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Construction and application of an indicator system to assess the ergonomic performance of large and medium-sized construction companies

Isabela Xavier Barbalho Bezerra[a] and Ricardo José Matos de Carvalho[b]
[a] *Masters student in Production Engineering, GREPE, UFRN, Campus Universitário, Lagoa Nova, Natal, RN, Brasil.*
[b] *Doctor in Production Engineering, Professor of Production Engineering, GREPE, DEP, PEP, UFRN, Campus Universitário, Lagoa Nova, Natal, RN, Brasil.*

Abstract. This article proposes a system of indicators to evaluate the performance of companies in ergonomics for buildings. The system was developed based primarily on studies related to the performance evaluation of the construction industry and on Brazilian standards of ergonomics and work safety and had also the contribution of national and international indicators related to ergonomics, work safety, quality, sustainability, quality of work life and to organizational behavior. The indicators were named, classified and their components were assigned to compose the theoretical model SIDECE – System of Performance Indicators in Ergonomics for Building Construction (as for the Portuguese acronym), serving the major goals of ergonomics: health, safety and workers' satisfaction and production efficiency. The SIDECE is being validated along with the building construction companies in the city of Natal, Brazil, whose practical results, deriving from the application of instruments to collect field data, are under process, to be presented on the occasion of the 18th World Congress on Ergonomics. It is intended that the SIDECE be used by building construction companies as a support tool for excellence management.

Keywords: Ergonomics, Indicators, Performance, Building construction, SIDECE.

1. Introduction

The Brazilian construction industry, particularly the sector of building construction, has no system of performance evaluation that takes into account the binomial production and health. Ergonomics seeks to equate their goals in aspects of production and health [1], with an understanding that the workers' safety and health are factors of production and that the way of production creates an impact on the workers' health, safety and quality of life.

This article aims at presenting the theoretical model SIDECE – System of Performance Indicators in Ergonomics for Building Construction, which was developed to evaluate the performance of companies in ergonomics for large and medium-sized buildings in the city of Natal. The development of this system occurred from a literature review and was based on regulatory standards for ergonomics (NR-17) and civil construction (NR-18) in Brazil, isolated indicators, systems of sustainability indicators, quality of work systems of indicators and general and specific systems of indicators related to organizational performance for the construction industry.

It appears that the main systems available to evaluate the performance of organizations neglect many aspects of the scope of ergonomics. This gap imposes a partial understanding by managers of organizations with respect to their performance, which could compromise their strategies, survival and longevity and unnecessarily burden the organization.

The development of SIDECE adopted the following process: identification of indicators and standards available in the literature, selection of relevant indi-

cators, creation of new indicators, classification of indicators, appointment of indicators and assignment of the indicators components.

The goal is that SIDECE indicators enable managers of construction sites to develop a diagnosis of the level of expertise in ergonomics of the companies, as these indicators allow the items of absence or scarcity of ergonomics to be identified and permit to establish an ergonomic program of actions based on them.

2. Civil construction industry in Brazil

The civil construction companies in Brazil face a situation of strong expansion of the buildings construction market, encouraged by the housing program "Minha Casa Minha Vida" ("My House My Life") from the Federal Government of Brazil, with the approach of two of the major sporting events in the world (the 2014 FIFA World Cup and the Olympics in 2016), and by the intense competitiveness of the sector, in which factors related to quality and prices of buildings are crucial.

The quality of the buildings and the sale price of the units have to do with the rational management of construction processes and manpower.

Historically, the civil construction industry in Brazil, specifically in the building sector, is regarded as producing high levels of waste and work accidents. However, there are no reliable overall indicators of waste in the sector, although there are systems of specific performance indicators developed and applied in some companies, in a local way, that function by assisting the management system.

The official statistics of work accidents in Brazil are not reliable, since there is underreporting of such events by the construction companies. Despite the underreporting, in 2009 the construction industry figured as one of the sectors with the highest number of accidents in Brazil, with a total of 54,142 accidents, or 7.48% of all work accidents at national level, only behind the sectors of Trade and Repair of Motor Vehicles (98,096; 13.56%), Food and Beverage Industry (66,554; 9.20%) and Health and Social Services (57,606; 7.96%) [2].

The building construction sector in Brazil lacks a global system of indicators that will enable the companies to obtain a diagnosis that encompasses both performance factors related to technical system and human factors.

3. Measurement systems of organizational performance

The available systems of performance indicators, such as the Balanced Scorecard (BSC), among others, are strongly focused on aspects related to organization and technology, but little attention is given to personnel or human factors, so that measuring the organizational excellence from these settings will result in a partial diagnosis, not as accurate as a new configuration that also incorporates the human factors adequately.

"The measurement system strongly affects the behavior of people inside and outside the company. If you want to survive and thrive in the information age, companies must use systems of management and performance measurement derived from their strategies and capabilities [3]."

