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ERGONOMIC SYSTEM, A FACTOR IN THE IMPROVED TRAFFIC PRODUCTIVITY

SUMMARY

Considering the fact that noise is mostly caused by the traffic flow with all its characteristics, and in the production system by machines, devices, and tools, it is necessary to implement measures for its prevention.

Noise has to be eliminated on humanitarian grounds, and then also with the aim of greater productivity and efficiency.

However, regardless of the fact that, according to the analyses, by reducing noise the efficiency is increased and the costs (both fixed and variable) reduced, these should not be the only reasons for its elimination; it should also be in the function of the organisation of the work place. Led by a human, rather than economic tendency, full satisfaction, good health, and most of all increase in the productivity will be achieved through safety and protection.

1. INTRODUCTION

For the operation process (in traffic and generally) to function normally (organisation, improvement) by using more sophisticated technical devices, constant care needs to be taken about its organisation, as well as about the evaluation of all the influencing factors (movements, activities, operations). This will ease and simplify the working process, and on the other hand, increase the productivity and efficiency. The technologists and task setters will study individually the activities and workers' movements, their ergonomic position, and thus productivity as well.

The level of productivity will depend then on the level of staff proficiency, and at the same time on the technical equipment used in the production process.

In today's modern times and the way of profit-making, a lower level of technology is not able to provide the same productivity as high-level technological traffic systems.

This leads to the fact that those industrial branches, including traffic, which produce (transport) in a mechanised way, by using complex instruments, machines and devices, applying automation, produce a huge amount of high-quality products. Such branches are: machine manufacturing, electrical industry, metal processing, and regarding the features of their production, they would not even be able to produce in the underdeveloped way. Other branches of industry, such as textile, food, building material industry, can produce in a less modern (craftsmen) way, although here again there is also the need for introducing mechanised technological production process (in order to increase productivity).

The same is happening with the level of technology, regarding the different levels of the country's industrial development. The industrially developed countries will have high productivity and consequently high living standard. They will have a greater variety of machines, cars, precision devices, television sets, and, of course, a better productivity.

For example, in the middle of the 19th century, a big ship could transport 2,000 tons of goods, and today the biggest super tankers can transport more than 1 million tons of oil.

The dominance of high technology would cause the increase of the volume of input and production leading to higher productivity which is here a term measuring the ratio between the overall product and pondered input volume. If e.g. the inputs of a typical company increase by 4 percent, and the production increases by 10 percent, then the productivity (production per input unit) would increase by 6 percent. This example indicates that the increase in per capita production and living standard can be partially caused by using the production economy.

The productivity is significantly influenced by its own organisation as well. The work needs to be scientifically organised, which means that it needs to be based according to the ergonomic efficiency and rationality.

To rationalise means to carry out the ergonomic work organisation, which will enable production of huge amounts of products (traffic services) at a possibly lower expenditure of working objects (materials) and working tools, with less trouble for the producer (service supplier), but in the possibly shortest time, still keeping the product - service in good quality (inexpensive, i.e. at a price acceptable for the users).

Productivity will greatly depend on the safety aspects of the modern organisation, which is taken care of by ergonomics, industrial hygiene and work organisation.

Ergonomics, as an interdisciplinary science, should provide a safer, faster, more comfortable and more efficient working process. This is achieved by adapting and forming of the working process (workplace) to suit the man, of the working means, working object, from a micro-aspect. Production engineering studies these factors from a wider macro-aspect.

In the production process, both productively and ergonomically the noise has a very damaging effect, among other ergonomically adverse factors. Human body cannot adapt to living with noise, and every so-called adaptation to noise causes various mental and physical disturbances.

Man is to the greatest extent subjected to noise in traffic, although other workplaces do not provide complete protection from it, either. Studying the conditions in industrial production in which a man - worker spends more than a half of his life, we might find the problem to be of quite sincere gravity, although it receives little attention regarding productivity and regarding health and life of people in general.

