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THE DEVELOPMENT OF COMPETENCIES AND INDUSTRIAL MAINTENANCE PRODUCTIVITY IN HIGH-RISK INDUSTRIES

Francisco Duarte: fjcmduarte@gmail.com; PEP/COPPE/UFRJ
Francisco Lima: frapalima@gmail.com; DEP/UFMG
Marcelle La Guardia: marcelle.laguardia.lara@gmail.com; *Situated* Consultoria e Pesquisa

ABSTRACT

This article aims to present a work carried out to develop interface skills, demanded by a company from the petrochemical sector. Due to low maintenance productivity rates, especially for the boiler teams, a study was carried out to understand the factors related to productivity and to propose improvements for the execution of activities. The diagnosis carried out was based on systematic observations carried out in the field and on self-confrontations with supervisors and boilers, and allowed the creation of the bases for a Systemic Model of Productivity for maintenance operations.

KEYWORDS: industrial maintenance; safety; petrochemical industry.

1. INTRODUCTION

The role of industrial maintenance has undergone modifications and innovations in high-risk industries. Over the past decades, this function has gained strategic relevance in company management. From initially being corrective, maintenance has evolved into preventive and predictive, with a current focus on asset management to enhance equipment and facility reliability and availability. A significant challenge, especially in these industries, is related to productivity in maintenance activities.

Performance measurements in companies highlight that, despite various efforts, productivity levels remain low, and there are still many bottlenecks in service execution. Surveys conducted in different companies reveal that productivity ranges from 40 to 60%. In high-risk industries, the crucial question is: how can we be more productive while ensuring safety?

This article seeks to identify, through the analysis of boilerwork in a large petrochemical company, opportunities for improving productivity, particularly in the competencies situated at the interface between boilermakers and other industrial maintenance technicians. Apart from understanding and highlighting factors impacting productivity, the aim is to characterize interface situations that can guide boilermaker training and the development of interface competencies.

2. METHODOLOGY

The methodology employed was based on the ergonomic analysis of work activities and involved observations of real-life situations in the field. This approach was complemented by verbalizations and self-confrontations regarding the actions taken and productivity problems encountered (FALZON, 2007; GUÉRIN et al., 2001). Consequently, the aim was to ground the diagnosis and recommendations in the everyday situations of boilermaking, i.e., in actual work.

Specifically, the chosen approach involved monitoring the activities of supervisors and managers in various boilermaking areas (equipment, piping, furnaces, and pipelines). This choice proved to be aligned with the intended objectives, as it was observed during field visits that the central role of supervisors and managers is to enable boilermaker teams to perform their tasks efficiently, with quality and safety.

To address daily difficulties and bottlenecks, these leaders develop action strategies that involve anticipation, regulation, and cooperation within a multifunctional, multi-company collective. The commitment of supervisors to this integration is the driving force behind boilermaking productivity.

Five visits to the production unit were conducted by three researchers, totaling 11 days of fieldwork. The main activities carried out during these visits were:

- Meeting with the maintenance team: Defining the study focus, including prioritized production units and key actors in the process.
- Understanding the maintenance process and its context.
- Meeting with boilermaking supervisors and managers.
- Systematic observations and self-confrontations of boilermaking activities.
- Meeting and validation with supervisors.

3. DIAGNOSIS: PRODUCTIVITY FACTORS

Organizational Diagnosis presented below categorizes the factors contributing to the increase and decrease in boilermaking productivity in the studied production unit into three categories. In this section, these categories are outlined, along with examples illustrating how each one impacts (in)productivity. They are divided into:

- **Productivity-Increasing Factors:** Such factors include the supervisory role of the foremen acting as "conductors" and the tools/devices already devised by teams that optimize or simplify task execution. These tools can be enhanced or extended to other areas for further improvement.

- **Productivity-Reducing Factors:** These factors encompass issues like insufficient feedback between the field and planning, infrastructure problems, and logistical challenges that result in "work hindrance" for boilermaking.

- **Interfaces of Boilermaking with Other Maintenance Teams:** This category explores the interactions between boilermakers and other maintenance teams, such as scaffold assemblers, insulators, welders, and pipefitters. Understanding and optimizing these interfaces can significantly impact overall productivity.

3.1 FACTORS CONTRIBUTING TO INCREASED PRODUCTIVITY:

3.1.1 The proactivity of supervisors and foremen: Anticipation, Integration, Regulation, and Cooperation.

Supervisors and foremen can be considered the conductors of productivity.

