



Analysis on Feasibility and Technology Transfer in Civil Construction: Capability Matrix in Conjunction with Ergonomic Strategies

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Conflicts of interest

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Abstract

Technological changes brought a need to review the architecture of operational activities, and it was up to ergonomics to turn to what would be called “external variables”, technological variables and sociological variables. The objective of this research is to build and test a tool that can guide the strategic actions of Ergonomics as to evaluating the feasibility of projects, in the operational phase, as well as in the technology transfer that these projects may present. For this work, the Methodology used was divided into two parts: building of the research portfolio and building details as to the Project Feasibility Analysis model. Based on the results found through the development of a tool to guide Ergonomics, by means of the operational feasibility of the project, in combination with technology transfer, a tool called Capability Matrix was built, which proved to be flexible and efficient, having a greater potential compared to that of its initial design. This investigation leaves as a perspective for future works the application of the matrix to other civil construction activities, in addition to enabling technology transfer to other activities belonging to civil construction and the industry in general.

Keywords: Technology transfer, Anthropotechnology, Feasibility Analysis, Civil Construction.

1. Introduction

Ergonomics, in its initial phase, was concerned with adjusting work instruments and equipment to man with a view to providing greater comfort at work and productivity. It was a great evolution compared to previous phases, when man needed to adjust to equipment. (Kiel et al., 2017).

After that initial phase, ergonomics expanded its area of operation when it turned its attention to other factors that also generate greater comfort and productivity for workers, such as lighting, ventilation, temperature, etc. Now, at the end of the 20th and beginning of the 21st century, the new area of expansion has reached what can be called “social conditions” of work, more difficult and complex (Csáfordi et al., 2020).

At least two elements are behind this evolution. They are: a) rapid change in the architecture of the organizations themselves and in their spaces and production processes; and b) the great interdependence of different organizational actors so that organizational products, whether tangible or not, can be built.

Said elements, in some way, boosted the need to readjust both the organizational culture itself, which now needs to focus on sustainable development, as well as its mental models, such as the individual and collective knowledge of those involved in the process. A third element, however, has acted strongly on the speed of the evolution of operating processes. It is what can be referred to as a change in the nature of productive structures. During the Fordist era, organizations were usually structured from the segmentation of activities called “departmentalization” (Luz et al., 2016).

Currently, these structures have had to become more flexible to remain competitive (in the private sector) or to be effective (in the public sector). This flexibility has transformed departmentalized organizations into a “collection of processes” or a “project workshop”. The situation of collection of processes broke the departmental structure, integrated different organizational areas and created the need for what is known today as “process management” as well as “process manager”. However, it is the organizational structure of the

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project workshop that requires the organization as a whole to develop the capability to permanently reinvent itself.

In parallel, funding agencies also have some models describing minimum elements that need to be included in the projects, which are useful when the organization is migrating to the “project workshop” organizational architecture. All of them have, nonetheless, in different ways, three stages: a) market feasibility analysis (MFA); b) operational feasibility analysis (OFA); and c) financial and economic feasibility analysis (FEFA). In some situations, these stages are more interconnected, especially when a draft is prepared, while, in other situations, they are less interconnected, in which cases there are actual stage closure protocols.

The important thing here, in project workshop organization, is that ergonomics needs to participate as the main actor in the second analysis (OFA). It can and should participate in the other stages, depending on the project type, but it really needs to participate intensely in the operational analysis phase.

When this participation occurs, ergonomics collaborates, in the ideal situation, in two systemic processes within the OFA. They are: a) the internal one, which analyzes “how” the process and its man-technology and man-man interactions will work; and b) the external one, which more specifically analyzes the implications with the other phases of the project, that is (OFA – MFA and OFA – FEFA). In this internal assessment, it is important to analyze the different forms, technologies and equipment with what can be called here the capability, culture and values of the people involved in the operational processes.

Therefore, both physical and emotional/psychological elements need to be taken into account, which considerably increases the complexity of the ergonomic element of the OFA.

Knowing that any significant technological change generates a need to review the architecture of operating activities, ergonomics needs to dedicate itself to what will be called “external variables”, which can be grouped into two sets of variables: a) technological variables, which are related to the management of organizational technology; and b) sociological variables, which are related to the management of social organization. There is thus a complex system with four sets of variables that are permanently inter-influencing over time.

At the same time, it is up to ergonomics to conduct the process and its course before and after the implementation of the change, generating and providing opportunities for the development of different capabilities. That said, this study will focus on the ergonomic strategy of designing and then developing what will be called capability here.

When the object of ergonomic analysis is the civil construction sector, the complexity is even greater, due to the characteristics of the processes and their sequencing, as well as the specificities of its organizational products.

Thus, the objective of this work is to build and test a tool that can guide the strategic actions of Ergonomics as to evaluating the feasibility of projects, in the operational phase, as well as in the technology transfer that these projects may present.