According to the estimates e.g. for the German counties (former Federal Republic), two million workers are, during production, exposed to noise which is health damaging, especially for the hearing, greater than 90 dB(A). About 3 - 4 million workers are exposed to the noise greater than 85 dB(A). In the mid 80s, in the production system of Germany as many as 175,000 workers suffered from loss of hearing, and were recognised as disabled due to noise (industrial disease - loss of hearing due to noise - BK 2301).

Therefore, this paper will pay special attention to the factors which reduce productivity due to ergonomic factors, and the calculation of noise at the workplace in traffic and in general.

2. ERGONOMIC CHARACTERISTICS OF PRODUCTIVITY AND THE WAYS OF MEASURING IT

Productivity of a working process is an indicator of the efficiency of the workers employed in a company, and it shows the amount of the overall production which refers to an employee.

The most striking way of measuring productivity is the produced quantity of goods in proportion to the amount of invested work.

The level of productivity is measured by dividing the total value of made products with the number of productive workers, or:

$$P = \frac{UVPP_r}{BPR}$$

where:
- $UVPP_r$ is the total value of the products,
- BPR is the number of productive workers.

This model gives the value of production per one productive worker.

In a company which produces only one kind of products, the level of productivity may be expressed also by natural indicators, by the following formula:

$$P = \frac{PKuNJ}{BPR}$$

where:
- PK is the produced quantity,
- NJ is the natural unit,
- BPR is the number of productive workers.

This expression cannot be applied in companies which produce a variety of products, since it is impossible to sum up heterogeneous products.

Instead of the number of productive workers, the number of their working hours can be taken as the indicator of invested labour, and then the level of productivity may be expressed by the formula:

$$P = \frac{UVPrPro}{SPR}$$

where:
- UVPrPro is the total value of products,
- SPR are the working hours of productive workers,

which indicates the value of traffic means or services produced by a productive worker within a working hour.

In this way, the productivity of individual workers, plants, and the whole traffic system (company) can be measured.

2.1. Measuring productivity

The efficiency will be greater in case of: higher level of mechanisation, higher quality of the material, greater technological change, higher operation skilfulness, better working conditions (reduced noise, vibrations, uniform temperatures, as well as other ergonomic benefits, better incentive payments etc.)

The level of mechanisation has, ergonomically, great influence on more intensive and safer efficiency. In order to be able to realise it, financial means (investments) need to be provided for purchase of mechanisation and automation, as well as the necessary equipment, that is to be adapted with the aim towards an optimal work organisation (Figure 1).

Better and higher quality materials provide better quality of products, and thus also greater organisation and efficiency.

