

Article

Ergonomics Applied on Drilling Centers in the Brazilian Oil Industry

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Abstract: Drilling centers are collaborative environments dedicated to facilitate decision-making in the well construction, where multidisciplinary teams work to support operations. The oil operators usually have drilling centers with different types of ergonomic features with considerable potential of integration, creating the opportunity to an Ergonomic Workplace Analysis. This paper aims to present the analysis of infrastructure requirements of one specific company in Brazil. The method was based on a survey with employees, which, coped with a statistical analysis, enabled understanding the impact of the layout requirements. The result is an approach to design collaborative environments, standardizing and defining models for the industry.

Keywords: Ergonomic Workplace Analysis; ergonomics solutions, collaborative environment, drilling centers

1. Introduction

The use of sustainable principles brings benefits that go beyond the environmental and social business, creating economic value [15]. Organizational sustainable principles based on information for internal and external benchmarking, obedience to laws and regulations, improving the company's image and constant monitoring. Whereas the use of sustainable principles is implemented in an operator oil company on the Brazilian coast, and with new technological advances, many data and information have been provided. The continuous monitoring of the rig¹ operation from the offices is getting a critical role to the extent that there are safety and expressive economical values involved [26].

Oil and gas well drilling activities are associated with numerous hazards that have the potential to cause injury or damage to people, property and the environment. These risks are also a threat to the reputation of drilling companies. In order to avoid accidents and unwanted events in drilling operations, it is essential to identify, evaluate, evaluate and control the associated risks [1].

To address to this reality, collaborative environments (called drilling centers) have been implemented. The drilling centers have multidisciplinary teams working 24 hours, using technologies for analysis and support operations, equipment and processes. In addition to access to

¹ Wells are used for petroleum production. The well construction is based on the operation of rigs, which are massive structures of equipment used to drill and equip water, oil or gas wells.

the images of off-shore units (CCTV), video conference systems are used, integrating support centers distributed for increased collaboration between operational staff and experts [21].

The drilling centers concept is used worldwide. They are designed to provide technical support for operational decision making in the rigs, during operations of drilling, completion or workover. These centers support the activities of monitoring and analysis of drilling parameters between others. Figure 01 gives a general idea the drilling centers in this context.



Figure 01. Drilling centers in the context of the well construction

The objective of this work is to propose the definition of a requirements model for multidisciplinary collaborative environments, provided to operators and users to get the most out of performing their activities, through Ergonomic Workplace Analysis, questionnaire surveys and statistical methods. The studied company has seven drilling centers, geographically located in different regions, with distinct functions and several types of layout and ergonomic features. As graphical representation, Figure 01 shows a layered architecture. In the core, it is possible to find data and information which are provided to all other spheres. From inside out, the first layer is formed by experts' teams. Currently, these experts are working on two separate physical environments. One team is focused on rig performance and operational safety, which uses data transmission tools and images in real time. In another environment, other sort of experts is concentrated in technical disciplines to build offshore wells, such as special services, cementing, completion, evaluation, etc. The integration of the rig performance and service experts' processes in a unique environment facilitates the continuous improvement, increasing the operational efficiency with time reduced and safety enhanced. In the subsequent layers, there are the drilling operation centers, responsible for the construction of the wells and the support staff in the company's offices. Finally, there is a layer of rigs, i.e. the representation of the offshore units and their operations.

To perform their activities, the drilling centers are provided with a number of software technologies and hardware solutions that integrate the information to support the work processes, such as data transmission solutions in real time. The operational need for integration of expert centers was an important opportunity to develop the study of the infrastructure requirements to be considered in this new integrated center of experts. Factors such as shared knowledge and experience may have a greater influence on team performance of execution tasks in command and control environments and can be substantially affected by cognitive processing load and by teammate's shared task-specific knowledge [16]. The creation of real-time data value depends on the adoption of technology, which is accelerated through effective training and implementation of change management [29].

Human differences influence human behavior and can result in variations in working behaviors, strategies, and methods that affect overall system productivity. There are many factors, including age, level of skill, gender, experience, background, and lifestyle, which might influence work performance positively or negatively. Pilot studies should be used to determine the suitability of the proposed data collection method, observing workers in the actual working environment and

recording their tasks for a short time. Group discussions and interviews can be used to explore the difficulties and problems of the workers with their current work practices, possible causes of injuries and illnesses, and their suggestions for work practice improvements. These group discussions and interviews also help in developing a friendly and participatory observational environment [22].

In the pursuit of an interdisciplinary view, the Ergonomic Workplace Analysis was performed, including an online search, based on a bibliometric survey of the resident employees. When it comes to design new workplaces and production systems, it may be difficult for the future workplace users to contribute, if the representations of the future design are solely in the language of engineers and architects [5]. So, to eliminate this effect, the interdisciplinary approach was used by ergonomics, as well as the feedback from those already working in the existing drilling centers. Interviews, questionnaires, observation and document studies are interesting tools to evaluate ergonomic models [40]. The questionnaire method combine the construct validity of existing techniques with the domain experience [43].

The work described here presents a new approach, going beyond the support paradigms of the disciplines, however taking the methods and tools that can interact and converge towards a unique knowledge through exchanges between the experts and on the degree of actual integration the disciplines.

A study was conducted with specialists from different disciplines who support remote industry activities in an integrated center. As a result, the exchange of experiences provided by a centralized collaborative environment shows that teams working in an integrated manner performed better than teams that were far from each other [39].

It aligns with the interdisciplinary concept of having only a single field of knowledge, not making use of values and beliefs present in practices already consolidated and difficult to dissolve in the current processes.

