Control-center design recommendations for critical sectors of Colombian infrastructure

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Abstract: Concepts in control-center design have quickly evolved during the past decade, particularly due to significant improvements in the fields of ergonomics and anthropometry as well as advances in information technology and learning methods. Nowadays, control centers are core elements toward productivity and reliability in different sectors such as power generation, national security and others, where critical processes are monitored, controlled and/or protected using centralized control structures. However, current control centers in South American countries are far from conforming to worldwide high-quality standards. In this article we present the weakest aspects of existing control centers in Colombia as well as practical recommendations to improve such conditions**.**

Palabras claves: control panels, control stations, ergonomics, human machine interface, critical areas

1. INTRODUCTION

Control centers represent some of the most important structures for monitoring and controlling critical infrastructure. However, Colombian control centers were designed according to old standards no longer valid in developed countries (Graanas and Rhea, 1988). In this paper we present a review of the current issues associated to control centers as well as the new international standards (Kumar, 2006). These standards provide guidelines on how to increase productivity and competitiveness within control centers in South American countries, considering occupational health risks for workers. First, we state the problem by showing the economic reasons that have led to an intensive use of control centers and also identify the most relevant challenges to build more centers in the future. Afterwards, a new proposal to be implemented at control centers (in compliance with international standards) is described. This proposal considers the current situation of control centers in Colombia as well as new advances available in terms of information technologies. Finally, conclusions are presented

2. PROBLEM STATEMENT

From the beginning of this century, a greater degree of process automation and centralized control has taken place in different sectors such as power generation, national security and major industries; yet, humans remain part of control processes at some level. Moreover, because the cost of processes managed by an operator at control centers have increased significantly, a growth in the risks associated to human behavior is expected.

It is expected that human beings continue to be in charge of monitoring and controlling processes. Recent studies (Sheridan and Parasuraman, 2005) suggest that an increase above the optimal automation level (cutoff) results in an indirect increase in staff (Fig. 1).

In this context, control centers around the world, particularly those built in the 90s in South American countries, require significant improvements. These centers were built according to old paradigms that focused on instrumental engineering (Dy-Liacco, 1991).

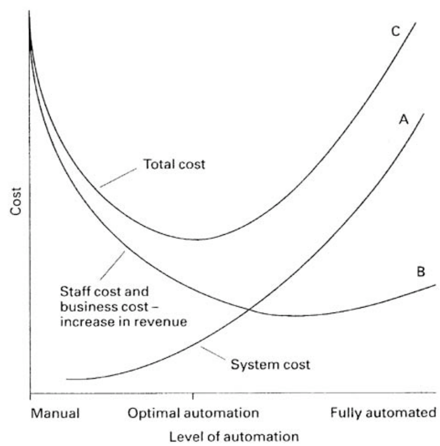

Fig. 1. Selecting the level of automation as an optimization problem.

The following challenges in the design of control centers were identified:

2.1. Increased productivity of control centers.

As shown in Figure 1, human machine interfaces for a process control center are most needed once the level of automation has been significantly increased. Additionally, a control center is usually located far away from where the process takes place. These facts lead to higher levels of responsibility falling on staff, which is a great challenge in terms of productivity

2.2. *Occupational health in control centers*

Current trends in the design of control centers focus on instrumental engineering and informatics infrastructure, leading to new data visualization tools and electronic control devices. These new elements were not available for system operators in past decades since such aids were not considered in the design. The challenge now is about how to incorporate all these new technologies without putting the operator at risk. New occupational health measures must be taken into account (O' Neill and. Albin, 2011). For instance, video projection systems must comply with some particular dimensions (measurements) in order to avoid negative effects on the people in a working environment.

2.3. New learning capabilities and information technologies in control centers

Initially, the workplace environment in control centers did not allow operators to assess their technical skills from time to time. However, this is now possible by means of process simulators and other advances in information technologies. Operators can interact with the real process without taking any risks. All these aids certainly improve workers training and shorten learning curves at the same time.

3. INTERNATIONAL STANDARDS

The following is a summary of worldwide standards, which represent the most relevant recommendations for control-center design in sectors like power generation, national security, and heavy industries.

3.1. ISO 11064- Ergonomic design of control centers

ISO 11064 (ISO 11064- 7, 2006) is an international standard that refers to the ergonomic design of control centers following a top down approach. This standard is divided into five main phases.

