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Ergonomics approach in entrepreneurship

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Abstract. The research focuses on determination of the workload and work strain in small and medium-sized metalworking enterprises of Latvia. A number of studies in the world prove that the effectiveness of an organisation is closely related to a human, performer of the work, whose skills and health affect the results of the organisation's activity. This research, by applying ergonomics load evaluation methods, showed that extensive workload and work strain in metalworking enterprises has a negative impact on workers' wellbeing and health. The economics effectiveness calculations confirmed that the investments in ergonomics in metalworking manufacturing processes maintain human resources and are economically favourable in ensuring enterprise effectiveness, but further studies are necessary to evaluate workers' contribution and willingness to participate in ergonomics interventions.

Key words: ergonomics, entrepreneurship, workload, work strain, effectiveness.

INTRODUCTION

Nowadays ergonomics aspects and values are quite essential in the entrepreneurship business strategy, which characterises process management and profitability of the enterprise. A number of studies in the world prove that the effectiveness of an organisation is closely related to a human, performer of the work, whose skills and health affect the results of an organisation's activity (Sperry, 2002). Wellbeing at work promotes an employee's feeling of belonging to and trust in the enterprise (Roja, 2008). Therefore, it is important to find out the coherence between an employee and the aim of the organisation and its effectiveness.

In entrepreneurship and increase in work productivity, as world experience reveals, the human factor or ergonomics is of great importance, especially, if proposals in the aspect of ergonomics are already taken into account in the stage of process designing. In Latvia, a human as a highly valuable and competitive resource at work is not sufficiently evaluated. Hence the issue on improving the management of organisations in ergonomics aspect is particularly topical. Misleading is the opinion that in introducing modern production technologies, the effect of the human factor on the process is decreasing. Employees, regardless of the introduction of wider and more modern technologies in many branches of Latvian economics, for instance, metalworking, are still subjected to hard manual work, monotonous work operations, harmful forced postures at work, and chronic work in night shifts, which negatively affect work performance, as well as workability, and decrease the productivity of the organisation in general.

The work of operators of automated technological lines is often related to mental stress, time load and high responsibility. In these cases overload and tiredness are caused by *cognitive design* and *organisation* ergonomics risks: long-term concentration on control panels, restricted time for the prevention of different faults in certain work cycles, etc. Therefore, it is necessary to find out and assess these risks, in order to help any operator to choose a proper workload and techniques. It is part of ergonomics management, whose aim is to adjust work process to a worker, changing his behaviour in positive direction, particularly emphasising their loyalty to the organisation. Nowadays ergonomics management, as well as process management in organisations, is of great significance in entrepreneurship to ensure effectiveness of the organisation. It is a new approach to entrepreneurship, where ergonomics aspects and values are taken into account in business strategy, including ensuring process management and profitability of the enterprise.

The aim of the research was to determine the workload and work strain of employees in metal working enterprises and find out its influence on entrepreneurship effectiveness.

MATERIALS AND METHODS

In two years period 10 small and medium-sized metalworking enterprises were investigated in the research. In total 310 workers in metalworking were analysed with average age 34.1 ± 5.4 and length of service 6.3 ± 3.8.

The Key Indicator Method for assessment of the manual handling of heavy loads developed by the German Federal Institution for Industrial Safety and Occupational Medicine was used to assess workers' ergonomics risks (Steinberg, 2006). By means of this method possible overloads lifting or moving heavy loads or performing other dynamic operations are identified. Risk assessment is carried out by physical workload risk score (*RS*) taken into account the key indicators (criteria) and using the following formula:

$$RS = (M + P + C) \times I, \quad (1)$$

where M – object mass rating points; P – the employee's posture rating points; C – working conditions rating points; I – working time/intensity value points.

According to this method work hardness categories (or risk range) are: I – light work or low load situation ($RS < 10$); II – moderate work or increased load situation ($RS = 10…25$); III – hard work or highly increased load situation ($RS = 25…50$); IV – very hard work or physical overload ($RS > 50$). If the risk range is II, physical overload is possible for persons older than 40 or younger than 21 years, newcomers in the job or people suffering from illness. In all other cases (risk range III or IV) redesign of the workplace is recommended or it is necessary. Design requirements can be determinate by reducing the weight, improving the execution conditions or shortening the strain time, also elevated stress can be avoided.

The NIOSH lifting equation developed in the National Institute for Occupational Safety and Health (USA) was used as an assessment method for lifting and lowering tasks (Waters et al 1993). The equation provides a recommended mass limit (RML) based upon task parameters and the duration the task is performed. The RML is obtained through the following equation (Dempsey, 2002):

$$RML = 23\left[\frac{25}{H}\right]\left[1-\{0.03(V-75)\}\right]\left[0.82+\left(\frac{4.5}{D}\right)\right]\left[1-(0.0032A)\right]\times FM\times CM\ , \qquad (2)$$

where H – the horizontal location, cm; V – the vertical location, cm; D – the distance, cm; A – the asymmetry angle, degrees; FM – the frequency multiplier; CM – the coupling multiplier.

