The use of working environment factors as criteria in assessing the capacity to carry out processes

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Abstract. One resource indispensable for securing the capacity to carry out processes is an environment made up of social, psychological, physical and other factors. The nature of such environmental factors and the manner in which they affect the capacity to carry out processes and produce goods and/or services translates into a company's ability to meet the expectations of stakeholders, including the organization's customers. In order to define the preconditions for the efficient implementation of processes, it is necessary, among others, to ascertain the manner in which such preconditions influence process operation. One of the criteria that should be applied in such an assessment is the impact of working environment factors (temperature, lighting, noise, toxicity, dust, electromagnetic fields) on the ability to carry out work processes effectively. The paper accounts for working environment factors seen as parameters for the assessment of processes and as criteria for ascertaining the ability to perform work. The impact of the working environment on the capacity to conduct processes was assessed by means of a relationship diagram.

1 Introduction

The acquisition of the capacity to carry out production processes ties irretrievably to ensuring a proper working environment for the labor force. Its pivotal part is the physical working environment whose specifications determine workers' ability to perform work and the organization's ability to ensure safety for persons responsible for work performance [1].

In assessing an enterprise's capacity to carry out tasks, particular emphasis should be placed on the processes employed in transforming stakeholder expectations into outcomes resulting from the provision of services, the manufacturing of products or decision making [2, 3]. The ability to carry out internal and other processes defines the ability to perform such tasks.

To conduct processes, an enterprise needs to ensure access to appropriate resources which will allow it to carry them out without unnecessary hindrances and limitations [2, 4]. Such resources are technical, organizational, human, financial and other. Frequently, being in their possession or having the ability to acquire them is a precondition for attaining a

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company's objectives. Such resources include the ability to adopt solutions that increase the capacity to perform work. One such solution is the establishment of a working environment that will not disrupt work performance [5]. The acquisition of resources should be preceded by an analysis of the existing state of working conditions.

One measure of equal importance for conducting the process is to identify criteria for evaluating an organization's performance. This is particularly vital for carrying out tasks that constitute a process, that are subject to systemic standards (e.g. the standards of a quality management system), and that require comparing work outcomes with any preliminary precepts and targets [6].

2 Process description and process performance conditions

Processes should be defined as a collection of mutually interrelated actions that influence one another and that are undertaken to transform inputs into outputs [6]. A simplified process-based task performance diagram is provided in Figure 1. To ensure that the transformation of inputs into outputs proceeds effectively, it is critical to consider the impact of conditions on process performance and minimize any existing or potential disruptions.

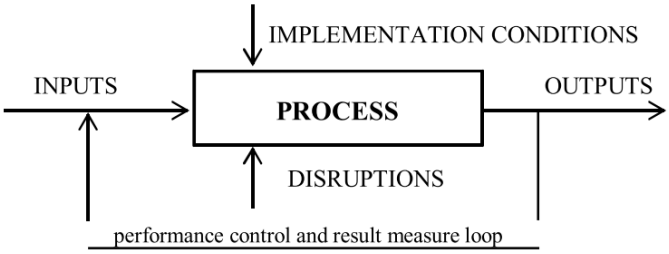

Fig. 1. Simplified process performance diagram.

A precondition for the effective performance of tasks in a process-based system is to [3, 7]:

- Identify, in advance, all processes found in an organization, arrange them into a sequence, recognize their mutual impacts, define input and output requirements and identify the processes that are particularly critical for the proper performance of tasks,
- Define the principles and methods for overseeing process performance, and
- Implement actions necessary for the achievement of planned outcomes and continuous process improvements.

The systemic approach employed in pursuance with ISO 9001 [6] may be associated with the view of an enterprise as a sum total of the effects of its processes. A process that underpins a given approach may be seen as a way to carry out tasks. Such tasks are defined in terms of the mutual relationships among them with a focus on organizational units, workstations and functions. Here, a particular role needs to be ascribed to [3, 8, 9]:

- The conditions in which specific tasks are conducted and which are central to an organization's ability to acquire and transform resources that are critical for the achievement of specific outcomes,
- Any disruptions that adversely affect the ability to carry out a process defined as a transformation of inputs into outputs. Every process disruption compromises an organization's ability to generate specific benefits. As such, it should be eliminated at the level of the components and specifications of a given process.

The performance of processes and the interrelations among them are influenced substantially by the environment in which the processes are conducted. Success in their improvement depends on the impacts of all component elements that affect process performance [10].