A technical and scientific literature does not have specific indicators of ergonomics for building construction, i.e., there is not a system of indicators to evaluate the ergonomic performance of organizations and especially the ones of the building construction industry.

"For the ergonomic practices to find shelter in organizations in the form of systematic practice, it is necessary, fundamentally, the identification and definition of 'ergonomic' indicators," argues [4].

From the mid-1980s, in the construction industry there was a growing interest in quality management and, consequently, the implementation of measurement systems. This move reflected the emphasis that was given to quality in other sectors of the economy and throughout the world, but also resulted from changes that were affecting the industry, among which stood out: the globalization of the economy, the shortage of construction funds, greater demands from customers about the quality and standard of buildings and also a greater degree of organization and manpower claims.

4. (Macro)Ergonomics

"Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance" [5].

Ergonomics as an area of professional practice is as a space where "professionals apply the technology of human-system interface for the design, analysis,

testing and evaluation, standardization and control systems. The overall goal of the discipline is to improve the human condition, including health, safety, comfort, productivity and quality of life" [6].

For [7] Hendrick and Kleiner, "macroergonomics deals with the analysis and design of work systems."

Ergonomics, therefore, is concerned with optimizing work systems, taking into account the economical (quality, production, productivity, efficiency, effectiveness) and health aspects (work accidents, work diseases, work absenteeism, workload) as a whole. This involves the knowledge of proactive and reactive indicators in organizational, technological and personnel aspects, which express the investments made, the actions taken and the human and material impacts generated by the work system.

5. Materials e methods

This research has an applied nature, for it aims to generate knowledge for practical application aimed at solving specific problems and involves local interests and truths [8].

5.1. Location and scope of the study

This research is being applied to large and medium-sized building construction companies in the city of Natal, Brazil.

According to the Brazilian Chamber of Construction Industry (CBIC – as for the Portuguese acronym), the conceptualization by the number of workers employed in working companies in the industry of construction sets the size of these companies.

"The use of this criterion is justified because this is the most prevalent one in most law systems, government agencies and research institutions in the country" [9].

The ranges of size classification of enterprises adopted by CBIC, according to the number of employees, are as follows:

a) up to 19 employees – Microcompany;

b) from 20 to 99 employees – Small Company;

c) from 100 to 499 employees – Medium-sized Company;

d) 500 or more employees – Large Company.

Therefore, this research covers building construction companies that have 100 (one hundred) or more employees.

According to the website of the Federation of Industries of Rio Grande do Norte (FIERN), there are two large companies and 34 medium-sized companies in building construction in the city of Natal, state of Rio Grande do Norte. [11] (FIERN).

5.2. Applied Research: Development of SIDECE (Modeling Process)

To develop the System of Performance Indicators in Ergonomics for Building Construction (SIDECE) proposed here, there was a literature research to find the key indicators and understand how they could be used to improve the performance of organizations.

There was a selection of relevant indicators to the ergonomic study in question, taking into consideration the possible applicability and help improving the management of the construction of multifamily buildings.

The development of SIDECE had as reference the following individual indicators or systems of indicators:

- The System of Indicators for Quality and Productivity in Civil Construction – SISIND [11];
- The System of Indicators of Performance for Production Management in Residential Edifications Enterprises [12];
- The existing indicators on the Norm of the Ministry of Labor and Employment nº 18 [13] – NR-18 (Work Conditions and Environment in the Construction Industry);
- The existing indicators on the Norm of the Ministry of Labor and Employment nº 17 [14] – NR-17 (Ergonomics);
- The Indicators of Ergonomic Costs established by studies on Macroergonomics [7];
- The Indicators proposed by Nogueira [4] ;
- The Measurement Scales of Organizational Behavior [15];
- The Indicators of Competences Management [16];
- The Indicators of [17] Gross National Happiness;
- The Indicators of Quality of Life at Work [18];
- The indicators in Brazilian Norm nº 14280:2000 [19], from the Brazilian Association of Technical Norms (ABNT);
- The OHSAS 18001:2001 [20] – Occupational Health and Safety Advisory Services.
- The Work Safety Indicators [21];
- The Global Reporting Initiative (GRI) [22], Sustainability Report.

The knowledge of these indicators or systems of indicators was essential, because it allowed a mapping of the key indicators and existing systems and facilitated the process of developing a system of specific indicators, proper and adequate to the main goals of ergonomics, oriented to buildings construction, as proposed by the SIDECE presented here.

5.3. Steps of the indicators development

The development of SIDECE had the following steps:

1) *Studies and exploratory research:* in this phase of SIDECE development, literature, documents and regulations researches were conducted, in order to clearly define the scenario in which the performance indicators were included, what are the main authors and documents that focused on the subject and what indicators and systems of indicators are better known and used in construction and other economic sectors, as well as ergonomic aspects that suggested the construction of the indicator.

