whom a university spin-off companies cooperate, place where the company is setting up, product and sale factor.

The evaluation methodology of supporting programs of innovative companies

The evaluation method is based on the work of Džupka Peter and William Vajda, who dealt with the supportive programs of innovative start-up companies and spin-off and they researched the difference of their innovation performance. Comparison and evaluation of company focused on Slovak spin-off and start-up businesses, whereas, according to the authors of work this issue has not yet been applied to the Slovak innovative company. The companies were interviewed online by an e-mail form. The database included small and young companies. The database of these companies was obtained from the start-up centre of the Technical University in Kosice. The authors addressed more than 100 innovative companies. 26 completely filled forms were returned to authors. From this group, 16 were identified as start-up companies and 10 spin-off companies. Following indicators were used as a tool for analysis the results:

1. Employment represents the number of full-time employees.
2. Research and development - funds invested in R & D.
3. Region - place of establishment of a new company.
4. Patents - number of patents requested by the founder and the inventor eventually just as the applicant.
5. Age - number of years of new company
6. Sales - the total value of sales within the last three financial years
7. Profit - within a three marketing years
8. Industries - a market area in which company operates [12].

The methodology of evaluation based on the work of María Beraza-Garmendia and Arturo Rodríguez-Castellanos

The methodology of evaluation is based on the work of María Beraza-Garmendia and Arturo Rodríguez-Castellanos who primarily dealt with the issue of efficiency the supporting programs of university spin-off companies. Their work is based on the results of European universities but mainly from universities in England and Spain. Due to the differences of individual supported programs for the creation of spin-off businesses at universities, it is needed to characterize the by using different identifiers and identify the determinants of their performance. The research was conducted on the base of online questionnaire, which was sent to more than 250 universities in Europe, with the presentation of research and invitation on the participants of this reconnaissance by answering various questions.

Information-gathering process ran from November 2005 to end of February 2006. Commission received responses from 67 universities, 25 universities of which belonged to the UK and 42 were European universities (except Spain). The level of participation in the survey was 20.36%. In the case of Spain reconnaissance was conducted separately. Online questionnaires were sent out virtually to all universities that deals with the technologic transfer. The level of participation represented 58% in Spain. Only about half of universities answered on almost all questions. Questions were classified into several categories, which were evaluated as separate indicators [13]:

1. Age of spin-off.
2. The size of the team in the spin-off.
3. Liabilities of university are indicative links of university to promotion of entrepreneurial culture
4. Selectivity is certain prudence in the selection and evaluation of results of studies dealing with the product launch.
5. Creativity of university in search of creativity and prospecting business ideas.
6. The degree of efficiency is an indicator that is based on the results of the number of based spin-off companies and the percentage of surviving on the market for at least three years.
7. Involvement in the management of spin-off is an indicator that assesses the degree of cooperation and active involvement of universities in spin-off companies [13].

3 Comparative analyses of indicators

On the base of all mentioned methodologies of individual authors there is possibility to search the relation between individual evaluations. Each of the methodologies represent sum of factors and indicators that have their common characteristic or characteristics adapted by the author. Each of the authors deals with a slightly different theme. That is the reason why the evaluation criteria differ on the base of its exact focus on their work. Selection of individual factors is also connected to the period of its elaboration because newer works are partially influenced by previous studies in which the authors express a view on these issues. By collecting all the evaluative factors in solving methodology it is possible to summarize all the indicators mentioned in the individual works.

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All of above mentioned indicators solved in the individual work is necessary to categorize into three main groups:

The first group is characteristics of founding team where we can find more the same or similar characteristics used by authors in their works. The importance can be attributed to emphasized characteristics. According to this table, important factors are: research AE - it represents the importance of having in founding's team at least one member who was participated in university research and the number of members with the academic degree. These factors along with other factors represents: experience in the individual sector and experience with start-up / spin-off, the importance attributed to acquired skills of founders the issue in the past.