As a prerequisite for its ability to improve its processes, an organization should [2-4, 10, 11]:

- Plan its actions and specifically identify its objectives and secure the required resources, including the environment in which the planned actions are to be taken,
- Make proper organizational arrangements such as the assignment of tasks and responsibilities and the acquisition of resources that are adequate to tasks and that enable the organization to respond to changes in the conditions in which tasks are performed,
- Lead and motivate the entities involved in the performance of specific tasks,
- Monitor the process by acquiring information on the effectiveness of conducting the planned actions.

In order to be capable of performing processes, an organization needs to secure the appropriate resources, including conditions for process performance. A key role among such resources is played by the working environment [12].

In an employee-friendly organization, processes are performed under strictly specified conditions which secure the satisfaction of worker needs and expectations and ensure working comfort and worker well-being. Another prerequisite for effectiveness is to abandon the policy of limiting controls to external procedures. Every employee should care for a specified section of their process thereby contributing to increases in work efficiency and ensuring that the tasks at hand are performed professionally [12, 13].

3 Working environment factors as process performance determinants

3.1 Impact of working environment factors on the ability to conduct processes

The working environment parameters defined for a workstation may be used as indicators in evaluating process performance conditions and as criteria for verifying workers' ability to operate and perform work in a specific working environment [1, 13]. The working environment may be described in terms of the level of negative and positive impacts on the worker.

Any negative or positive impacts exerted by working environment factors are a function of the conformity of working environment characteristics, as measured by means of specific indicators, with the criteria prescribed to achieve welfare in the working environment and ensure the ability of human operators to work efficiently. Where no negative impacts take place, i.e. where no such factors exist as would potentially disrupt the proper operation of processes, the broadly-defined capacity to perform occupational tasks in a proper manner is greatly increased. Such a capacity produces the following key benefits at enterprise level [1, 7, 13-16]:

- A reduction in losses caused by occupational accidents and diseases,
- Increased levels of employee motivation, teamwork and morale,
- A more efficient spending of funds earmarked to improve occupational safety,
- Greater efficiency in the performance of work,
- The ability of fewer workers to complete work within a shorter time,
- Greater efficiency achieved with the use of specific work methods,

- Unscheduled workloads (costs) reduced by effectively planning to achieve work continuity,
- Prevention of work disruptions and successful retention of most valuable workers,
- Reduced insurance expenses,
- Improved enterprise image and reputation,
- Lower risk of civil liability lawsuits.

All of the above benefits contribute to boosting the enterprise's bottom line.

Such impacts are identified with reference to the indicators and parameters used in assessing elements of the working environment. Depending on their level, individual impacts may be viewed as deleterious (hazardous) or untoward [17]. The most critical of them are such working environment factors as temperature (characteristics of the thermal environment), workstation and workplace lighting, noise and vibrations which affect workers, toxicity resulting from the use of chemicals and their mixtures in the work process, non-toxic dust, electromagnetic fields and, e.g. laser radiation levels. Their effect may be assessed by the measuring methods that help identify the actual impact of a factor on employee health and safety and on the presentation of subjective assessments of risks by workers. In the course of such evaluations, one should bear in mind that working environment factors affect [17-19]:

- Process performance, described in terms of e.g. process efficiency and effectiveness,
- The alignment of process outcomes with stakeholder expectations.

Table 1 describes the deleterious and untoward factors found in the working environment that are accounted for in assessing the capacity to conduct processes in a manufacturing company. These include the parameters applied in the assessment of [17]:

a) The thermal environment, measured by:
   - The predicted mean vote (PMV) indicator which describes the thermal comfort of a person remaining in a moderate environment on a seven-point numerical scale (from -3.0 to +3.0),
   - The conformity of the wet bulb globe temperature (WBGT) [°C] with the admissible values corresponding to the ability to perform work in a hot environment,
   - The chilling temperature indicator t_{wc} [°C] used to describe cold environments,
b) Illumination, and specifically:
   - The mean level of illumination E_{ave} [lx] relative to the required operating illumination,
   - Illumination uniformity relative to the minimum allowable illumination uniformity,
   - Light color and luminance depending on light source, measured against the requirements of the EN 12464-1:2011 standard,
c) Noise loads, described in terms of:
   - The equivalent noise level L_{Aeq},
   - The maximum noise level L_{Amax},
   - The peak noise level L_{Cpeak}.

During the evaluation, reference is made to device measurements used to formulate an objective assessment as well as subjective assessments of working conditions by workers employed at specific workstations.

The impact of environmental factors on the ability to carry out work was assessed exclusively on the basis of the disrupting factors found at the assessed workstation at the time at which the analyzed processes were performed.

Table 1. Description of the acceptability of exposure to selected deleterious and untoward factors found in the working environment.