It is noteworthy that the interest of this work is based on the concept of a lasting and sustainable management, with the use of efficient and consistent models capable of measuring the performance of internal processes, which can give more support to strategic decisions. Into this line, the purpose of this article is to describe and identify the ergonomic requirements to provide the integration of drilling centers of experts, and propose a consolidated ergonomic model to serve the other drilling centers of the studied company, including disciplines, like lighting, acoustics, air conditioning, layout, furniture and technology, in an integrated approach, to be used for standardization and project design of the next generations of collaborative environments in the oil and gas industry.

2. Theoretical Background

Industrial companies face new challenges due to increasing international competition, e.g. higher productivity, new product design and shorter lead times. At the same time, ergonomic considerations in the design of work and workplaces may support productivity and quality, promote the health of the employees and attract new employees [37]. The need to ensure safe working environment is a prerequisite to providing high quality products and services [19]. Occupational safety is one of the most important factors contributing to productivity increases, which consequently lead to more benefits from business activities. A comprehensive analysis of working conditions allows corporate managements to adjust employee pay for risks, faced in a given workplace and define competences required in specific jobs. Management often focuses on productivity, quality and economic profits, while work environment issues sometimes tend to be neglected. A commonly used management tool today is visualization of key figures concerning performance of productivity, quality and cost, and such graphs are displayed on the shop floor [8]. However, visualization of the ergonomic status of workplaces is neither common nor readily available.

The evolution of the information and communication systems, the organizational structure and the nature of the work contributed to the restructuring of work environments. In these new types of workplaces, employees do not have workplaces designated by function, but on demand according to what is prioritized in terms of importance for increasing operational efficiency or issues related to safety in operations [17].

This is in contrast to several studies showing the relation between ergonomics, quality and productivity [12,13,14,42]. Due to these mentioned aspects, it was opted for an interdisciplinary approach, in order to add greater knowledge in the design of the drilling centers, with greater comfort and well-being of its users.

The people who work in the operational system are the “internal customers,” and the system must be designed to satisfy their needs; simultaneously, the manufacturing system must produce products that satisfy the needs of the “external customers” [20]. The continuous nature of this sort of activity requires that the employee acts in the variables monitoring and surveillance. However, it is known that the information processing capacity is limited, as cognitive functions. This fact should be considered in the design of projects and in the work organization, in the way that methods, consistent with diversity and variability, can be used [18].

The context of the oil platform design is changing in order to increase competitiveness and be prepared for difficult operations [32]. First, it is important to point out that all the work can be considered collective, as it depends and influence others. The process control is also a collective activity [28], because there is a common goal and, to be achieved, it requires simultaneous and coordinated actions of several people. Regarding to the ability to absorb and address the instability of production systems, the human system seems to be the most efficient. The machines have limited rationality, that is, perform that for which they were planned and programmed. Vary their actions, according to the variability of the system, is not an easy task.

In that way, even if the technology is complex, it should not be the focus of operators, but a tool to be used [44]. The growing interest in human factors among engineers reflects the irony that the more advanced the control system, the most crucial may be the contribution of the human operator [2]. The human factor, much more than just a coadjutant to the production or just workforce, it is the strength of the production system, being like intrinsic barriers against the production process variability [10]. Regularity and safe operations are important issues for a control center [34]. The various models presented in the literature, information processing-based three-level model is the most popular description of Situation Awareness as a product comprising three hierarchical levels: the perception of task relevant elements in the environment, the comprehension of their meaning in relation to task goals and the projection of their future states [35].

One difficulty for researchers and ergonomics professionals is to manage different perspectives, with differences arising between themselves and their clients in the business world. For the latter group, an attractive business case generally prevails over the benefits of the most recommended ergonomic interventions, such as reducing risks, errors and accidents. The arguments for any ergonomic intervention need to be expressed in commercial language and therefore should focus specifically on the financial costs incurred in comparison with the costs that are prevented. These problems include factors related to the working conditions in companies, which are usually targets for ergonomic improvements [7].

The influence of ergonomists are limited and they are restricted in their perspective due to the organizational context within an enterprise. If ergonomists are not clearly mandated by top management, they are in a weak position to influence design engineers [4]. In this work, the author does not look at the ergonomists as a professional group that can be active actors in the organizational dynamics taking place in an enterprise. Newer studies point out that ergonomists might be able to influence design processes if they are politically skilled and able to navigate within an organization.

Ergonomics is the study of the adjustment of the labor to the man. Work in this case involves not only men and machines, but also all the situations in this relationship [23]. It is found that the knowledge of human issues related to the automation of processes and its importance are fundamental in the design of control centers [36]. The key assumption in assessing the strenuousness of specific workplace factors is to evaluate the workplace itself rather than the employee. As some factors can be assessed either subjectively or objectively, whereas others can only be assessed subjectively, the following classification of evaluation criteria has emerged [27]. So, when it comes to physical environments, the ergonomics goes beyond the purely architectural aspects and focuses on the adaptability and compliance space to work where it is developed. In this sense, it is important to recall elements of environmental comfort, anthropometry, environmental psychology, cognitive

ergonomics and EWA - Ergonomic Workplace Analysis [41]. The ergonomic disciplines considered for the physical environment are described below.

Lighting - According to ISO 11064-6, the project must address the different tasks performed by the employee, optimizing the visual range, readability and surveillance capability, minimizing the degradation of visual acuity, with comfort to the user. The lighting of rooms must have intensity adjustments made by a set of luminaires installed in the ceiling. The positioning of luminaires must be compatible with the audiovisual project to avoid reflection and dazzling monitors.