2. Theoretical framework

This chapter will work on three topics. They are: a) Ergonomics and workstation adaptation; b) transfer and evolution of civil construction technology; and c) factors for project feasibility assessment as to safety and ergonomics.

2.1 Ergonomics and workstation adaptation

The efficiency and success of the global civil construction industry depends on the well-being and workstation adaptation provided to employees at construction sites through technology developed in the various tools used during the execution of activities, and the integrated ergonomics in the evaluation of these activities (Zare et al., 2015; Falck and Rosenqvist, 2012; Santos et al., 2015).

By means of integrated ergonomics, constantly evaluating and monitoring the production systems at the construction sites of construction companies contributes to well-being, quality of life and the prevention of work-related musculoskeletal disorders (WMSD). These disorders, however, are still considered the main cause of occupational diseases in this industry (Turk et al., 2020; Henderson et al., 2018).

According to Speklé et al. (2010) and Zare et al., (2015) reports of work-related diseases had a considerable increase among civil construction workers, and the rise in costs with treatment through occupational health for companies was estimated at 40%. Forty-five million workers have been affected by WMSDs in Europe. In France, regarding occupational diseases in 2017, 91% of them were connected to WMSDs (López-Alonso et al., 2020).

For these high rates to decrease, an Ergonomics integrated with construction sites and adapting workstations to workers are important elements. To this end, it is necessary to focus on fighting diseases related to work in the construction industry, in combination with using suitable tools for each activity at a construction site.

According to Vujica Herzog and Harih (2020), Ergonomics is the appropriate field of science to explore and study the physical and mental capabilities of workers during their workday and to adjust their daily workload, considering the working conditions of each activity. With a suitable workstation design, it is possible to adapt the activity to be performed in accordance with the physical and mental human characteristics of workers and reduce or prevent adverse health effects.

A proper workstation design can, in theory, improve effectiveness and productivity, as well as the safety of workers while they carry out their jobs. The factors that influence stress at work can be divided into: a) work environment, with working conditions that involve noise, heat, humidity, lighting and air speed; and b) body postures, especially inadequate ones that can cause health problems (Ojstersek et al., 2020).

Now, by looking for the best adaptations of different operating workstations, ergonomics needs to seek what can be called “suitable design”, which, in its turn, is the function of at least two elements. They are: a) productivity (effectiveness); and b) safety and comfort for the operator of the activities. It is worth remembering that these two elements are desirable and important, both for the organization and its management, and for the workers themselves (Figure 1).

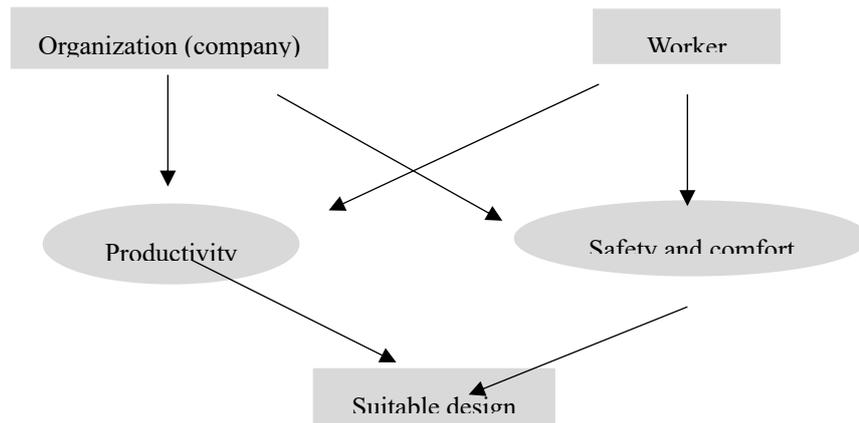


Figure 1. Focuses of Ergonomics

Still according to Ojstersek et al. (2020) and Zhang et al. (2019), for an effective workstation design, the following steps must be followed:

- a) subjective analysis of the workstation, followed by an assessment to define the basic characteristics of the workstation in question;
- b) analysis of the existing dimensions of the workstation, with regard to work postures and the perception of workers;
- c) workstation analysis, considering the work environment;
- d) accurate simulation of workers' positions and movements, if possible, using software for workstation analysis and design together with software for analysis on ergonomics and mechanical overload;
- e) use of different pieces of software for ergonomic analysis, such as: OWAS, RULA, NIOSH and OCRA checklist;
- f) proposals and suggestions for changes in the work procedure, based on the results of the ergonomic analysis.

As for the transfer of technologies and knowledge to work fronts, the organization must permanently deal with what will be here called Project Feasibility Analysis (PFA). It is at this moment that ergonomics changes, or can change, its status, as it is fundamental in one of the most important phases of PFA and in the evolution of the construction industry.