Deleterious (untoward) factor	Measurement indicator (device-based assessment)	Working conditions evaluation (subjective evaluation by employees)
Thermal working environment (temperature and other parameters contributing to temperature impact)	· Thermal comfort $-0.7 \leq PMV \leq 0.5$ · Acceptability of moderate environment $-2.0 \leq PMV \leq 2.0$ · Acceptability of hot environment $WBGT \leq WBGT_{(accept.)}$ · Acceptability of cold environment $t_{wc} > -24°C$	Desired state - Satisfactory thermal conditions (considering the employee's protective clothing and work organization) Undesired state - Overly hot working environment (body overheating), - Overly cold working environment (body overcooling)
Lighting	· Average luminosity relative to the required operating light $E_{ave} \geq E_{(operating)}$ · Uniformity of lighting $d \geq d_{min}$ · Color of light and other evaluation parameters (such as luminance distribution) determining the ability to perform work, compliant with the EN 12464-1:2011 standard	Desired state - Ability to observe work details in performing eyesight-intensive work Undesired state - Lighting conditions (luminosity, uniformity, luminance distribution) hindering the observations of work details in performing eyesight-intensive work, - Light distribution causing the blinding of workers
Noise	$L_{Aeq} < 85$ dB $L_{Amax} < 115$ dB $L_{Cpeak} < 135$ dB	Desired state - No negative impact of noise on ability to perform work, - Acoustic comfort ensured at workstation Undesired state - Harmful effects on employee hearing organs, - Work performance hampered by negative impact of noise on the ability to communicate, - Inability to focus on task

Source: author's work based on EN 12464-1:2011, EN ISO 7730:2005, EN 27243:1993, PN-N-01307:1994 and Polish laws.

3.2 Evaluation of the impact of working environment factors on work performance

The study was conducted in a provider of gas installation services. The processes during which exposures to the disrupting factors referred to in Table 1 occurred were:

– Gas line preparation, and

– Gas line joining.

The above processes lie at the core of the operations of the assessed enterprise. The effectiveness with which they are performed is pivotal to the enterprise's market standing.

Irregularities were identified based on the activities which the workers associated with excessive exposures to working environment factors. By accounting for working environment factors, it became possible to assess their impact on the ability to carry out work tasks and conduct processes. This led ultimately to identifying circumstances in which the stresses to which the workers were subjected became excessive, forcing them to operate in improper working conditions.

In defining the existing links, use was made of the relationship diagram, which falls into the category of new quality management tools [4, 20, 21]. The relationship diagram may be used to collect and process data on the conditions affecting the performance of tasks. The diagram relies on procedures suited to the accomplishment of specific goals, including process design, by finding areas that may jeopardize process performance effectiveness [4, 20].

The study was conducted by an in-house team appointed by the company's management, comprised of technical and executive department engineers and occupational health and safety services. An auxiliary role of overseeing the investigation was entrusted to an external expert. The relationship diagram was created by:

– Describing the issue at hand, which became the central node of the diagram,
– Identifying the causes of the issue, which became the remaining nodes of the diagram,
– Identifying mutual links among such causes,
– Identifying the key causes, i.e. the parts of the diagram to or from which the greatest number of links are connected.

The parts of the diagram to or from which the greatest number of links are connected were the starting point for assessing the need to take specific improvement measures [17, 22]. The analysis of the circumstances leading to risks and strenuousness is presented in Figures 2-4.

The circumstances that caused specific irregularities are described in Table 2.

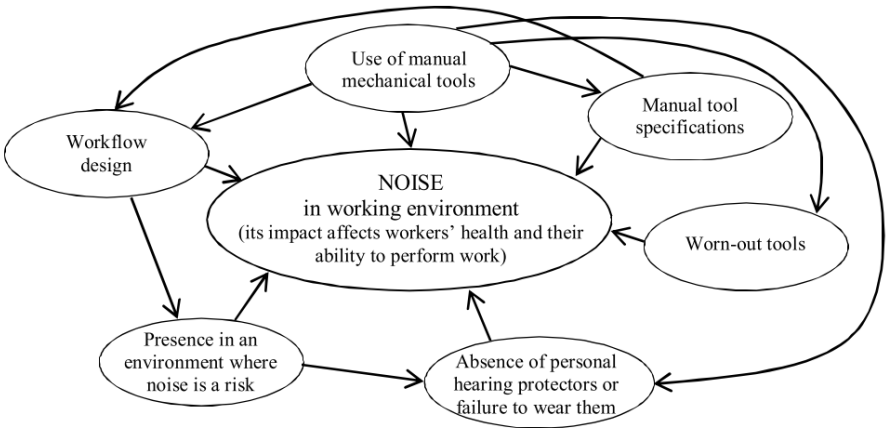

Fig. 2. Relationship diagram showing sources of noise exposures in working environment.