Listening - For the work, two functions are considered: the transmission of specific information and the alarm system. Some aspects can difficult the activity of workers by the decrease in performance due to noise, interference with cognitive functions and loss of essential audible information. The noisiest equipment must be stored in specific rooms.

Air Conditioning - Variations in the room temperature, for workers who remain much time sitting, may affect the blood flow (too cold) or produce sleepiness (excessive heat). The level of comfort should be as suitable as possible to prevent time dispersion or low concentration. In all environments, it should be considered the spread of cooled air through ducts located in the plaster ceiling. The equipment must have individual adjustment per room.

Layout - Designing the layout of a building is a complex issue, given the diversity of requirements to be considered. According to the ISO 11064:2, the functional design of the control centers should be guided by the functions of the operators and their interactions, in addition to the allocation of equipment and instruments [23,36]. The workstation is the space formed by the set of information and control devices, plus the space generated by the displacement of the operator or its members in completing the task [30]. It is a production unit involving a man and the equipment he uses to do the job, as well as the environment that surrounds him. In the man-machine-task system, the operator receives information from the machine and the environment, makes decisions and acts on the machine by the control devices [23].

Furniture - Process control demands specific furniture. Even when placed in administrative environments, control centers workstations have higher requirements than traditional administrative stations. They support a greater volume and weight of specific equipment, are utilized uninterruptedly (accelerated wear) and their work requires special treatment of cognitive operators. This furniture must accommodate the necessary equipment and organize the appropriate information and control devices.

Audiovisual Technology - Whenever possible, in the workplace, it is interesting to opt for wireless technologies, to make the environments simplest and intuitive for users. Software must be customized with new features such as room scheduling, projection and content management to video walls in order to enhance productivity.

Finally, the literature describes several approaches to redesigning work methods in the most appropriate way and to increase the chance of successful implementation—regarding productivity, but also well-being. The ergonomic interventions in redesign of offshore platform control rooms has become more frequent and proven efficient in improving work conditions [9]. The participatory approach is one of these successful initiatives. For instance, the European Foundation for the Improvement of Living and Working Conditions [11] reported that direct participation in production organizations most often leads to quality improvements (90% of the cases), reduction in throughput times (60% of the cases), and reduction in costs (60% of the cases). Improved throughput times and costs are directly related to productivity and therefore are relevant to this study.

3. Bibliographic Review

A survey was carried out in the Scopus Base, targeting articles and conference papers about the subject of this paper. The search was from 1990 to September 2015, involving five rounds, with the keywords shown in Figure 02.

Cycle	keyword	Result
1	Drilling center and ergonomics	2
2	Integrated operation + cycle 1	85
3	Colaborative environment + cycle 02	85
4	Ergonomic analysis + cycle 03	85
5	Process control plant, design process, participatory ergonomics, ergonomic intervention, integrated operations center, colaborative environment, deep	196 (173 with filter)

Figure 02. Keywords

A total of 196 results were obtained at the end of the process. Applying filters, it was possible to reach 173 results. Then, after a careful examination of the documents, considering those oldest, the latest, the most cited and most important, it was possible to select 11 documents to compose the bibliographic, reference base of this work. In addition to Scopus, other Scientific Bases were also consulted, like Onepetro.

4. Materials and Methods

In order to improve the methodological rigor and look for reliability of the quantitative study, the information obtained by measurements with the online search applied to drilling centers was compared to the Ergonomic Workplace Analysis. For the development of this research, a road map is shown in Figure 03.

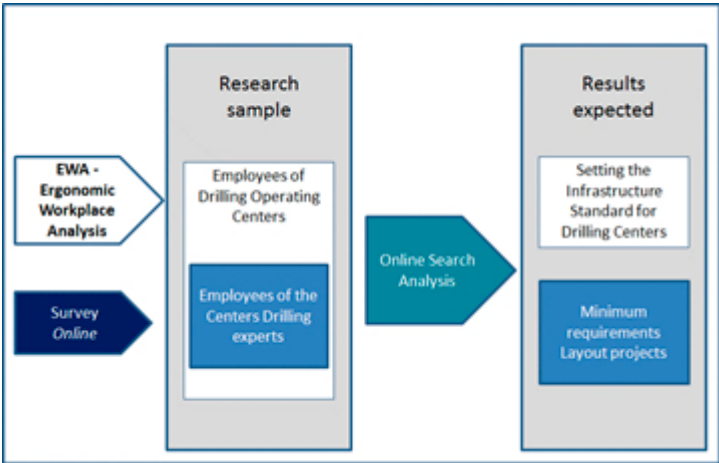


Figure 03. Method Framework

This analysis, combined with the online survey, allowed conclusions about the ergonomics of existing drilling centers, as will it be seen in the following items. Attention points were raised, as well as opportunities for new collaborative environments. The statements prepared for the online research tool were from specific literature on ergonomics, assessments of internal and external standards in the studied company (national and international) and experts' opinion to identify ambiguities of understanding. Based on the literature, the statements have been prepared in three clusters of subjects (illumination, climate control and layout). Suggested the use of Likert Scale, allowing to obtain the degree of agreement of respondents with statements [45]. Pehkonen presented an interesting study to perceive changes in ergonomics using similar questionnaires [33].

Ergonomics has several methods of analysis for the development of projects, but all they are based on the understanding of activities in real work situations. The method presented here was developed through stages: identification and mapping of work critical situations in terms of reliability, operational safety and physical load (efforts and postures) in different areas and working environments. The prescribed tasks and activities performed by the employee were assessed primarily through direct observation and online search performed in the field. Finally, there was the

validation step of the recommendations together with the other technicians involved in the project (architects and engineers) and users (process engineers, geologists and operators).

