



Ergonomics vs economics in the construction logistics: a case study from the “Hexagon Construction” company in Poland

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Abstract

The purpose of this study was to analyse the relationship between the aspects of ergonomics and economics in the construction industry. Ergonomic cost calculation mainly as a result of down time due to accidents and incidents was evaluated. The impact of ergonomics intervention on construction economic in the logistics network was also determined. This impact was simulated using an annual total of accidents for the year 2021. Organizations, particularly businesses, must implement ergonomics diagnosis measures in order to reduce occupational hazards and accidents in their supply chain. Ergonomics measures are implemented to reduce and eliminate workplace accidents, but most manufacturing companies and employers overlook this aspect because it is seen as an expense. The case study was performed in Hexagon Steel Construction company. This is due to the fact that such a business operative is responsible for a wide range of activities in the logistical network, from manufacturing to warehousing and distribution, and finally to final structure installation on the construction site.

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1. Introduction

Striking a balance between economics and ergonomics has always been difficult for management. It is a common assumption among executives that spending more on ergonomics will not assist the company financially. Apart from that, physically demanding tasks such as working in awkward positions, lifting heavy materials, handling irregular loads, bending and twisting the body, working above shoulder height, working below knee level, and pushing and pulling put construction workers at a high risk of work-related injuries. Employee performance becomes unpredictable as a result, resulting in variability (Kim, 2017).

Europe 2020 is the European Union's development strategy designed for this decade 2020 to 2029. According to José Manuel Barroso, in the EU, intelligent and sustainable economic growth is required since it is beneficial not only to pay attention to safeguard the natural environment and ecology, but also to increase proactive social commitment (Hendrick, 2021). Corresponding action on these areas should assist the EU as well as member nations in growing their economies in a global perspective by increasing employment, productivity,

and social cohesion (Barroso, 2020). Furthermore, negative environmental downscaling (particularly in waste management) and increased employer responsibility of knowledge of working conditions should be achieved. The key goals for firm development based on knowledge and viewing people as a valuable resource should improve possibilities for satisfying core nutritional, medicinal, and developmental needs, which means a continuing desire to improve employees' living conditions (Krynke et al., 2021). In order to realize this premise, the European Union also stated that enterprises must keep the human as a significant item in the human-machine-environment system. This serves as the foundation for microergonomics. In a macroergonomics perspective, the internal structure of dependent objects of technological systems, internal relations between objects, and dependency on the external environment are all taken into consideration in many-objected depiction, perceived as a system. Because industrial activities are complex, they cannot be understood from a single perspective. Companies and production system models may reflect a few aspects, but they do not provide a comprehensive picture. Three significant interest groups can be identified: employers, employees, and customers.

Safety, health, well-being, and efficiency are the primary goals of work. Ergonomics is a field of study that focuses on the design of technologies and organizational structures. Interactions between persons, technology, organization, and work environment are another perspective on a corporation. In this aspect, ergonomics and quality have a lot in common in terms of goals (Teymourian et al., 2021).

More holistic approaches have been successful. One explanation for this is that the interactions between the previously stated components are frequently overlooked. In the subject of ergonomics, there is a lot of evidence that a lack of contact between humans and technology, or between humans and poor work environments, can lead to less efficiency and production losses, not to mention the ramifications for the people involved. Ergonomists have frequently attempted to justify ergonomics advances by citing increased productivity or lower labour costs (Wandzich and Płaza, 2017).

Frequently, the people who know the most about human factors and ergonomics in a corporation are not the people who "own" the design problem or the design of assembly solutions; that is, they do not have the authority to modify the workplace. This is especially true for ergonomists, who must develop interpersonal skills and a "language of economics" in order to use cost-related persuasive arguments when communicating with people who have the authority to allocate money and resources to change (for example, engineers, production leaders, and economists). Along with ergonomics, problem owners frequently have a slew of additional factors to consider.

