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THE REPRESENTATION OF WORK AS A COMMON THREAD OF SIMULATION: THE CASE OF THE PROJECT OF AN INTEGRATED OPERATIONS CENTER IN THE PETROLEUM INDUSTRY

Barbara de Macedo Passos Oggioni[1]*

Francisco José de Castro Moura Duarte[2]

Abstract

Simulation, in ergonomics, is characterized by a variety of approaches that differ according to the desired objectives and modalities. Two main types of simulation are frequently used: engineering simulation and work simulation. While the former seeks to predict the future behavior of a production system, focusing on quantitative aspects, the latter focuses on the work process and the difficulties faced by workers.

In the work simulation approach, the objective is to understand the work process and its characteristics, aiming to produce knowledge about situations that do not yet exist. Simulation becomes an essential tool during the design process, allowing the exploration of different possibilities and reducing uncertainty.

There are three main orientations regarding the consideration of work activity in the design process: crystallization, plasticity and development. Each of these orientations influences the simulation approaches adopted. Crystallization focuses on the representation of users and their activity in the designed artifacts, while plasticity recognizes the variability and unforeseen events of the real activity. Development, on the other hand, seeks to integrate the activity of operators into the design process, promoting a participatory dialogue between designers and users.

Work analysis is essential to support simulation, providing information for building models and scenarios. Simulation, in turn, broadens the understanding of professional problems and allows them to be manipulated to find solutions. Methods such as Characteristic Action Situations (SAC) and use configurations are developed to represent work activity in a more generic way and guide the design process.

A case study of the restructuring of an Integrated Operations Center (IOC) exemplifies how work analysis and simulation can be applied in Operational Integration (IO) projects. This study involved analyzing the functioning of the IOC, mapping the layout of the new facilities and conducting simulation cycles to discuss the future functioning of the space with the workers and managers involved. This participatory approach based on understanding the work activity shows how simulation can contribute to the design of more efficient and ergonomically appropriate workspaces.

Keywords: Simulation; Ergonomic Work Analysis; Design Process.

1. INTRODUCTION

[1] PEP/COPPE/UFRJ. * barbarap@pep.ufrj.br.
[2] PEP/COPPE/UFRJ.

Simulation is marked by a strong heterogeneity depending on the objectives to be achieved and the modalities of implementation that are requested (BÉGUIN; WEILL-FASSINA, 2002). During the design process, two types of simulation can be conducted: engineering simulation and job simulation. The first, simulation in engineering, aims to build a representation of the reality of a production system to predict its future behavior (MALINE, 1994).

This type of simulation addresses the quantitative aspects of the phenomena, that is, it works as a test bench of a situation or a procedure aimed at testing efficiency, validating this or that material, improving a device a posteriori, among others (BÉGUIN; WEILL-FASSINA, 2002; MALINE, 1994).

The second, the simulation of work (or simulation in ergonomics), changes the point of view of analysis. Simulation no longer refers to performance, but to the work process, its characteristics and its difficulties (BÉGUIN; WEILL-FASSINA, 2002). The interest is greater in the work necessary to achieve the expected results of the production or service and less in the technical process to achieve this objective (MALINE, 1994).

According to Béguin and Weill-Fassina (2002), simulation, in this case, is an intrinsic dimension of conception: at the same time that it allows an exploration of the field of possibilities, it participates in the process of reducing uncertainty, being an instrument of project management and ergonomic intervention.

Béguin (2010) explains that, in project situations, it is not enough to analyze only the current work: before the transformation, it will be modified as a result of the act of conception and, after this act, it is too late because the decisions have already been made. Thus, according to Béguin *et al.* (2019), the simulation of work appears as an inevitable method to produce knowledge about work situations that do not yet exist, configuring a response to the "paradox of ergonomics of conception" (THEUREAU; PINSKY, 1984).