2) *Selection of isolated indicators and systems of indicators and creation of new ones from the exploratory research:* this phase was composed of mapping, analysis and definition of indicators relevant to SIDECE, according to their relevance to ergonomics and building construction. New indicators were also created from these ergonomic norms and suggested the construction of the indicator.

3) *Classification of available systems and indicators in categories:* in this phase, we established categories of ergonomics, to which each selected indicator would be allocated. The categories of established ergonomics for the classification of the indicators were: the External Environment or Context; Environmental conditions of work; Work efficiency; Machinery and Tools of work sites; Work sites furniture; Work organization; Workers' satisfaction; Workers' Health and Safety; and Transportation of materials.

4) *Modeling of SIDECE Indicators*: setup of required components of each indicator selected for the system as well as methods of data collection and/or formula calculations for each one, which constituted a protocol for collecting performance data, necessary for the attainment of indicators, called SIDECE Model.

a) Modeling 1 – development of conceptual *General SIDECE Model* (table 1);

b) Modeling 2 – development of *Detailed (operational) SIDECE Model*: this model was developed and concerns the data collection instrument in building construction companies, which are part of the performance indicators. This instrument will undergo its first changes, from the results of the research which is in progress (section c below) and possibly different changes will take place after testing, from which the instrument will be definitely applied;

c) Research for exploration and verification of acceptance and managers' opinions (civil engineer, engineer work safety and safety technician) based on the generic model: before heading for testing, validation and application of detailed direct SIDECE Model (Modeling 2, letter b), it was decided as a precaution, to consult these professionals as to whether they produced indicators, what these indicators were and what was, in their perception, the relevance and applicability of the indicators that had been anticipated in the SIDECE Model. For such, we developed a specific tool called "Preliminary protocol to map the SIDECE indicators in the organization", composed of two tables to be filled by the managers. These tables are structured as follows:

Table 1: Name of indicator; Purpose of the indicator; The manager uses this indicator; Reason to use or not the indicator; Suggestions.

Table 2: Name of indicator; Purpose of the indicator; Classify the importance of the indicator (1-unimportant, 2-little important, 3-undecided, 4-important and 5-very important); Justify the choice.

5) Testing: concerns the phase designed to test the detailed SIDECE Model tool.

6) Application: direct research phase, corresponding to the collection of field data in order to produce performance indicators, using the instrument tested.

7) Data processing and analysis of the results: phase of the survey responses, when the results of the indicators collected in the field will be processed and analyzed. In this phase various types of responses will be generated, such as: comparisons between works/construction companies, the appearance or non-appearance of a construction company in which its processes will be ergonomically models for the other ones in market; discussions and debates may be initiated; several graphics and tables will be generated; among many other results.

6. Proposed SIDECE Model

6.1. General SIDECE Model

Table 1 shows the generic SIDECE model, composed by the considered relationship of categories (column

1), by the indicators themselves (column 2), by the form or data collection instrument (column 3) and by their classification as to the opportunity to use the indicator (column 4).

Table 1

SIDECE Indicators

Category of Indicators	Indicators	Form or instrument of Data Collection	Classification (Proactive or reactive)
External environment or context	• Evaluation of suppliers and contractors	Form	Proactive
	• Degrading Impacts of production to the environment	Form	Proactive
	• Indicator of external pressures over the company	Form	Proactive
	• Index of customer satisfaction	Formula	Proactive
Environmental work conditions	• Good practices in logistics and worksite layout	Form	Proactive
	• Volume of generated waste	Formula	Proactive
	• NR-17 indicator of adequacy to environmental conditions on worksites	Checklist	Proactive
Work efficiency	• Efficiency in autonomous units sales	Formula	Proactive
	• Average productivity of each employee	Formula	Proactive
	• Rate of production errors	Formula	Reactive
	• Rate of activities that do not add value to the product	Formula	Reactive
	• Overall work productivity	Formula	Proactive
	• Rework index	Formula	Reactive
Worksite machines and tools	• Total maintenance cost	Formula	Proactive
	• NR-17 Indicator of machinery and tools adequacy on worksites	Checklist	Proactive
	• NR-18 Indicator of machinery and tools adequacy on worksites	Checklist	Proactive
Worksite furniture	• NR-17 indicator of furniture adequacy	Checklist	Proactive
	• Number of departures due to ergonomically inappropriate furniture	Formula	Reactive
Work organization	• Repair and replacement of material cost	Formula	Reactive
	• Cost on assistance to the insured	Formula	Reactive
	• Total cost	Formula	Reactive
	• Costs for the period of removal	Formula	Reactive
	• Compensation received by the company	Formula	Reactive
	• NR-17 indicator of adequacy to work organization	Checklist	Proactive
	• OHSAS 18001 indication of adequacy to work organization	Checklist	Proactive
	• Indicator of employee satisfaction with coworkers	Scale	Proactive
	• Indicator of employee satisfaction with supervisors	Scale	Proactive
	• Indicator of psychological overload	Form	Proactive
	• Indicator of organizational performance according to their collaborators	Scale	Proactive
	• Improvements in work process and technology	Form	Proactive
	• Number of conditions of insecure environment by sector/workplace	Formula	Reactive
	• Absenteeism rate	Formula	Reactive
	• Turnover rate	Formula	Reactive
	• Training rate	Formula	Proactive
	• Total of investments in ergonomics actions	Formula	Proactive
	• Total workforce by employment type, employment contract and region	Formula	Proactive