2.2 Technology transfer and evolution in Civil Construction

The civil construction industry is considered one of the oldest, but when it comes to technology evolution and transfer, it is one of the pioneers. On the other hand, concerning the evolution of Ergonomics and prevention of work-related diseases, the construction industry still has a lot to evolve (Zou et al., 2017).

This statement is in line with the fact that this industry is responsible for a large number of incidents related to workers' health. This problem oftentimes stems from the lack of perception of the workers involved in the several activities that make up this industry, as well as from the failure of companies in identifying the risks to which these workers are exposed (Mo et al., 2018). Other reasons can be presented to show how the

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construction industry is a complex environment for risk management, both in terms of ergonomics and technology transfer.

The construction environment has a particular nature, which includes difficult conditions in the workplace and lack of safety and ergonomics management practices, and the unpredictable and complex nature of the industry leads it to embrace new technologies in order to reduce these incidents as much as possible. In this sense, many tools can be put into practice, such as construction information modeling and other visualization tools that can help in the identification and evaluation of workstations, and in the management of ergonomic issues in a construction environment. (Shafiq and Afzal, 2020; Malekitabar et al. (2016).

Technology Transfer (TT) has proved to be crucial as part of the solutions to the problems that the construction industry faces in its different areas. TT is also deemed to be extremely important for economic development, and fundamental for the advancement of society and social well-being (De Laet and Mol, 2000, Rogers, 2010).

In addition to these factors, the various challenges that society faces, such as intense urbanization and maintenance of the high level of employability in the construction sector, can affect the latter as a whole. These factors, especially urbanization, presented as a global result, in the North American construction industry, a record investment of around 1.4 trillion dollars in 2018 (Brege, 2017, Deloitte, 2019, Uusitalo and Lavikka, 2020).

In addition, the effectiveness of TT depends on the following fact: meeting the criteria of the technology to be transferred, in compliance with the three main criteria that exist in several fields of science. They are: product, process and knowledge. They are not the only ones, however; anthropologists and sociologists consider people and culture as the fourth criterion, since both process-related and embedded technologies have no clear boundaries and are embodied in both products and processes, besides being strongly related to people themselves. In construction, TT occurs from one project to another, through a guided approach (Dubois and Gadde, 2002; Koskela, 2003; Uusitalo and Lavikka, 2020).

In order to transfer and implement technologies for the productive sector of civil construction, a thorough monitoring of all stages is necessary so that everything goes as planned; moreover, the people involved in this process must implement a methodology in a natural and direct manner, observing control points, as well as monitoring them (Silva et al., 2015).

To exemplify the evolution of TT in the construction industry, the development of house building technology in an industrialized way, technology dominated by Swedish companies, gives these companies a very large competitive advantage when entering new markets around the world (Pereira and Navarro, 2018; Uusitalo and Lavikka, 2020).

The construction platform that the technology is based on is governed by a complex of requirements that are defined on site, and by circumstances specific to the country where the project will be executed. The technology that companies that execute houses in the industrialized format are transferring is the platform of the product, with the latter being characterized by a high degree of standardization of materials and processes,

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and predictable networks of suppliers. In this way, the technology allows a company to offer houses in selected niche markets (Johnsson, 2013; Jansson et al., 2014; Uusitalo and Lavikka, 2020).

In this sense, TT can also be used as an ally in the management of ergonomic issues in civil construction, as shown in studies aimed at construction workers (Anton et al., 2020; Akanmu et al., 2020; Silva et al., 2020; Dutta et al., 2020; Peters et al., 2020; Hess et al., 2020; Katoch e Mohan, 2019; Rodriguez et al., 2019; Visser et al., 2018; Izobo-Martins et al., 2018), and can be put into practice using the four TT criteria.

Ergonomics management in construction companies can occur through the conceptual model of Technology Transfer (Figure 2).