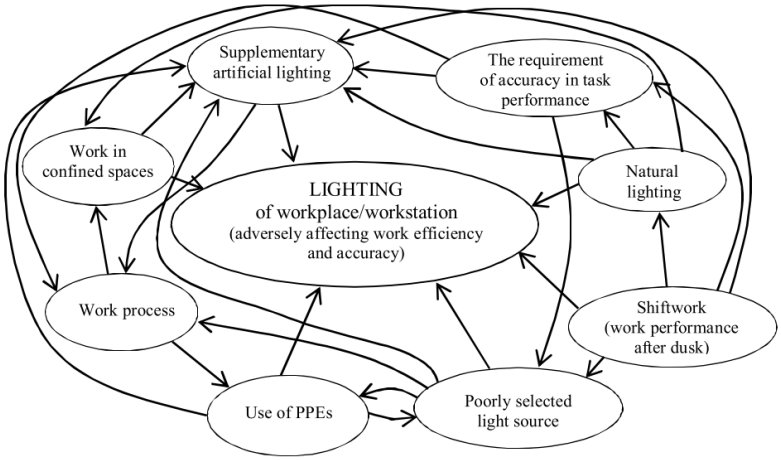

Fig. 3. Relationship diagram showing the risk of strenuous factors arising that are caused by failures to ensure efficiency and accuracy as a result of inadequate lighting in the workplace/workstation.

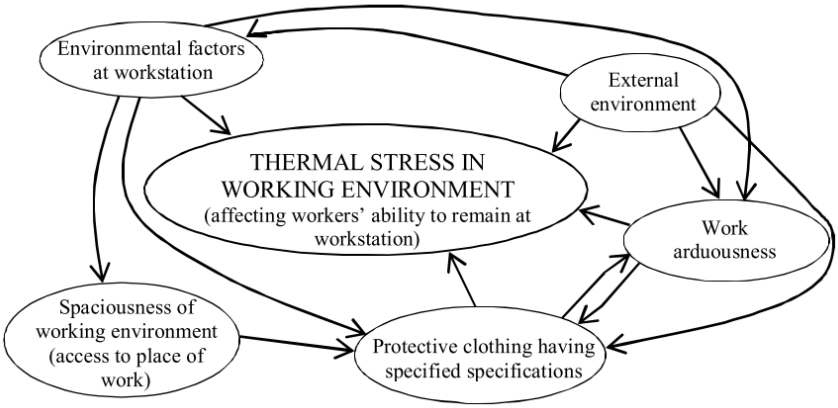

Fig. 4. Relationship diagram showing the causes of thermal discomfort in working environment.

Table 2. Description of irregularities and their causes.

Issue	Cause of issue	Description of issue
NOISE in the working environment (its impact affects workers' health and	Workflow design	Employee unable to move equipment away from his/her ear
	Use of manual mechanical tools	Due to work parameters and work methods applied at workstation, tools available to employee are a key significant noise source
	Manual tool specifications	Device parameters such as rotational torque and impact driver strength of drill or grinder) should be recognized as factors affecting noise generation
	Worn-out tools	Worn-out tools are an extra noise source in the

		performance of work
	Noise exposures	Since workers have no choice but to remain in the working environment (which is intrinsically noisy), they are exposed to noise regardless of the specific tasks they are performing at any given time
	Absence of personal hearing protectors or failure to wear them	Due to the specific nature of the work, personal hearing protectors may be the only practicable way to protect workers against noise; if workers do not wear them, this opportunity to protect them will be wasted
LIGHTING of workplace and workstation (affecting work efficiency and accuracy)	Natural lighting	The use of natural light is critical for ensuring proper workstation lighting
	Shiftwork	Work in conditions deprived of natural light (sunlight) causes significant stress, especially where supplementary artificial lighting cannot be used
	Supplementary artificial lighting	If poorly suited to working conditions and if no natural light is available, it results in inadequate illumination of the workstation
	Work in confined spaces	Makes it impossible to employ proper artificial lighting while making natural light insufficient; the issue should be recognized as particularly pressing alongside the use of proper PPEs
	Work process	Significantly affects workstation lighting, particularly if improper PPEs are worn
	Use of PPEs	
	Poorly selected light source	Results in inadequately lit work space and workstation, affecting in particular the accuracy of the performance of individual tasks
THERMAL STRESS IN WORKING ENVIRONMENT (affecting workers' ability to remain at workstation)	External environment	Impact of external environment and the inability to influence it results in significant thermal stress
	Environmental factors at workstation	Working conditions are a function of the external environment – they mirror the specific factors which result in work stress
	Work arduousness	The amount of metabolic energy tied to the arduousness of work is a critical criterion that defines thermal stress levels
	Protective clothing	Poorly selected protective clothing (i.e. one with inadequate specifications) may significantly affect thermal stress levels
	Spaciousness of working environment	The amount of space available at a workstation affects the ability of a worker to wear well-selected protective clothing