This means that if you want to improve ergonomics, you'll need to be able to analyze and articulate the trade-off between the short-term needs of company leadership and the long-term benefits of ergonomics — in cost-benefit analysis terminology. In the "economics of ergonomics," there is a paradox: when you choose to invest in good ergonomics ahead of time, it's difficult to tell exactly how much wasteful expenditure has been avoided. This can make persuading management, who are hesitant to invest in ergonomics, difficult. On the other hand, waiting until the workforce has been injured to address poor work environments and work design can result in a cascade of costly consequences (assembly errors, quality deficiencies, sick leave, rehabilitation, compensation, costs for new recruitment, training of new staff, and quality/speed deficiencies while new staff is being trained, and so on).

As a result, learning from case studies and corporate records is an excellent method to construct arguments that demonstrate how the consequences of poor ergonomics can spread. From a different perspective, numerous case studies have shown that enhanced ergonomics can improve safety, productivity, efficiency, and quality, all of which lead to increased profitability. Your ability to argue in these terms can help you persuade other stakeholders and execute workplace improvements in general, rather than just ergonomics.

The construction business is a booming industry in the United States. While, according to European data the industry is classed as one of the sectors of the economy with significant occupational risks and a poor standard of occupational safety. (Figure 1S)

Biological, chemical, and ergonomic risk factors, as well as the effects of noise and temperature, are more prevalent among construction workers. Approximately 45% of construction employees believe that their job has a detrimental influence on their health. The construction business has a high level of occupational risk, as well as a high prevalence of workplace accidents, illnesses, and absenteeism. According to Eurostat statistics from 2011 (for 28 European Union countries), the fatal accident rate in the construction business was 6.39 (per 100,000 people employed), with an overall rate of 1.94. This is further supported by reports from Poland's General Labour Inspector, which reveal that construction workers are frequently involved in deadly workplace accidents.

The main aim of the study was to determine how management in the construction logistics sector view relation between ergonomics and economics and the possible economic impact of ergonomic intervention with particular reference to the whole logistics network of Hexagon Construction company.

The specific objectives were to:

- present the ergonomic findings,
- describe ergonomic cost calculation mainly as a result of down time due to accidents and incidents,
- determine the company's behaviour and attitude towards safety,
- evaluate impact of economics of ergonomics intervention.

2. Experimental

Characteristics of the Hexagon Steel Construction company

"Hexagon Construction" is a Polish construction company based in Ostrów Mazowiecka. Since its inception in 2012, the company has been involved in construction projects as both a main contractor and a subcontractor. The majority of the company's projects are in Poland, with 60% in Poland and 40% in other European countries, which are France, Norway, Ireland and Finland (Hexagon Construction Catalogue 2022). Construction specializes in the design and construction of custom metal structures such as:

- industry (production halls, warehouses, hangars),
- services (low car, station diagnostic),
- agriculture (henhouses, stables, equestrian centres) (Europa scoreboard, 2016).

The procurement of construction materials is handled by "Hexagon Construction" company. The company arranges for the purchase of all building materials on behalf of the customer and in accordance with their specifications. The company goes above and beyond to create all transport documents, including any necessary customs documents. Document manufacturer-specific on-site storage requirements; and transport construction materials to the final installation site, all with complete documentation from a single source.

The data used in the experimental part was primarily taken from two sources: primary data and secondary data. The primary data was gathered from the company's safety department, which contained all of the incidents or accidents that

occurred in the company over the previous years. The company's safety department is in charge of keeping track of all work-related accidents and incidents both inside and outside the company. Any work-related accident or incident, as well as the causes thereof, are also recorded in the company's log book or computer system. This primary data included the:

- type of accident,
- time of the accident,
- duration of the accident,
- losses caused by the accident,
- causes of the accident,
- degree of injury encountered by the injured employee, etc.

Secondary data was gathered outside of the organization or company and includes research journals, articles, online publications, and so on. Secondary data is just as vital as primary data when it comes to gathering of data. Secondary data can be used as a reference in the event of an accident or incident, as well as in any work-related problems. Secondary data includes previous research papers on a specific topic or problems, articles by researchers, online publications by the author, and so on, and includes important points and facts, the reason for a specific problem and its related solution, and a satisfactory conclusion. Secondary data can be very important or vital in some advanced research or additional research on the same topic.