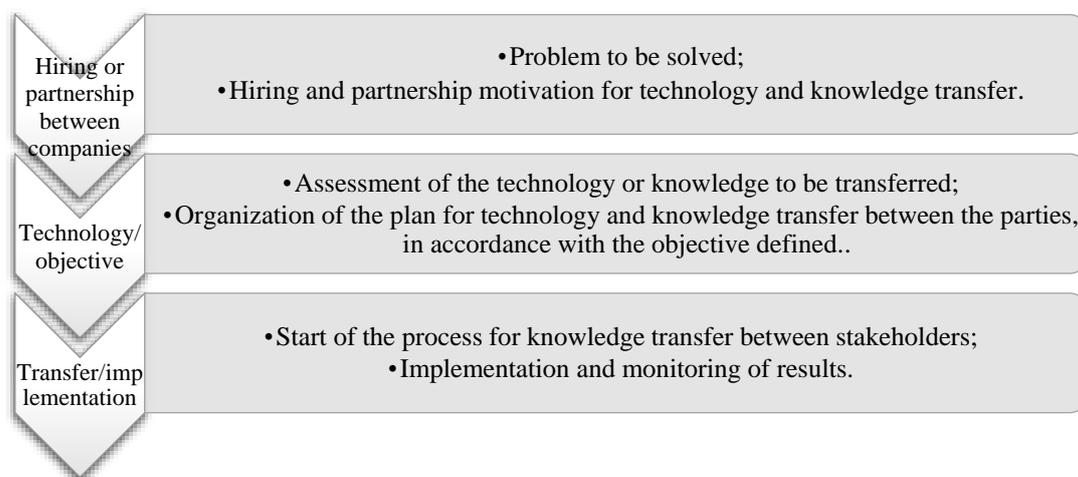


Figure 2. Conceptual Model of Technology Transfer

Ergonomics participates in the three steps of the Technology Transfer process – for instance, in a “technological change”. An analysis of change, for ergonomics, needs to assess feasibility in at least two areas. They are: a) real and potential knowledge of those involved; and b) mental model (function of culture) of those involved. These elements encompass what can be called “internal or individual variables”.

2.3 Project Feasibility assessment factors as to Safety and Ergonomics Projects

Projects, the way they are currently planned and executed, are defined by countless types of relationships (inter-organizational, intra-organizational, and interpersonal) with multiple dimensions (communication, friendship, power and social). Project relationships are also contingent and context-specific, and increasingly sophisticated. At the same time, they question the effectiveness of traditional approaches for project management based on linear models that ignore relational complexities (Loosemore et al., 2020).

The constant improvement of current practices in the civil construction industry should be at the top of the list on the agenda of professionals and policy makers in the field, especially in Ergonomics. A corrective and simple action taken when it comes to project feasibility is the adoption of adequate and prudent assessment strategies, through a proper risk and safety analysis. Risks and accidents that pose threats to workers can be successfully identified, analyzed and evaluated. To this end, several methods and techniques have been

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developed for feasibility and risk analysis. (Mure et al., 2006; Pinto et al., 2011; Aminbakhsh et al., 2013; Mucenski et al., 2015; Biyikli et al., 2016; Gul et al., 2018; Sadeghi et al., 2020).

The assessment of safety risks at construction sites in the civil construction industry has received attention from researchers in recent decades. Several models have been proposed, such as Hallowell's Model, which suggests assessing the safety and health risks of construction processes. It can be used as a systematic method for the strategic selection of elements of a company's safety and ergonomics programs, functioning as a database for the experience of experts in the sector of risk prevention, and occupational safety and health (Hallowell, 2008).

The author quantifies the construction risk using probability and severity to assess the risk of construction activities or elements in the occupational safety and health program. With the rapid advancement of computing power and related methods in recent years, different models and programs for assessing construction risk can be introduced and used (Hallowell, 2008; Sadeghi et al., 2020).

Aminbakhsh et al., 2013 proposed a safety risk assessment framework based on the Safety Cost Theory model and on the Analytic Hierarchy Process (AHP) to address construction budget excess, without compromising the safety of workers. In addition, as the activities of a construction are interrelated in several aspects and executed simultaneously, Esmaeli and Hallowell (2013) developed a decision support system to evaluate the level of safety of workers, using the Delphi method.

A study conducted by Souza et al. (2015) developed a model to increase the safety of workers for resource management, in conjunction. For this model, a statistical tool was developed, by Isaac and Edrei (2016), to monitor workers' exposure during various activities. The model used a series of data related to the length of each activity performed at construction sites.

Finally, to show the evolution of tools for assessing project feasibility in Safety and Ergonomics, Sadeghi et al., 2020 proposed a Predictive-Assessment Model for Safety and Risk based on the integration of neural networks with diffuse interference systems. It was developed to prudently assess Occupational Health and Safety risks related to workers at construction sites.

The project feasibility analysis, then, needs to focus simultaneously on the risk and safety analysis of the activities that are or will be carried out, as well as on the productivity and comfort of the operators themselves of said activities. At this stage, Ergonomics must necessarily conduct the process (Figure 3).

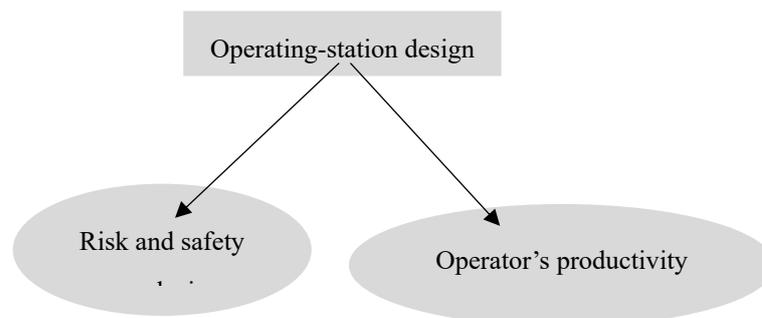


Figure 3. Project Feasibility Analysis

There are many possible structures for designing the assessment steps of an organizational project, be it linked to the operating structure, such as relocation, technological change, equipment change, or to the Occupational Health and Safety field. The important thing, however, was the evolution that this relevant tool presented for the safety and quality of life of workers in the construction industry.

