Engineering

A WAY OF GAINING COMPETITIVE ADVANTAGE THROUGH ERGONOMICS IMPROVEMENTS IN WAREHOUSE LOGISTICS

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ABSTRACT:
HEALTH PROBLEMS RELATED TO WORK PROCESSES CAN DRAIN COMPANY RESOURCES BOTH FINACIALLY AS WELL AS IN TERMS OF END PRODUCT QUALITY. DESPITE THE FACT THAT IT HAS BEEN PROVEN THAT SECURING WORKPLACE ERGONOMIC IMPROVEMENTS LEADS TO QUICK AND HIGH RETURN ON INVESTMENTS, COMPANIES ARE STILL STRUGGLING TO SECURE FUNDING FOR ERGONOMICS OPTIMIZATION PROJECTS. THE OBJECTIVE OF THIS PAPER IS TO PRESENT THE USEFULNESS OF A TOOL THROUGH WHICH A COMPANY CAN ANALYZE THE SMALLEST OVERALL THEORETICAL EQUIPMENT INVESTMENT NEEDED IN ORDER TO IMPROVE PHYSICAL LOAD RELATED ERRORS AND INJURIES TO THEIR WORKERS. THE RESEARCH WILL BE SUPPORTED BY AN ANALYSIS OF THE WAREHOUSE CASE WHERE MANUAL HANDLINGS ARE DOMINANT AND REPETITIVE, BUT COULD BE REPLACED BY ADEQATE EQUIPMENT. IN THIS CONTEXT, A FORMULA FOR MAXIMUM EFFICIENCY IS PROPOSED WITH REGARDS TO THE MOST RELEVANT ERGONOMIC ASPECTS AND ALL WAREHOUSE HANDLING EQUIPMENT IS RATED IN ORDER TO SUPPORT THE DECISION MAKING PROCESS FOR THEIR AQUISITION.

KEY WORDS: WAREHOUSE, LOGISTICS, ERGONOMICS, COMPETITIVENESS

INTRODUCTION

Ergonomics is well recognized as the study of the design of a workplace, equipment, machine, tool, product, environment, and system which takes into consideration human being's physical, physiological, biomechanical, and psychological capabilities. The main objective of the ergonomics design approach is to optimize the effectiveness and productivity of work systems while assuring the safety, health, and well-being of the workers[2]. As an applicative subject, it plays a critical role in understanding the physical capabilities of

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[2] Fernandez, Jeffrey E. and Marley, Robert M., *Applied Occupational Ergonomics: A Textbook*, Kendall-Hunt Publishing, 1998

workers and translating those into requirements related to those workers' assigned tasks, tools and equipment as well as the procedures they have to follow within their day to day work environment. Furthermore, different ergonomics "definitions are largely consistent but they lean toward the needs of the organization". Various ergonomics approaches have addressed the occupational needs of different types of employees, workplaces and organizations in a holistic and interdisciplinary manner[3].

Today's ergonomic knowledge has been exploited to different economic sectors or areas. The principles and different problem approaches have been extended from the traditional industrial context (factories or offices related to factories) to address the needs of different employees' working environment in the field of services (as commerce, logistics systems etc.), health care and recreational industries.

The present research context is defined by the ergonomics problems that occur in logistics systems. Logistics is the process of strategically managing the procurement, movement and storage of materials, parts and finishing inventory (and the related flows of information) through the organization and its marketing channel in such a way that current and future profitability are maximized through the cost-effective fulfilment of orders[4]. Within the management of the storage and movement a warehouse is a facility in the supply chain that is used to consolidate products, achieve economies of scale in manufacturing or in purchasing[5], or provide value added processes and shorten response time[6], being one of the main areas where logistics companies can gain competitive advantage by offering their clients tailored services. This competitive advantage is hard to discern, as it is not easy to predict what skills will be essential to retail survival and which are the unsubstantiated *new hot trend in the business*. While serious amounts of research has been done with regard to warehouse maintenance, inventory control, stacking solutions or cross docking solution implementation, there has not been a large amount of attention paid to human factors and the way in which these can be leveraged to not just reduce overall costs and improve the quality of work, but also add value to the final customer.