Simulating work situations is a method that combines a situation model (or part of the work elements) and the activity of one or more subjects (BÉGUIN; PASTRÉ, 2002). To do this, simulation support is needed to "put the work on stage" and allow dialogue between operators and designers.

However, the passage from the analysis of the activity to the construction of the simulation is not a trivial exercise: it requires a better identification of what, based on the analysis of the work, can and should be staged and in what form (BÉGUIN, 2006). Thus, this

article aims to analyze how the representation and translation of the result of the Ergonomic Work Analysis is performed during simulation in a design process.

To allow this analysis, it is based on the consecutive reflection of the ergonomic intervention in the restructuring project of an Integrated Operations Center (IOC), in the context of Operational Integration in the Brazilian oil industry, in which it was sought to expand its capacity to support maritime operations.

2. THEORETICAL FRAMEWORK

There are three orientations regarding the consideration of the work activity in the design process: crystallization, plasticity and development (BÉGUIN, 2010). Thus, there are also different simulation approaches mobilized by these three orientations.

In the orientation of crystallization, every technical device and every artifact mobilizes a model of the user, his activity and his work during the design process. This representation, once crystallized in the artifact, is conveyed in the work situation (BÉGUIN, 2005).

According to Béguin (2006), in the ergonomics of the activity, this approach does not focus only on modeling the functioning of the subject, but on building a model of the activity in a given situation, which can be characterized as a "simulation of situations" (VAN DAELE, 1997 *apud* BÉGUIN, 2006).

In this sense, it is necessary to obtain a model of future activity. To carry out this anticipation, ergonomics has general knowledge about human functioning and knowledge about the adaptation of technical devices to human beings (BÉGUIN, 2010).

The model of future activity is built from data obtained with the analysis of the activity in reference situations. The association between these types of data makes it possible to reconstruct the coupling and, by association, to build scenarios to be mobilized in the simulation. However, the objective is not to build a model of the subject's functioning, it is a matter of modeling and simulating a coupling, whose purpose is to make a prognosis (BÉGUIN, 2010).

The plasticity orientation considers that in real situations there are variabilities that are not always possible to be anticipated. According to Béguin (2008a), operators encounter unforeseen events and resistance linked to the contingencies of the situation and the fluctuations of their own state during their work.

In this way, design decisions can open or close the possibilities of activity in the future for operators (DANIELLOU, 2005). The challenge is not, therefore, to predict in detail the activity that will be developed in the future, but to assess to what extent the design choices will allow the implementation of operating modes compatible with the chosen criteria, in terms of health, productive efficacy, personal development, among others (DANIELLOU, 2007b).

In this orientation, according to Daniellou (2005), the main objective of simulation is to include in design decisions the space for "possible forms of future activity". According to the author, the ergonomist starts from the reference situations to understand the variabilities of the work situation and build scenarios on which this type of simulation will be based. Also according to the author, the simulation can demonstrate whether, for any action situation that the ergonomist has considered, there are one or more acceptable modes of operation from the point of view of health, skill development and efficiency. Likewise, it should allow the operator to create other possibilities after the project.

In a way, as the activity cannot be fully anticipated, the predictive function of the simulation is reduced, but it is not abandoned: while the simulation of the previous orientation argues that it is necessary to anticipate with maximum precision, in this orientation, the simulation must anticipate the plasticity or the margins of maneuver left to the operator (BÉGUIN, 2005).

The development orientation considers that the constructive activity of the operators should be an integral part of the design process and that the inventiveness of the activity should be brought into line with the developments of the designers. Development consists, therefore, in articulating in the same movement, the development of situations, such as the artifact and/or organization, by the designers and the development of the resources of the action by the operators, constituting a "distributed conception" (BÉGUIN; CERF, 2004).

Simulation in the orientation of development seeks to contribute to the dialogical process of conception (BÉGUIN, 2010; BÉGUIN; CERF, 2004). Thus, according to Béguin (2005, 2007b), orientation is intrinsically participatory, since, during conception, it favors dialogical processes in which designers and operators participate in the design process based on their diversity and specificities.