	• Monetary value of significant fines and total number of non-monetary sanctions for non-compliance with laws and regulations	Formula	Reactive
Workers Satisfaction	• Actions that enable the contributor a good quality of life	Form	Proactive
	• Indicator of employee's trust towards the organization	Scale	Proactive
	• OHSAS 18001 indicator of adequacy to work safety	Checklist	Proactive
Workers Health and Safety	• Statistics of occupational diseases to occupational activities	Formula	Reactive
	• Statistics of occupational diseases by occupational activity	Formula	Reactive
	• Incidence of unsafe acts by man/hours worked	Formula	Reactive
	• OHSAS 18001 indicator of adequacy to work satisfaction	Checklist	Proactive
	• NR-18 indicator of adequacy to workers' health and safety	Checklist	Proactive
	• PCMAT indicator of adequacy to workers' health and safety	Form	Proactive
	• Rate of personal factors of insecurity	Formula	Reactive
	• Number of medical care by workers	Formula	Reactive
	• Average number of days charged due to permanent disability	Formula	Reactive
	• Average number of days lost due to total temporary disability	Formula	Reactive
	• Percentage of impersonal species accidents with higher incidence	Formula	Reactive
	• Percentage of impersonal accidents	Formula	Reactive
	• Percentages of injury sources with higher incidence	Formula	Reactive
	• Percentage of personal accidents	Formula	Reactive
	• Percentage of types of personal accidents with higher incidence	Formula	Reactive
	• Frequency rate of accidents with removal injuries	Formula	Reactive
	• Frequency rate of accidents with injuries without removal	Formula	Reactive
	• Average time computed	Formula	Reactive
	• Accident severity rate	Formula	Reactive
Transportation of Materials	• Material circulation index	Formula	Proactive
	• NR-18 indicator of adequacy to loading, transportation and unloading of materials	Checklist	Proactive
	• NR-17 indicator of adequacy to loading, transportation and unloading of materials	Checklist	Proactive

6.2. Detailed SIDECE Model

All forms and instruments of data collection (column 3) to obtain the indicators have been developed and constituted an operational protocol called (detailed) "SIDECE Model".

The detailed SIDECE was structured with 6 (six) categories of indicators components, taking as reference the systems of indicators listed in item 5.3 of this Article:

Category 1: Name of indicator
Category 2: Goal/Objective
Category 3: Form of data collection
Category 4: Time of data validity
Category 5: Variable(s) of reference
Category 6: Responsible professional

On Table 2 it is presented an indicator and its respective categories.

Table 2

An example of Indicator according to the detailed SIDECE model

Name of indicator	Goal/Objective	Form of data collection	Time of data validity	Variable(s) of reference	Responsible professional
Percentage of production errors	Check the amount of errors when constructing an edification unit (tower or building) and calculate the percentage of errors corresponding to each step of the work	E(%) i = NEi / NET E(%): Percentage of production errors NEi: Number of errors found on the "i" phase when constructing a unit NET: Total number of errors when constructing a unit	The data regarding the amount of errors must be frequently collected during the work, but the percentage can only be calculated at the end of a constructed unit	Ergonomic costs	The data collection can be done by trainees. The analysis and disclosure must be done by the production manager

7. Discussions

The SIDECE consists of proactive and reactive indicators, and it can be widely applied in building construction companies. This system will be applied in large and medium-sized building construction works in the city of Natal-RN.

During the development of the survey, we realized that indicators of ergonomics need to be integrated with every part of the company. To apply these indicators the company must be willing to properly inform the data needed for research.

The participation and collaboration of the company's employees are of fundamental importance to have an effective SIDECE.

We conclude that in order to establish real changes in the workplace it is necessary to establish in the company an "Organizational Culture in Ergonomics." The mandatory conducts have to be inserted not only in the process, but must also compose the whole culture of the organization.

The research developed to elaborate this system of indicators aimed at contributing to the maturation of the building construction industry, by integrating socio-technical criteria [7] for the construction of indicators that will help in the analysis and management decision-making of companies in this industry.

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