Table 1: Characteristics of founding team

Charakteristics of founding team	Goethner and Cantner (2010)	Goethner and Cantner (2011)	Garmendia and Castellanos	Czarnitzki, Rammer and Toole	Džupka and Vajda	Erden and Yurtseven
AE				X		
Research AE	X			X		
Non-research AE				X		
The number of team members with an academic title	X			X		
Team size				X		X
Entrepreneurial personality		X				
Wages		X				
Founding team		X				
Experience in a sector	X	X				
Previous experience with management	X					
Previous experience with research	X					
Experience with start-up/spin-off	X	X				

The second major group of allocation all the criteria mentioned in the described work is characteristic of the new, already existed company. In this group we can see an intensive occurrence of various factors mentioned by said authors. The most commonly used criteria included in this group are values representing the growth in employment, investment in research and development, number of patents and rating granted by independent reputable rating agency. Other evaluative criteria which are referred to several authors are values representing the amount of capital, increase of sales, number of years on the market, but also factors dealing with the issue of a new product in company, its novelty and also region and target market to which the company wants to penetrate.

Table 2: Characteristics of new company + external environment

Charakteristics of new company + external environment	Goethner and Cantner (2010)	Goethner and Cantner (2011)	Garmendia and Castellanos	Czarnitzki, Rammer and Toole	Džupka and Vajda	Erden and Yurtseven
Science				X		
Engineering				X		
Other sector				X		
Company	X	X		X	X	

patents						
Research and development	X	X		X	X	X
Employment	X	X	X	X	X	X
Rating	X	X	X	X		
Limitation of liability				X		
Region, target market	X				X	X
Number of years on the market			X		X	X
Sales	X				X	
Profit					X	
Sector		X		X	X	X
New product	X	X				X
Capital	X	X				
Salvage business	X					
Competitiveness on the market	X					
Process innovation						X
Product-sale						X

The third group of factors represent relations and cooperation with universities. In this group, most of individual criteria is not repeated, but they have some connection. For some authors, this category is difficult to evaluate, some other authors do not solve the principle and intensity of company cooperation with universities. The tables below show the evaluative factors of individual methodologies that represent relationship between university and company from different perspectives. Interconnection with university is one of the factors mentioned in two different methodologies and represents training of staff and students but also interconnection in research activities. Despite the low intensity of occurrence and solution of these factors it is necessary to attribute them an important role within the frame of well operating spin-off company. After the establishment of company and consequently without next cooperation, the company can show good results in terms of profits, increase in employment or create perfect product for the market. But without active participation and sharing of university on its operation, company do not sufficiently exploit its potential wherewith the University spin-off companies dispose.

Table 3: Relations with universities and cooperation

Relations with universities, cooperation	Goethner and Cantner (2010)	Goethner and Cantner (2011)	Garmendia and Castellanos	Czarnitzki, Rammer and Toole	Džupka and Vajda	Erden and Yurtseven
Links with universities				X		X
Involvement in the management of spin-off			X			
Cohort				X		
University liabilities (supporting of business activities)			X			
Creativity			X			
Cooperation with other firms						X

Conclusions

Reasons of process performance measurement do not have to be same for each organization. Through that, some reasons have common features and one of them is implementation of quality standards. Results that were found by measurement of processes performance:

- analyse problem that happened and deals with obtaining of information. On the base of obtained information it is possible to eliminate concrete problem and manage individual processes effectively without unnecessary losses,
- help identify key business processes and their inadequacies. (It is more efficient to ignore the process that is not significant for company, but it is important to deals with key processes that have a significant impact on earnings, turnover, etc. and eliminate processes which are irrelevant and unprofitable.),
- provide a real background papers of problem (Business management intuitively anticipate that something is not all right but only results of measurement allow them to compare the actual situation with the plan.),
- are available for identifying relationships between inputs and outputs as well as for analysis of total results and their assignment fractional.

Table 4: Recommended factors for evaluating method of the innovation potential

Factor	Characteristic
Research AE	At least one member worked in university research
The number of team members with an academic title	% of members with the academic degree
Entrepreneurial personality	Indicators of enterpreneurial personality describes the characteristic features of the founder personality and the conditions of their use in favor of business
Team size	Number of employees in the company
Experience in a sector	The variable indicating the experience of one or more members in a sector of new business
Experience with start-up/spin-off	Previous experience with start-up, or spin-off companies at the time of setting up a business
Company patents	Number of patent application form
Research and development	Company activity in the field of research and development
Rating	Value rating from an independent agency
Sales	The total amount of company sales
Capital	Amount of capital input
Employment	Number of employees in first financial year
Competitiveness on the market	Level of competition operating on the market
Region, target market	Target group, the market, the company plans to enter
Number of years on the market	The number of years of company from entering the market
Sector	Industry in which the company operate
University liabilities	Support of business activities
Link with university	Relations in time of establishment
Innovation	Product innovation of new company

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