2.1. Minimum Units of Work Analysis and the relationships with simulation

The analysis of the work is a prerequisite for simulation. To simulate, the analysis of the work helps to make choices, identifying work problems, which allows the construction of the model. However, simulation usefully expands the analysis of the work: it objectifies

professional problems, stages them in order to manipulate them, in an attempt to understand or solve them (BÉGUIN, 2006).

In ergonomics, work analysis and simulation must be carefully articulated, as these methods complement each other. However, it is necessary to move from the analysis of existing situations to simulation and to the design of new situations. To deal with this paradox, the ergonomics of the activity sought to reflect on the formulation of work situations in an elementary, minimal form of the activity (DUARTE; LIMA, 2012).

In the search for more general models to support simulation and design, some proposals have been developed for the ergonomics of the activity. Some propositions seek to describe the minimum units of representation of the activity in the simulation of the work, such as: (i) the Characteristic Action Situations (SAC), developed from the approach of the future activity (DANIELLOU, 1992); and (ii) the usage settings (DUARTE; LIMA, 2012), developed to allow the creation of project recommendations.

2.1.1. Characteristic Action Situations (SAC):

The approach to future activity (DANIELLOU, 1992) seeks to intervene in projects with the prediction of the space of possible forms of future activity, evaluating to what extent the design choices will allow the implementation of operating modes compatible with the chosen criteria, in terms of health, productive effectiveness, personal development, among others (DANIELLOU, 2007a).

The approach consists of analyzing the work in the existing reference situations (current situation that will be modified or situations with technology similar to the planned), where it will be possible to identify the Characteristic Situations of Action (SAC), with different degrees of detail, combined descriptions and structured in scenarios that will instruct the simulations of the possible future activity (DUARTE; LIMA, 2012; GARRIGOU et al., 1995). The SACs (or typical situations), whose concept originates from Jeffroy (1987 apud DANIELLOU, 1992), constitute the elementary units of ergonomics of conception (MALINE, 1994).

The result of the analysis of the reference situations is an identification of the forms of variability that may arise in the future system (DANIELLOU, 2007b). In this way, it is possible not only to highlight the normal operating situations, but also the situations related to incidents, adjustments, cleaning, maintenance, among others (GARRIGOU et al., 1995).

For Maline (1994), the SACs constitute the irreducible and operational link that allows an instruction of the future based on the existing. However, the enumeration of them in the

project still offers a partial view of the conditions in which operators carry out their work activities. In addition, according to Maline, it is not the sum of identified SACs that provide a global picture of the future: there is a need to put into play the typical situations, based on the SACs, in the simulation, placing them in a temporal perspective and articulating them with the design criteria.

Thus, the analysis of the work within the framework of a simulation approach to identify typical situations in the work is a projective phase, of elaboration of scenarios, and also depends on a previous understanding of the characteristics of the project (MALINE, 1994). The identified work logics, transported to the future situation, offer a possible structuring of the activity while offering the freedom to evolve to explore different scenarios of action logics (VAN BELLEGHEM, 2018).

2.1.2. Usage Settings:

The concept of use configuration aims to answer the question of how to integrate ergonomics into the project. It is a way of translating the knowledge of the activity, in a more generic way, based on the ergonomic analysis of the work of a reference situation, to guide the design process.

According to Duarte et al. (2008), the general principle that guides the cooperation between ergonomics and engineering is to build project specifications based on the activity, based on a strong conception of migration from the user experience to the design function. But, for the authors, this migration from work experience to the project presents itself as a resource and, at the same time, brings a challenge, precisely because of the situated, historical and singular character of the work activity analyzed.

In this sense, as a response to this challenge, the configurations of use function as substantive content and as a scenario for designers to engage with future users through the experience of current users (DUARTE; LIMA, 2012). In this way, they allow the specifications that will guide the conduct of the project to be built based on the work experiences of the workers themselves.