Clarification. Different aspects of the Project must be detailed, namely: system management, timeline of the project, equipment restrictions and budget. Ergonomics must be present at all stages of development, even in this first step.

Analysis and definition. Functions in the control room and performance indicators must be specified together with work assignments.

Conceptual Design. The physical layout of the room is defined as well as furniture design. Moreover, control and visualization devices must be designed.

Detailed Design. In this phase, ergonomic specifications of control and visualization equipment as well as furniture must be detailed.

Operational Feedback. The process is revised in order to guarantee success in the deployment of this methodology and so have it as reference for future projects.

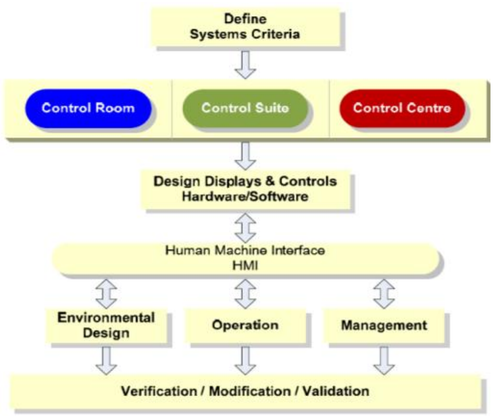

Fig 2. ISO 11064-1 STANDARD

The applications of ISO 11064 to complex systems are divided into eight parts:

Part 1: Control-center design principles

In part 1 there is a list of nine principles of ergonomic design for control centers:

- Principle 1: It is necessary to develop a point of view based on human-centered design (HCD) in order to apply the methodology depicted in Figure 2.

- Principle 2: Ergonomic integration must be considered as a regular practice of informatics engineering within the overall project management.

- Principle 3: Improvements must be designed based on iterative processes. Control room projects are dynamic. Then, from start to finish, it is necessary to deploy an iterative design cycle.

- Principle 4: System behavior must be monitored based on a situational analysis centered on the workplace environment.

- Principle 5: System behavior must be monitored based on tasks analysis of the industry operator

- Principle 6: Design fault-tolerant Systems. It must be considered that human mistakes cannot be avoided altogether.

- Principle 7: Make sure that customers are involved in the design processes.

- Principle 8: Interdisciplinary teams are essential.

Part 2: Arrangement Principles of control suites

Part 2 is centered on the arrangement of control suites, which perform complementary tasks in addition to the supervision tasks carried out within the control room. These complementary tasks are extremely important and deal with different functions such as: maintenance activities, environment conditions, control room security and information servers, leading to supervision activities.

Part 3: Control room layout

Part 3 focuses on physical layout within the room according to some recommendations; for instance, 15m long by 9 m wide and 2m in height. Other aspects such as distance between operators are also considered.

Figure 3 shows the different parts of a control center according to ISO 11064

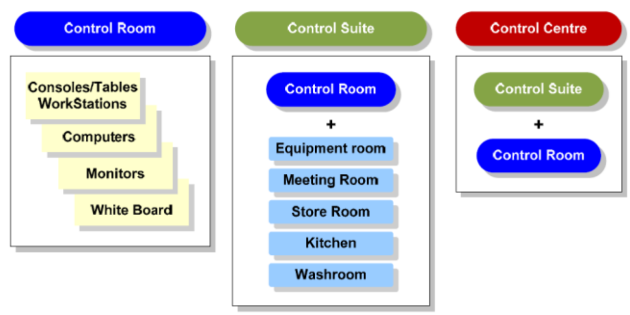

Fig 3. ISO 11064-3 STANDARD

Part 4: Layout and dimensions of workstations

Part 4 establishes the design of workstations so that they fit operators. For instance, the study of operator postures when sitting to carry out supervision tasks. Distance between the user and the computer screen (750-1000 mm) is greater than that in the design of office workstations (500-600 mm)..

Part 5: Displays and controls

Part 5 provides specifications for the design of control equipment and displays. For the latter, ergonomic specifications are described in ISO 9241, which include comments on graphical user interfaces in terms of operator performance measures and satisfaction levels (ISO 9241-11).

Part 6: Environmental requirements for control centers

Part 6 considers the environmental requirements of control rooms, namely ambient noise, light and temperature levels; these variables are extremely important because operators work in consecutive shifts during the morning, afternoon and night.