In this context, the paper will analyze the ways in which ergonomic lessons can be used within a warehouse environment to improve productivity and reduce injury via the help of material handling equipment. In addition, the presented research will show how ergonomics can be proofed as an adequate tool that support the decision making processes by offering a grading of the possible improvement results (that could be adopt or implemented) with the lowest level of financial investment.

HOW TO USE ERGONOMICS

The source of competitive advantage is found firstly in the ability of the organization to differentiate itself positively in the eye of the customer from the competition and secondly by operating at a lower cost and hence a greater profit[7]. To this point the application of ergonomic principles and approach in the workplace context have been conducted to the following results[8]:

- Increasing productivity;
- Improving workers' health and safety conditions;

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- Lower workers' compensation claims;
- Compliance with government regulations such as Occupational Safety and Health (OSH) standards;
- Improving job satisfaction;
- Increasing work quality and defining well-being at work;
- Lower worker turnover;
- Lower lost time at work;
- Improving workers morale;
- Decreasing the absenteeism rate.

With an average warehouse size between 2000 and 4000sqm, warehousing activities take up to between 2% and 5% of the cost of sales of a corporation meaning that improved efficiency and throughput time can lead to significant reduction of costs even in companies in which warehousing is not the core business[9]. The increase in productivity that ergonomic system implementation can lead to will also almost automatically lead to an improvement in throughput time which in turn leads to higher returns. This is achieved by reducing the number of errors and reducing the effort put into the picking and transportation. Reduced throughput also leads to less time in the warehouse, emptier warehouses as a result, therefore the realization that the need of space is not directly proportional to the amount of items to be picked and shipped, but is a function of complexity, error and performance of the warehouse workers. It has been proven that investment in ergonomic improvements in the workplace can result on a return on investment ranging from 3:1 to 15:1[10]. Previous research has demonstrate that in the case of a workstation redesign in an assembly factory, settings made by ergonomists led to an increase of over 15% of the productivity and because of the higher quantity of the work output, the productivity per worker has been increased to $2250-3000[11].

There are three areas in which ergonomic principles can be used to improve the quality of the work environment and help reduce negative incidents such as injuries:

1. Removing physical loads that cause error by fatigue;
2. Structured processes and training implemented to reduce the number of errors caused by lack of knowledge;
3. Leveraging emerging intelligent technologies to aid workers in recognizing mistakes.

In this context, the article will focus on the first area of improvement, while the second and third will be covered in subsequent research articles.

ASPECTS OF REMOVING PHYSICAL LOADS

Warehousing operations involve a series of activities that a worker or collection of workers must do to ensure the inbound arrival of goods in the warehouse, the storage of said goods and then subsequent picking, packing and outbound shipping operations. These operations include a vast majority of handling activities of which, depending on the level of warehouse automation, a part can be manual. Manual handling is defined as any transporting

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or supporting of a load by one or more workers. It includes the following activities: lifting, holding, putting down, pushing, pulling, carrying or moving of a load[12].

a) Lifting and putting down - Work related low back pain and injuries are some of the most common musculoskeletal disorders that manual handling causes. About a quarter of European workers consider that work related back pain injuries affect their health, and in areas such as construction, agriculture and transportation as many as 47% of people are suffering from some form of work related back problems[13]. Within a warehouse environment one of the most incorrectly done activities is the lifting and putting down of weights. A majority of people chose to pick up a weight by bending rather than squatting. This causes undue strain on the muscle ligaments and vertebrae that can lead to herniated disks, strains on the thoracolumbar fascia or latissimus dorsi muscles or sciatica.

b) Holding and carrying - Holding and carrying involve static endurance, which can be determined by the length of time a limb can maintain a certain position. The amount of muscular strength is the maximum amount of force that a muscle can exert under maximum contraction. It has been shown that isometric (or static) activities cause greater levels of exhaustion than isotonic ones, meaning that holding a weight for a period of time is more straining that moving it[14]. Holding a weight also changes the point of gravity, thus putting a strain on posture muscles such as the trapezius and the erector spinae muscles in order to maintain a proper upright position.