3. Methodology

The methodology procedures were divided into two parts: 3.1) building of the research portfolio, which will be the basis for building the theoretical framework and discussing the proposed model; and 3.2) building details as to the Project Feasibility Analysis model.

3.1 Research Portfolio

In order to identify and understand the research object of this work, contextualizing the evolution of Ergonomics in relation to technology transfer and the feasibility of work safety projects in civil construction, a systematic literature review was carried out by means of the multi-criteria methodology *Methodi Ordinatio* (Pagani et al., 2015; Campus et al., 2018).

For prospecting and choosing the scientific articles used in the research portfolio, the following steps that the method recommends were followed, in accordance with Pagani et al., 2015 and Corsi et al., 2020 (Figure 4).

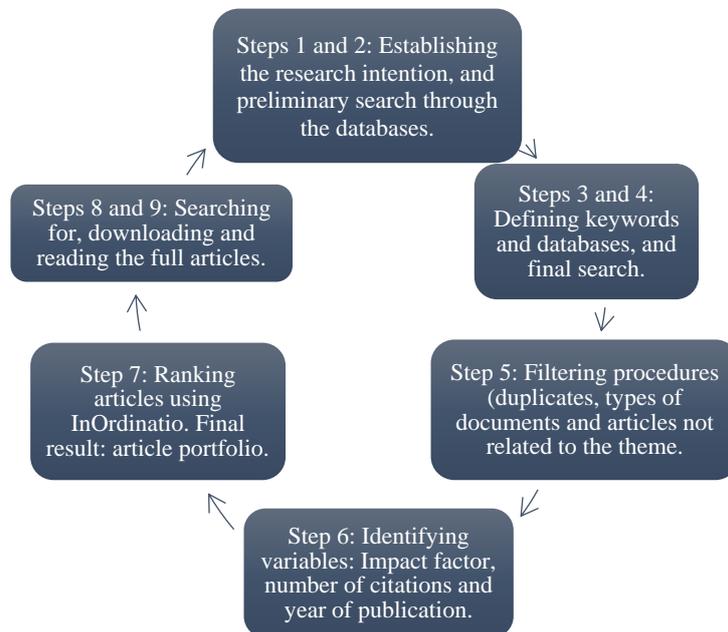


Figure 4. Ordinatio methodology steps

Also in accordance with Pagani et al., 2015 and Corsi et al., 2020, the nine steps are described below:
a) intention; b) keywords; c) filtering; d) impact factor; e) equation; and f) reading and analysis.

a) Steps 1 and 2 establish the intention of the research and an exploratory search through the databases. As the objective of this research is to develop a project feasibility model involving ergonomics

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and technology transfer, the following keywords were used: “Anthropotechnology”; “Technology transfer*”; “Ergonomics”; “Project Feasibility *” and “Civil Construction*”. For this exploratory search, the Web of Science and Scopus databases were used, as they have a large number of high-impact newspaper articles.

b) Steps 3 and 4 are about defining combinations of keywords and databases; and in the final search, preliminary tests confirmed the keyword combinations, thus ending the search.

c) Step 5 consists of filtering procedures: this procedure is performed to eliminate duplicate articles, conference articles, books, book chapters and articles whose themes fall outside the scope of the research; they were disregarded after having their title, abstract and keywords read.

d) Step 6: identification of the impact factor (IF), year of publication of the selected articles, and number of citations (Ci). The metrics of the selected articles were collected through CAPES and Scopus, and the number of citations for each article was sourced from Google Scholar.

e) Step 7: after the variables were collected, the InOrdinatio equation (Equation 1) was applied, resulting in the final portfolio, which ranked the selected scientific articles.

$$\text{InOrdinatio} = (\text{IF}/1000) + \alpha * [10 - (\text{Research Year} - \text{Publish Year})] + (\text{Ci}) \quad (1)$$

The alpha (α) value is defined by values between 1 and 10, by the researchers, in accordance with the importance and originality of the research theme; for this research, the α valued was set at 10, because the object of this work has recently published articles.

f) Steps 8 and 9: finding the full articles, reading and analyzing them; with the final portfolio organized and ranked, the full articles are collected and archived for the research.