Accident types and classification

Accident types can vary depending on factors such as injury severity, and durability. A significant accident is one in which the injured individual dies or suffers permanent or long-term disability as a result of the accident. A minor accident is defined as a slight scratch or cut to the body that does not render the worker handicapped. When an employee sustains an outward injury, such as a cut or a tear on a body part, it is referred to as an external injury. When an employee sustains an inside injury, such as a rip of internal bones, veins, or organs, it is referred to as an internal injury. A temporary accident occurs when an injury leaves an employee handicapped for a brief length of time, such as a day or a week. In the event of a temporary accident, man hours are lost for a limited time or for a few days only. In a permanent accident, the injured employee is permanently unable to perform his or her normal employment or is permanently incapacitated. In the event of a permanent injury, the injured worker loses man hours for the rest of his or her life, resulting in an immense or tremendous loss to the firm or industry. Employees' disabilities are also categorized as partial or total, non-fatal or deadly (Deborah. 1974). Partial disabilities occur when only a portion of a specific body part is affected by an accident or incident, such as carpal tunnel syndrome, hearing loss, or blurred vision, and total disabilities occur when a worker's working capacity is reduced for the rest of their life, for example losing body organs or parts. Non-fatal accidents involve serious injury, including the loss of body parts or organs, but do not result in death of the employee, whereas fatal accidents result in death. The classification criteria are based on the actual damage, the potential for injury, and the unintentional release.

Serious Incident or Accident

A major accident is characterized as a fatality or a long-term injury that requires hospitalization (Arjun and Marais, 2015). In a catastrophic accident, the employee suffers a significant degree of injury or suffers a severe body injury, resulting in company losses. It is generally classified as a reportable accident.

Incident/Accident of Medium Intensity

A medium incident is described as a lost time injury that does not necessitate hospitalization, medical treatment, or work restrictions. In a medium mishap, the employee suffers significant injuries and the company suffers fewer damages. It may or may not be a reportable incident or occurrence. It is classified as a non-reportable accident under the Factory Act of 1948.

Insignificant Incident/Accident

Minor incidents such as first aid injuries and/or near misses. In a minor accident, there is very little injury to the employee and very little loss to the company. It is generally classified as a non-reportable accident under the Factory Act of 1948.

Accident causes: accident models

Accident prevention in the workplace or in any industry focuses on the underlying causes of the accidents. The reason for the incident or accident should be determined in order to prevent similar incidents in the future. Inspection, monitoring, and analysis are the foundations for revealing the cause of accidents for a better and easier theoretical understanding of how accidents occur at a workplace or industry, as explained by the accident causation model. The domino theory of Heinrich is a well-known causation model that states that 88% of accidents are caused by unsafe acts, 10% by unsafe conditions, and 2% by the others factors. Other models have been developed since, but the domino theory is the most commonly used. Because the majority of accidents are caused by unsafe acts or human error, they can be avoided. Accidents are caused by a combination of factors rather than a single cause. These accident factors are inextricably linked, and when these factors collaborate or work together with joint forces, it creates the conditions for an incident or accident to occur.

Some health and safety experts divide the various causes of accidents into three broad categories.

- 1) Dangerous act /Unsafe act
- 2) Dangerous situation /Unsafe condition
- 3) Other factors /Other causes

Dangerous Acts

Unsafe acts are human actions that deviate or differ from safe practices, safety regulations, standard job procedures, and instructions. Unsafe acts are primarily caused by insufficient skills, a lack of knowledge, and inappropriate behavior or attitude. The majority of accidents that occur in any industry are generally the result of an unsafe act. According to some studies, psychological and physical factors play a significant role in unsafe acts. The following are some examples of dangerous acts:

- operating without permission or authority,
- failure to use Personal Protective Equipment (PPE),
- removal of safety devices,
- using the wrong PPE or the wrong PPE incorrectly,
- using the wrong and defective equipment,

- attempting to do something faster or horseplaying,
- working in an unsafe posture or position for an extended period of time,
- intentionally intending to injure someone,
- working after consuming alcohol or drugs,
- lack of skills and knowledge,
- failure to comprehend the SOP, instruction, process, method, and so on,
- teasing, distracting, abusing, and quarrelling, among other things.