The configurations of use are an abstraction of the analysis of Characteristic Action Situations (SACs) and constitute an intermediate path, situated between the general principles of ergonomics, such as "facilitate access to the operator", and the details of this access in a given project (DUARTE; LIMA, 2012).

Thus, what defines the configuration of use is always the combination or *couplage* (coupling) between, on the one hand, the physical-technological aspects (environment, space,

instrument, object, equipment), the social context and the cognitive orientations (example: "open a valve for ...") and, on the other hand, the practical scheme, which underlies a given activity (DUARTE; LIMA, 2012).

3. METHOD

This research is based on the restructuring project of the Integrated Operation Center (here called COI-Alfa), where an Ergonomic Work Analysis and three cycles of Ergonomic Simulations were carried out to support discussions with workers and managers for the creation of project solutions. The subsequent analysis of the ergonomic design process used in the case study aimed to understand how Work Analysis and Ergonomic Simulations can contribute as participatory methods in IO projects.

3.1. Context of the case study:

This research was carried out in an oil production unit of a Brazilian oil industry. With the expansion of the pre-salt operation and the arrival of new platforms in 2021, the production unit started the restructuring project of the Integrated Operations Center (IOC), an existing initiative to support onshore production

The new IOC project would move its operating site, currently in separate rooms, to a large center that would be located in an old unoccupied restaurant and kitchen in the same building. The goal was for the center to be able to accommodate the increase in staff and allow the reinforcement of interactions between teams, making the integrated support character more effective.

3.2. Participants and Intervention Approach

The study participants are composed of the existing CCO teams, which are: 3 predictive monitoring cells of equipment and systems of offshore platforms; 1 logistical support team; 1 operational support team, which controls the gas network and provides emergency support for offshore operations; 1 support team for planning and optimization of the gas pipeline network; 1 infrastructure support team for the CCO itself and the IO management team, project demanders.

The field research was divided into three main stages:

(1) Study of the work, which consisted of:

- the initial analysis of the general functioning of the IOC-Alpha, seeking to understand how these teams work and what are the integration relationships between them;
- a more in-depth analysis of the IOC-Alpha's activity, accompanied by brief visits to other reference situations, such as the IOC of the Beta Production Unit;
- the formulation of the configuration of use (DUARTE; LIMA, 2012) for discussion among the actors during the simulation phase.

(2) Study of the design and specification of the workspaces, which consisted of:

- in mapping the layout of the facilities available for the new IOC spaces and the forecast of expansion of the teams;
- in the integration of the technical team (architects, engineers and designers);
- and in the creation of the initial layout hypotheses, these hypotheses being the starting point for the dialogue between the simulation actors and the development of the layout.

(3) Simulation cycles, developed in three stages to advance the discussion on the future functioning of the IOC in a new space, as follows:

- First cycle of simulations, whose objective was to start the dialogue with the teams and managers, in order to select between two layout proposals created by the team of ergonomists. This was the first contact of the workers with the space project;
- Second cycle of simulations, which aimed to understand the integration relationships between teams in space. To this end, an interactive floor plan (such as a game board) and paper plans were used as discussion aids on the organization of spaces. This simulation was carried out in two stages and in the same environment that would be transformed to receive the new IOC;
- Third cycle of simulations, whose objective was that the participants – operators and managers – could discuss the work. These dialogs were based on the previously produced layout, which was supplemented by a 3D representation of the future layout, including devices, workstations, windows, etc. As in the previous simulation, the meeting took place in the room to be transformed and a game board, paper plans and 3D images were used. As the game board was

two-dimensional with a superior view of space, the intention was to give other dimensions to the discussion.