The exploratory search started with 261 articles; after all the procedures that the Methodi Ordinatio recommends, especially the filtering procedures (elimination of duplicate articles and articles outside the scope of the research), a total of 209 articles were eliminated at this step, resulting in the total number of 52 articles for the final research portfolio. These were the ones that served as basis for the development of both the Theoretical Framework and the building of the proposal presented here.

3.2 Building the Project Feasibility Analysis model

This research can be classified as a qualitative one and has an exploratory nature as to its technical procedure, since it does not use statistical rigor for analysis.

The initial stage of the work consisted of building a model that served as a prototype to observe a company in the civil construction industry in the city of Porto Alegre, Brazil. At the second stage, the operation of the different processes in the company’s departments was observed and, at the third stage, a specific department was chosen, in accordance with the objective of this research – the Occupational Health and Safety department was chosen to prepare the model.

The intention here was to map how the processes unfolded (real situation) and how they could unfold (ideal situation) by gathering capabilities to incorporate and operate new technologies, as well as to know and respond to new demands. At the fourth and last stages, aimed at building the model, both the stages and phases of what was called the ideal model were determined.

4. Results and discussion

The first step in modeling the proposal was to identify, based on the theory, in which phases of a project feasibility analysis (PFA) Ergonomics would participate, and how it would participate. Considering the three phases of the feasibility analysis (market – MFA; operational – OFA; and financial-economic – FEFA), Ergonomics needs to participate in all of them, and it is in the operational one (OFA) that it becomes the protagonist, due to the building of what was here called “operating-station design” or, to put it another way: Ergonomics is key in the systemic process of analyzing operational viability.

To understand the boundaries and dynamics of the PFA, one can consider that it can be made up of a set of at least five strongly related systems. Two of them between phases (between the market and operational analyses; and between the operational and financial-economic analyses), and three intra-phase systems (market; operational; and financial-economic). The two initial systems will be called “external” (βE), and the last two, “internal” (βI) (Figure 5).

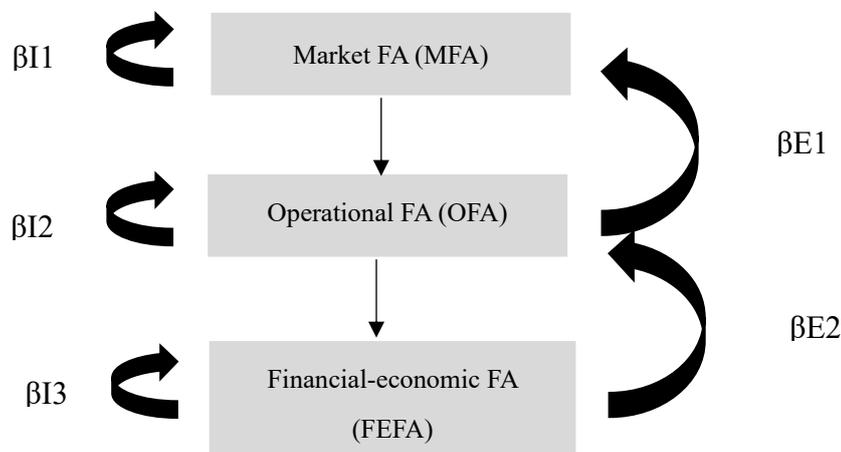


Figure 5. PFA Phases and Interphases

It is important to consider that the first analysis is the market analysis (MFA), and that it is only after its internal feasibility system ($\beta I1$) is satisfied that one can proceed to the operational analysis (OFA). When this stage is reached, the internal operational system ($\beta I2$) must be activated along with the external system in relation to the previous phase ($\beta E1$), if, for some reason, it is not possible to make the organizational product described and/or identified in the market phase. This dynamics of two simultaneous systems repeats when the operational feasibility analysis is partially done (internal: $\beta I3$; external: $\beta E2$).

While the operational system ($\beta I2$) is being operated, due to a change, such as the incorporation of a new operation technology, two internal elements are fundamental and can be deemed as basic analysis variables. They are: a) the knowledge of those involved and the management itself of the knowledge associated with it; and b) the mental model of those involved, which is often embodied in the very culture of the organization and/or sector – in this case, that of civil construction.

In addition to these internal variables, which are strongly associated with individuals (workers), at least two basic external variables need to be analyzed. They are: a) technology and the management of the

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organizational technology associated with it; and b) sociological variables and social-organizational management. These last two variables are related to what can be called “activity architecture”.

Ergonomics, by combining and establishing the relationships between these four basic variables (knowledge (K); mental model (MM); technology (T); and social (S)), as well as using any known model, can conduct the process (historical course), as well as generate and provide opportunities for the development of the different capabilities of the organization and of the analyzed process itself. These capabilities can be presented in the form of a matrix (capability matrix – CM), in which the axes are internal variables (elements associated with individuals) x external variables (environmental elements).

The great virtue of the matrix (CM) is to show different situations so that an ergonomic interaction strategy can be designed for each one of the different situations (Figure 6).