Unsafe Conditions

The physical and chemical properties of hazardous materials, machines, and environments that could result in damage/loss or injury to man, machine, material, and other company assets, or losses in any form. The term "unsafe condition" refers to a situation in which defective equipment, plants, tools, machines, or materials are present. According to some studies, one of the major causes of incidents or accidents is unsafe conditions. The following are some examples of hazardous conditions:

- inadequate and wet surfaces,
- improper and unstable material stacking,
- electric wire cut and live conductors exposed,
- machines and equipment without guarding systems,
- inadequate storage of hazardous materials and storage of different types of flammable liquid, chemicals, and combustible material in the same place or room.

Other Factors

These causes are caused by climate conditions, variations in climate, acts of God, and so on. Other causes include extremely high temperatures, high levels of humidity, poor working conditions, excessive light intensity, excessive noise, an unhealthy environment, slippery floors, excessive dust and fumes, and so on. Other causes include the following:

- an earthquake, tsunami, or tornado strikes the workplace, for example,
- extremely low or high temperatures and wind speed at work,
- rapid change in any workplace environment.

3. Results and discussion

Ergonomic research findings

The information was obtained from the company's safety department. In data collection, all major, medium, minor, reportable and non-reportable incidents or accidents were collected, and the total man days, man days lost, severity rate, accident rate, injury frequency rate were calculated and represented in a graph that shows the most number of accidents or incidents in previous years, or which year has the highest accident rate, as well as the type of hazard. The hazards or accidents are classified based on accident reporting and investigation reports, which are displayed in tabular form and categorized according to nature of construction logistics.

Material Handling logistics

The following were the major hazards discovered during process monitoring or observation.

Forklift truck loading and unloading of raw materials:

- Improper lifting can cause material to fall and structures to bend or be damaged.
- Excessive weight/load may cause system failure, structural damage, or brakeage.
- Because of the uneven surface, materials and forklift trucks may fall.
- An inexperienced/untrained person collided with a wall, people, materials, machines, and so on, resulting in an accident.
- Improper forklift maintenance may result in system failure, breakdown, and component wear/tear.

Pickling process

- Splash: it can cause skin burns, eye damage, and other body parts to be damaged.
- Fumes: prolonged exposure to fumes may result in chronic effects such as carcinogenic disease.
- Tank leakage: this can result in chemical hazards such as corrosion, fire, and eye, skin, and skin damage, among other things.
- Chemical hazard: corrosion, fire, inhalation, ingestion, eye, mouth, skin injury, and so on.
- Sludge is an environmental hazard because it pollutes the soil and destroys aquatic flora and fauna.

Wire drawing

- Entanglement – the body parts may be cut or stuck.
- Wire breakage – injury/damage to man, machine, and material lubricating powder.
- Chemical hazard – causes skin damage and, in some cases, carcinogenic effects when exposed for an extended period of time.

Material handling Packaging

- Compressed air/packing gun: it has a high risk of pressure release and flying objects.
- Metal strip: improper packaging with metal strip can result in cut/struck body parts.
- Wire strand: it can also cause injury to body parts when it is struck by a hazard.
- Packing by lifting the coil: it includes a fall and being struck by a hazard.

Table 1. Material handling logistics

Accidents	Number of accidents	Percentage (%)	Accident intensity	Hours Lost
Pickling process	3	13.64	1	5
Forklift accident	6	27.27	2	7
Slip/Trip/Fall	5	22.73	5	13
Wire drawing	4	18.18	1	3
Struck by object	3	13.64	3	9
Packaging	1	4.55	2	4
Total	22	100.00		41

Manufacturing logistics

Steel structure assembly workers are frequently subjected to long hours, strenuous conditions, and constant danger. Steel workers face a variety of hazards in the course of their work, whether in mills or on construction sites.

1) Falls

Significant heights, uneven ground, and obstructed walkways are all common hazards in steel work. It's no surprise that slips, trips, and falls are the leading cause of injury among steel workers around the world.

2) Heavy machinery

In the steel industry, powerful machinery is essential. It also contributes to a large number of injuries and deaths. Accidents occur despite ample warnings, thorough training, and built-in safeguards. People take shortcuts, equipment deteriorates, and safety mechanisms fail (Table 1).

