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The charge of ergonomics – A model according to the influence of ergonomic workplace design for economical and efficient indicators of the automotive industry

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Abstract. The importance of ergonomic workplace design has been rising incredibly. The knowledge of the interaction with a view to many indicators (e.g. operators' health, quality, productivity etc.) in the automotive assembly shop pushed into another thinking of ergonomics and an increasing awareness of economic possibilities relating to benefits and cost savings aligned with ergonomics. The paper discusses exemplary the various indicators and factors which could be influenced by ergonomic workplace design. These factors are linked each other and support the statement of ergonomic efficiency. Thus, the aim of this paper is to present a model which describes that investments in ergonomic work placement acts with preventive measurements, minimization of losses (refinishing operations, compensation money etc.) and extensive economies on the whole company.

Keywords: ergonomics, economics, efficiency, productivity, quality

1. Introduction

The automotive industry faces worldwide hardly in ergonomics and occupational health [7]. The increasing importance of considering ergonomics is well-known and discloses a need to research for implementing ergonomics in the practice. Companies, especially in the automotive sector, act towards an ergomization pushed through legal factors like the legislation concerning health and safety at work, EU-guidelines, handicaps of professional associations and the social welfare legislation. Equally normative factors, e.g. general agreement on pay grades (AUDI AG) and in particular established strategies (Volkswagen with its own Volkswagen-Way), leads towards an integration of ergonomics in the organizational culture.

Companies are reminded of their duty in creation of workplaces without any health spoiling and avoidance of non-ergonomic exposures (e.g. injuries and accidents) with regard to guidelines of the maintenance of industrial health and safety. This need for action occurs obviously in industries with aging workforces. In the past the failure of personnel policy was created by reason of missing personnel recruitment. Besides the recruiting of junior members with the respect to workforces it is highly recommended to thread new paths in direction of ergonomic workplace design (EWD) to enable a healthy working life for all generations of operators.

For an economical analysis it is necessary to do research for company and business related data. Therefore, it is unavoidable to differentiate between (non-) ergonomic aspects and external effects which are not

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associated with the workplace. This based on the fact that not all conditions cause of non-EWD, e.g. illnesses, sport accidents, motivation etc. The aim of this paper is to identify indicators which are influenced by (non-) EWD and to analyze the interactions with help of a model focused on the return-on-investment (ROI). The ROI should disclose benefits and costs of an EWD to give preventive advices for the follow-up cars in the future. An ergonomic problem should be easily defined and dissolved. For this reason an overview of the relevant benefits and costs belonging to the ergonomic interventions and changes will be evident [4]. To look from the cost-side the product and work processed should be evaluated as soon as possible to avoid unnecessary costs caused of redesign. This leads towards proactive ergonomics of preventive handling and planning in the early phases of the production planning which is going to become more important and successful for including in the product creation process [5], [7] and [12].

2. Indicators of determining costs and benefits

The following part explains and characterizes the different influences and connections of diverse company specific indicators and EWD. Another point is the fact of increasing benefits and cost-savings [1] for companies which are focused on operators' health, quality and productivity [8].

2.1. Overview of indicators and discussion levels

Figure 1 gives an overview of indicators which are linked to EWD and the aligned efficiency.

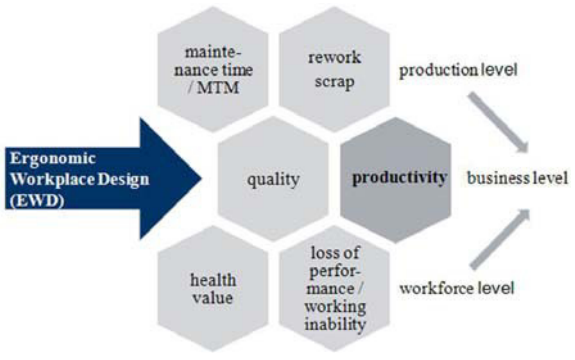


Fig. 1 - Indicators for efficient ergonomics

There are different levels in which ergonomics could effect:

- Production level: includes process and production time but also losses of time for rework or scrap and trash through mistakes based on non-ergonomic work.
- Workforce level: contains the health value (the percentage of operators who are healthy and do not miss the working hours) and the loss of performance or working inability (employee down time [8]) because of a long-term absence owing to an accident or may be musculosketal disorders (MSD) for example.
- Business level: summary of all factors. Time influences quality and productivity as well rework and scrap on the one hand. On the other hand health value, loss of performance and working inability affect quality and productivity in different ways (detailed in the following paragraphs).

Obviously there exist a huge amount of connections and influences between the separate indicators. Therefore, EWD could influence different indicators in different levels and generates within benefits, cost-saving and finally efficiency. According to this, it is useful and strongly recommended to design workplaces corresponding ergonomic guidelines. In the past studies already pointed out that well done ergonomics affect positively health and entrepreneurial economics [5]-[7]. More details will be explained in the following sub-paragraphs.

2.1.1. Production level

Relating to the production level has to be distinguished two factors: maintenance time / Methods Time Measurement (MTM) and time losses as a result of rework and scrap production.

The maintenance or so called cycle time "[…] is the period of time available to carry out a task on a assembly line […]" [9]. In the majority of human automotive companies the maintenance time is defined by MTM modules which mete chronologically the time of every production step. The model was established for a "[…] consistent use of the MTM idea and supplementary industrial engineering methods in the whole of the value-added chain […] [10]. There are different possibilities to reduce time with ergonomic background. Figure 2 gives a view of these kinds of ergonomic time reduction.

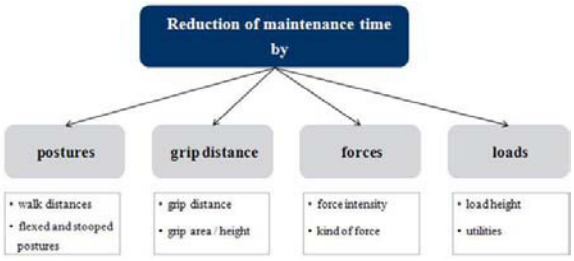


Fig. 2 - Reduction of maintenance time by decreasing postures, grip distance, forces and loads

In this figure are four possibilities shown that have a significant influence on maintenance time by EWD. For example, a quite difference referred to a production step with the overhead work and a simple upright working position. As well, means a reduction of the grip distance of 80 to 20 cm approximately 0.01 seconds. Calculated to a whole working day, week, working shifts and year this also provokes a cost-saving caused of some changes in the EWD. Similar examples could be examined with forces and loads. This wasting of time are costs. Assuming $1.5 for one minute of lost time increases costs unimaginably. Thus, this lost time could be transformed easily in economic benefit with some ergonomic arrangements [8].

Like mentioned before it might be possible that non-EWD occur quality problems and so far reworking measure and scrap. Reducing the incidence of mistakes by an operator corresponds to a monetary value [1]. Eklund's study has shown that quality problems with ergonomic deficiencies were three times higher than regularly failures [5]. Nevertheless, it does not mean that bad quality is produced just because of non-ergonomic workplaces. With regard to EWD and quality it has to be divided between ergonomic and other sources as noted before. On the one side are workplaces with high distances and circumstances like invisibilities and on the other side put points like lack of training, motivation and tact working pressure on the operators. For a significant cost and benefit analysis this issue has to be considered. In the following table are shown some examples of non-EWD and the developing problems.

Table 1
Relationships between non-EWD and quality

Action	Posture	Result
connecting the climate cable	overhead work	leckage
pushing / punching in the tailgate wiring	overhead work	loose clips
wiring enine compartment	highly flexed posture	sometimes passed falsely and scrubbing of the cables
assembly center console	mainly flexed	neglecting screws, incorrect clearance
fitting roof railing / antenna	shoulder work	crooked placing

Facing the pushing and punching of the wiring in the tailgate the overhead work might (Figure 3, left picture) produces mistakes like loosed and missed clips. Or the highly flexed posture of assembling the center console could generate neglecting of screws and incorrect clearance (Figure 3, right picture).