The actual load lifted or lowered divided by the RML provides the lifting index (LI). LI values greater than 1.0 are assumed to represent tasks posing risk to the worker population (Waters et al 1993).

For the **work strain evaluation** the computer software *ErgoIntelligence* of Canadian Company *NexGen Ergonomics Inc* was applied[1]. The work strain index (SI) is determined by such values: SI = < 3 – safe work, strain practically doesn't exist; SI = 3..5 – minor work strain; SI = 5...7 – work strain causes risk, potential errors in the work process, SI = > 7 – intensified work strain, harmful, possible accidents in the work process (Kalkis, 2008).

In ***assessment of economic effectiveness*** the mathematical calculations were used (Devisilov, 2010). If working conditions improved in the stated period of time the profitability E can be determined:

$$E = \Delta S + \Delta P + \Delta L \text{ (EUR)}, \qquad (3)$$

where ΔS – the margin of work accidents expenses before and after the stated period of time; ΔP – the margin of profit increase considering workers' workability increase and work environment improvement; ΔL – the margin of expenses of recompense or other expenses before and after the stated period of time.

Annual improvement effect (*EG)* can be calculated:

$$EG = E - R \text{ (EUR)}, \qquad (4)$$

where E – the profitability of improved working conditions in the stated period of time; R –the investments to realise improvements.

The investments to realise improvements can be calculated as:

[1] http://www.nexgenergo.com/ergonomics/ergointeluea.html (07.11.2012.).

$$R = \varphi A + L \text{ (EUR)}, \quad (5)$$

where A − capital investments; φ − coefficient describing the efficiency of capital investment (0.08 is stated for work environment improvement); L − additional costs for the improvement complex realisation.

The efficiency of improvements or absolute (total) economics effectiveness can be calculated by the formula:

$$EA = (E - L)/A . \quad (6)$$

If $EA \geq 0.08$, then capital investments can be considered as effective. The payback time of investments can be predicted as $T = 1/EA$.

RESULTS AND DISCUSSION

The physical workload of employees was evaluated at the 10 small and medium-sized metalworking enterprises of metalworking in the most characteristic production processes: *1) production of non-ferrous metal (brass, bronze) articles; 2) production of steel plates and pipes; 3) production of metal constructions.*

The results of workers' physical workload evaluation are shown in Table 1. The results of the KIM-A method shows that workers in various metalworking processes are subjected to compulsory work postures and physical overload especially for such professions: locksmiths, grinders, metal sawyer, warehouse workers, metal justification, lathe, casting, and cutting operators.

Table 1. KIM-A method evaluation scores (M, P, C, I), standard deviation (SD), risk score (RS), risk degree (R_d) for metalworking workers (n = 310)

Profession	M ± SD	P ± SD	C ± SD	I ± SD	RS	R_d
	Scores					I − V
Locksmiths (n = 30)	4.3 ± 1.1	4.4 ± 1.3	0.4 ± 0.2	7.3 ± 1.8	66.43	IV
Grinders (n = 20)	4.2 ± 1.5	4.1 ± 1.6	0.3 ± 0.2	4.1 ± 1.2	35.26	III
Metal sawyer (n = 50)	3.7 ± 1.3	6.9 ± 1.4	0.4 ± 0.4	7.1 ± 1.5	64.9	IV
Lathe operators (n = 30)	3.9 ± 1.7	7.4 ± 1.1	0.4 ± 0.3	2.4 ± 1.7	28.08	III
Warehouse workers (n = 20)	4.2 ± 1.6	4.2 ± 1.8	0.2 ± 0.3	3.8 ± 0.9	32.68	III
Painters (n = 25)	1.6 ± 1.9	1.5 ± 1.0	0.4 ± 0.2	4.3 ± 1.4	15.05	II
Welders (n = 15)	7.4 ± 0.8	7.3 ± 1.3	0.3 ± 0.3	2.2 ± 1.2	33	III
Mechanics (n = 25)	4.3 ± 1.1	4.1 ± 1.8	0.4 ± 0.3	4.4 ± 1.6	38.72	III
Metal cutting operators (n = 30)	7.1 ± 1.5	4.3 ± 1.6	0.3 ± 0.4	4.1 ± 1.1	47.97	III
Metal casting operators (n = 20)	8.7 ± 1.3	4.1 ± 1.2	0.2 ± 0.2	2.2 ± 1.8	28.6	III
Justification operators (n = 28)	9.1 ± 1.7	2.6 ± 1.1	0.4 ± 0.4	6.3 ± 1.2	76.23	IV
Blacksmiths (n = 10)	3.8 ± 1.2	2.7 ± 1.9	0.6 ± 0.3	4.2 ± 1.5	29.82	III
Gas welders (n = 35)	4.3 ± 1.1	4.1 ± 1.2	0.7 ± 0.1	2.5 ± 1.1	22.75	II
Compressor operators (n = 18)	2.5 ± 1.8	1.4 ± 1.5	0.7 ± 0.5	2.1 ± 0.9	9.66	I
Foremen (n = 20)	2.1 ± 1.3	2.1 ± 1.1	0.8 ± 0.6	4.3 ± 1.1	21.5	II
Metal smelters (n = 9)	4.6 ± 1.6	2.4 ± 1.3	0.7 ± 0.2	2.2 ± 1.7	16.94	II