Whether anticipating what is foreseeable, such as field visits before maintenance activities, or regulating unforeseen situations, like the search for loading machines and other necessary equipment not included in the schedule. Additionally, they optimize both the use of technical resources (equipment, tools, and trucks) and human resources (welders, valve mechanics, and torch operators). Noteworthy characteristics of this role include:

● Regulation of Physical Effort Demand in Activities: Boilermaking work involves significant physical effort, necessitating redesigns of working conditions. To offset the high workload under current conditions, foremen seek to increase the workforce for certain tasks or allocate tools that allow activities to be carried out with less physical strain.

● Prioritization Hierarchy in the Field: New demands arise during activity execution that must be prioritized for completion. There are cases where boilermakers only realize the need to expand the size of a section of piping to be replaced after they have already started the planned task. The assessment made by foremen and supervisors in prioritization considers the risk of the situation, material availability, equipment, and workforce.

● Team Management to Avoid Inactivity: In addition to activity prioritization, including when technical and human resources are requested for their team (prioritizing activities with a greater impact on production), foremen also work to prevent the team from being idle. The team often faces periods without activities due to the difficulty of obtaining Work Permits (PT) issued by operations, especially for tasks not scheduled for the day, or due to a lack of "quick" planned activities—those requiring fewer man-hours and interfaces.

3.1.2 Projeto de Dispositivos de Apoio à Atividade

Some devices, such as mobile platforms, were mentioned and others were outlined by boilermakers to improve working conditions and increase productivity. In one of the verbalizations, the external platform (reel) of heat exchangers was mentioned, reducing the boilermaking team's reliance on the scaffolding team. This mobile platform replaces the scaffolding and can be moved by boilermaintenance personnel. At various points in the factory, the presence of these devices would signify less dependence on other teams.

3.2 Productivity-Reducing Factors

3.2.1 Planning, Programming, and Operation

Despite bi-weekly planning meetings and the daily development (every afternoon) of the Next Day Program (PDS), it can be said that there is a low feedback loop between what actually happens in the field and the planning, programming, and operation itself. The observed gap between the field, programming, and planning leads to issues such as: (i) activities continuing from the previous day not being programmed in the PDS; (ii) allocation of resources different from what was requested; (iii) failure to allocate resources for a specific activity that should have been included in the PDS of other companies. This low feedback of information makes it challenging for foremen to visualize future activities, even in a general sense. It also impacts the programming and planning's understanding of daily occurrences. Apart from hindering productivity, this difficulty and, in some cases, renders the optimization of technical and human resources in activities challenging or impossible.

3.2.2 Unavailability of Support Equipment

Some support equipment faces issues regarding both quantity and specifications. For instance, in the first case, there are activities that require equipment that is not always possible to predict, as is the case with the vacuum truck. If the point in the pipeline is low, then drainage is not complete, and the demand for the truck can be anticipated. However, there are situations difficult to predict, such as whether the liquid inside the equipment will be viscous or if there might be a deficiency in the equipment internally. The low availability of these trucks and prioritization of activities with a greater impact on production ultimately lead to delays.

3.2.3 Unavailability of Materials in the Warehouse

Foremen report that often they request materials, and the warehouse claims to have them, but upon arrival, the materials are not physically present. The alternative found by foremen is storing materials in "big bags" and support houses throughout the process. The low computerization of the parts control is an important aspect to be explored.

3.2.4 Tooling and Logistics Issues

The tooling department also faces issues regarding quantity and quality. In some cases, tools have even shown cracks, necessitating the interruption of execution to locate and retrieve another tool.

Logistics, in this context, is an integrator of available and necessary technical resources for task completion. It is related to mobility and agility in sourcing the resources needed for task execution. Support houses have become an important resource for practical material storage, especially in urgent situations. Therefore, the layout, expansion, and integration of support houses from different areas can be areas for improvement in productivity.

3.2.5 Infrastructure Problems

Another crucial point relates to support infrastructure. There are few water points, requiring teams to recharge their thermal bottles at distant locations. The restrooms are also limited, demanding long distances for access. The restaurant is identified as a productivity barrier, with transportation difficulties and the size of the queues being issues to be addressed. Situations were observed where each queue could have up to 50 people waiting without protection from the sun. Despite these queues having been larger in the past, they still present a problem that requires constant attention.