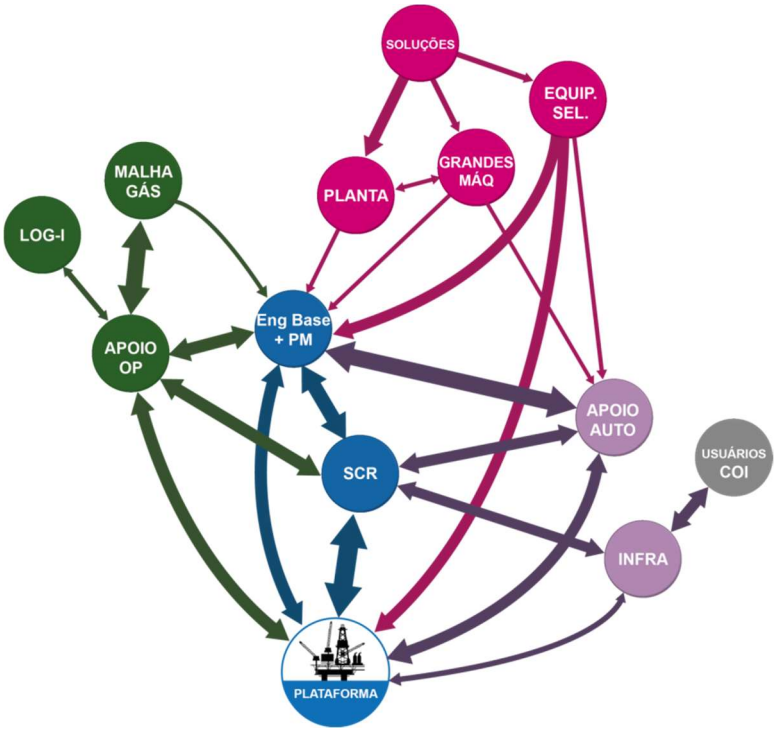
4. FINDINGS

The initial analysis of the work, with the understanding of the general functioning of the IOC-Alpha and the main activities of the teams, a stage of the ergonomic analysis of the work, allowed the construction of the first layout proposals for discussion with operators and managers in the first simulation cycle. At this stage, knowledge of the work and key interactions between teams guided the discussions.

The study of the general functioning made it possible to characterize the existing integration between the IOC-Alpha teams, which were represented through a scheme of interactions, presented in Figure 1. This scheme allowed the ergonomics team to visualize the relational intensity and communication between operators on the same team and between different teams.

The frequency of interactions is represented by the thickness of the arrows. The thicker the arrow, the greater the intensity of the relationship between the teams. These relationships were due to the need for communication and exchange of information and data to carry out the work. Each color in the sociogram represents a nature of integration between *the onshore* teams to support the oil platforms, here called integration groups.

Figure 1 - Scheme of interactions between the IOC teams



Source: The author

For the simulation cycles, the deepening of the analysis of the work allowed the creation of the usage configurations, bringing elements of the work to the simulation dynamics. Consequently, the discussions among the project actors covered both the definitions of the choices of the physical arrangement and the future work to be performed in these environments.

The second phase of the study of the work had the objective of deepening the analysis of the work for the creation of the configurations of use of each team analyzed. In this way, it was possible to build the scenarios in the simulation cycles. Each configuration of use sought to describe both routine tasks and work variabilities, such as emergency situations.

During the simulation meetings, the references in relation to the work allowed the operators to reflect on the construction of new ways of working, which necessarily involves reflecting on the current work performed in the teams. This reflection was possible from the mobilization of the use configurations by the team of ergonomists during the simulation dynamics.

The excerpts of dialogues between ergonomists and operators during the second stage of simulation exemplify how the elements of the work influenced the changes in the layout, such as: (1) the sharing of information between team members, (2) the monitoring characteristic

and the consequent physical organization of the workstations in view of these specificities, and (3) the interaction between different monitoring teams.

For the monitoring teams, which carried out predictive monitoring of turbomachinery, safety equipment and processes of the *offshore* plant, there was a managerial demand for the use of large screens (videowall) in the future environment. Thus, the question of whether or not to use the videowall was an important topic in conducting the simulations. During the second simulation cycle, a monitoring operator emphasized the difficulty of understanding what the large screens would be used for, since they were not needed today, but were leading to a line layout, with all workstations facing the videowall.