The types of other professions, e.g. in processes of metal enclosure fabrication, gas welding of metal structures, automotive cleaning, rolled metal processing, etc., was not included in Table 1 due to evaluated risk degree I and in further study these results were not analysed.

The recommended weight limit for employees in metalworking (n = 310) were calculated for the following professions for which the KIM-A method showed the highest risk degree III or IV. The results are illustrated in Table 2.

Table 2. Recommended mass limit (RML), lifting and moving load (M), lifting index (LI) and standard deviation (SN) for metalworking employees (n=310)

Profession	M ± SN, kg	RML ± SN, kg	LI
Locksmiths (n = 30)	4.6 ± 1.5	3.1 ± 1.3	1.48
Grinders (n = 20)	5.1 ± 1.5	4.2 ± 1.9	1.21
Metal sawyer (n = 50)	9.6 ± 1	5.8 ± 3.2	1.66
Warehouse workers (n = 20)	32.3 ± 5	9.4 ± 1.6	3.44
Welders (n = 25)	10.8 ± 2	4.1 ± 1.2	2.63
Mechanics (n = 25)	21.7 ± 2	8.3 ± 1.3	2.61
Metal cutting operators (n = 30)	15.1 ± 2	9.8 ± 2.2	1.54
Metal casting operators (n = 20)	22.4 ± 2	8.1 ± 1.1	2.77
Metal justification operators (n = 28)	25.2 ± 3	8.6 ± 1.3	2.93
Blacksmiths (n = 10)	37.9 ± 5	10.7 ± 1.6	3.54

The results in Table 2 show that the recommended weight lifting and moving limit is exceeded by 1.2 to 2.5 times, but for some professions even higher, e.g. warehouse workers and blacksmiths (3 to 4 times).

Hence it can be concluded that workers in various metalworking processes are subjected to physical overload at the workplaces, the moved and lifted weight is exceeded by more than twice the norm and it influences workers' health and wellbeing.

In Table 3 the estimated results of work strain index in the investigated metalworking enterprises are shown.

Table 3. The average values of the work strain index (SI) and standard deviation (SN)

Profession	SI ± SN
Metalworking (average):	*3.4 ± 1.3*
Locksmiths (n = 30)	3.4 ± 1.2
Metal sawyer (n = 50)	3.2 ± 1.2
Mechanics (n = 25)	3.5 ± 1.3
Metal justification operators (n = 28)	3.6 ± 1.4
Blacksmiths (n = 10)	3.2 ± 1.2
Grinders (n = 20)	3.2 ± 1.2
Metal casting operators (n = 20)	3.8 ± 1.4
Warehouse workers (n = 20)	3.4 ± 1.2

One can conclude that employees in metalworking enterprises before the ergonomics interventions are subjected to moderate and high working strain. It can be explained by stress situations at work, which increases tension (for example, work at a high pace, complex machinery utilisation, time limits, etc.). It shows that in the investigated metalworking enterprises workers' health and wellbeing are influenced not only by the physical workload, but also by mental workload.

In order to evaluate the entrepreneurship effectiveness of ergonomics interventions and to improve physical and mental wellbeing at the workplaces the one medium-sized metalworking enterprise was chosen that has invested in ergonomics measures. The organisation fully renovated the working plant considering the ergonomics approach. The capital investments for ergonomics measures are shown in Table 4.

Table 4. The costs of ergonomics solutions

The preventive measures for eliminating the ergonomics risks		Costs, EUR
1.	New metal production line purchase and assembly	20,000
2.	Ventilation system equipment	1,000
3.	Purchase of lifting worktables for heavy weight lifting and moving.	4,000
	TOTAL:	25,000

The calculated amount of finances that remains for the enterprise after the ergonomics measures is $\Delta S = 111{,}000 - 16{,}300 = 94{,}700$ (EUR).