Steel mills and construction sites are not quiet places. Hearing loss is common among steel workers, particularly when proper ear protection is not used on a regular basis. Continuously loud noise has a psychological impact, causing fatigue and anxiety.

3) Toxins

Dangerous chemicals and toxins in the air are a fact of life in steel mills. Chemical burns, blindness, and lung damage can result from improper handling. Furthermore, long-term exposure to toxins like asbestos can lead to life-threatening cancers and lung diseases.

Many steel workers use heavy machinery or power tools on a daily basis, which causes vibration. Long-term vibration exposure from this equipment can cause nerve damage, particularly in the hands and fingers. It can also cause tendons and ligaments to wear down, resulting in chronic pain and decreased mobility.

4) Heavy lifting

Steel industry jobs are physically demanding. They necessitate repeated lifting, bending, and other forms of physical exertion. Workers' bodies deteriorate when they perform strenuous tasks on a daily basis, year after year. Steel workers are especially prone to back, neck, knee, and shoulder injuries (Table 2).

Table 2. Manufacturing accidents in 2021

Accidents	No. of Accidents	Percentage (%)	Accident intensity	Hours Lost
Fall from height	3	15.00	1	5
Burn	6	30.00	5	17
Slip/Trip/Fall	5	25.00	5	13
Electrical burn/shock	5	25.00	1	9
Struck by object	1	5.00	3	9
Total:	20	100.00		53

Final Construction

The common accidents incurred during the last phase of the construction process of steel buildings were as follows:

1) Falls

Slips, trips, and falls accounted for 23 percent of all injuries in 2014/15, accounting for the majority of work-related injuries in construction. Although it is unsurprising that construction sites have uneven surfaces and unstable terrain, it is surprising that so many accidents occur when so many could be avoided.

2) Materials and harmful objects

Construction necessitates the use of numerous tools and materials, many of which can be hazardous to workers. Failure to use PPE correctly, or using damaged or inadequate PPE, can expose workers to hazardous materials such as asbestos, as well as a long-term risk from dust particles (emanating from plaster, brick, stone, cement).

3) Overexertion

Manual handling injuries continue to injure workers as a result of poor lifting item selection, lifting heavy items too frequently, and poor postures. Manual handling and body stress can occur as a result of prolonged sitting, long hours behind the wheel, and performing manual and physical tasks.

4) Electrical burn/shock

Electrical shocks and burns are very common in the steel construction sector during final installation of a steel building. In the Table 3 the accidents activities at Hexagon Construction are presented.

Table 3. Construction accidents in 2021

Accidents	Number of Accidents	Percentage (%)	Accident intensity	Hours Lost
Fall from height	4	17.39	5	13
Burns	6	26.09	5	17
Slip/Trip/Fall	5	21.74	5	9
Electrical burn/shock	4	17.39	1	1
Struck by object	3	13.04	3	8
Overexertion	1	4.35	2	7
Total	23	100.00		55

Ergonomic evaluation calculation

In Table 4 the time lost due to the number of accidents in "Hexagon Construction" company is presented.

Table 4. Number of accidents and calculated total lost time

Process	Hours	Number of accidents
Material handling	41	22
Packaging		
Manufacturing logistics	37	20
Final Construction	55	23
Total lost time	133	65

The following calculation is based on yearly data (01-01-2021 to 31-01-2022).

- Number of reportable accidents = 65
- Total number of lost man days = 133/8 = 16.625 days
- Total number of working days = 63 x 312 = 19 656 Days

- There are a total of 63 employees, including contractors and visitors.
- Total cumulative number of hours worked = $63 \times 312 \times 8 = 157\,248$ Hrs (19 656 days)
- Total cumulative number of lost hours = $63 \times 16.625 \times 8 = 8\,379$ Hrs (1 047 days).
- Accident rate = (number of reportable accidents) divided by employee count = 1.03
- Accident Frequency rate = $1 - (\text{Number of reportable accidents} / 100 / \text{Man hours worked}) = 0.67$

Economic value of lost time

This economic valuation of lost time calculates the financial value of time lost due to injuries that occurred. This information was extracted from company documents and also from models calculated earlier on.