From this, the ergonomists guided the discussion, citing the characteristic of monitoring of trying to anticipate deviations in the equipment on board, as shown in the extract from the following dialogue:

> ***Ergonomist:*** *- Your actions are not immediately, they are not in real time.*
>
> ***Operator:*** *- Our maintenance is predictive, it is medium and long term. Because, for the short term, you have the operator in front of the screen, the unit's supervisor. It's no use for me to talk, for me to call the guy and say: look, it's alarming there high temperature in such and such a place! He is already seeing this there, his supervisor is already alarming him! I want to see it first!*
>
> ***Ergonomist:*** *- What can you anticipate, right?*
>
> ***Operator:*** *- Exactly! I'll see before I alarm at it! Nice to follow, but it's not an operation... Our focus is not that! It's not putting out a fire and solving a problem that's about to happen that day. That's right, the unit on board has to solve it.*

This dialogue ends up being a driver for the operator to reflect on what could effectively help in the task of monitoring, if there was a videowall:

> ***Operator:*** *- What has already happened, I don't want to get involved. But I think it's interesting to put the machines, their status, their efficiency so that we can be there to follow them. Suddenly, you look at it and see: oh, the efficiency of this machine here is falling, people! Let's focus on it! Maybe it would be interesting to put these efficiency tags, which is the same thing that will serve for plant monitoring! Process plant has a very close border there with the big machines.*

5. DISCUSSION

The knowledge that work is at the center of the development of Activity Ergonomics as a discipline, with the objective of building knowledge about the human being in activity

(FALZON, 2007). However, ergonomics has a transformative perspective: it aims at action. In order for this knowledge to effectively transform the reality of work, the discipline has been transforming its methods to contribute to the point of view of the activity still in the conception phase.

In this way, the work activity is the integrating element (GUÉRIN et al., 2001) that allows structuring the conditions for carrying out the work from the origin of the project, in the sense that it articulates and recomposes in action a set of technical, organizational and social determinants (DANIELLOU, 2007a; MALINE, 1994).

The analysis of the activity is, therefore, the basis that makes it possible to understand the professional practices to be considered in the conception. However, transposing the knowledge of the work to the project is not trivial and requires the development of strategies that allow its mobilization during this process.

In order for the work to be at the center of the dialogue promoted by the simulation, it is necessary that a representation of the work be built and mobilized during the simulation. It is necessary to transpose and put on stage the result of the analysis of the work in the simulation.

To transpose means to pass, in some way, from the analysis of existing situations to the simulation of new situations. Thus, work situations must be formulated from the elementary form of the activity. This minimum unit of activity contributes to the construction of scenarios (MALINE, 1994) that allow guiding the simulation meetings so that it is possible for the construction to work in the future.

However, the choice of the way in which the work activity is transposed to the simulation indicates what kind of orientation regarding the consideration of the work activity in the design process will be mobilized. In the crystallization approach, for example, the challenge is to produce a model of future activity, that is, a better-founded model of the coupling between the subject and the object projected as a project resource (BÉGUIN, 2010).

To this end, Béguin (2010) highlights that the association between Characteristic Action Situations (SACs) (DANIELLOU, 1992) and typical situations (MALINE, 1994) allows the construction of this coupling and, therefore, also allows the creation of scenarios that will be experienced during a simulation. However, the purpose is to make a prognosis, an anticipation of the future situation.

In the plasticity approach, which is anchored in the concepts of diversity and variability, simulation should contribute to the design of possible forms of future activities, defining

margins for maneuver for the project. In this orientation, according to Béguin (2010), the analysis of the SACs no longer aims to identify units of tasks that can be transposed to future situations, but rather to allow a balance of the diversity and variability of the work contexts so that the operator, in view of the variability of the situation and his own state, can implement modes of operation that allow him to achieve the production objectives without putting his health at risk.