In calculations the total loss before the ergonomics interventions (111,000 EUR) and after the ergonomics interventions (16,300 EUR) were taken into account. The savings derived from the less worker training, fewer incidents at the workplaces and of the profit increase due to extended production ($\Delta P = 23{,}000$ EUR). At the same time the expenses for the ergonomics implementation (service personnel, purchase of additional equipment and service parts, etc.) stated 14,000 EUR in one year ($\Delta L = -14{,}000$ EUR year^{-1}).

Hence the calculated economic effectiveness or profitability E (see formula 3) in money value was: $E = 94{,}700 + 23{,}000 + (-14{,}000) = 103{,}700$ EUR.

In order to evaluate the effectiveness of ergonomics interventions, the yearly economics effectiveness (EG) and total economic effectiveness (EK) were calculated. In these calculations:

A – capital investments = 25,000 EUR; φ – coefficient that characterises the capital investment effectiveness = 0.8; L – costs for new technology utilisation (incl. the personnel wage) = 14,000 EUR.

Expenses for the realisation of the ergonomics interventions (see formula 5): $R = (25{,}000 \times 0.8) + 14{,}000 = 34{,}000$ EUR.

Yearly economics effectiveness (see formula 4) $EG = 69{,}700$ EUR. The absolute economics effectiveness (see formula 6) $EA = (103{,}700 - 14{,}000)/25{,}000 = 3.59$. Therefore, capital investments can be considered as effective and the payback time of investments can be predicted $T = (1/EA) = 0.28$ years. So the investments in ergonomics interventions will be paid off in less than four months. The summary of the ergonomics approach in entrepreneurship is illustrated in Table 5.

Table 5. The summary of the ergonomics approach in entrepreneurship

Total loss (due to workers illness or nonattendance, non-manufactured products, etc.)		
Before the ergonomics intervention		After the ergonomics intervention
111,000 EUR		16,300 EUR
Economics effectiveness after the ergonomics intervention		
Yearly economics effectiveness	Absolute economics effectiveness	Investment payoff time
$E = \Delta S + \Delta P + \Delta L$	$EA = (E - L)/A$	$T = (1/EA)$
103,700 EUR	3.59	0.28 years

Applying the calculation of economic effectiveness of ergonomics solutions, it was found that in other enterprises that had implemented ergonomics in processes, the absolute effectiveness of investments (*EA*) and investment payoff period (*T*) were the following: EA = 0.85–5.5; T = 1.17–0.18 years.

Hence investments in ergonomics solutions in order to improve metalworking manufacturing processes pay off in the short term (the payoff period is less than 1 year), and ensure annual economic effectiveness of organisations from the start of introduction of ergonomic solutions, since costs decrease because of absenteeism of employees, training of new employees, as well as losses reduce due to unproduced products.

Measures of ergonomic intervention consist of purposeful activities in order to make changes and make them stable and long-term. Ergonomics specialists are not always able to persuade organisation managers on necessary financial investments in the introduction of ergonomic solutions, if economic benefit is not proved. A researcher in ergonomics, H. Hendrick, working out measures of ergonomic intervention, pointed out that it is important to determine costs and benefits to be acquired, which should be measurable (Hendrick, 2003). Scientist H. Hendrick discovered that ergonomic intervention, which is aimed at introduction of ergonomic solutions, increases the efficacy of the organisation by 60...90%.

Costs of ergonomic measures or solutions are easily understandable, as they are fixed financial means for improvement of the used equipment, acquisition of more modern equipment, training of employees, etc. But it is more difficult to evaluate benefits, as they are related to decrease in costs due to illnesses of employees, reduced losses due to unproduced goods within a certain period, etc. (Freivalds, 2009). In addition, there are benefits that are difficult to convert in monetary value, for example satisfaction of employees, loyalty to the enterprise, etc.

Costs of ergonomic solutions can be single (capital investments) and long-term. If the equipment and spare parts are produced on the spot, the costs are determined by using accounting data and costs on personnel.

One can conclude that most commonly measures for ergonomics improvement decrease exploitation costs and therefore in calculations they appear as benefits. Sometimes measures for ergonomics improvement are related with a short-term stoppage of the processes. In its turn, it can cause decrease in the amount of production or sales in a certain period of time. Hence, calculating costs, one should keep in mind the costs of this not obtained benefit as well.

CONCLUSIONS

1. Despite the technology improvements, the extensive workload and work strain in metalworking enterprises still exist and have a negative impact on workers' wellbeing and health.
2. Investments in ergonomics intervention for metalworking manufacturing processes maintain human resources and are economically favourable in ensuring enterprise effectiveness, which was proved with the case study.
3. Further studies are necessary to evaluate workers' contribution and willingness to participate in ergonomics interventions.

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