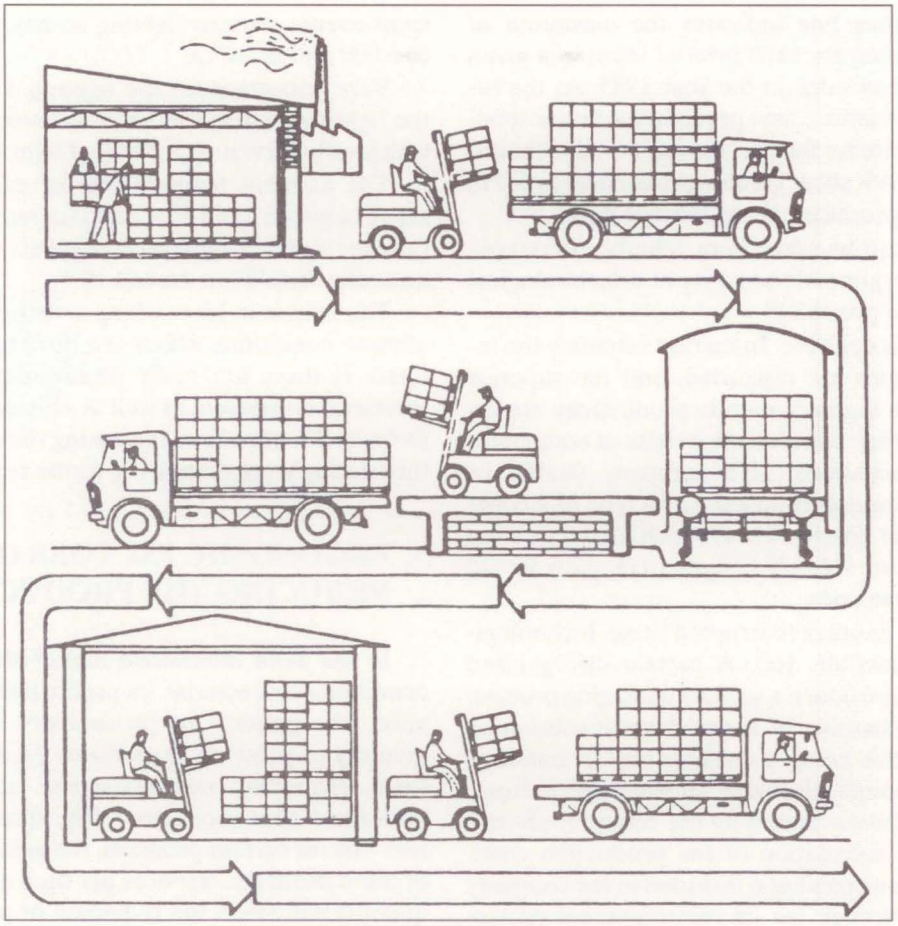

Figure 1 - A pallet chain

Technological changes refer to changes in the working technology - invention of new products or changes in the production processes, goods, supply of services in the traffic system and in general etc.

Technological changes occur when the new engineering and technological knowledge provides greater production (service supply) which can be ergonomically achieved with the same inputs or when the same production can be realised (service supplied) with fewer inputs, using ergonomic facilities. In the sense of the production technology in traffic e.g. it appears when the function of the service supply changes, which means when the process is ergonomically safe, efficient, and fast, with fewer injured passengers - workers in traffic and an increase in the transported ton kilometres (quantities of goods).

Recent technological changes include the development in electronics and prove this, providing, on the other hand, the production of wide-body jet aircraft, increasing the number of passenger-miles per input unit almost by 40%, optical fibres which reduce the costs and increase the reliability of telecommunications, as well as improvements in computer technology, speeding up annually by 15%, taking into account a period of three decades.

Figure 2 presents the technological advances by increasing the production function.

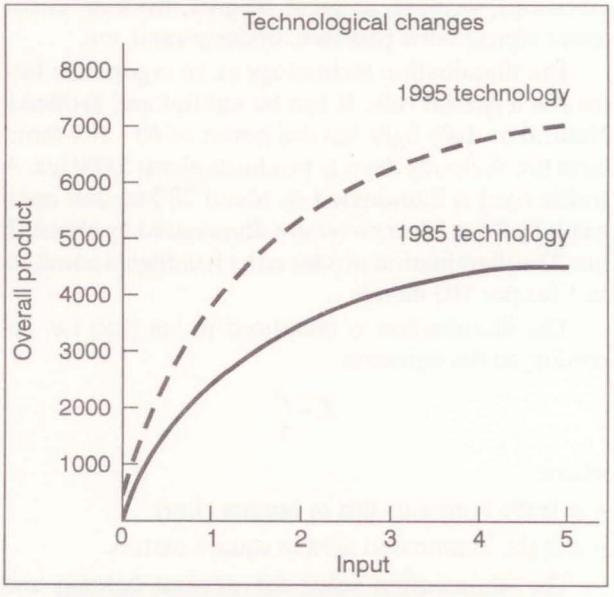

Figure 2 - Technological advances cause the production function to move up.

The continuous line indicates the maximum of possible production for each level of input at a given technological knowledge in the year 1985. As the result of computerisation, new procedures, better quality control, and similar factors, the improved technical knowledge in 1995 allow greater production by 50%, which could be produced at any level of input.