As the activity cannot be fully anticipated, even in plasticity, the predictive function of the simulation, although reduced, is not completely abandoned, since in this orientation, the simulation must anticipate the margins of maneuver that will be left to the operator.

In the development approach, however, simulation aims to contribute to the process of joint development of situations and activity (BÉGUIN, 2010). In this sense, the simulation cycles of the IOC-Alpha project articulated in the same movement the development of the layout and the development of the activity by the operators, contributing to a dialogical process of the conception.

It is observed that, in this case, the simulation contributed to the project being configured as a non-teleological process (BÉGUIN, 2010). From a layout pre-established by the ergonomics team, based on the analysis of the work and the inferences of the managers, the simulations began a process of "construction, exploration and journey" (BÉGUIN, 2010), in which the artifact (IOC layout) and the activity are developed in parallel in the design process itself.

However, for this development to occur, the way in which the work activity is represented during the simulation must lead to an articulation, a coupling (*couplage*) between the task and the subject (BÉGUIN, 2010). No longer fitting in, in this way, into a perspective of anticipation, but of building a way of working in a new place, with new tools and technical devices designed together.

In the example of the IOC, the unit of analysis used to represent the work in the simulations was the Configuration of Use (DUARTE et al., 2008), which allowed the representation of a dimension of the situation (the task, with such means) and a dimension of the action (the activity of the operator, the actions he uses to achieve such a task).

According to Duarte and Lima (2012), the configurations of use are abstractions of the Situations of Characteristic Actions. It can be considered that the SACs are an inventory of the diversity of situations that operators may encounter and, therefore, are related to the tasks. The

configurations of use are based on the situations expressed by the SACs and reveal a way of doing, they are invariant of the activity: it is related to "how the operator will do to meet the task, given a certain condition".

There is a change in the way the usage settings are used in the project. Created to serve as a basis for decision-making to the act of designing by designers, simulation becomes a vehicle for the representation of work for the construction of new ways of doing things for operators.

In the case of the monitoring team, the in-depth analysis of the work to identify the usage configurations also allowed an understanding of the characteristics and specificities of monitoring, issuing and controlling alerts for the platforms. This characteristic of the monitoring work of trying to anticipate possible deviations in the equipment on board guided the discussions in the simulation so that the operators reflected on what would be the positioning of workstations and what equipment would be needed.

"Our maintenance is predictive, it is medium and long term" or "it is not an operation, (...) It's not putting out fires", are the operators' statements that indicate the way the team is monitored and the reason for not needing the videowall for a job that needs analysis and not short-term actions: "Because, in the short term, you have the operator in front of the screen of the offshore unit".

In the operators' conception, large screens were necessary equipment for those who effectively operate the equipment and need to have the variables readily available during this task. Unlike the operators' view, the manager saw the videowall as a way to share unified information (which he did not yet know would be relevant) to the teams, equalizing the knowledge of the situation among the operators.

In this way, conducting the simulations through scenarios based on the configurations of use allowed the work to be mobilized and put on stage by the workers, even when the managers insisted on a vision of integration from large screens (videowalls). It is observed, however, that during the simulations, when there was no representation of the work originated by the elements of the activity, the dialogues between the actors (including the workers) were more centered on the technical devices and less on the work.

6. CONCLUSIONS

The objective of this article was to understand how the perspective of work is mobilized and represented in simulation. In this point of view, the analysis and simulation of the work maintain dialectical ties while the project is executed.

On the one hand, the ergonomic analysis of the work allows the production of knowledge of the work, which guides the choices made during the project. On the other hand, the detailed analysis of the activity promotes debates about the work in the simulations to contribute concretely to the transformation of working conditions in the future.

For this, it is necessary that the result of the analysis of the work be transposed to the simulation from the elementary form of the activity, contributing to the construction of scenarios and to the discussion about the development of new ways of working in the future.

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