4 INTERFACES OF BOILERMAKING

The conducted diagnosis allowed for the identification of low-complexity activities that can be performed by boilermakers, a validation carried out by supervisors and experts in the field. Training in these activities and identifying locations where they could be performed, excluding high-risk areas of the plant, works towards increasing productivity and mitigating variability that, even with more aligned programming and planning, is not exempt from occurring on the frontline of maintenance.

The interfaces occurring between boilermakers and other functions can be divided into two types: external interfaces with other companies and internal interfaces within the company itself. The most frequent interfaces, which can be included in boilermaker interface competency development plans, will be highlighted:

- External Interfaces: Isolation and scaffolding.
- Internal Interfaces: Welder, mechanic, and torch operator.

4.1 EXTERNAL INTERFACES

As interfaces with insulation occur before certain boilermaking activities, i.e., during the removal of insulation for task execution. The removal of silicate and smooth plate insulation is an example of an activity that could be performed by boilermakers after training, specifically assigned to tasks on low-risk lines, to be jointly identified by the operation and maintenance companies involved. On the other hand, the removal of corrugated plate insulation is more complex, requiring the development of greater precision skills, which is achieved through repetition over time. It is important to note that insulation situations integrated into boilermaker training only encompass the removal, not the installation of the material.

Interfaces with scaffolding can occur both before and during a task. In some instances, scaffolding must already be assembled for the initiation of the execution. There are situations where boilermakers and the team's welder can only access the piping after the scaffolding is assembled, and they must wait to start the task. The assembly of low-complexity scaffolding, such as cabins at low heights, is an example of a task that could be carried out by boilermakers. In other cases, the interface occurs during the task, i.e., when they need the removal/movement of a scaffolding component, such as boards, bracing, etc. Small alterations with low structural impact on scaffolding, such as moving boards and bars hindering the activity, could also be performed by boilermakers, avoiding delays due to the scaffolding team.

4.2 INTERNAL INTERFACES

Situation analysis revealed instances where low-complexity activities of welders and torch operators can be incorporated into boilermaker training. For instance, electrode welding, which involves tacking, welding sheets, supports, and small structures, is easier to perform and could be part of a competency development plan. Conversely, argon welding requires more experience and the development of highly specialized skills, achievable only through more frequent repetition of this task. Boilermakers may not reach the same level of precision as welders, given their occasional execution of argon welding, making its inclusion in the boilermaker training plan impractical.

The torch operator's activity has increasingly been integrated with that of boilermakers. Some tasks are of low complexity, such as heating a piece and making certain cuts (sheet, tube, threaded bar, etc.), and can be trained so that boilermakers can also perform them. Examples include heating and cutting pieces using an oxy-acetylene torch. However, cuts requiring greater precision, such as those near high-risk equipment, necessitate repetitive practice over time for the development of this practical skill. Hence, the experience of torch operators should be consulted to determine what can be included in the boilermaker training plan and what should be restricted, excluding activities in high-risk locations/equipment or establishing a minimum experience period for the development of this precision.

5 DISCUSSION: ELEMENTS OF A SYSTEMIC PRODUCTIVITY MODEL

One aspect always present in discussions about the productivity of maintenance activities in high-risk industries is the safety of facilities and work (DANIELLOU; SIMARD; BOISSIÈRES, 2010). The goal of productivity is confronted with the execution of activities safely. The right to refuse is considered a necessity in the face of adversities. However, often safety measures can have significant repercussions on productivity without a debate on the rules taking place within the collective of workers (LIMA, 2015).

In the studied production unit, several examples of prohibitions (bicycles, use of wire in cabins) and role deviations were mentioned, which can be considered obstacles to productivity increases related to the existing safety culture but do not impact safety. According to OGP (Oil&GasProducers), actions like these are considered part of a pathological safety culture, typical of organizations where accident analyses primarily aim to find culprits for these events and create rules and standards primarily focused on controlling operators' behaviors.

The current challenge for these companies is to move towards Proactive and Disseminating Safety Cultures, where safety measures are based on dialogue and continuous improvement of facilities with a decrease in organizational silence (LLORY; MONTMAYEUL, 2014). Low utilization rates of maintenance labor, represented by waiting times for execution, can signify increases in maintenance backlog and a reduction in process safety.

The situation in boilermaking regarding productivity is common to companies involved in maintenance in continuous and high-risk process industries. In this sector, Man-hour (Hh) utilization rates are around 50%, indicating the possibility of achieving productivity gains and process safety improvement. Our analysis shows that these indicators result from a multitude of factors, internal and external to maintenance companies, making productivity a systemic effect.