c) Pushing and pulling - The amount of force that can be exerted by your limbs depends on body posture and the direction of force. For example, when standing, you can exert more force when pulling backwards than when pushing forwards. Pushing is preferable to pulling for several reasons such as the awkward positioning of the arm stretched behind the body during pulling while facing in the direction of the walk that places the shoulder joint in a posture that can increase pain and possible injuries. Similarly, pulling while walking backwards can lead to accidents very easily as there is no line of view to see the travel path[15]. Further, research demonstrates that people can usually exert higher push forces than pull forces. In some situations, pulling may be the only viable means of movement, but such situations should be avoided wherever possible, and minimized when pulling is necessary. It has been shown[16] that pushing and pulling lead to an increase in shoulder aches on a dose response relation and that sometimes lower back issues can also occur.

EFFICIENCY ANALYSIS (RESEARCH RESULTS AND ANALYSIS)

The experimental research has been developed in an existing warehouse of an industrial company. The purpose of the study was to identify and presents scientific arguments for the warehouse equipment' acquisition by taking into consideration ergonomics aspects of their use.

[12] Council Directive 90/269/EEC, *Minimum health and safety requirements for the manual handling of loads where there is a risk particularly of back injury to workers*, Office for Official Publications of the European Communities, 1990

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A) Research method

An analysis of the existing warehouse material handling equipment has been made based on three areas of importance, namely the total investment amount, ergonomic efficiency and ease of use[17]. These aspects have been graded on a scale of 1 to 5 (1 being least desirable and 5 being most desirable) based on which would maximize the efficiency equation (1):

$$E = \frac{I*p1+Ee*p2+Te*p3}{p1+p2+p3} \quad (1)$$

where E is the overall efficiency;

I = Investment volume;

Ee = Ergonomic efficiency;

Te = Training effort;

p_1, p_2, p_3 = weights given to each considered factor.

The grading explanations presented in Table 1, show that the best possible grade that an equipment can get is 15 if all the weights in the formula are equal to 1 ($p_1 = p_2 = p_3 = 1$), which is the case that will be further examined. Furthermore, the investment refers exclusively to the amount needed for the purchasing of the equipment and not subsequent to the training costs. The ergonomic efficiency refers to the capacity of the equipment to reduce strain of the employees' human body that would otherwise be caused by the manual manipulation, which the equipment is replacing. The ease of use refers to the average duration (amount of time) that workers will need to spend for trainings in order to be able to correct use the equipment.

Table 1. Grading explanation

Grade	Investment	Ergonomic efficiency	Training effort
1	€50000-€100000	Minimal manipulation strain reduction	> 1 week training
2	€10000-€50000		1 week training
3	€5000-€9999	Average manipulation strain reduction	1-3 days training
4	€1000-€4999		1/2 day training
5	<€500	Complete manipulation strain reduction	< 1/2 day training

B) Research results

The grading of all handling equipment analyzed is presented in presented Table 2.

Table 2. Grading of material handling equipment

Equipment type	Equipment name	Investment	Ergonomic efficiency	Training effort	Overall grade
Cranes	Jib cranes	4	2	5	11
	Gantry cranes	4	2	4	10
	Bridge cranes	2	2	4	8
	Stacker cranes	1	5	2	8
Conveyors	Chute conveyor	4	3	4	11
	Wheel conveyor	4	3	4	11
	Gravity roller conveyor	4	3	4	11