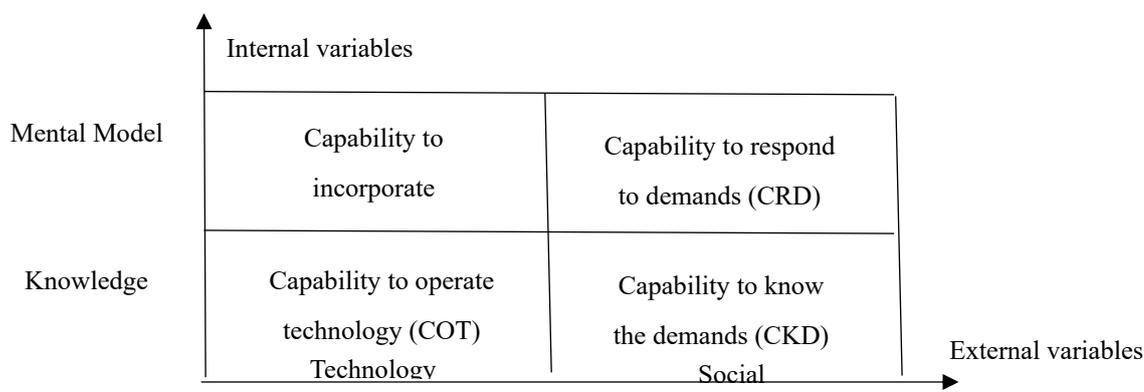


Figure 6. Capability matrix

It is important to remember that the ergonomic strategies of the management of the system (β_{II}) must meet, at each step, both the internal demands (of the different operating stations involved in the process or even the other processes, if they are connected in any way) and the external demands (users-consumers, whether internal or external to the organization itself).

The ideal and final situation of the design, “suitable design”, will be one in which the situation of having “capability to respond to demands” (CRD) is reached. The ergonomic strategy of building a suitable design can, in theory, take two paths. They are: a) CKD → CIT → COT → CRD; and b) COT → CKD → CIT → CRD.

To exemplify the consistency and adequate understanding of the proposed project feasibility model, one can resort to a study by Stradioto and Michaloski (2021) on the aggravation of biomechanical overload of the upper limbs during work at height in civil construction, involving the activity of externally plastering building façades. In addition to showing the minimization of the risk of biomechanical overload in the analyzed activity, that study also brought the feasibility analysis that the company needed to carry out to improve the workstation, within the capabilities and steps that the model recommends.

While being normally executed at construction sites, the activity of external plastering on building façades presented a result of biomechanical overload, in accordance with the OCRA checklist method, of high risk and with a need for immediate intervention.

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The company, concerned with the well-being of its workers, as well as desiring an increase in productivity in this activity, performed a project feasibility analysis for incorporating and transferring technology to improve the workstation. To this end, it used the Capability Matrix in order to implement an ergonomic strategy in conjunction with the technical and financial issues that the company takes into account.

For this analysis, the CKD → CIT → COT → CRD path was used to build the “suitable design”, taking into account the workers’ knowledge and social aspects, in combination with technological options and the mental model to find the best option to the problem proposed for technology transfer. For a better understanding, Table 1 shows the analyses performed at each step.

Table 1. Feasibility Analysis in accordance with the

Capability matrix

	CKD →	CIT →	COT →	CRD
Workers’ biomechanical overload	Yes. Use of ergonomic analysis and medical certificates by the company’s Work Safety and Occupational Health department.			
Technology acquisition (Equipment)		Yes. Use of financial feasibility analysis in conjunction with ergonomic analysis to prove the effectiveness of the incorporated technology.		
Technology operation and			Yes. By training operators	

<p>handling (Equipment)</p>	<p>and doing equipment maintenance.</p>
<p>Implementation and monitoring of new technology</p>	<p>Yes. After installing the equipment and training the team, supervision and monitoring through ergonomic and productivity indexes.</p>

The technology chosen and implemented by the participating company was the replacement of cradles with mast climbers, as this equipment provides greater safety and comfort to employees, considering that the area of the workstation increases, due to its extensions on the floor for cut façades, thus enabling a better movement during work and a better posture while performing the activity.

Another advantage of mast climbers, where vertical displacement along the façade is totally mechanized, is to provide a better vertical reach for the façade as a whole, especially in corners that are hard to access, reducing the ergonomic risk in terms of inadequate postures.

They were also proposed due to their larger work area, taking into account productivity, the addition of another worker, making a team of two (referred to as construction workers I and II), since only one worker was used before, so the cost of purchasing this equipment was justified.

The results found by Stradioto and Michaloski (2021), after the technology was implemented and the work team for the activity was resized (Table 2), in comparison with the traditional way of executing the analyzed activity, can be observed through the results of the evaluation of biomechanical overload found by the OCRA checklist method, in the traditional form and after the implementation of the technology transfer.