4.1. Interviews

The survey was applied in the seven drilling centers, including all the 129 employees, in the period from 10.20.15 to 11.13.2015, totalizing 68% of responses. The direct worker participation and the strong commitment of the management of the enterprise are experienced to be essential like key factors to success. As the totality of the interviewees was not achieved, due to the fact of the employees work in shifts, the research on all drilling centers was essential to a complete analysis of what should be considered in the global design [8].

Table 01 shows the Group A of the questionnaire, consisting of statements to investigate whether the respondents really perform activities in drilling centers and its main characteristics.

Survey On-line - Classification					
Cluster A		Answer options	Aims	Reference	Analysis
Question					
A1	The work performed by you require constant attention and care to avoid any unscheduled outage that can represent a breakdown in the production system or even risk the safety of operators and the population?	Never	Identify if there is danger in the work carried out	(Iguti, 1994)	Knowing the profile of the public who are participating in the search and map the task / activity performed.
		In much not			
		Reasonably			
		In much yes			
		Always			
A2	The continuous nature of activity, forces you engaged in continuous monitoring of variables?	Never	Identify whether the work still has character.	(GUÉRIN, 2004) (Iguti, 1994)	
		In much not			
		Reasonably			
		In much yes			
		Always			
A3	Your job requires simultaneous and coordinated actions with people from other areas due care to a common goal?	Never	Identify whether the work has collective character.	(LEPLAT, 1994) (Iguti, 1994)	
		In much not			
		Reasonably			
		In much yes			
		Always			
A4	The environment in which you work is uncertain and evolved independently of their performance? In other words: the unpredictability of events is intrinsic to the system and not a system failure?	Never	Identify whether the work is performed in dynamic environment and consequently, if the work requires special cognitive treatment.	(GUÉRIN, 2004) (Iguti, 1994)	
		In much not			
		Reasonably			
		In much yes			
		Always			

Table 01. Participants Assessment

4.2. Questionnaire Surveys

The more effective the participation of users, the lower the chances of nonconformities. Thus, rather than ex-post evaluations, pointing nonconformities and proposing modifications, the goal of the design ergonomics is to anticipate situations of discomfort, inadequacy or inefficiency and act directly on them, before they occur [31]. To be effective in implementing ergonomics, it is important not to focus only on technology. The context in using comprehensive change management concepts must be understood [46]. For example, understanding group's norms, language and concerns of the different actors are critical to successful interventions [25].

This research applied a quantitative method through an online survey to test the model of evaluation of drilling centers. The construction of the questionnaire with the respective reference is presented in Apendix A.

The graphs in Figure 04 refer to the answers in Group A of Table 01. It can be concluded that the respondents mostly have direct involvement in the routine of support center decisions, whether

operational or support, providing better precision in the responses obtained from the next groups of questions, which have focused on ergonomics.

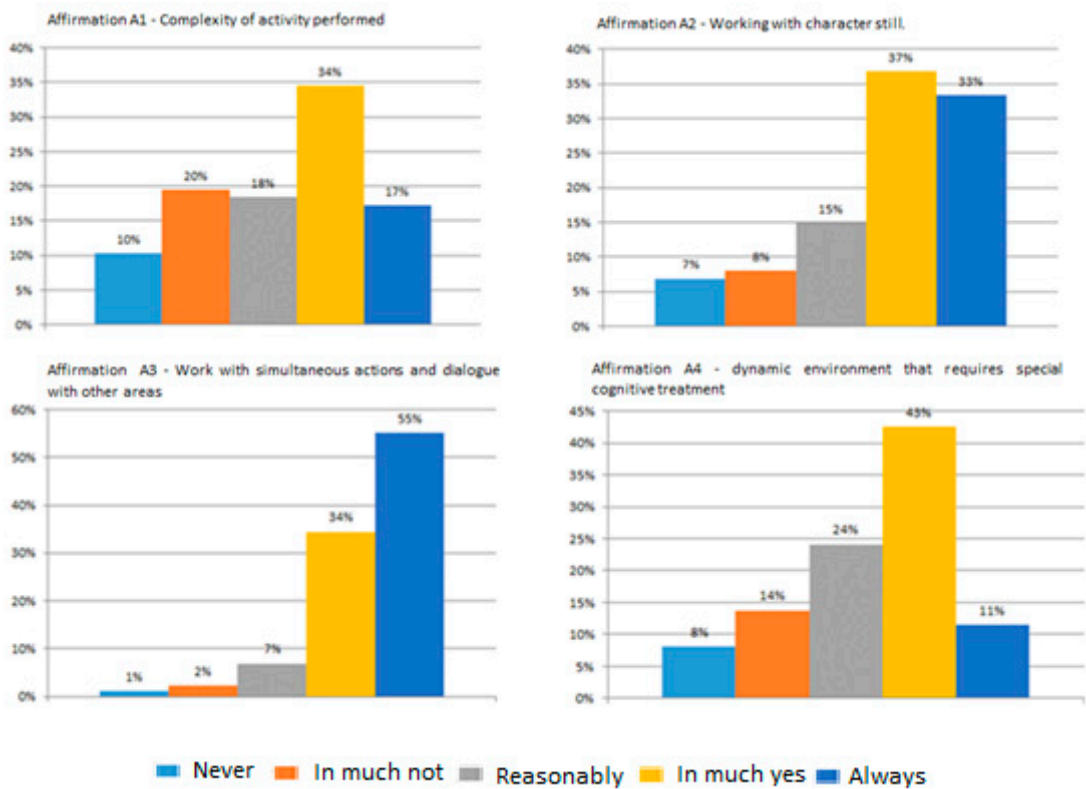


Figure 04. Participants Assessment Results

The data collected in the surveys were tabulated with Microsoft Excel for Online Research. Statistical analysis was performed using Minitab 16 and SPSS 15.0. For each questionnaire item, values were assigned from 1 to 5 on a Likert scale. In order to make the scale purification by removing items that somehow adversely contribute to the final result of reliability analysis, the internal consistency of the scale used in the questionnaires was assessed by Cronbach's Alpha. The coefficient can vary from 0 to 1, and the higher the score, the more reliable the questionnaire. Conceptually, reliability reflects how much the observed values are correlated to the true values [6]. Table 02 shows the results of coefficients.