Starting from the daily routine of maintainers, it was possible to identify factors that negatively or positively influence productivity, leading to the construction of a Systemic Productivity Model, whose main elements are presented below. Action, in terms of productivity, should consider these different elements. Specific actions may not have the expected impact, given the predominant weight of the various interfaces identified in the efficiency of local activities.

Therefore, the main elements of the proposed model are:

(i) Ongoing debate between different logics: Predictive, preventive, or corrective maintenance operates according to different and coexisting logics within an organization, including quality, safety, production, costs, and the environment. Creating generic concepts such as "total productive maintenance" does not eliminate conflicts between these different logics, necessitating constant trade-offs, especially challenging when safety takes necessary precedence in high-risk industries;

(ii) Management of Interfaces: The maintenance service itself depends on a series of related activities performed before, during, and after maintenance actions: equipment shutdown and lockout, PT release, resource planning, scaffolding assembly, etc. Final productivity depends on the synchronization of all these activities, organized by different priorities;

(iii) Reinforcement and improvement of planning activities: Ideally, preventive or predictive maintenance should occur more frequently than corrective maintenance. The advantage is better and more extensive planning for the former, as opposed to emergency actions. However, planning still faces challenges due to information loss during execution;

(iv) Planning for the unforeseen: Even with improved planning, not everything can be anticipated in maintenance. Some needs and problems are only identified during or after equipment opening. Therefore, while reinforcing planning, it is necessary to organize to respond to unforeseen events that will continue to occur, rather than considering the difference between planned and executed as a mere "deviation" or residual to be eliminated.

(v) Activity intelligence: The difference between planned and executed is not a simple deviation to be eliminated over time. Maintenance activities involve an element of unpredictability and require skills from the performers to deal with uncertainties and unknown situations, which even experienced workers find difficult to predict, given the complexity of the task (LEPLAT, 2004). This requires "activity intelligence," real-time solutions, and practices to address unforeseen problems, depending on the experience accumulated by maintainers and immediate supervision, who have been performers for years;

(vi) Coordination of different temporal dynamics: In addition to activities directly involved in maintenance, various temporal dynamics defined by different companies involved in interfaces complicate the synchronization needed to avoid downtime during maintenance. Thus, maintenance productivity depends on labor laws related to working hours (overtime, lunch breaks, mandatory training, etc.) and the organization of other related activities (operator shift changes, inspector availability, etc.);

(vii) The central role of proximity hierarchy (supervisor and foreman): Given the previous characteristics, the proximity hierarchy (supervisors, foremen, and team leaders) plays an essential role in coordinating, providing resources, and managing the temporal aspects of activities at interfaces.

Parte superior do formulário

To address the entirety of these factors influencing productivity, it is necessary to create an equally comprehensive and articulated system at different levels, integrating devices and strategic actions with day-to-day operational actions without disruptions. This is why interfaces have proven to be so decisive for efficiency. We believe that recommendations for improving maintenance productivity need to rely on a coordinated action of the elements presented in this model.

The goal is not to create more systems, meetings, or procedures that would generate additional work for the entire team. Instead, with a more innovative approach, one can seek to imbue existing organizational devices and procedures with new content, revitalizing them and providing a direction that can genuinely contribute to solving the encountered difficulties. The advantage is that the proposed solutions can be more easily appropriated and integrated into the daily functioning of the company. There are organizational procedures and devices (typically those related to planning or control) that may be inefficient and time-consuming. Giving these devices a new character and direction is a significant innovation in maintenance. This approach also avoids following the trends of consulting firms that sell products, not genuine innovations, creating solutions that are not aligned with the reality of the work.

The general principle for building transformations aimed at increasing productivity in maintenance, consistent with the methodology adopted in this research, is to generate innovations in line with operational practices and the complexity of work situations, preferably starting from germinal solutions, potentiated by recognition and formalization in an emerging process. This has the advantage of perpetuating innovations, rooting them in existing trends and movements that need to be recognized and supported. Regardless of whether the invention is co-constructed by researchers and participating workers, as in this project, from experiences of other benchmark companies, or from internal germinal experiences, the innovation process does not take place without this blend of the new and local experience—that is, without a systemic local appropriation, in constant construction, of what comes from outside. Normally, this appropriation process requires adaptations or partial reinventions so that the novelty can be integrated into local practices.

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