The analysis that was conducted as well as the use of the relationship diagram helped identify the factors that significantly contribute to process disruptions. To ensure that an organization's processes are conducted efficiently, it is vital to establish a thorough monitoring system and take measures that will lead to improvements. These include with respect to:

a) Workstation noise: the adoption of rules governing the use of manual mechanical tools with a view to reducing the negative impact of noise on the workers,

b) Workstation spaciousness and lighting, which affect work performance efficiency and accuracy: providing workers with a supplementary portable source of artificial light which they can use at any site during the performance of work,
c) Thermal stress experienced by workers in a working environment: using protective clothing with properly identified and selected specifications; such clothing should not hinder work performance in any adverse external conditions regardless of the degree of spatial confinement at the workstation.

As part of the detailed analysis aimed at identifying the measures that need to be taken, the organization should [4, 17-19, 21]:

- Take into account such circumstances (factors) as are likely to contribute to causing the targeted issue,
- Consider factors that might potentially hinder the organization's ability to adopt the selected solutions,
- Identify the measures that are necessary and practicable,
- Select priority measures which will make the biggest contribution to the achievement of desirable effects,
- Identify special measures associated with the innovative solutions in place,
- Define the conditions for the implementation of the project, including the selection of contractors, the planning of actions, the identification of adequate resources and the allocation of resources that are necessary of project completion.

Notably, however, none of the above matters fall within the scope of this paper.

4 Conclusions

The presumption made in the study in question was that working conditions significantly determine a man's ability to operate in a working environment and perform tasks. If such tasks are presented as a process, working environment factors need to be seen as prerequisites for work performance, whereas ensuring proper working conditions should be recognized as a disrupting factor that adversely affects process performance and the capacity to achieve the desired outcomes [18, 23].

By analyzing the issue in view of process performance described in reference to working environment factors, emphasis may be placed on the significance of working environment parameters for assessing the ability of human operators to work in specific conditions which determine their safety and their ability to perform work efficiently. Such factors are described in terms of the requirements laid down in relevant standards as well as subjective assessments by workers. Both are used in evaluating workers' ability to perform their tasks.

The relationship diagram has helped examine the issue and, on that basis, identify advisable improvement measures. The diagram has made it possible to correlate "causes" with "effects", and, as a consequence, identify links connecting individual causes. The study has found that:

- The central measure required to ensure proper thermal conditions in the working environment is to select functionally appropriate clothing,
- To ensure that workstation illumination is adequately suited to the nature of the work performed, workers should be equipped with a portable light source,
- To reduce the adverse impact of noise, it is crucial to train the workers and establish rules for the use of manual mechanical tools.

The above measures should be seen as the most critical ones for improving the current conditions. The analysis also makes it possible to identify other actions and assess their usefulness for the achievement of the desired improvements. To that end, reference should

be made to the number of links found in the aforesaid relationship diagrams. The links show both the sources of problems and ways to reduce their impact.

The improvement measures adopted on that basis and aimed at eliminating or mitigating disruptions should be seen as a way to increase the capacity to carry out work processes.

By applying the above methodology to workstations exposed to other disruptions in the form of deleterious, untoward and hazardous factors having a potentially harmful effect on human health, it is possible to identify the measures that should be taken. Such measures will help improve work efficiency and effectiveness and, in effect, satisfy the expectations of the concerned enterprise's stakeholders, who include its employees. The improvement measures that allow the enterprise to enhance the conditions in which its processes are performed and reduce the disruptions to which its processes are exposed will ultimately help, inter alia, to:

- Improve work efficiency by e.g. reducing the time needed to complete tasks,
- Boost the effectiveness of task performance,
- Reduce loads having adverse impacts on workers,
- Reduce the biological cost resulting from the performance of work,
- Improve the quality of work,
- Reduce the time needed to perform tasks,
- Improve work productivity.

While no other factors having deleterious effects on the workers were observed during the study, the insights obtained suggest that the methodology described above can be successfully employed to assess the causes of other issues. Another consideration that may prove to be of significance is the possible interactions among individual deleterious factors that may produce a synergy effect.

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