Figure 3 - Examples for non-EWD and quality problems – Tailgate wiring and center console

In a study containing relationships between ergonomics and quality in the assembly work some operators in the final interview mentioned discomfort during operating tasks with non-ergonomic background or difficult design. This discomfort led to advance problems of various parts of their body and imperfect work actions. Therefore, the operators risked for more comfort poor quality. That means that higher comfort of the workplaces leads to a better quality and productivity in the assembly line [13]. Besides this point operators got demoralized and disencouraged if they had to work repeatedly to correct the failures of others. It was discovered that quality shortfalls increased the further the car proceeded in the production process [5]. So, that rework got more difficult and expensive. This could be easily prevented by EWD and save a lot of money with reducing reworking time and repeated work caused

reworking time and repeated work caused of the produced scrap.

Another fact of generating benefit and cost-saving will be pointed out in the next sub-paragraph.

2.1.2. Workforce level

In the assembly work the companies have the duties to arrange healthy and non-endangering work for their operators. EWD makes healthy and safe working for the operators possible. This level characterizes to 2 issues: One is the health value and the other one means the development of long-time sickness and of performance changed operators which cannot operate in all workplaces because of diverse corporal limitations (e. g. shoulder or back problems).

First of all, the health value is the difference between the days of the contractual agreed value the operator should work and the illness days in which the operator is not available to work measured in percent. Again in this case it is also necessary that we separate (non-) ergonomic and influences from other effects like accidents (excepting work), diseases (colds) etc. Every divergence between the real and the recommended and aimed health value costs the company a lot of money. This monetary value is a loss which could be used for improving the work conditions including the EWD in the assembly lines. Unfortunately, this is not integrated in the entrepreneurial thinking yet because every cost-saving means more benefit and misleads to an increasing work pressure to the operators, e.g. raising the distribution numbers [14]. Like figured in the following graphic the development of the health value leads to unhealthy and unsafe workforces. One reason is the problem with MSD, but also the psychological aspect grows continuously.

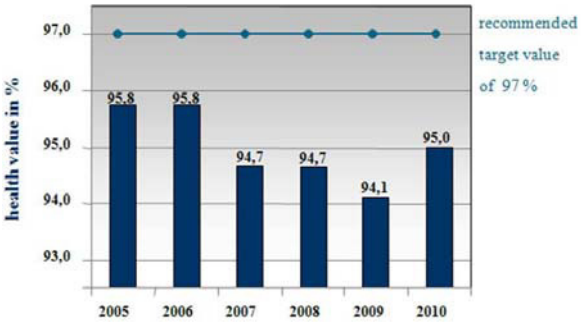


Fig. 4 - Development of the heath value from 2005 until 2010 exemplary for the automotive industry

The following chart (Figure 5) shows the development of the sick days in different age groups. Apparently, operators of the younger age are fewer than in the older age groups, but the average of the sick cases is much higher than the older groups. This fact suggests that the younger operators have a higher number of sick cases but less sick days (1-3 days) caused of infections etc. However, the bigger amount of operators in the older age groups are less but long-time sick (>3days, weeks, months), for instance in consequence of MSD, than the younger age groups [14].

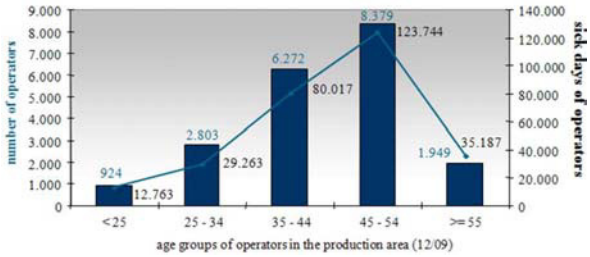


Fig. 5 - Correlation between numbers of operators in different age groups and the amount of sick days

The obviously need of action displays that companies should improve the workplaces considering to ergonomic issues. This need does not just focus on the older generation for operating the whole working life. Also, the younger operator should be protected for endangering provoked by non-EWD.