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	Live (powered) roller conveyor	4	3	4	11
	Flat belt conveyor	4	3	4	11
	Screw conveyor	4	3	4	11
	Sortation conveyor	5	5	1	11
	Vertical lift conveyor	4	3	4	11
	Reciprocating vertical conveyor	4	3	4	11
	Troughed belt conveyor	3	3	4	10
	Bucket conveyor	3	3	4	10
	Vibrating conveyor	4	2	4	10
	Carrier-system pneumatic conveyor	4	1	5	10
	Magnetic belt conveyor	3	3	4	10
	Chain conveyor	3	3	4	10
	Tow conveyor	4	3	3	10
	Slat conveyor	3	3	3	9
	Dilute-phase pneumatic conveyor	3	3	3	9
	Trolley conveyor	4	2	3	9
	Power-and-free conveyor	4	2	3	9
	Monorail	4	2	3	9
	Cart-on-track conveyor	4	2	3	9
Positioning equipment	Ball transfer table	4	2	5	11
	Hoist	4	2	5	11
	Parts feeder	4	3	3	10
	Air film device	3	4	3	10
	Balancer	5	2	3	10
	Dock leveler	2	2	5	9
	Rotary index table	2	3	3	8
	Lift/tilt/turn table	1	2	5	8
	Manipulator	4	2	2	8
	Industrial robot	2	5	1	8
Industrial trucks	Two-wheeled hand truck	5	1	5	11
	Dolly	5	1	5	11
	Floor hand truck	5	1	5	11
	Manual pallet jack	5	1	5	11
	Powered pallet jack	4	2	5	11
	Manual walkie stacker	4	1	5	10
	Powered walkie stacker	4	2	4	10
	Narrow-aisle straddle truck	3	4	3	10
	Sit-down counterbalanced lift truck	3	4	3	10
	Walkie platform truck	3	3	3	9
	Personnel and burden carrier	2	4	3	9
	Rider platform truck	3	3	3	9
	Stand-up counterbalanced lift truck	3	3	3	9

	Narrow-aisle reach truck	3	3	3	9
	Operator-down turret truck	3	3	3	9
	Operator-up turret truck	3	3	3	9
	Order picker	3	3	3	9
	Side loader	3	3	3	9
	Tractor-trailer	2	4	3	9
	Pallet truck	3	2	3	8
	Tow AGV	2	4	2	8
	Unit load AGV	2	4	2	8
	Assembly AGV	2	4	2	8
	Light load AGV	2	4	2	8
	Fork AGV	2	4	2	8

C) Discussion

The presented data offers an example of how to design the grading scale for a medium size warehouse with average weight loads. However, each individual company operates under different industrial constraints (in a particular environmental context), therefore it is required that the grading scores have to be modified to suit each particular operational situation needs in order to bring the level of detail pertinent for the decision making process (when establishing the corrective and/or improvement measures). In the case study above it has been clearly seen that the company would most benefit from the investment in the case of 17 overall pieces of equipment, covering each of the 4 types of equipment analyzed, however the solution is not, as mentioned, industry transversal, but rather a firm specific result. An extra level of flexibility in this equation is given by the individual weights that each of the three factors in the formula have, that allow users to tweak the relative importance of one factor over the other, based on the company's culture and strategic objectives.

CONCLUSION

The research conclusions and debates have well argued that minimal investment in the ergonomic well-being of employees can lead to increase in productivity and reduction of costs. The fact that this information is not clearly obvious as well as applied within the industry leads to the conclusion that there is a gap between what sciences/scientists know and what managers are willing to apply. A cross functional working environment as well as more popular science oriented publications in business magazines would be recommended to disseminate and share knowledge and make sure it benefits more people, employees through its practical implementation.

The analysis method proposed in this paper could offer a first step in bridging that gap, by offering managers an easy to understand formula and measuring tool and also, easily changing to their particular needs. The analysis method used within this research will also be applied during the subsequent research papers that will discuss the other two areas in which ergonomic principles and approach can be used to improve the quality of the work environment and help reduce negative incidents (finely define real well-being of workplaces).

Furthermore, more researches are needed in order to analyzing the direct impact of warehouse processes mechanization and automation on the day to day behavior of the workers, especially in relation with the training support that is needed. A special attention should be payed to aspects such as employees' rate of acceptance, their behavioral modifications and persistence in use as the end goal is not to invest in the equipment in itself, but make sure that the equipment is being properly used to reduce repetitive physical pain.

Finally, more extensive researches have to be focus on the possible combination of employee' handling equipment and the synergy of which this will lead to the highest possible work efficiency.

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