A question can be asked here, whether the opposite case, with ergonomic benefits of a technological regress would be possible?

The answer is negative. In market economy the inferior technologies are discarded, and the superior ones, those with high ergonomic productivity are introduced since they increase the profits of companies introducing innovations. If a company (traffic or other) invented and introduced a new type of a copying machine that costs twice as much as the existing (old) machine, no sensibly oriented company would produce such machines.

However, in another (corrupted) case, technological regress is possible, too. A certain disorganised company could introduce a socially damaging process, such as e.g. discharging of harmful waste substances into the river, this being a cheaper way of handling them. The economic advantage appears only because the costs of pollution caused by the company are not included in the calculation of the production costs. Had the pollution costs been included in the company decisions, say through tax or environmental protection regulations, no competitive company would introduce an inferior technology.

Better working conditions, and greater productivity influence: the working climate, and other working conditions, that depend mainly on the illumination system, air-conditioning, ambient temperature, noise, vibrations, working at great heights, working under lower atmospheric pressure, underground, etc.

The illumination technology as an ergonomic factor has a special role. It can be natural and artificial. Natural or daily light has the power of 60 - 100 thousand lux. A cloudy day e.g. produces about 5,000 lux. A traffic road is illuminated by about 20 lux, and open roads by 8 lux. Motorways are illuminated by about 15 lux. The illumination produced by headlights amounts to 1 lux per 100 metres.

The illumination is measured in lux (Lx) i.e. according to the equation

$$E = \frac{\varphi}{S}$$

where:

- φ is the luminous flux in lumina (Lm)
- S is the illuminated area in square metres.

The illumination value for general lighting and higher productivity (working area - place) amounts to 30 - 600 Lx, and for workplaces up to 1,000 Lx, for sport events, various fighting arenas, displays etc. up to 3,000 and more Lx.

Very important for the lighting is the position of the lighting source, the form and colour of the walls, which reflect even up to 70% of light beams.

The ambient temperature for easy work has to range between 1 and 20 °C, and for more difficult work (greater strain of muscles energy) 10 - 18 °C. Relative humidity should not exceed 18%.

The man is in his working activities threatened by adverse conditions which are not ergonomically defined. If these are really disadvantageous, the performance is reduced, as well as efficiency and productivity, at the same time increasing the energy expenditure during work (supplying traffic services, etc.)

3. ERGONOMIC FACTORS OF NOISE IN REDUCING THE PRODUCTIVITY

It has been mentioned earlier that the working conditions characterise its productivity and performance. The greater the productivity, the greater the quantity of products reproduced (machines, devices, tools, materials, raw materials, transport means, household appliances, etc.). The shorter the production time of certain products, the greater the quantity of these products - services per time unit. The greater quantity will affect the reduction of prices, and these will in turn enable consumers to buy more versatile and expensive products.

Therefore, all the ergonomically adverse factors with damaging influence such as noise, various vibrations, inadequate (high or low) temperatures, and others, need to be eliminated.

3.1. Ergonomic effects of noise and the characteristic amounts

The noise, as the adverse factor, has been officially, clinically and terminologically recorded in medicine a hundred years ago.

As such, it occurred in the ancient history, since forged objects, to which it is connected, were worked by a hammer on an anvil, thus automatically generating noise.

At present there is no one volume which would satisfy in evaluating the noise (in traffic or in general), especially not one that would be adequate for all kinds of traffic or that would be valid generally for a variable noise such as the traffic noise.

There is no such term that would unambiguously determine noise. It is difficult to define since its perception is related to the person noticing it, which can be a very insecure measurement. Physical measurements are needed, which are not subjective, and which

help us make the concept of noise acceptable and understandable to everyone. This is of relevance for the safety precautions and the work productivity, since the damaging effect of noise has been proved, and the safety precautions and productivity cannot be efficient if based on subjective feelings.