Cluster	Cronbach's alpha
illumination	0,6629
Climate Control	0,81
Layout	0,7439

Table 02. Alfa de Cronbach

As the values were above 0.60, it was not necessary the scale purification, in order to keep the coefficient closer to 1. The coefficients obtained in Table 03 express a good interrelation between the questions with a high values. Redundancies, as well as the repeatability of the subject, are factors that could mask the Cronbach's Coefficient. Thus, it follows that the value obtained for Cronbach's Alpha reflects good consistency and inter-relationship between the questions.

Table 3 presents a summary of the online search results.

Cluster		Affirmation	Strongly Agree	Totally agree	Disagree with largely	Strongly Disagree	Indifferent
Illumination	B1	P5	36%	36%	1%	6%	22%
	B2	P6	38%	28%	2%	2%	30%
	B3	P7	15%	15%	7%	17%	46%
	B4	P8	31%	54%			15%
Climate Control	B9	P13	30%	30%	14%	16%	10%
	B10	P14	30%	15%	29%	17%	9%
	B11	P15	26%	16%	13%	22%	23%
Layout	B12	P16	41%	24%	15%	8%	11%
	B13	P17	36%	33%	9%	3%	18%
	B14	P18	40%	45%	13%	1%	1%
	B15	P19	28%	44%	17%	9%	2%
	B16	P20	34%	53%	7%	1%	5%
	B17	P21	38%	48%	5%	1%	8%
	B5	P9	40%	39%	5%	2%	14%
	B6	P10	33%	30%	5%	8%	24%
	B7	P11	21%	28%	8%	5%	39%
	B8	P12	32%	26%	15%	16%	10%

Table 03. Online Search Results

In general and regardless of the type of drilling center, the expert or operating, there is a wide agreement with most of the answers on the need to have the requirements indicated by the statements of online search in these environments. Table 04 reflects an acceptance in most ergonomic requirements raised by the literature and confirmed by online search.

5. Results

This research allowed conclusions about which infrastructure resources are relevant to the operation of decision support centers. From this analysis, attention points were raised, so that these resources are sized and included in the technical specifications. The identification of the most relevant ergonomic items is important not only considering the aspects of application and scalability, but also in the degree of assertiveness of what is really necessary to the operational needs, rather than an increase in the cost of the project without justification. An example can be applied to the use of individual luminaires in the consoles, which was a point raised by EWA (Ergonomic Workplace Analysis) and confirmed by research.

For each group of questions related to the same topic (clusters), indexes were created in order to summarize each individual response, through a single value for each cluster. These indexes were created for each individual using the simple average of responses in each cluster. Table 04 presents the descriptive statistics of these indexes.

Cluster	Questions	Mean	Standard Deviation	Min	1° Quartile	Median	3° Quartile	Max
Illumination	B1 to B4	3.81	0.71	1.75	3.50	3.75	4.25	5.00

Climate Control	B9 to B11	3.14	1.20	1.00	2.33	3.33	4.00	5.00
Layout	B5 to B8 and	3.88	0.63	2.50	3.40	4.00	4.30	5.00
	B11 to B17							

Table 04. Descriptive Statistics

5.1. Descriptive Analysis of the Clusters

The data analysis used the Box Chart or Boxplot. The Boxplot Graph is proper to visually represent the descriptive statistics and the distribution of a data set. In this type of graph, a rectangle (box) is drawn in which the extremes represent the first (Q1) and third quartile (Q3) and a line within the box is drawn showing the second quartile (Q2), or the median [3].

From the ends of each side of the rectangle, two lines are drawn. At the lower limit, it is extended to the lower value of the sample or to $Q1 - 1.5 \times (Q3 - Q1)$, whichever is greater. At the upper limit, the line is extended to the higher value of the sample or to $Q3 + 1.5 (Q3 - Q1)$, whichever is less. Points outside these limits are considered outliers and are denoted by an asterisk.

The best ratings were assigned to Cluster Layout (mean 3.88, median 4.00) and the worst ratings were to the Cluster Climate Control (mean 3.14, median 3.33). The Kruskal-Wallis Test was employed to test the null hypothesis (H_0), that all populations have identical distribution functions against the alternative hypothesis that at least one of the populations has different distribution functions (median or different behavior). When the Kruskal-Wallis Test leads to significant results, then at least one of the samples is different from the other. The test does not identify where the differences occur. Only points the level of significance using the p-value ($p \leq 0.05$). For smaller p-value than 0.05, the null hypothesis that the distributions are identical should be rejected. A confidence interval of 95% ($-1.96 \leq z \leq 1.96$) was used to identify where there were differences.

The Kruskal-Wallis Test indicated that the Cluster Climate Control response pattern is significantly lower than the others, just as the pattern response of the Cluster Layout is significantly higher.