Part 7: Evaluation principles of control centers

Part 7 refers to the evaluation principles of control centers. Some recommendations are given on the different elements of a control center, namely control rooms, screens and workplace environments.

Part 8: Ergonomic requirements for specific applications

Part 8 refers to ergonomic requirements for the specific applications usually found in control centers (Figure 4).

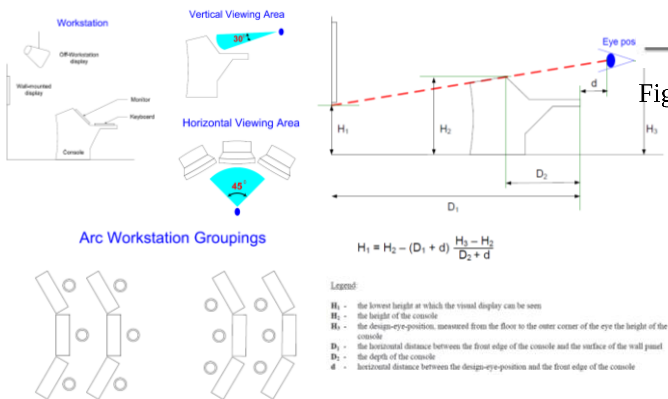

Fig 4. Ergonomic Functional Model Examples. Source: ISO 11064-3

3.2. ANSI/HFES 100

This American standard covers operator-machine interface issues associated with computer workstations commonly used in offices (ANSI-HFES 100, 2008) (i.e., intentionally built indoor office workplaces) intended for text-, data-, and simple graphics-processing tasks. This standard applies to computer workstations for a wide range of users; in general, the physical dimensions and force requirements are designed to fit at least 90 percent of the North American population. Some key aspects of this standard are the following:

- The number and type of computer input devices commonly used (such as mouse, trackball, joystick, etc) have increased dramatically since the original standard was released. Thus this standard incorporates specifications for these new devices.

- It is commonly recognized that people at work need to frequently change their posture during the day to maintain comfort and productivity. From this perspective, this standard places particular emphasis on all four recommended work postures (Figure 5) for computer workstation users.

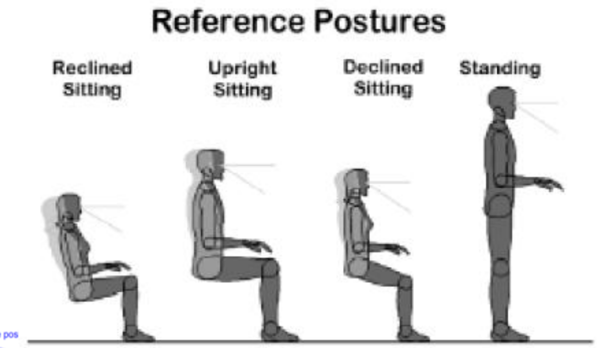

Fig 5. Reference Postures. Source: ANSI/HFES 100–2007 Human Factors Engineering of Computer Workstations

- Workspace design used to be thought of in terms of specific individual components, and did not consider how the necessary parts fit together as a whole. This way of thinking has shifted to a holistic perspective in which individual workstation components are specified in terms of how well they work together.

3.3 MIL-STD-1472G

This American military standard MIL-STD-1472G (MIL-STD-1472G , 2012) establishes general human engineering criteria for the design and implementation of military systems, equipment, and facilities.

Figure 6 shows some examples of ergonomic functional models that meet this standard. Different work postures are recommended to users sitting in front of a computer screen.

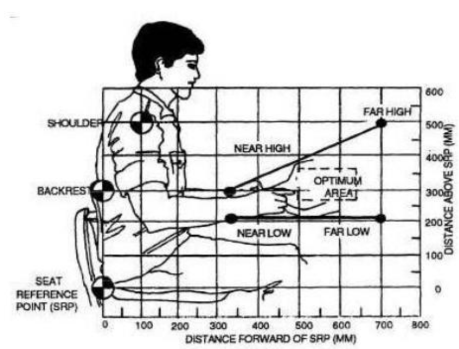

Fig 6. Ergonomic Functional Model Examples. Source: MIL-STD-1472G, 2012.