Table 2. Results found

	Final score	
	Right limb	Left limb
Traditional construction worker	35.06	4.92
Construction worker I	17.22	17.22
Construction worker II	12.30	12.30

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The benefits of technology transfer can be better understood, according to Stradioto and Michaloski (2021), as there was a 50.88% reduction for the position of Construction worker II in relation to the traditional role of Construction worker I, and a 64.91% reduction for the position of Construction worker III.

Another advantage of reorganizing the technical procedure in the execution of the activity was the use of the right and left sides of the upper limbs together, thus not overburdening only one of the limbs, and equally distributing the use of force by the worker, in addition to increasing productivity in the analyzed activity, according to the company.

Regarding the discussion around the feasibility of using the Capability Matrix, the main objective of the present work, it can be said that it was useful, suitable and enough to guide the strategic actions of Ergonomics. As for the paths, it was initially thought that the process would be linear, insofar as the development of a “capability” would generate the opportunity to set up a strategy to face a next capability.

The monitoring and implementation of said path showed, however, that it may, in some situations, present a course different from the one initially proposed, and this process may present non-linear but systemic situations instead (Figure 7).

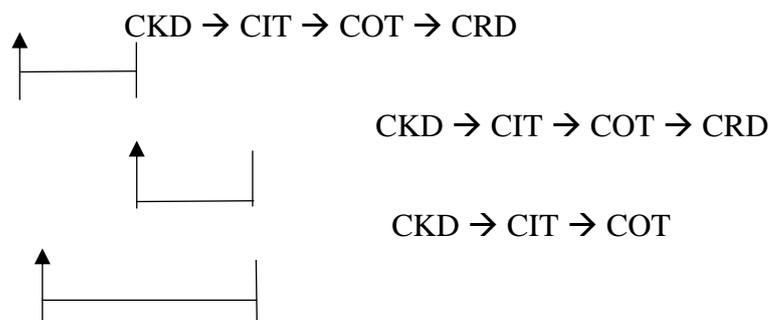


Figure 7. Course with return points

Now, the praxis of the Operational Feasibility Analysis project, which had Ergonomics as its protagonist, showed that the Capability Matrix (CM), developed here, proved to be more flexible than theoretically imagined, as it can be used in different ways and, in all of them, it is found to be adequate to guide and monitor the Ergonomic strategy, which, in its turn, is or may be a major player in the operational feasibility analysis.

At the same time, it is believed that the prospect of expanding the use of the CM was due, in large part, to the complexity of the different processes of civil construction, as well as the complexity of the relationships between these different processes. In a simpler environment, as many industrial processes are, it is believed that the linear systems of the paths of the ergonomic strategy, while one is evaluating the operational feasibility of a project, is a more adequate and sufficient solution.

5. Conclusion

The objective of the work was to develop a tool that could be used to guide Ergonomics during the assessment of the operational feasibility of a project, in combination with technology transfer.

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Based on the theory, a matrix was built, which was called Capability Matrix, since it is up to Ergonomics to guide and evaluate activities, both at the internal levels of individuals (knowledge and mental model) and at the external levels (technology and social). With the Capability Matrix built, two courses were initially identified from the four elements of the matrix.

The next step was to test the Capability Matrix in a real situation, using the civil construction industry as a reference. This industry was chosen to test the CM due to the wide spectrum of its activities, ranging from the simplest to the most complex ones.

By testing the CM, it was possible to perceive that the flexibility and the possibility of guiding Ergonomic strategies was much greater than previously thought. That said, it is clear that the very “usefulness” of the CM has a greater potential. Thus, the very design of the analyzed operating station can be improved, as Ergonomics focuses on the ongoing improvement of capabilities.

The design of the operating station must comply with at least two elements. They are: a) safety; and b) productivity and comfort. With the CM, one can have an analysis and monitoring tool, as well as constant improvements that guide Ergonomics strategies.

The conduction of a systematic literature review, addressing themes such as Ergonomics and workstation adaptation, technology transfer in the civil construction sector, and project feasibility assessment, was of great value, as it showed that the topic covered in this research has a vast field to be researched, and technology transfer through project feasibility analysis is one of the ways to minimize the biomechanical overload on workers together with the adaptation of their workstation, making it more comfortable and safer.

This work leaves as perspective for future works the application of the Capability Matrix to other civil construction activities, with the aim of minimizing biomechanical overload, adapting workstations to workers, as well as enabling technology transfer to other activities belonging to this branch of engineering; furthermore, the CM can be applied to other areas within the industry in general with the aim of improving the Ergonomic strategy of companies.

DECLARATIONS OF INTEREST

The authors declare no conflict of interest. The authors are responsible for the content and article writing.

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