The next sub-paragraph describes the correlations between all indicators more in detail.

2.1.3. Company level

Quality and productivity are indicators which collude with the explained factors. For example, the maintenance time could be reduced with the help of ergonomic design of the workplaces, but there is another point that should be considered. Of course, the companies save time with EWD and get a better result of the ergonomic evaluation (Figure 6), but it is also demanded that the workplaces have to be highly utilized (early 100%). So, it is necessary to switch other tasks into the improved workplace to generate a better charging and productivity which could be affect negatively the ergonomics. Therefore, not every task could be switched. The question is if it is useful to increase productivity with downgrading the ergonomics or the other way around.

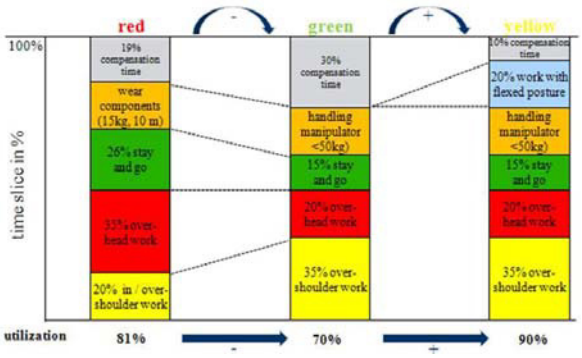
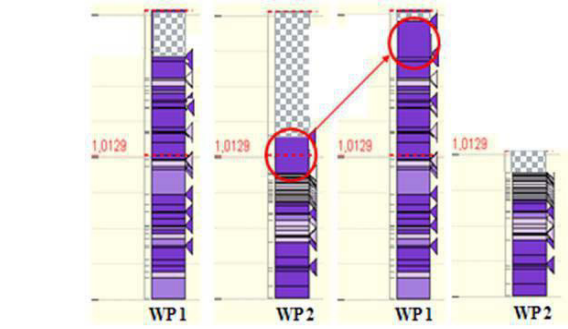


Fig. 6 - Ergonomics and time optimization and productivity

With respect to cycle times and the length of the cycle it is possible to improve and change workplaces without EWD (Figure 7). It just needs to switch one task from one workplace in another workplace and one operator might exemplary change to another workplace (may be in a workplace for performance changed operators). Hence, the ergonomics does just change minimal, but the utilization is more advanced than before.



utilization	78%	58%	91%	90%
N° operators	2	2	2	1

Fig. 7 - Task changing and utilization without EWD

In this case it has to be separated in the same way between (non-) ergonomic and other influences without ergonomic contents.

From another point of view quality reflects on the one hand on the operations during the cycle time if there is enough time to assembly the tasks without endangering themselves, create failures and scrap and on the other hand the permanent changes of the workplace to replace an operator who is absence because of an illness or treatment. Without any trainings and detailed introductions the spare man (who switched from another workplace) loses time and is therefore responsible for more rework and scrap.

Finally, quality is the most important indicator for productivity. Without any product quality it is not possible to sell cars and reach a leading marketing position. Nonetheless, every indicator has its own part to generate productivity.

The following chapter shows the modeling of these different factors and the effect on efficiency, benefit-generating and cost-saving of companies in the automotive industry.

3. Modeling the charge of ergonomics

3.1. Parameters

Modeling the costs and benefits of EWD affords to consider different values which have an objective character and are not influenced by subjective aspects or assessed by any weighting factors.

The following paragraphs show the different impacts in making ergonomics chargeable and the influence on benefit-generating and cost-saving.

3.1.1. Productivity Value (PV)

The productivity value includes the time change with help of ergonomic arrangements. Examples here fore are decreasing distances and highs and the anticipated loss through reworks and scrap production [3]. And also the savings caused of better quality and associated reduce of rework, manpower and time.