4. CONTROL-CENTER DESIGN

4.1 Current situation in Colombia

In order to provide an appropriate representation of control centers in Colombia regarding critical infrastructure industries (Garcia, 2002), a survey was conducted in conjunction with three firms of consultants. These firms are currently working with different companies and have implemented (so far) more than 10 control centers throughout the country. The results show the following common features:

- The designs were made more than a decade ago. These industries do not meet current international standards because no periodic evaluations or adjustments are carried out.
- The designs were made according to old paradigms of instrumentation engineering and computer-controlled systems. People in charge of control centers claim they know virtually nothing about international ergonomic standards.
- Workspace dimensions are smaller than suggested by international standards. The actual spaces have been arbitrarily changed (over time) by people who placed new obstacles. Some spaces were redefined to become either warehouses or new offices for commercial or business purposes. Spaces now differ to a great extent from their original layouts intended for control-center operation activities.
- The workplace is usually a confined space and there is a series of physical obstacles throughout the control center areas.
- Each operator has been assigned a certain area, which is his/her responsibility. Operators are not allowed to exchange activities with other operators on working days.
- The Operator’s skills are tested just to follow formal procedures before the company hires the operator. There is no training course for operators to enroll in when activities and shifts are not as demanding (off-season activity).
- Corporate audits do not include formal assessment of ergonomics aspects as well as of specific control-center standards.
- A lot of software and hardware devices have been increasingly incorporated into the original designs of control centers.
- Illumination is not adjustable according to specific needs or environment conditions, which may vary during shifts (night, sun, rain, presence of external illumination).
- Operators are usually evaluated according to their corrective-action responses, which represent the main index of work performance. Operators are not as visible employees for companies since their shifts seldom coincide with the rest of the staff.

4.2 Expected Scenario

Once international standards were revised, the following characteristics were identified as best practices:

- Any design should prioritize all aspects and focus on creating a healthy environment for humans. People involved in working activities within control centers should be allowed to participate in activities associated to the design of centers themselves.
- Ergonomic requirements must be applied to control centers. Also, a formal documentation procedure is necessary in order to assess improvements.
- Actions resulting in psychological welfare of operators must be considered, e.g. inclusion of windows in the workplace.
- Assessment of control-center design must be constant (especially regarding ergonomic aspects) whenever changes in visualization systems take place or new devices are incorporated.

- Evacuation routes must be updated every time configuration changes in the control center take place.
- Simulation environments should be incorporated in order to train operators in their functions within the control center (similar to the training undertaken by air traffic controllers).
- Ergonomic standards and operators’ standard of living must be audited on a regular basis.
- The application of international standards to Colombian companies should be aimed at preventing physical and mental fatigue as well as risk costs associated to operator disability caused by ergonomic reasons.
- Software applications in control centers must be revised in order to assess stress conditions and short term memory response of operators.

- Flexibility is privileged in all phases of design. For instance, in shift changes, validating the ability of the workplace to be adjusted to the different heights of people should be relevant.
- In general, the number of colors and options are limited to the minimum required as part of human-error mitigation strategies.
- Control-room resource planning depends on how much responsibility is taken by operators, and also on implementation impact on critical infrastructure.
- Emergency aspects such as seismic capabilities, fire response plans and evacuation routes must be taken into account when designing a control center.
- Workspaces and elements within the control center should be analyzed in different scenarios. For instance, swivel chairs must be tested in diverse positions or in different tasks according to their operational demands.

In summary, the design of control centers involves a holistic analysis that yields long-lasting solutions (Cummings, Bruni and Mitchell, 2010) and is intended to avoid immediate, yet temporary approaches.

5. CONCLUSIONS

After carrying out a comprehensive review of increased productivity resulting from improvements in workplace environments and great advances in ergonomic design applied to control centers, the implementation of ISO 11064 standards is highly recommended in South American countries like Colombia. The implementation of this standard covers different sectors such as energy, national security and large industries.

It can be identified that people in charge of companies usually know very little about international standards for the design of control centers (e.g. ISO 11064) and about the adverse effects of lacking ergonomic criteria. Training courses in this subject are necessary. Additionally, it is necessary to understand that adopting international standards has very positive effects in productive processes and healthy working environments.

International experience suggests a great deal of other opportunities in terms of new product development and competitiveness improvement as long as international standards are adopted.

As best practices to be implemented in Colombia, external and internal audit processes as well as training courses in control-center standards within the companies must be carried out in order to ease the adoption and dissemination of standards.

Finally, all these new standards must be incorporated into the design of new control centers around the country as well as into existing centers whenever new equipment for control and visualization systems is added. The full adoption of these standards is expected to occur in the near future.

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