Table 5. Economic evaluation of lost time

Cost category	Explanation for calculations	Unit	value	Final cost value (PLN)
Lost man time		23pln/hr	23 x 8379	192,717.00
Cost of project delay	6 projects were delayed		1,617,389.00	1,617,389.00
Medical cost	treatment and replacement		18,500.00	18,500.00
Other cost	accident reactive activities		12,000.00	12,000.00
Total				1,840,606.00

Table 5 shows that the company lost 1,840,606.00 PLN due to ergonomic related lost time. The total cost was derived by calculating the following aspects:

- Lost man time: the economic value of lost time was calculated by determining the amount of money that was disbursed through salaries to no active employees as a result of injuries leave.
- Cost of project delay: lost time due to occupational accidents amounted to 133 hours and in addition to this cost 4 projects failed to finish on time with 2 projects failing to kick start. This led to a loss of 1,617,389.00 PLN which amounted to the highest amongst other failed activities.
- Medical cost: the totalled all the cost that the company paid in medical bills for injuries incurred during the construction process.
- Other cost: this cost includes costs of replacements, re-training, and other post-accident expenses.

Company behavioural examination

As an intervention plan the aspect of economics was assessed using the check list presented in Table 1S. The check list evaluated the company’s preparedness in terms of safety and gives an overview on how the aspect of ergonomics is generally viewed by showing how the company has invested in worker safety at all construction sites.

The primary objective of the ergonomics survey was to review current practices and demand for training in the following areas:

- employee orientation and skills training,
- site inspection consistency,
- occupational health and safety communication logistics,
- specific ergonomics valuation.

Employee orientation and skills training:

Orientation of employees before a construction project is mandatory but the key issue to evaluate is the importance that the construction company gives to this process. This objective evaluates how much the company invests into employee orientation with focus on the ergonomics side. Ergonomics training can be time consuming and expensive that some companies prefer to save by vaguely training employee. The aspects which were evaluated by the researcher during oral discussive interviews were:

- Has the company hold site induction meetings?
- How often is the company in contact with occupational health and safety coordinator?
- Does the company verify meeting as required by occupational health and safety before issuing a permit to proceed?

Site Inspection consistency:

This aspect was meant to view the importance of ergonomics through assessing how the Case company economically incorporate work safety activities through investing in ergonomic awareness campaigns. Such questions were asked in the discussive interview:

- Are periodic Inspections carried out at the sites?
- Does the contractor, in addition to imposing requirements, help achieve a higher level of safety?
- Does the general contractor assume more responsibilities for occupational health and safety of subcontractors?

Occupational Health and Safety communication logistics:

Ergonomics communication logistics is also vital as it aims to assess the feedback efficiency which in turn exposes the company’s attitude towards safety measures. To assess this aspect the following questions was used in the interactive interview with site managers:

- Are periodic Inspections carried out at the sites?
- Has the contractor verified the personal records of employees (medical examinations, safety training, licences, qualifications)?
- Are periodic inspections results communicated?

Specific Ergonomics valuation:

This objective was meant to determine the value ergonomics if given through financial support by the company. This was assessed by asking the following questions during the assessment:

- Does the company extant sub-contractor with occupational health and safety requirements at the bidding stage?
- Are they possibilities to improve occupational health and safety by improving co-operation with all stakeholders?
- Does the general contractor assume more responsibilities for occupational health and safety of subcontractors?

Procedure:

The procedure for completing this check list was done at six construction sites and the check list was completed through interviewing Site-Managers. The researcher then completed the questionnaire during the interactive interviews held with each site manager at the construction site. The site managers were meant to offer reliable information as they are the ones who manage the day-to-day operation at the construction sites. They are also the bridge between the company management to construction workers and can provide the relevant information on the company's attitude towards ergonomics in respect to economics.

Impact of ergonomics Intervention of company economics

The purpose of triangulating the ergonomic cost analysis with the on-site interactive interview was to determine the source of the high losses of ergonomics and then make a simulation model on the potential economic impact of introducing a new Safety and Occupation plan.

Intervention measure and cost

Table 6 shows the areas of intervention and the annual cost of the intervention.