Therefore, this problem is viewed from different angles: statistical, psychological, sociological, gerontological, and others, such as work organisation, movement, etc.

Within the ergonomic approach to the workplace and the analysis of the relation man - machine or traffic means, the attention of the medical workers is primarily directed towards the human body. Although human body does not serve as the direct energy source any more, the energy expenditure in his (various) activities has to be considered. There are still jobs that require greater or lesser physical efforts of man, and there are cases in which the man is, out of ergonomic reasons, the main source of energy for work.

In evaluating (calculating) the physical efforts, energy expenditure has an important role, so that a whole range of scientists in various countries considered the problem like e.g.: Bink (1962), Streimer (1963), Durnin, Passmore (1958), Snook, Iruine (1969), Hettinger (1960), and Stegemann (1971).

A linear correlation has been determined between the energy expenditure and working effects. Also, it could be noticed that in case of very difficult jobs, that would present an overload for the body if lasting over the whole working time, short breaks interpolate spontaneously and they enable further work and increase in the productivity.

How these parameters are manifested in the traffic activities can be seen from the parameters calculating methodology, which consider noise and its ergonomic aspects.

Level L_{10}, is the level which is exceeded over a period of 10% of the monitoring period. It represents in fact the mean value of the peak traffic noise levels and it may be said to be one of the most important magnitudes in noise evaluation for man.

Level L_{50} is the statistical mean value.

Level L_{90} is the level which characterises the basic ambient noise.

Sometimes other statistical levels such as: L_{O1}, L_{O5}, L_{95}, L_{99} are used.

Apart from the mentioned, there are also the equivalent noise levels L_{eq}, which is also called the energetic mean value. It is obtained by energetic summing up of variable levels, according to the formula:

$$L_{eq} = 10 \log \frac{1}{T}\left[\sum_{1}^{n} t_i \, 10^{L_i/10}\right] \quad \text{dB(A)}$$

where:

- L_i is the level at the i-th statistical class dB(A),
- t_i the duration of one statistical class,
- $T = \sum_{1}^{n} t_i$ - is the total time of study.

According to the most recent studies L_{eq} stays as the main value for assessing the effect of variable noise on man.

Level L_{dn} (day - night, A - weighted average sound Level) is the energetically mean level at which the night period receives more attention by adding 10 dB(A) and the measured equivalence of the noise level:

$$L_{dn} = 10 \log \frac{1}{24}\left[15 \cdot 10^{L_d/10} + 9 \cdot 10^{L_n + 01/10}\right] \quad \text{dB(A)}$$

where:

- L_d - is L_{eq} for the day - 7 a.m. to 10 p.m.
- L_n - is L_{eq} at night from 10 p.m. to 7 a.m.

The Traffic Noise Index (TNI) is a purely statistical amount used for assessing the road traffic noise, with an approximately uniform statistical distribution.

It consists of two basic noise levels and some variability measures:

$$\text{TNI} = L_{90} + 4(L_{10} - L_{90}) - 30$$

where:

- L_{90} and L_{10} are the appropriate deciles of the statistical distribution of levels in dB(A).

The index or L_{NP} level (Noise Pollution Level) is a combined value in which a certain measure of dispersion is added to the energy mean level, as with TNI:

$$L_{NP} = L_{eq} + 2{,}56\sigma \quad \text{(dBNP)}$$

where:

- σ - is the standard deviation of the noise level dB(A).

For the approximately normal level, the following simplified formula can be applied:

$$L_{NP} = L_{50} + (L_{10} - L_{90}) + \frac{(L_{10} - L_{90})^2}{60} \quad \text{(dBNP)}$$

There are two basic factors that need to be taken into consideration when estimating the traffic noise, which also means when increasing the performance and productivity, and these are the type of traffic and the part of the day.

Since there are: free flow traffic through towns, congested and stop-start traffic through streets, and motorway traffic, none of the mentioned, nor of the up-to-now known values satisfy completely all types of traffic, regarding noise, productivity and performance estimate, especially not for the night.