It is possible to notice that the group of experts has a lower average rating, leading to the conclusion that the requirements pointed out in the questionnaire are not covered in the existing infrastructure and the environment redesign would be very welcome. In the other hand, some drilling centers have, in their configuration, requirements considered in the search. The last ones must not be considered priority in the ergonomic review.

For the analysis of correlation between the different aspects discussed, Spearman Correlation Coefficient [38] was used. This coefficient is suitable for situations in which the data are measured on an ordinal scale, as in the questionnaire, where it was used the Likert Scale.

The position to which Equation 01 refers to is the relative position of each observation in relation to the data set. Thus, the lowest value gets rank 1 and the highest value gets rank n. In that way, d_i is the difference between the rank of observation i in the variables x and y. The coefficient can vary from -1 to 1. The closer to 1, the greater the positive correlation, and the closer to -1, the greater is the negative correlation between variables. Coefficient values close to zero indicate no correlation between the variables. Correlation analysis was completed using the scatter plot for groups of variables that show a significant correlation. In the scatter plot, stratification between different groups of respondents was made, to identify the existence of patterns and similarities in perceptions of research participants. With the correlation between clusters is possible to identify that the Cluster Layout is the one with most significance, and in the integration project, it should be considered more severely than the other clusters. Table 05 shows the correlation between clusters (Spearman Correlation Coefficient):

385

	Cluster Illumination	Cluster Climate Control	Cluster Layout
Cluster Illumination	1.00	0.22*	0.34**
Cluster Climate Control		1.00	0.46**
Cluster Layout			1.00

386

* Correlation is significant at 0.05

387

** Correlation is significant at 0.01

388

Table 05. Correlation Analysis Between the Clusters

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Table 06 gives the Spearman correlation between the questions:

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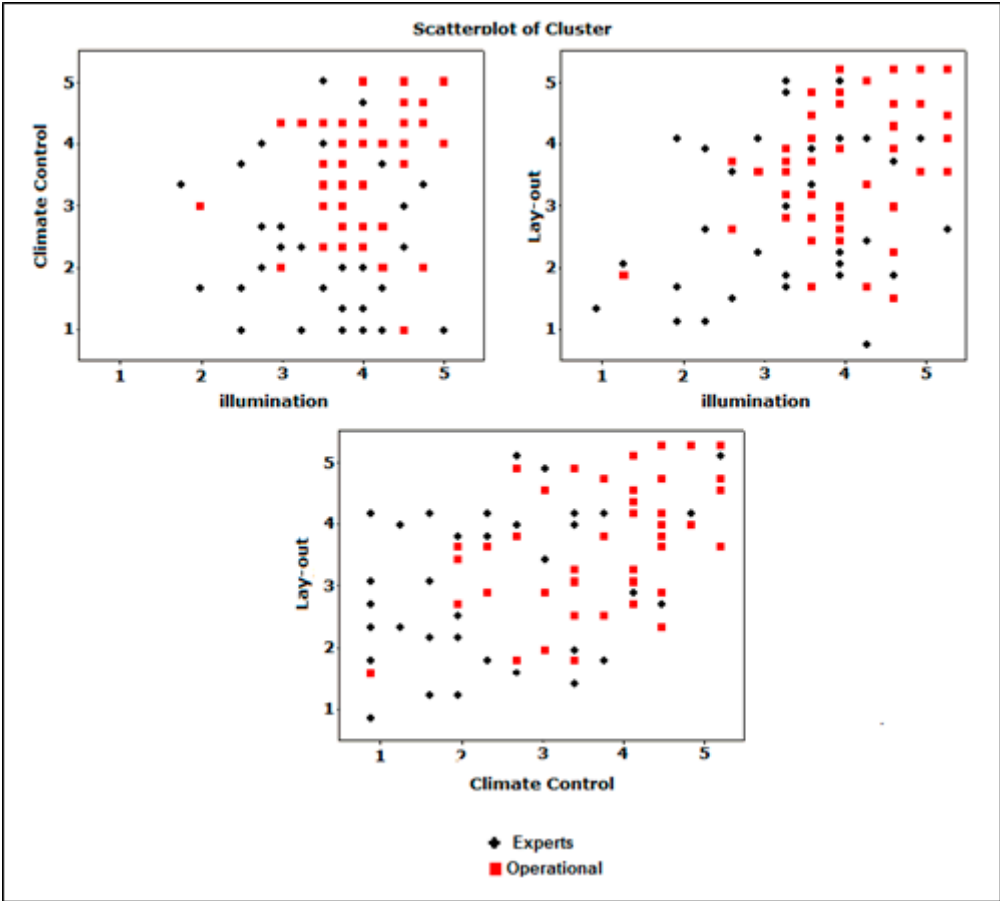
	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20	P21
P5	1.00	0.41	0.41	0.25	0.35	0.25	0.21	0.17	0.27	0.08	0.09	0.12	0.24	0.09	0.08	0.19	0.04
P6		1.00	0.26	0.18	0.41	0.35	0.37	0.39	0.34	0.32	0.38	0.38	0.28	0.30	0.19	0.30	0.27
P7			1.00	0.31	0.33	0.11	0.16	0.15	0.13	0.06	0.12	0.11	0.07	-0.11	-0.28	-0.03	0.02
P8				1.00	0.20	0.15	0.06	-0.02	-0.05	-0.05	0.12	0.13	0.13	0.04	-0.12	0.21	0.35
P9					1.00	0.39	0.34	0.17	0.27	0.19	0.25	0.03	0.20	0.09	0.04	0.08	0.27
P10						1.00	0.24	-0.02	0.13	0.03	0.14	-0.02	0.22	0.11	-0.06	0.01	0.14
P11							1.00	0.36	0.40	0.40	0.42	0.33	0.15	0.22	0.10	0.15	0.20
P12								1.00	0.23	0.16	0.29	0.46	0.30	0.40	0.35	0.26	0.27
P13									1.00	0.67	0.53	0.23	0.20	0.26	0.22	0.25	0.16
P14										1.00	0.54	0.44	0.14	0.25	0.22	0.27	0.29