Table 6. Intervention measure and cost per annum

Element	Comment	Value (PLN)
Safety training	Per employment training and continuous retraining	18 120
Acquisition of PPE	PPE for the 63 employees with constant replacement	143 000
Medical insurance	NFZ for all employees	82 600
Site inspection	Safety inspection at every stage of construction	24 500
Safety staff	6 employees working as Occupation and health Safety personnel	36 820
Other	Includes all accidents prevention method and procedure	20 000
Total		324 440

4. Summary and Conclusions

The conclusion is based on the thesis finding that are in line with the objectives. The objectives of this thesis was to:

- present the ergonomic findings,
- describe Ergonomic cost calculation mainly by as a result of down time due to accidents and incidents,
- determine the company's behaviour and attitude towards safety,
- evaluate impact of economics of ergonomics intervention.

Presenting the ergonomic findings

This objective listed all recorded accidents and accidents sources in the network of construction logistics. Using "Hexagon Construction" company as a reference it was noted that workshop activities had the greatest incidences and accidents rate compared to the other sectors in the construction logistics network.

According to data collected from the reference company pertaining to accidents and incidents recoded in 2021 it show that slips trips and fall accounted for over 25% of all accidents.

Ergonomic cost calculation mainly by as a result of lost time due to accidents and incidents

The final results of the lost time due to ergonomics related accidents and incidences are presented in Table 7. The total cost also incorporated all costs such as delays, lost contracts and medical bills that were incurred.

Table 7. Summary of value of lost time

Aspect	Value
Reported accidents	65
Total annual lost hours	157 248 Hrs(19 656 days)
Accident frequency rate	0.67
Total cost	1 840 606.00 PLN

Lost time due to occupational accidents amounted to 133 hours, with an additional cost of four projects failing to finish on time and two projects failing to begin. This resulted in a loss of 1,617,389.00 PLN, the highest among failed activities.

Determine the company's behaviour and attitudes towards safety

In summary its was observed that the company places little emphasis on accident preventions. They prefer to use the reactive approach when dealing with ergonomics aspects. They also do not have or strongly observe ergonomics practices. The company needs to reveal their culture in terms of approach to ergonomics aspect as it lacks particularly in area like:

- pre-employment health and safety induction training,
- carrying out routine and periodic safety inspections,
- verification of employee documents particularly medical insurance related paperwork,
- effective issuance of PPE,
- conducting management health and safety planning and assessment.

Evaluate impact of economics of ergonomics intervention

In summary the cost of innovation with respect to adopting new and improved ergonomics management measures required 324 440 PLN per year. This calculation was made based on a simulated theoretical model using events for the year 2021 were the company lost 1,840,606.00 PLN. Therefore, with proper ergonomics management, the company would have gained (1,840,606.00 - 324 440.00) PLN = 1 516 166.00 PLN.