Most of the mentioned values are adequate for the free flow traffic through settlements. For the jammed city traffic, all values are in general less adequate but those more adequate than others are L_{10} and L_{eq}.

For the motorway traffic, the correlation with subjective influence is even worse, and most adequate are the values TNI and L_{NP}.

The literature shows that comprehensive studies are being carried out world wide with the aim of finding out the unique methods and values for evaluating and estimating the influence of variable noise levels on people and their efficiency, and that a lot more needs to be done in this area.

The introduction and application of special digital processors in noise measurements, will provide a more objective and faster determination of its levels, influence, and its reduction in traffic and elsewhere.

According to the valid rules and legislation (Traffic Safety Act, "NN - Official Gazette 84/1992, 51/1993, 26/1993, Croatian Roads Act - revised text, "NN 56/1991, 26/1993, Domestic Transport Act, "NN 53/1991 and 26/1993) the noise in Croatia is measured as L_{eq} equivalent noise level, during the day from 6 a.m. to 10 p.m. and night from 10 p.m. to 6 a.m.

4. CONCLUSION

In the ergonomic and production system, special significance belongs to the work organisation regarding workplace, which considers the relation of one man towards another - the employee (the one who sets the tasks, organises them, towards the one who carries out the tasks) and of course, the relation of the man towards the working tools (tools, machines, measuring instruments), that he uses during working process and towards the object of work, in order to be able to produce it in the best conditions regarding high productivity and health.

High productivity and efficiency can be achieved within high technology system.

Fundamental technological changes include the inventions of products such as telephone, radio, aircraft, phonograph, and television. The most dramatic technological development in modern times has been in the field of electronics and computers, when the performance of today's computers in the form of small notebooks can exceed the most spectacular examples of technological changes. The technological change is, however, a continuous process of small and big improvements. It means that the same input of capital and labour can produce more output.

By measuring productivity, we denote it as the amount of production per unit of labour, productivity of capital as production per unit of capital and the total productivity as the production of total input of capital and labour. And all this, of course, in normal working conditions and ergonomic benefits of the working process.

Since, among other ergonomic disadvantages, noise has been emphasised as the most severe ergonomic occurrence damaging the workers' health, it needs to be continuously monitored - reduced and controlled.

The widely accepted rules for noise mitigation accompany the technological progress. The validity of documents about fulfilling the mentioned regulations on noise protection is time-restricted, and they need to be renewed every 5 years - even when the limiting levels of noise emission (rate level: L_r=90 dB(A), and lower rate level L_r= 85 dB(A)) are fulfilled.

Considering the character of noise, there is at present no fixed magnitude that would provide a satisfactory estimate, especially not in traffic of all vehicles and in all the situations, nor one that would be adequate for all types of traffic. Therefore, the paper mentions the approximate values for measuring noise in traffic, that could most probably be used, and on the other hand, could contribute to greater productivity and efficiency.

SAŽETAK

ERGONOMIJSKI SUSTAV, ČIMBENIK VEĆE PRODUKTIVNOSTI RADA U PROMETU

Polazeći od činjenice da buku najviše izaziva prometni tijek sa svojim značajkama, a u proizvodnom sustavu strojevi, uređaji i alati, neophodno je provesti mjere za njezino sprečavanje.

Buka se ponajprije mora spriječiti iz humanitarnih razloga, a onda radi veće produktivnosti i proizvodnosti rada.

Koliko god istraživanja pokazuju da se smanjenjem buke povećava radni učinak i da se tako smanjuju troškovi (fiksni i varijabilni), toliko njeno sprečavanje ne smije imati dovoljan razlog samo u povećanju učinkovitosti i smanjenju troškova, nego mora biti i u funkciji uređenja radnog mjesta. Vođeni humanom, a ne gospodarskom tendencijom, sigurnošću i zaštitom ostvarit će se potpuno zadovoljstvo, zdravlje čovjeka, a ponajprije povećati radni učinak.

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