3.1.2. Health Value (HV)

From the parameter aspect considered the HV means the costs of the absence of the operators. Depending on the business one day of sick leave costs more than 3.5 times the costs of one day's payment [3]. Besides the absence costs flows the loss of performance changed operators and their limitations into the calculation. This value will be measured in $. Not considered will be costs of losing employees and costs of hiring and training new employees [3].

3.1.3. Ergonomic Value (EV)

This value consists of the cost of EWD like acquisition costs of manufacturing resources, tooling equipment and materials. Relating to the acquisition

it will be calculated with the amortization amount over years. Other fixed costs are electricity, energy and administrative outlays like decision process and training costs which should be considered.

3.2. Cost-Benefit Model of EWD

For a cost-benefit analysis firstly should be calculated the benefits and costs of an ergonomic workplace change. For measuring the benefit has to be considered:

Equation 1:

t = value after ergonomic arrangements
t-1 = value before ergonomic arrangements

$$Benefit = \int_{t-1}^{t} (\Delta PV + \Delta HV)\, dt \tag{1}$$

For summarizing the costs have to be discussed direct costs relating the amortization value per year of an ergonomic acquisition and indirect costs like energy, installation, training etc.

Equation 2:

$$Costs\ (EV) = DC + IC \tag{2}$$

For a significant statement about a worthwhile investment in an ergonomic arrangement or EWD generally the ROI might be a useful instrument for convincing the management to invest in the liability for the operators and additionally the clients from a prospective point of view. Depending on the industry or the sector a recommendation could be an agreement for implementation or installation of the ergonomic utilities with a result of ROI more than 20%.

Equation 3:

$$ROI = \frac{Benefit}{Costs} * 100\% = \frac{\int_{t-1}^{t} (\Delta PV + \Delta HV)\, dt}{DC + IC} * 100\% \tag{3}$$

By comparing benefits and costs should be defined a reasonable value for investing in EWD. With this model it is possible to get a detailed benefit and cost overview concerning to ergonomic arrangements and changes. Also might be identified a tendency which indicator influence mostly the efficiency of the production area and the company in its entirety.

Finally all results and suggestions will be summarized afterwards.

4. Discussion

This paper explained that ergonomic benefits might easily overwhelm the costs with help of EWD because of the account in quality and productivity. With reducing financial losses through injuries, accidents and absenteeism, arising productivity, ergonomics might act like a kind of insurance to shut down the liability of the companies in demanding for compensation and purchasing conditions [3]. Clearly it is much easier to identify the costs of EWD. The challenge consists to calculate the benefits and oppose them to the belonging costs [4]. The cost and benefit analysis of ergonomic changed workplaces is extensive and needs a high information degree. For agreeing to ergonomic interventions the management wants a detailed overview of costs and benefits. The best case could be a calculated benefit after the integration of EWD. Worst case might be a decline of the project caused of missed data or a result without any benefit-generating and cost-saving.

Economic benefits may arise from the health value, but it is difficult to divide the work related and non-work related MSD [4]. A huge economic benefit would be generated if an operator was unable to work or performance limited could be reintegrated after the renewing of the workplace according ergonomic guidelines. An exemplary project from Looze et al. in consideration of EWD in manufacturing saved about $105.000 year per integration [4]. Cost-saving might be created if ergonomic arrangements will be implemented quickly [12].

These results lead to two main issues: Ergonomics can be benefit-generating and cost-saving if the company integrates the ergonomics from a systematic point of view. With ergonomics as a business concern it will be an integral part of the business. Hence, ergonomics should be seen as a major contributor to a systematic improvement of the company with cost avoidance and ergonomic initiatives [12]. Now companies understand that a benefit potential occurs between prevention and financial saving according to quality, productivity and efficiency. For example, due to inclusion of ergonomists in the early phases of the product creation process [1] and [11].

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