P15											1.00	0.40	0.16	0.26	0.16	0.31	0.33
P16												1.00	0.40	0.48	0.32	0.48	0.46
P17													1.00	0.46	0.32	0.36	0.45
P18														1.00	0.56	0.48	0.61
P19															1.00	0.58	0.44
P20																1.00	0.53
P21																	1.00

Table 06. Correlation Analysis between Questions

Analyzing the extreme results, the lowest correlations rates (P7 x P19 / P08 x P19), it is possible to note that the P7 and P8 questions belong to illumination discipline that has low correlation to P19 question, which specifically deals with the features of the workstation. With correlations of higher grades (P13 x P14 / P19 x P20), it is observed that, being within the same discipline group, there is a higher correlation between P13 and P14 questions, that are about facilities for adjustment of room temperature and P19 and P20 questions that are related to adjustments of the workstation and the chair.

Graph 01 shows the cluster dispersion, with significant correlation, stratified by group of respondents.



Graph 01. Cluster Dispersion

In the correlation between the clusters Climate Control and the illumination, some dispersion with the group of the specialists in relation to the operational ones is observed. This reflects the lesser evaluation for the Climate Control and Lighting clusters by the specialists. These disciplines probably are of average importance to be considered in the integration project of the Drilling Centers of the specialists. In the correlation between Lay-out and lighting, it is possible to identify a greater dispersion between the groups of specialists in relation to the operational ones. This dispersion reflects the minor evaluation for the clusters of Layout and Illumination for the specialists, being these disciplines of greater importance, to be considered in the project of integration of the Drilling Centers of the specialists.

Finally, it is possible to identify a great dispersion between the groups of specialists in relation to the operational ones. This dispersion reflects the minor evaluation for the clusters of Layout and Climate Control for the specialists, being these disciplines of great importance to be considered in the integration project of the Drilling Centers of the specialists. In general, worst evaluations for the experts are observed in the correlations of all clusters. These results reinforce the initiative to integrate the drilling centers.

6. Discussion

The drilling center concept is associated with the implementation of various work processes related to the company's value chain, in the same environment, equipped with infrastructure and appropriate technology to perform a collaborative and integrated work. A control center is characterized by continuous processes. Any unscheduled interruption may represent a breakdown in the system or even risks to the operators. In the activities of drilling centers, quick decisions are needed, with risks, such as operational disruptions, with time loss and daily costs. Neither the products nor their transformations are visible or manipulable and the only way to know what happens is by monitoring indicators.

Complex systems are unpredictable and uncertainty is one of its characteristics. Communication devices are essential and there is a growing investment so that the information can be transmitted without barriers, assisting in effective decision making and integration within teams and between them. The knowledge of ergonomics complements the other numerous disciplines who participate in such a study. The challenge is to integrate all areas in order to improve the quality, productivity and worker health. The employees' participation is fundamental to obtain a standard model of requirements for these collaborative environments, through the identification and assessment of ergonomic disciplines that should be prioritized.

7. Conclusions

Based on the literature review, it is concluded that there are approaches in many organizations of Ergonomic Workplace Analysis and researches with the workforce. However, this study did not find an approach to the evaluation of statistical analysis that could be the base not only for the model, but also as defining a framework of requirements for multidisciplinary collaborative environments with operational focus. It is recommended to use for defining infrastructure requirements for new drilling centers.

The possibility of using a real operating environment brought the opportunity to conclude about the different perceptions of two main teams of drilling centers: operational and experts. With the proposed method for this work, it was concluded that the expert contributors, who participate in the integration process in the studied company, are the worse evaluations of the ergonomics disciplines of this research.

It was possible to point to some findings. The first is the integration need of drilling centers of experts, considering a redesign of the layout. The answers indicated that the integration should not be restricted to aspects of work processes, but also to a realignment of all the ergonomic disciplines that are being considered.

The second consideration is related to the focus on ergonomic disciplines that are more directly involved in the integration of the drilling centers. The statistical results showed that the layout, according to the experts, is the discipline that received the lowest evaluation, which includes not only the layout of workstations, but also acoustics and audio visual resources.

The third finding is related to the climate control discipline. In the experts and operational clusters, the response pattern was significantly lower than the others. This reflects that implementation of previous projects did not succeed and the lessons learned from other drilling centers were not considered. The combination of knowledge, based on the perceptions of the online research contributed to the creation of a design model for drilling centers, which must include at least the following requirements:

- Barriers must be avoided in all functional interactions, including verbal communications;
- Informal meeting's places increase the availability of communication resources, avoiding inappropriate decisions;
- Workstations must have necessary adjustments allowing flexibility in positioning;
- The chairs settings (as reclining backrest with screen, seat height and arm adjustment) generate greater comfort in the workplace;
- Audiovisual technologies should have adequate resources to carry out the work;
- The noise reduction should be promoted with the use of specific rooms for allocating equipment such as desktops, workstations and servers;
- The work environment noise can be attenuated, considering the use in the whole area of elements that increase the absorption of sound, such as double glass walls, drywall with internal acoustic layer and absorbent panels (acoustic plates of tissue);
- The number of professionals by environments should be adequate, so that the noise from radios, telephones and alarms will not interfere the job;
- The illumination adjustment should be considered;

- The luminaires' positioning must be analyzed to avoid reflection and glare of the monitors;
- Articulated individual luminaires must be used for each worker, for several tasks that require different luminance intensities, such as writing, reading and using the computer;
- Use blackout to reduce heat;
- The temperature control should compensate for variations among the early hours of the morning and the other hours of the day;
- The air vents should enable effective regulation of room temperature.