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SUPPLEMENTARY MATERIALS

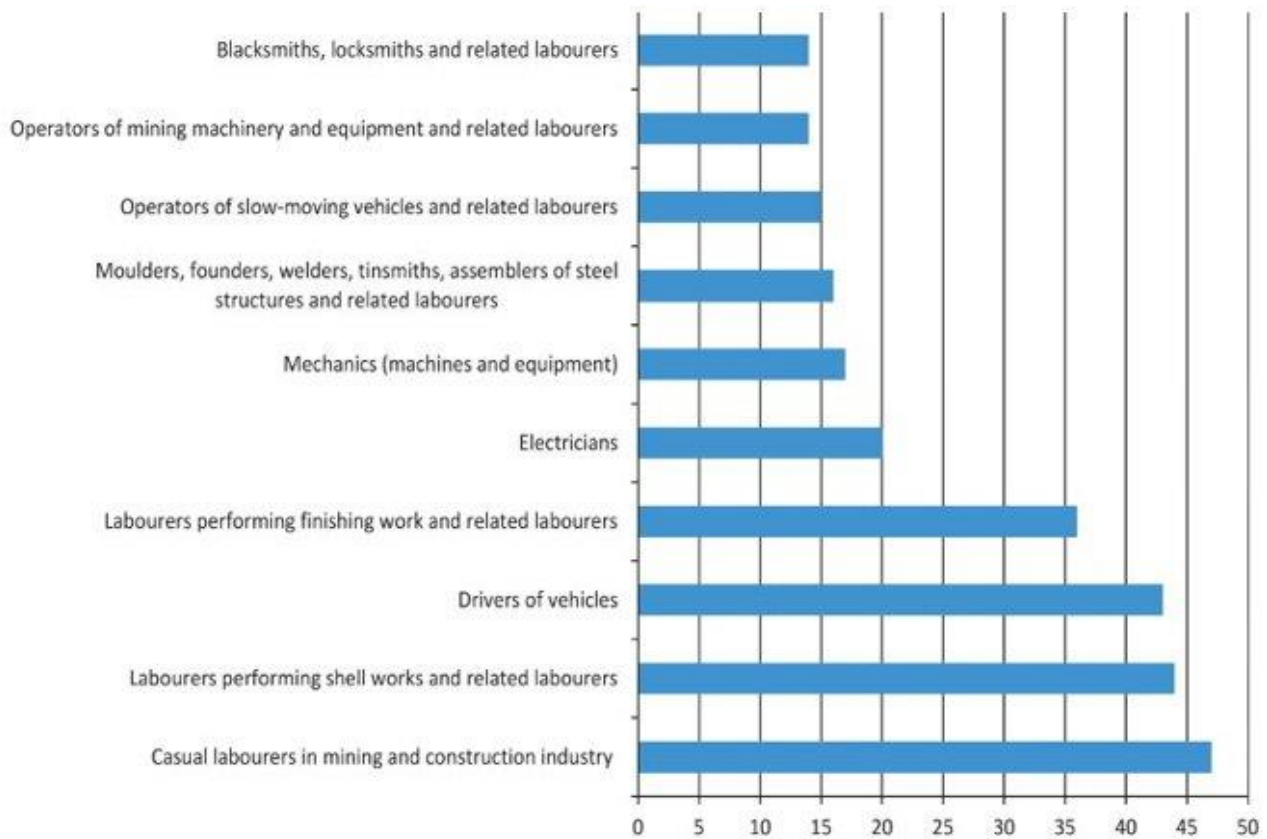


Figure 1S. Victims of fatal accidents in 2011 in Poland by occupation (%)

Table:1S. Results of interactive interview

Research Questions	Score	Researcher's remarks
Has the company held site induction meetings with?	3	The site inductions are done for job orientation and conducted by under qualified employees.
Are periodic Inspections carried out at the sites?	4	No Inspections are done at all
Has the contractor verified the personal records of employees (medical examinations, safety training, licences, qualifications)?	3	No thorough verification is done
Are periodic inspections results communicated?	4	No safety inspection records are kept
Does the contractor, in addition to imposing requirements, help achieve a higher level of safety?	3	The employer only intervenes after an accident has occurred
How often is the company in contact with occupational health and safety coordinator?	4	The company has little priority on safety
Does the company supply sub-contractors with occupational health and safety requirements at the bidding stage?	5	The agreements only exist on paper and are put into action
	2	The main contacts they have are reactive contacts to use only after an accident has happened
Are there possibilities to improve occupational health and safety by improving co-operation with all stakeholders? (Manager)	1	The opportunity for improved is highly available and the management is also willing to change
Does the function of occupational health and safety coordinator have a practical importance to improvement of the state occupational health and safety? (Management view)	3	Currently the influence is minimum but can be improved with time after the intervention

建筑物流中的人体工程学与经济学：“Hexagon Construction”公司的案例研究 在波兰

關鍵詞

人体工程学、
经济学
施工事故
安全工作

摘要

本研究的目的是分析建筑行业人机工程学和经济学方面的关系。人体工程学成本计算主要通过因事故和事故造成的停机时间进行评估。还确定了人机工程学干预对物流网络中建筑经济的影响。使用 2021 年的年度事故总数来模拟这种影响。组织，尤其是企业，必须实施人体工程学诊断措施，以减少其供应链中的职业危害和事故。实施人体工程学措施以减少和消除工作场所事故，但大多数制造公司和雇主忽略了这一方面，因为它被视为一种费用。案例研究是在 Hexagon Steel Construction 公司进行的。这是因为这样的业务操作员负责物流网络中的广泛活动，从制造到仓储和配送，最后到施工现场的最终结构安装