After integration project deployment of the drilling centers, a new online survey cycle should be considered, in order to apply the adjustments to the ergonomic requirements. It was possible to define an ergonomic model of drilling centers and to identify corrective actions for the improvement of existing projects, providing the definition of a standard to be considered in any other multidisciplinary collaborative environment in the oil industry.

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614 **Appendix A: Questionnaire**

Question			options							
B1	illumination	The possibility of the rooms illumination intensity regulation creates greater comfort in the workplace.	Strongly Disagree	Verify compliance of the implemented lighting system, it is appropriate to the work that it is developed.	Validate the implemented illumination project.	Menezes (1976) Iida (2005) Santos et al. (2009) ISO 11064 (GUÉRIN et al., 2004)				
B2			The positioning of the luminaires prevent flare and glare of the monitors.				Disagree with largely			
							Indifferent			
							A great extent agree			
							I totally agree			
		B3					The use of individual articulated lamps for each worker, meets in different tasks that require different luminance intensities, such as write / read and use the computer.	Strongly Disagree		
Disagree with largely										
Indifferent										
A great extent agree										
I totally agree										
B4		In the meeting rooms, the use of blackout type shutters reduces heat stroke, contributing to the lighting and climate control.	Strongly Disagree							
			Disagree with largely							
			Indifferent							
			A great extent agree							
			I totally agree							
B5		Layout	Decreasing the noise coming from the use of specific rooms for allocating equipment				Strongly Disagree	The environment is designed so that the noise inherent in the environment	To analyze the noise in the environment interferes with	Menezes (1976) Iida (2005) Santos et al. (2009) ISO 11064
							Disagree with largely			

		as desktop's, workstations and servers, helps to reduce noise in the environment, increasing the quality of their work.	Indifferent A great extent agree I totally agree	does not affect the user.	the cognitive functions, audible and loss of essential information.	(GUÉRIN et al., 2004)
B6		The noise from your work environment can be mitigated considering the use throughout the area of mounting elements that help the sound absorption, such as double-glazed partitions, drywall with internal acoustic mesh and absorbent panels (acoustic plates of tissue).	Strongly Disagree Disagree with largely Indifferent A great extent agree I totally agree			
B7		The use of rooms for visitors to avoid the noise and not distracts from work.	Strongly Disagree Disagree with largely Indifferent A great extent agree I totally agree			
B8		The amount by professional environment is appropriate, so that the sounds provinientes radius (UHF / VHF), telephones and audible alarms do not draw the attention of the work.	Strongly Disagree Disagree with largely Indifferent A great extent agree I totally agree			
B12		The layout were considered all	Strongly Disagree	Check whether the current design of	Validate that the layout was	

		functional interactions between desktops and between aqueleas that often need to communicate verbally with each other.	Disagree with largely Indifferent A great extent agree I totally agree	the layout covers the whole range of necessary requirements for increased collaboration between the areas.	guided by the functions of the operators and their interactions, as well as allocation of equipment and instruments.	
B13		The spaces for informal meetings included in the layout, increase the availability of communication resources, avoiding making decisions in inappropriate places.	Strongly Disagree Disagree with largely Indifferent A great extent agree I totally agree			
B14		Workstations have the features necessary for the implementation of work.	Strongly Disagree Disagree with largely Indifferent A great extent agree I totally agree		Validate that the workstations	
B15		The workstations have necessary adjustments such as height adjustment of the top and pneumatic arms to the height of the articulation of monitors, allowing for flexibility in positioning.	Strongly Disagree Disagree with largely Indifferent A great extent agree I totally agree	Identify the furniture provided meets the functional requirements for work execution	have the requirements of a production facility involving the man and the equipment he uses to do the job as well as the environment that surrounds it.	
B16		The settings that the chairs have (such as reclining backrest with screen, seat height adjustment and arm) generates greater	Strongly Disagree Disagree with largely Indifferent A great extent agree			

		comfort in the workplace.	I totally agree				
B17		The available audiovisual technologies are suitable for carrying out the work.	Strongly Disagree	Identify whether the visual aids were sized properly	Validate audiovisual resources.		
			Disagree with largely				
			Indifferent				
			A great extent agree				
			I totally agree				
B9	Climate Control	The rooms of temperature control allows you to compensate for variations between the early morning hours and other times of day.	Strongly Disagree	Temperature variations are appropriate for workers	Validate the air conditioning project implemented as service to the level of comfort should be as suitable as possible to avoid moments of dispersion and low concentration	Menezes (1976) Iida (2005) Santos et al. (2009) ISO 11064 (GUÉRIN et al., 2004)	
			Disagree with largely				
			Indifferent				
			A great extent agree				
			I totally agree				
B10		The air vents located in environments enable effective regulation of temperature for the room.	Strongly Disagree				
			Disagree with largely				
			Indifferent				
			A great extent agree				
			I totally agree				
B11		The thermometers available indicators informing the ambient temperature help to adjust the proper temperature.	Strongly Disagree				
			Disagree with largely				
			Indifferent				
			A great extent agree				
			I totally agree				